JEPPIAAR
INSTITUTE OF TECHNOLOGY
"Self-Belief | Self Discipline | Self Respect"

QUESTION BANK

Regulation	: 2013
Year/Semester	: IV
Semester	: 07
Batch	: 2016-2020

DEPARTMENT OF
COMPUTER SCIENCE AND ENGINEERING

Vision of the Institution

Jeppiaar Institute of Technology aspires to provide technical education in futuristic technologies with the perspective of innovative, industrial and social application for the betterment of humanity

Mission of the Institution

To produce competent and disciplined high-quality professionals with the practical skills necessary to excel as innovative professionals and entrepreneurs for the benefit of the society.

To improve the quality of education through excellence in teaching and learning, research, leadership and by promoting the principles of scientific analysis, and creative thinking.

To provide excellent infrastructure, serene and stimulating environment that is most conducive to learning.

To strive for productive partnership between the Industry and the Institute for research and development in the emerging fields and creating opportunities for employability. To serve the global community by instilling ethics, values and life skills among the students needed to enrich their lives.

DEPARTMENT VISION

To produce Engineers with visionary knowledge in the field of Computer Science and Engineering through scientific and practical education in stance of inventive, modern and communal purpose for the improvement of society.

DEPARTMENT MISSION

M1: Devise students for technical and operational excellence, upgrade them as competent engineers and entrepreneurs for country's development.

M2: Develop the standard for higher studies and perpetual learning through creative and critical thinking for the effective use of emerging technologies with a supportive infrastructure.

M3: Involve in a constructive, team oriented environment and transfer knowledge to balance the industry-institute interaction.

M4: Enrich students with professional integrity and ethical standards that will make them deal social challenges successfully in their life.

PROGRAM EDUCATIONAL OBJECTIVES (PEOS)

PEO 1: To support students with substantial knowledge for developing and resolving mathematical, scientific and engineering problems.

PEO 2: To provide students with adequate training and opportunities to work as a collaborator with informative and administrative qualities.

PEO 3: To motivate students for extensive learning to prepare them for graduate studies, R&D and competitive exams.

PEO 4: To cater students with industrial exposure in an endeavour to succeed in the emerging cutting edge technologies.

PEO 5: To shape students with principled values and to follow the code of ethics in social and professional life.

PROGRAM SPECIFIC OUTCOMES (PSOS)

PSO 1 : Students are able to analyse, design, implement and test any software with the programming and testing skills they have acquired.

PSO 2: Students are able to design and develop algorithms for real time problems, scientific and business applications through analytical, logical and problems solving skills.

PSO 3: Students are able to provide security solution for network components and data storage and management which will enable them to work efficiently in the industry.

BLOOM'S TAXONOMY

Definition:

- A theory to identify cognitive levels (Levels of thinking)
- Represents the full range of cognitive functions.

Objectives:

- To classify educational learning objectives into levels of complexity and specificity. The classification covers the learning objectives in cognitive, affective and sensory domains.
- To structure curriculum learning objectives, assessments and activities.

Levels in Bloom's Taxonomy:

- **BTL 1** – **Remember -** The learner is able to recall, restate and remember learned information.
- **BTL 2** – **Understand -** The learner grasps the meaning of information by interpreting and translating what has been learned.
- **BTL 3** – **Apply -** The learner makes use of information in a context similar to the one in which it was learned.
- **BTL 4** – **Analyze -** The learner breaks learned information into its parts to best understand that information.
- **BTL 5** – **Evaluate -** The learner makes decisions based on in-depth reflection, criticism and assessment.
- **BTL 6** – **Create -** The learner creates new ideas and information using what has been previously learned.

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CS6701 CRYPTOGRAPHY AND NETWORK SECURITY LTPC 3 0 0 3

OBJECTIVES:

The student should be made to:

- Understand OSI security architecture and classical encryption techniques.
- Acquire fundamental knowledge on the concepts of finite fields and number theory.
- Understand various block cipher and stream cipher models.
- Describe the principles of public key cryptosystems, hash functions and digital

UNIT I INTRODUCTION & NUMBER THEORY 10

Services, Mechanisms and attacks-the OSI security architecture-Network security model-Classical Encryption techniques (Symmetric cipher model, substitution techniques, transposition techniques, steganography).FINITE FIELDS AND NUMBER THEORY: Groups, Rings, Fields-Modular arithmetic- Euclid's algorithm-Finite fields- Polynomial Arithmetic –Prime numbers-Fermat's and Euler's theorem-Testing for primality -The Chinese remainder theorem- Discrete logarithms.

UNIT II BLOCK CIPHERS & PUBLIC KEY CRYPTOGRAPHY 10

Data Encryption Standard-Block cipher principles-block cipher modes of operation-Advanced Encryption Standard (AES)-Triple DES-Blowfish-RC5 algorithm. Public key cryptography: Principles of public key cryptosystems-The RSA algorithm-Key management – Diffie Hellman Key exchange-Elliptic curve arithmetic-Elliptic curve cryptography.

UNIT III HASH FUNCTIONS AND DIGITAL SIGNATURES 8

Authentication requirement – Authentication function – MAC – Hash function – Security of hash function and MAC –MD5 – SHA – HMAC – CMAC – Digital signature and authentication protocols – DSS – EI Gamal – Schnorr.

UNIT IV SECURITY PRACTICE & SYSTEM SECURITY 8

Authentication applications – Kerberos – X.509 Authentication services – Internet Firewalls for Trusted System: Roles of Firewalls – Firewall related terminology- Types of Firewalls – Firewall designs – SET for E-Commerce Transactions. Intruder – Intrusion detection system – Virus and related threats – Countermeasures – Firewalls design principles – Trusted systems – Practical ofcryptography and security.

UNIT V E-MAIL, IP & WEB SECURITY 9

E-mail Security: Security Services for E-mail-attacks possible through E-mail – establishing keys privacy-authentication of the source-Message Integrity-Non-repudiation-Pretty Good Privacy-S/MIME. IPSecurity: Overview of IPSec – IP and IPv6-Authentication Header-Encapsulation Security Payload (ESP)-Internet Key Exchange (Phases of IKE, ISAKMP/IKE Encoding). Web Security: SSL/TLS Basic Protocol-computing the keys- client authentication-PKI as deployed by SSLAttacks fixed in v3- Exportability-Encoding-Secure Electronic Transaction (SET).

TOTAL: 45 PERIODS

TEXT BOOKS:

1. William Stallings, Cryptography and Network Security, 6th Edition, Pearson Education, March 2013. (UNIT I,II,III,IV).
2. Charlie Kaufman, Radia Perlman and Mike Speciner, "Network Security",
3. Prentice Hall of India, 2002. (UNIT V).

REFERENCES:

1. Behrouz A. Ferouzan, "Cryptography & Network Security", Tata Mc Graw Hill, 2007.
2. Man Young Rhee, "Internet Security: Cryptographic Principles", "Algorithms and Protocols", Wiley Publications, 2003.
3. Charles Pfleeger, "Security in Computing", 4th Edition, Prentice Hall of India, 2006.
4. Ulysess Black, "Internet Security Protocols", Pearson Education Asia, 2000.
5. Charlie Kaufman and Radia Perlman, Mike Speciner, "Network Security, Second Edition, Private Communication in Public World", PHI 2002.
6. Bruce Schneier and Neils Ferguson, "Practical Cryptography", First Edition, Wiley Dreamtech India Pvt Ltd, 2003.
7. Douglas R Simson "Cryptography – Theory and practice", First Edition, CRC Press, 1995.
8. http://nptel.ac.in/.

Subject Code: CS6701 **Year/Semester: IV/07**

Subject Name: Cryptography & Network Security **Subject Handler: Mr. S. Deepan**

UNIT I-INTRODUCTION & NUMBER THEORY

Services, Mechanisms and attacks-the OSI security architecture-Network security model-Classical Encryption techniques (Symmetric cipher model, substitution techniques, transposition techniques, steganography). FINITE FIELDS AND NUMBER THEORY: Groups, Rings, Fields-Modular arithmetic-Euclid‟s algorithm-Finite fields- Polynomial Arithmetic –Prime numbers-Fermat‟s and Euler‟s theorem-Testing for primality -The Chinese remainder theorem- Discrete logarithms.

PART* A

Q.N O	QUESTIONS
1.	**Specify the four categories of security threats.** BTL1 ✓ Interruption ✓ Interception ✓ Modification ✓ Fabrication
2.	**Define active and passive attack with example.**BTL1 **Passive attack:** ✓ Monitoring the message during transmission. ✓ Difficult to detect ✓ Does not affect syatem **Eg: Interception** **Active attack:** ✓ It involves the modification of data stream or creation of false data stream ✓ Easy to detect ✓ Easily affects system **E.g.: Fabrication, Modification, and Interruption**
3.	**Define integrity and non-repudiation.**BTL1 **Integrity:** Service that ensures that only authorized person able to modify the message **Non repudiation:** This service helps to prove that the person who denies the transaction is true or false.
4.	**Differentiate symmetric and asymmetric encryption.**BTL1

Symmetric	**Asymmetric**

It is a form of cryptosystem in which encryption and decryption performed using the same key. Eg : DES,AES	It is a form of cryptosystem in which encryption and decryption performed using two keys. Eg : RDA, ECC

5. **Define cryptanalysis.** BTL1

Cryptanalysis is a process of attempting to discover the key or plaintext or both.

6. **Define security mechanism**. BTL1

It is process that is designed to detect prevent, recover from a security attack.

Example: Encryption algorithm, Digital signature, Authentication protocols

7. **Define steganography**. BTL1

Hide in plain sight .Hiding the message into some cover media. It conceals the existence of a message

8. **Why network needs security?** BTL1

When systems are connected through the network, attacks are possible during transmission time.

9. **Define confidentiality and authentication.**BTL1

Confidentiality: It means how to maintain the secrecy of message. It ensures that the information in a computer system and transmitted information are accessible only for reading by authorized person.

Authentication: It helps to prove that the source entity only has involved the transaction.

10. **Define cryptography.**BTL1

It is a science of writing Secret code using mathematical techniques. The many schemes used for enciphering constitute the area of study known as cryptography.

11. **Compare Substitution and Transposition techniques.** BTL1

SUBSTITUTION	TRANSPOSITION
A substitution techniques is one in which the letters of plaintext are replaced by other letter or by number or symbols **Eg: Caeser cipher**	It means, different kind of mapping is achieved by performing some sort of permutation on the plaintext letters. **Eg: DES, AES**

12. **Define Diffusion & Confusion.** BTL1

Diffusion

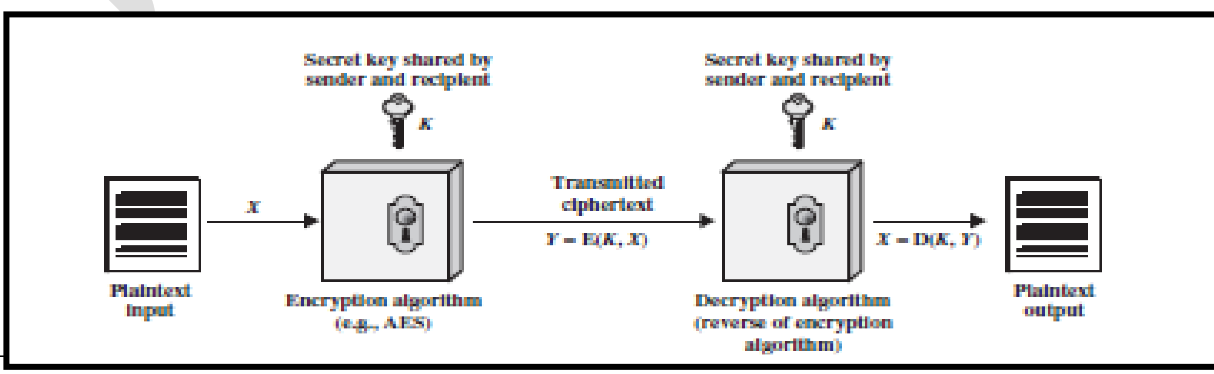
It means each plaintext digits affect the value of many ciphertext digits which is equivalent to each ciphertext digit is affected by many plaintext digits. It can be achieved by performing permutation on the data. It is the relationship between the plaintext and ciphertext

Confusion:

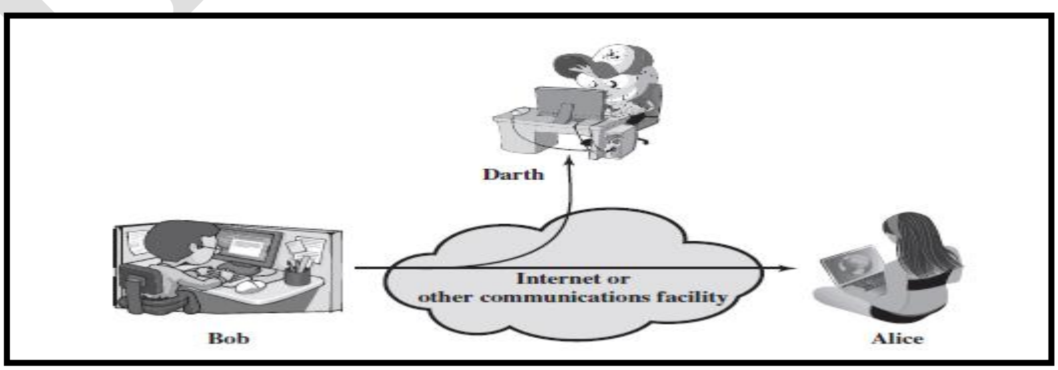
	It can be achieved by substitution algorithm. It is the relationship between cipher text and key
13	**Define Multiple Encryptions.** BTL1 It is a technique in which the encryption is used multiple times. Eg: Double DES, Triple DES
14	**Specify the design criteria of block cipher.** BTL1 Number of rounds Design of the function F Key scheduling
15	**Define Reversible mapping.** BTL1 Each plain text is maps with the unique cipher text. This transformation is called reversible mapping
16	**Specify the basic task for defining a security service**BTL1 A service that enhances the security of the data processing systems and the information transfer of an organization. The services are intended to counter security attack, and they make use of one or more security mechanism to provide the service
17	**Define network security.** BTL1 This area covers the use of cryptographic algorithms in network protocols and network applications.
18	**Define computer security.** BTL1 This term refers to the security of computers against intruders and malicious software.
19	**What are hill cipher merits and demerits?** BTL1 Completely hides single letter and 2 letter frequency information.
20.	**List-out the types of attack in ceaser cipher.** BTL1 Brute force attack. Just try all the 25 possible keys
21	**Define integrity and nonrepudiation?** BTL1 **Integrity:** Service that ensures that only authorized person able to modify the message. **Nonrepudiation:** This service helps to prove that the person who denies the transaction is true or false.
22	**Write short notes Congruence.** BTL1 Let a,b,n be integers with $n \neq 0$. We say that $a \equiv b \pmod n$) If a-b is a multiple of n.
23	**What is Key?** BTL1 A sequence of symbols that controls the operation of a cryptographic transformation. A key is normally a string of bits used by a cryptographic algorithm to transform plain text into cipher text or vice versa. The key should be the only part of the algorithm that it is necessary to keep secret.

24	**What is Plain text &Ciphertext?** BTL1 **Plaintext:**An original message is known as the **plaintext(Readable format)** **Ciphertext:**coded message is called the **Cipher Text.(Unreadable format)**
25	**List the different Types of Ciphers.** BTL1 ✓ Shift Ciphers. ✓ Affine Ciphers ✓ Vigenere Cipher ✓ Substitution Ciphers ✓ Sherlock Holmes ✓ Playfair and ADFGX Ciphers ✓ Block ciphers ✓ One-Time pads

	PART *B
1	**i)Explain about symmetric cipher models.(May/June 2012) (13M)** BTL 2 **Answer:Page-57 to 59 in William Stallings** ✓ Symmetric cipher model (2M) A **symmetric key cipher** (also called a secret-**key cipher**, or a one-**key cipher**, or a private-**key cipher**, or a shared-**key cipher**) Shared_secretis one that uses the same (necessarily secret) **key** to encrypt messages as it does to decrypt messages. ✓ Plain text (1M) Original message or data ✓ Encryption Algorithm (2M) Various substitutions and transformations ✓ Decryption Algorithm (2M) Produces plaintext ✓ Cipher Text (1M) Scrambled Message ✓ Principles of Security (2M) ✓ Diagram (3M)



2	**Explain the various substitution techniques. (AU Nov/Dec 2011) (13M)** BTL2 **Answer:Page-62 to 69 in William Stallings** ✓ **Ceaser cipher** : replacing each letter of the alphabet with the letter standing three places further down the alphabet (1M) ✓ **Formula :(**1M**)** $C = E(3, p) = (p + 3) \bmod 26$ ✓ **Example:**(1M) ✓ **Mono alphabetic Cipher**: permutation of the 26 alphabetic characters (1M)) ✓ **Example:**(1M) ✓ **Hill Fair cipher**:polygraphic substitution *cipher* based on linear algebra (1M) ✓ **Formula:(**1M) $C = E(K, P) = PK \bmod 26$ $P = D(K, C) = CK^{-1} \bmod 26 = PKK^{-1} = P$ ✓ **Example:**(1M) ✓ **Play Fair cipher:** treats digrams in the plaintext as single units and translates these units into ciphertext ✓ **Example:**(1M) ✓ Poly alphabetic cipher : technique is to use different monoalphabetic substitutions as one proceeds through the plaintext message (2M) ✓ One time pad (2M): Each new message requires a new key of the same length as the new message
3	**Describe about transposition techniques.(10M)** BTL2 **Answer:Page-77 to 82 in William Stallings** ✓ **Rail fence technique**: the plaintext is written down as a sequence of diagonals and then read off as a sequence of rows (1M) ✓ **Example:** (2M) ✓ **Coloumnar technique:**It is a transposition **cipher** that follows a simple rule for mixing up the characters in the plaintext to form the ciphertext. (1M) ✓ **Example:** **(**2M) ✓ **Rotor machines:** principle of multiple stages of encryption was a class of systems known as rotor machines. (2M) ✓ **Stegnography:** conceal the existence of the message (2M)

4	**Explain Security Services.(10M)**BTL2 **Answer:Page-101 to 105 in William Stallings** ✓ **Authentication:** assuring that a communication is authentic (2M) ✓ **Access Control :** the ability to limit and control the access to host systems and applications via communications links. (2M) ✓ **Data Confidentiality :** protection of transmitted data from passive attacks (2M) ✓ **Data Integrity:**protecting information from being modified by unauthorized parties (2M) ✓ **NonRepudation:** prevents either sender or receiver from denying a transmitted message. (2M)
5	**Explain various Security Mechanisms.(8M)** BTL2 **Answer:Page-105 to 107 in William Stallings** ✓ **Pervasive Security Mechanisms:** Mechanisms that are not specific to any particular OSI security service or protocol layer. (2M) **(i)** **Trusted Functionality** : perceived to be correct with respect to some criteria (1/2 M) **(ii)** **Security Label:** marking bound to a resource(1/2 M) **(iii)** **Event Detection:** Detection of security-relevant events. (1/2 M) **(iv)** **Security Audit Trail:** facilitate a security audit(1/2 M) ✓ **Specific Security Mechanism :** incorporated into the appropriate protocol (2M) **(i)** **Encipherment** : mathematical algorithms to transform data into a form that is not readily intelligible (1/2 M) **(v)** **Digital Signature**: allows a recipient of the data unit to prove the source and integrity of the data unit and protect against forgery (1/2 M) **(vi)** **Access Control** : enforce access rights to resources. (1/2 M) **(vii)** **Data Integrity** : assure the integrity of a data unit or stream of data units. (1/2 M)
6	**Explain various Security Attacks.(13M)** BTL2 **Answer:Page-107 to 109 in William Stallings** ✓ **Passive Attack:**nature of eavesdropping on, or monitoring of, transmissions (1M) (i) Release of Message Contents(1/2 M) **(ii)** Traffic Analysis(1/2 M) **(iii)** Diagram(2M)  ✓ **Active Attack** :involve some modification of the data stream or the creation of a false stream

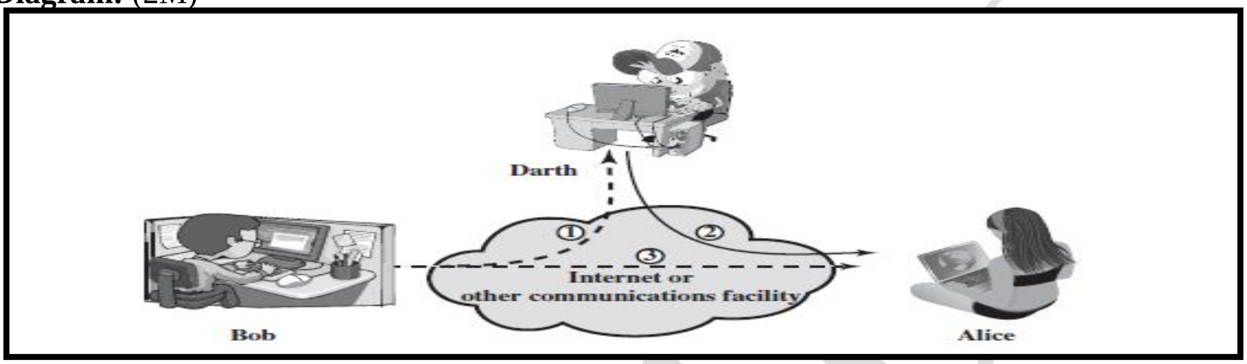
(i) **Masquerade:**when one entity pretends to be a different entity (1/2M)

(ii) **Replay:**involves the passive capture of a data unit and its subsequent retransmission to produce an unauthorized effect (1/2M)

(iii) **Modification of message:**some portion of a legitimate message is altered, or that messages are delayed or reordered, to produce an unauthorized effect (1/2M)

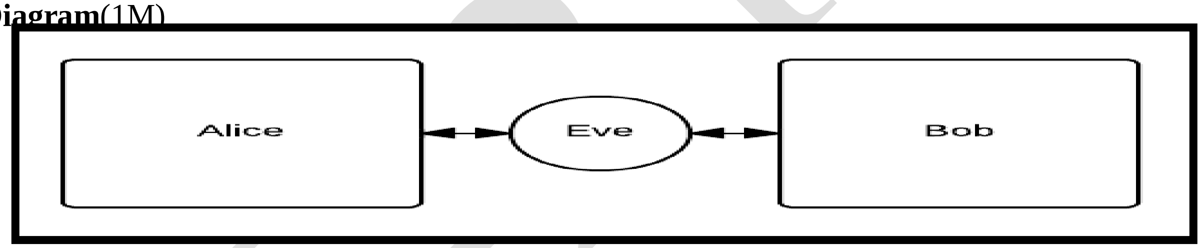
(iv) **Denial of service:**prevents or inhibits the normal use or management of communications facilities (1/2M)

Diagram: (2M)



- ✓ **Man in Middle Attack :**attack where the attacker secretly relays and possibly alters the communication between two parties who believe they are directly communicating with each other. (2M)

Diagram(1M)



8 **Explain about finite fields.(13M)** BTL2

Answer:Page-144 to 147 in William Stallings

- ✓ Groups, Rings, Fields (2M)

  A **group** *G*, sometimes denoted by {*G*, ~}, is a set of elements with a binary operation denoted by ~ that associates to each ordered pair (*a*, *b*) of elements in *G* an element (*a* ~ *b*) in *G*

  Properties(1/2M)
- ✓ Rings:A**ring** *R*, sometimes denoted by {*R*, +, *}, is a set of elements with two binary operations, called *addition* and *multiplication*,6 such that for all *a*, *b*, *c* in *R* the following axioms are obeyed.(1/2M)
- ✓ Fields(1/2M)

  A **field** *F*, sometimes denoted by {*F*, +, *}, is a set of elements with two binary operations, called *addition* and *multiplication*, such that for all *a*, *b*, *c* in *F* the following axioms are obeyed.(1/2M)
- ✓ **Modular Arithmetic :(**2M)

  If *a* is an integer and *n* is a positive integer, we define *a* mod *n* to be the remainder when*a* is divided by *n*. The integer *n* is called the **modulus**.

Formula(1M)

$a = qn + r \quad 0 \le r < n; q == [a/n]$

$a = [a/n] \times n + (a \bmod n)$

$11 \bmod 7 = 4; \qquad -11 \bmod 7 = 3$

- ✓ **Euclidean algorithm :**(2M)
  One of the basic techniques of number theory is the Euclidean algorithm, which is a simple procedure for determining the greatest common divisor of two positive integers.
  Formula(1M)
  $\gcd(a, b) = \gcd(b, a \bmod b)$
  $\gcd(55,22) = \gcd(22,55 \bmod 22) = \gcd(22,11) = 11$
- ✓ **Finite fields of form GF(P)** :(2M)
  For a given prime, *p*, we define the finite field of order *p*, GF(*p*), as the set Z*p*of integers {0, 1, c, *p* - 1} together with the arithmetic operations modulo *p*.
- ✓ **Polynomial arithmetic** :(1M)
  Polynomial arithmetic in which the arithmetic on the coefficients is performed modulo*p*; that is, the coefficients are in GF(*p*).

9 **Explain about Euclidean algorithm. (13M)** BTL2

Answer:Page-129 to 132 in William Stallings

- ✓ **Euclidean algorithm :**(2M)
  One of the basic techniques of number theory is the Euclidean algorithm, which is a simple procedure for determining the greatest common divisor of two positive integers.
  - ✓ **Formula:** (2M)

$$
\left.
\begin{array}{ll}
a = q_1 b + r_1 & 0 < r_1 < b \\
b = q_2 r_1 + r_2 & 0 < r_2 < r_1 \\
r_1 = q_3 r_2 + r_3 & 0 < r_3 < r_2 \\
\vdots & \vdots \\
r_{n-2} = q_n r_{n-1} + r_n & 0 < r_n < r_{n-1} \\
r_{n-1} = q_{n+1} r_n + 0 & \\
d = \gcd(a, b) = r_n &
\end{array}
\right\}
$$

✓**Greatest common divisor**(2M)

$\gcd(a, b) = \gcd(b, a \bmod b)$

$\gcd(55,22) = \gcd(22,55 \bmod 22) = \gcd(22,11) = 11$

✓**Finding GCD**(2M)

$$\boxed{a = q_1 b + r_1 \qquad 0 \le r_1 < b}$$

✓ **Example**(5M)

10 **Explain Fermat Theorem. (10M)** BTL2

Answer:Page-272 to 275 in William Stallings

✓ **Fermat's Theorem:** (2M)

Fermat's theorem states the following: If *p* is prime and *a* is a positive integer not divisible by *p*, then

✓ **Formulas :**(2M)

$$a^{n-1} = 1(\text{mod } p)$$

✓ **Proof :**(3M)

$$\begin{aligned}
&a - 7, p - 19\\
&7^2 - 49 = 11 \pmod{19}\\
&7^4 = 121 = 7 \pmod{19}\\
&7^8 = 49 = 11 \pmod{19}\\
&7^{16} = 121 = 7 \pmod{19}\\
&a^{p-1} - 7^{18} - 7^{16} \times 7^2 = 7 \times 11 = 1 \pmod{19}
\end{aligned}$$

✓ **Example :**(3M)

11 **Explain about Euler's theorem. (13M)** BTL2

Answer:Page-273 to 276 in William Stallings

✓ **Euler Theorem :** (2M)

Euler's theorem states that for every *a* and *n* that are relatively prime:

✓ **Formula :**(3M)

$$a^{\phi(n)} = 1(\text{mod } n)$$

✓ **Proof :**true if *n* is prime, because in that case, f(*n*) = (*n* - 1) and Fermat's theorem holds. However, it also holds for any integer *n*. Recall that f(*n*) is the number of positive integers less than *n* that are relatively prime to *n*. (4M)

Consider the set of such integers, labeled as

✓ **Euler's Totient Function** : (4M)

Before presenting Euler's theorem, we need to introduce an important quantity in number theory, referred to as **Euler's totient function**, written f(*n*), and defined as the number of positive integers less than *n* and relatively prime to *n*. By convention,

	$\phi(1) = 1$.
12	**I)Explain Chinese Remainder Theorem. (10M)** BTL2 **Answer:Page-278 to 281 in William Stallings** ✓ **Chinese Remainder Theorem :**(3M) The *Chinese remainder theorem* is a *theorem* which gives a unique solution to simultaneous linear congruences with coprime moduli ✓ **Statements:** (2M) $(A + B) \bmod M \leftrightarrow ((a_1 + b_1) \bmod m_1, \ldots, (a_k + b_k) \bmod m_k)$ $(A - B) \bmod M \leftrightarrow ((a_1 - b_1) \bmod m_1, \ldots, (a_k - b_k) \bmod m_k)$ $(A \times B) \bmod M \leftrightarrow ((a_1 \times b_1) \bmod m_1, \ldots, (a_k \times b_k) \bmod m_k)$ ✓ **Example :**(5M)
13	**Explain Modular and Discrete Algorithm.(10M)** BTL2 **Answer:Page-281 to 284 in William Stallings** ✓ **Modular algorithm** :(2M) If *a* is an integer and *n* is a positive integer, we define *a* mod *n* to be the remainder when*a* is divided by *n*. The integer *n* is called the **modulus**. ✓ **Modular arithmetic formula :(**1M) $a = qn + r \quad 0 \le r < n; q == [a/n]$ $a = [a/n] \times n + (a \bmod n)$ $11 \bmod 7 = 4; \qquad -11 \bmod 7 = 3$ ✓ discrete algorithm(2M) ✓ Fundamental to public key algorithm(2M) ✓ Formula(3M)

PART* C	
1	a) **Find 3^{21} and 11 using Fermat's Theorem.(7M)** BTL2 b) **Find 11^7 and 13 using fermat's Theorem.(8M)** BTL2 **Answer:Page-272 to 274 in William Stallings** ✓ **Formula:**(4M) $a^{p-1} \equiv 1 (\bmod p)$

	✓ **Steps:**(3M) ✓ **Formula:**(4M) $a^{p-1} \equiv 1(\bmod p)$ ✓ **Steps**:(4M)
2.	**Encrypt the following using play fair cipher using the keyword MONARCHY “SWARAJ IS MY BIRTH RIGHT”. Use X for blank spaces.(15M)** BTL 3 **Answer:Page-65 to 67 in William Stallings** ✓ **Rules:**(6M) (i) If both the letters are in the same column, take the letter below each one (going back to the top if at the bottom) (ii) First, a plaintext message is split into pairs of two letters (digraphs) (iii)If both the letters are in the same column, take the letter below each one (iv)If both letters are in the same row, take the letter to the right of each one **(v)** If neither of the preceding two rules are true, form a rectangle with the two letters and take the letters on the horizontal opposite corner of the rectangle ✓ **Solution:**(9M)
3	**Apply Caesar cipher and k=5 decrypt the given Cipher text “YMJTYMJWXNIJTKXNQJSHJ”. (15M)**BTL3 **Answer:Page-62 to 63 in William Stallings** ✓ **Defintion:**(3M) It is a type of substitution cipher where each letter in the original message (which in cryptography is called the plaintext) is replaced with a letter corresponding to a certain number of letters shifted up or down in the alphabet. ✓ **Formula:**(2M) C = E(3, p) = (p + 3) mod 26(2) ✓ **Solution**(10M)
4	**Encrypt the message “PAY” using hill cipher with the following key matrix and show the decryption to formulate original plain text. (15M)**BTL3 $K=\begin{vmatrix} 17 & 17 & 5 \\ 21 & 18 & 21 \\ 2 & 2 & 19 \end{vmatrix}$ **Answer:Page-67 to 69 in William Stallings** ✓ **Encryption:**(5M) turn our keyword into a key matrix plaintext into digraphs into a column vector perform matrix multiplication modulo the length of the alphabet (i.e. 26) on each vector converted back into letters to produce the ciphertext. ✓ **Decryption:**(3M)

	must find the inverse matrix ✓ **Example:**(7M)
5	**Assess the following cipher Text using brute force attack**. **(15M)** BTL3 CMTMROOEOORW (Hint: Algorithm-Rail fence) **Answer:Page-69 to 71 in William Stallings** **Defintion:**(3M) The simplest such cipher is the **rail fence** technique, in which the plaintext is written down as a sequence of diagonals and then read off as a sequence of rows **Encryption:**(6M) **Decryption:**(6M)
6	**Explain Security Attacks.(15M)** BTL3 **Answer:Page-39 to 41 in William Stallings** ➢ Security Attacks (3M) ➢ Passive attacks (3M) ➢ Active attacks (3M) ➢ Network security model (3M) ➢ Diagrams (3M)
7	**Explain Network Security Services. (15M)** BTL2 **Answer:Page-43 to 45 in William Stallings** ➢ Authentication (3M) ➢ Access control (3M) ➢ Data confidentiality (3M) ➢ Data integrity (2M) ➢ Non repudiation (2M) ➢ Availability services (2M)
8	**Explain Fermats and Euler Theorem.(15M)** BTL2 **Answer:Page-272 to 275 in William Stallings** ➢ Explanation (5M) ➢ Theorem (10M)

9	**Illustrate how to solve x2≡1(mod 35) using Chinese remainder theorem.(15M)**BTL2 **Answer:Page-278 to 281 in William Stallings** $A = \left(\sum_{i=1}^{k} a_i c_i\right) \bmod M$ (2M) $C_i = M_i \times (M_i^{-1} \bmod m_i)\ for\ 1 \le i \le k$ (3M) **Encryption :**(5M) **Decryption:**(5M)
10	**Estimate 11^{13} mod 53 using modular exponentiation.(15M)** BTL3 **Answer:Page-112 to 113 in William Stallings** ➢ **Z_n = {0, 1, . . . , (n – 1)}** (2M) ➢ **a+b mod n = [a mod n + b mod n] mod n** (3M) **Encryption:**(5M) **Decryption:**(5M)
11	**State the CRT and find X for the given set of congruent equations using CRT.** X≡2(mod 3) X≡3(mod 5) X≡2(mod 7) **(15M)** BTL2 **Answer:Page-278 to 281 in William Stallings** $A = \left(\sum_{i=1}^{k} a_i c_i\right) \bmod M$ (2M) $C_i = M_i \times (M_i^{-1} \bmod m_i)\ for\ 1 \le i \le k$ (3M) **Encryption :**(5M) **Decryption:**(5M)
12	**Solve the following system of congruence's:** X≡12(mod 25) X≡9(mod 26) X≡23(mod 27) **(15M)** BTL3 **Answer:Page-278 to 281 in William Stallings** $A = \left(\sum_{i=1}^{k} a_i c_i\right) \bmod M$ (2M) $C_i = M_i \times (M_i^{-1} \bmod m_i)\ for\ 1 \le i \le k$ (3M) **Encryption :**(5M) **Decryption:**(5M)

UNIT 2- BLOCK CIPHERS & PUBLIC KEY CRYPTOGRAPHY	
Data Encryption Standard-Block cipher principles-block cipher modes of operation-Advanced Encryption Standard (AES)-Triple DES-Blowfish-RC5 algorithm. Public key cryptography: Principles of public key cryptosystems-The RSA algorithm-Key management -Diffie Hellman Key exchange-Elliptic curve arithmetic-Elliptic curve cryptography.	
PART* A	
1	**Compare stream cipher with block cipher with example.**BTL1 **Stream cipher:** Processes the input stream continuously and producing one element at a time. **Example: caeser cipher**. **Block cipher:** Processes the input one block of elements at a time producing an output block for each input block. **Example: DES**
2	**Differentiate unconditionally secured and computationally secured .**BTL1 An Encryption algorithm is unconditionally secured means; the condition is if the cipher text generated by the encryption scheme doesn't contain enough information to determine corresponding plaintext. Encryption is computationally secured means, ✓ The cost of breaking the cipher exceeds the value of enough information. ✓ Time required to break the cipher exceed the useful lifetime of information.
3	**What are the design parameters of Feistel cipher network?** BTL1 ✓ Block size ✓ Key size ✓ Number of rounds ✓ Sub key generation algorithm ✓ Round function ✓ Fast software encryption / decryption ✓ Ease of analysis
4	**Define Product cipher.** BTL1 Product Cipher means two or more basic cipher are combined together and produces the resultant cipher which is called the 'product cipher'.

<table>
<tr><td>5</td><td>Explain Avalanche effect. BTL1
A desirable property of any encryption algorithm is that a small change in either the plaintext or the key produce a significant change in the ciphertext</td></tr>
<tr><td>6</td><td>Define Diffusion & Confusion. BTL1
Diffusion:
✓ In diffusion, the statistical structure of the plaintext is dissipated into long-range statistics of the ciphertext.
✓ This is achieved by having each plaintext digit affect the value of manyciphertext digits; generally, this is equivalent to having each ciphertext digit beaffected by many plaintext digits
Confusion:
It can be achieved by substitution algorithm. It is the relationship between cipher text and key.</td></tr>
<tr><td>7</td><td>Give the five modes of operation of Block cipher. BTL1
✓ Electronic Codebook(ECB)
✓ Cipher Block Chaining(CBC)
✓ Cipher Feedback(CFB)
✓ Output Feedback(OFB)
✓ Counter(CTR)</td></tr>
<tr><td>8</td><td>State advantages of counter mode. BTL1
✓ Hardware efficiency
✓ Software efficiency
✓ Preprocessing
✓ Random access
✓ Provable security
✓ Simplicity</td></tr>
<tr><td>9</td><td>Define Multiple Encryption BTL1
Multiple Encryption is a technique in which the encryption is used multiple times. Eg: Double DES, Triple DES</td></tr>
<tr><td>10</td><td>Specify the design criteria of block cipher. BTL1
✓ Number of rounds
✓ Design of the function F
✓ Key scheduling</td></tr>
<tr><td>11</td><td>Define Reversible mapping. BTL1
Each plain text is maps with the unique cipher text. This transformation is called reversible mapping</td></tr>
<tr><td>12</td><td>Specify the basic task for defining a security service. BTL1
A service that enhances the security of the data processing systems and the information transfer of an organization. The services are intended to counter security attack, and they make use of one or more security mechanism to provide the service.</td></tr>
<tr><td>13</td><td>What is the difference between link and end to end encryption? BTL1
<table><tr><th>Link Encryption</th><th>End to End Encryption</th></tr><tr><td>✓ With link encryption, each vulnerable communication link is</td><td>✓ With end to end ncryption, encryption process is carried out at the two end systems</td></tr></table></td></tr>
</table>

	equipped on both ends with an encryption device	
	✓ Message exposed in sending host and in intermediate nodes	✓ Message encrypted in sending and intermediate nodes
	✓ Transperant to user	✓ User applies encryption
	✓ Host maintains encryption facility	✓ Users must determine algorithm
	✓ One facility for all users	✓ Users selects encryption scheme
14	**What is traffic Padding? What is its purpose?** BTL1 Traffic padding produces ciphertext output continuously, the purpose of padding is that even in the absence of the plain text, a continuous random data stream is generated.	
15	**List the evaluation criteria defined by NIST for AES?** BTL1 The evaluation criteria for AES is as follows: ✓ Security ✓ Cost ✓ Algorithm and implementation characteristics	
16	**What is Triple Encryption? How many keys are used in triple encryption?** BTL1 Triple Encryption is a technique in which encryption algorithm is performed three times using three keys.	
17	**List the schemes for the distribution of public keys.** BTL1 ✓ Public announcement ✓ Publicly available directory ✓ Public key authority ✓ Public key certificates	
18	**Drawback of 3-DES.** BTL1 ✓ Algorithm is sluggish in software ✓ The number of rounds in thrice as that of DES ✓ 3DES uses 64 bit block size ✓ To have higher efficiency and security a larger block size is needed.	
19	**List out an evaluation criteria for round 2.** BTL1 ✓ General security ✓ Software implementation ✓ Hardware implementation ✓ Attacks ✓ Encryption Vs Decryption ✓ Key ability-Ability to change keys quickly with minimum of resources.	
20	**List out the attacks to RSA.** BTL1 ✓ **Brute force** - Trying all possible private keys. ✓ **Mathematical attacks** - The approaches to factor the product of two prime numbers. ✓ **Timing attack** - Depends on the running time of the decryption algorithm	

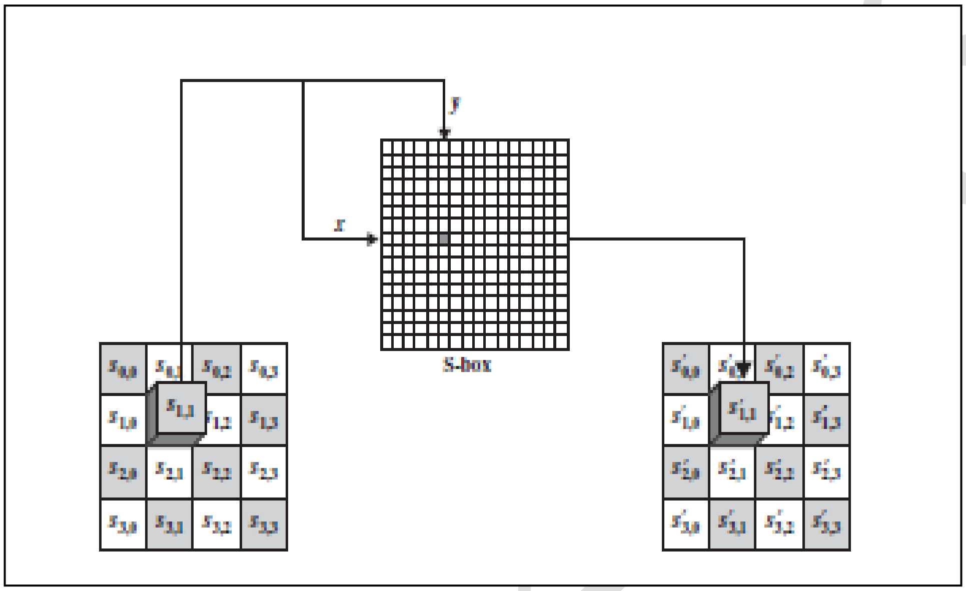
21	**What is Primality Test? List the types of Primality Testing.** BTL1 A primality test is an algorithm for determining whether an input number is prime or not. Types of Primality Test: Fermat Primality Test. Miller-Rabin Primality Test. Solovay-strassenPrimality Test.
22	**What is Factoring ?**BTL1 Factoring is the decomposition of an object into a product of other objects, or factors, which when multiplied together give the original.
23	**Define RC4.** BTL1 RC4 is a stream cipher designed in 1987 by Ron Rivest for RSA Security. RC4 is used in the SSL/TLS (Secure Sockets Layer/Transport Layer Security) standards that have been defined for communication between Web browsers and servers. It is also used in the WEP (Wired Equivalent Privacy) protocol and the newer WiFi Protected Access (WPA) protocol that are part of the IEEE 802.11 wireless LAN standard.
24	**What is the meet in the middle attack?** BTL1 This is the cryptanalytic attack that attempts to find the value in each of the range and domain of the composition of two functions such that the forward mapping of one through the first function is the same as the inverse image of the other through the second function-quite literally meeting in the middle of the composed function.
25.	**List Four possible approaches to attack the RSA Algorithm.** BTL1 Brute Force Mathematical Attacks Timing attacks Chosen Cipher text attacks

PART * B

1 **Explain Block cipher design principles and modes of operation. (Apr/May2014) (13M)** BTL2

Answer:Page-116 to 118 in William Stallings

- ✓ DES Design criteria (2M)
- ✓ Criteria for permutation(2M)
- ✓ Number of rounds(2M)
- ✓ S-Box design Diagram(2M)

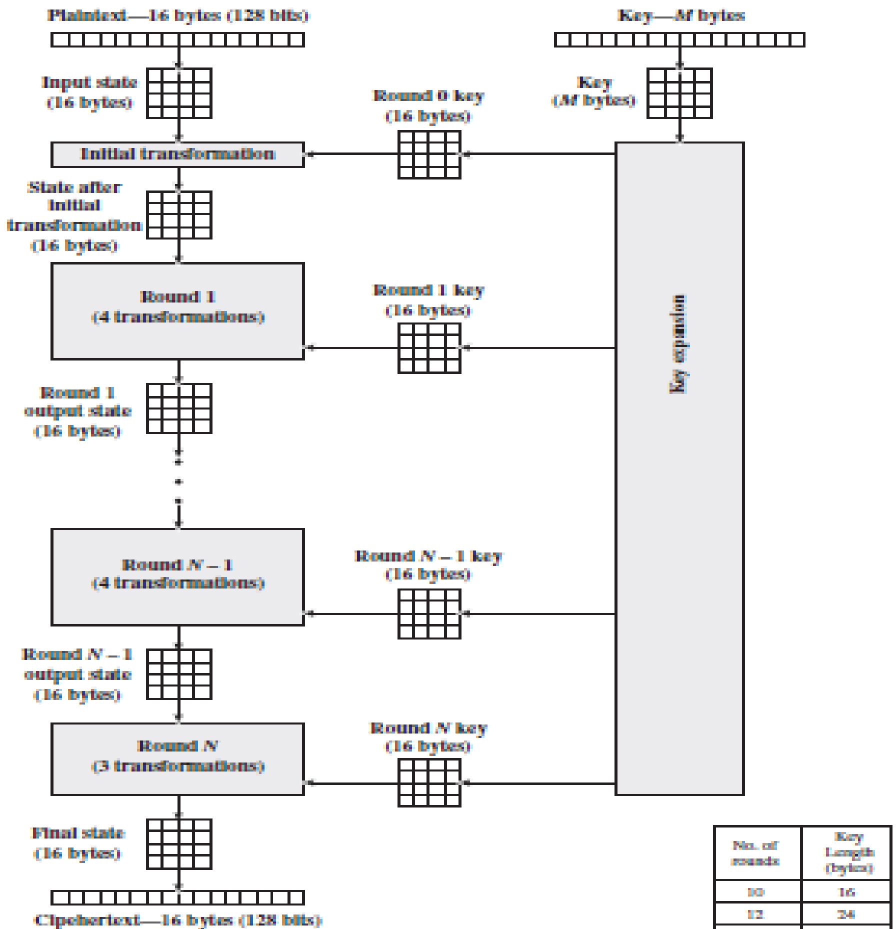


- ✓ Key schedule algorithm(2M)
- ✓ Electronic code book(2M)
- ✓ Cipher block chaining(1M)

2 **Explain about Advance Encryption Standard. (13M)** BTL2

Answer:Page-174 to 176 in William Stallings

- ✓ Evaluation criteria for AES (2M)
- ✓ Security(1M)
- ✓ Cost(1M)
- ✓ Implementation(1M)
- ✓ AES cipher(2M)
- ✓ AES Encryption and decryption(2M)



- ✓ Inverse substitution bytes(1M)
- ✓ Mix column(1M)
- ✓ Key expansion in AES 192 and AES 256 (2M)

3 **Explain Triple DES. (13M)**BTL2

Answer:Page-101 to 103 in William Stallings

- ✓ Triple DES with 2 keys(3M)
- ✓ Diagram with formulas(4M)

$$\boxed{\begin{aligned} C &= E(K_1, D(K_2, E(K_1, P))) \\ P &= D(K_1, E(K_2, D(K_1, C))) \end{aligned}}$$

- ✓ Triple DES with 3 keys(4M)
- ✓ Diagram with operation formulas(2M)

$$\boxed{C = E(K_3, D(K_2, E(K_1, P)))}$$

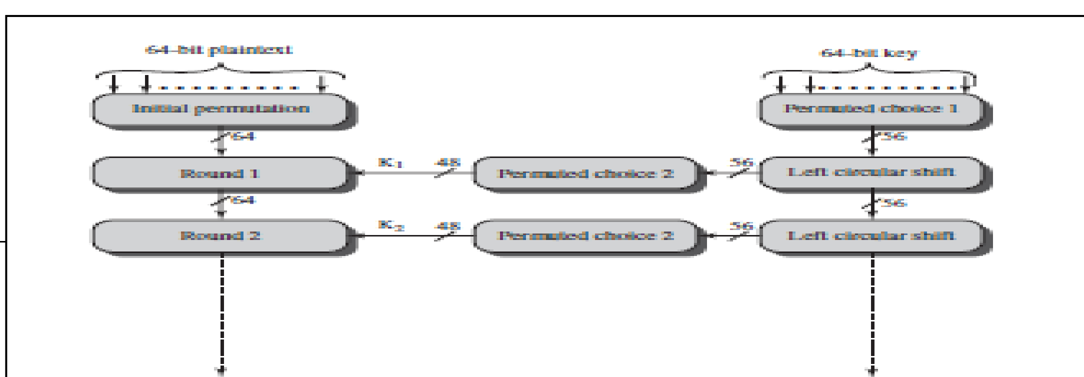
4 **Explain about RC4 algorithm. (13M)** BTL2 **(May/June/2012)**

Answer:Page no-PPT given covering all topics

- ✓ Explain RC4 algorithm (2M)
- ✓ Parameters (2M)

	✓ Primitive operators(1M) ✓ Characteristics(1M) ✓ Key expansion(2M) ✓ Encryption(1M) ✓ Decryption(1M) ✓ RC4 modes (3M)
5	**Explain public key algorithm. (13M)** BTL2 **Answer:Page-293 to 295 in William Stallings** ✓ Public key algorithm(2M) ✓ Characteristics of public key cryptography(2M) ✓ Six ingredients(3M) ✓ Decryption algorithm diagram(2M) ✓ Steps to create public key(2M) ✓ Diagrammatical representation(2M)
6	**i)Explain RSA algorithm. (6M) (Apr/May 2011,Nov/Dec 2011,2012)** BTL2 **Answer:Page-301 to 309 in William Stallings** ✓ Explain the process in mathematical fact(2M) ✓ Choose, select, encrypt, transfer cipher text, decrypt.(3M) ✓ Discuss with an example(1M) **ii)Explain blowfish encryption algorithm. (7M)** BTL2 **Answer:Page-119 to 120 in William Stallings** ✓ Algorithm(1M) ✓ Feistel network(3M) ✓ Working methodology(2M) ✓ Example with diagram(1M)
7	**Explain Diffie Hellman key exchange. (13M)** BTL2 **Answer:Page-325 to 327 in William Stallings** ✓ Key management techniques(3M) ✓ Explain Diffie Hellman algorithm with steps (3M) ✓ Provide diagrammatical explanation with example(4M) ✓ Process explanation with steps and diagram(3M)
8	**Explain Elliptical Curve cryptography. (13M)** BTL2 **Answer:Page-341 to 343 in William Stallings** ✓ Elliptical curve over Zp(4M) ✓ Equation of elliptical curve over Zp(3M) ✓ Elliptic curves over GF(2m) (3M) ✓ Elliptic curve cryptography(3M)
PART * C	

1	**Explain block cipher principles and modes of operation. (15M)** BTL2 **Answer:Page-216 to 218 in William Stallings** ✓ DES design (3M) ✓ CBC mode (3M) ✓ AES (3M) ✓ Triple DES (3M) ✓ RC 5 Algorithm(3M)
2	**Explain Public Key cryptography. (15M)** BTL2 **Answer:Page-290 to 292 in William Stallings** ✓ Public Key Cryptography (2M) **Public-key cryptography**, or **asymmetric cryptography**, is any cryptographic system that uses pairs of keys:*public keys* which may be disseminated widely, and *private keys* which are known only to the owner ✓ Characteristics (3M) ✓ Six ingredients with explanation (5M) ✓ Diagrams (2M) ✓ Steps (3M)
3	**Explain DES in detail . (15M)** BTL2 **Answer:Page-**101 to 108 in William Stallings ✓ Definition (3M) **DES** key length and brute-force attacks. The Data Encryption Standard is a block cipher, **meaning** a cryptographic key and algorithm are applied to a block of data simultaneously rather than one bit at a time ✓ Structure (6M) ✓ Diagrams (6M)



	✓ Function (3M) ✓ Key generation (3M)
4	**Evaluate encryption and decryption using RSA algorithm for the following. p=7, q=11; e=17; m=8. (15M)** BTL3 **Answer:Page-247 to 249 in William Stallings** ✓ computing their system modulus N=p.q (2M) ✓ note ø(N)=(p-1)(q-1) ✓ STEPS(3M) ✓ to encrypt a message M the sender: ✓ obtains public key of recipient KU={e,N} ✓ computes: $C=M^e \bmod N$, where $0 \le M < N$ ✓ to decrypt the ciphertext C the owner: ✓ uses their private key KR={d,p,q} ✓ computes: $M=C^d \bmod N$ ✓ Encryption(5M) ✓ Decryption(5M)
5	**Evaluate using Diffie-Hellman key exchange technique.Users A and B use a common prime q=11 and a primitive root alpha=7.** **(i) If user A has private key XA=3.What is A's public key YA?** **(ii)If user B has private key XB=6. What is B's public key YB?** **(iii) What is the shared secret key? Also write the algorithm. (15M)** BTL3 **Answer:Page-208 to 211in William Stallings** ✓ prime *p*, element $g \in Z_p^*$ (5M) $h_A = g^x \bmod p$ $h_B = g^y \bmod p$ ✓ Encryption(5M) ✓ Decryption(5M)
6	**Estimate the encryption and decryption values for the RSA algorithm parameters. P=3, Q=11, E=7, d=?, M=5. (15M)** BTL3 **Answer:Page-247 to 249 in William Stallings** ✓ computing their system modulus N=p.q (2M) ✓ note ø(N)=(p-1)(q-1) ✓ STEPS(3M) ✓ to encrypt a message M the sender: ✓ obtains public key of recipient KU={e,N}

	✓ computes: $C=M^e \bmod N$, where $0 \leq M < N$ ✓ to decrypt the ciphertext C the owner: ✓ uses their private key KR={d,p,q} ✓ computes: $M=C^d \bmod N$ ✓ Encryption(5M) ✓ Decryption(5M)
7	**Implement RSA Algorithm for the given values, trace the sequence of calculations in RSA. P=7,q=13,e=5 and M=10. (15M)** BTL3 **Answer:Page-247 to 248 in William Stallings** ✓ computing their system modulus N=p.q (2M) ✓ note ø(N)=(p-1)(q-1) ✓ STEPS(3M) ✓ to encrypt a message M the sender: ✓ obtains public key of recipient KU={e,N} ✓ computes: $C=M^e \bmod N$, where $0 \leq M < N$ ✓ to decrypt the ciphertext C the owner: ✓ uses their private key KR={d,p,q} ✓ computes: $M=C^d \bmod N$ ✓ Encryption(5M) ✓ Decryption(5M)
8	**Users Alice and Bob use the Diffie Hellman Key exchange technique with a common prime q=83 and primitive root $\alpha = 5$.** **i) if Alice has a private key X_A=6,what is the Alice's public key Y_A?** **ii) If Bob has a private key XB=10, what is Bob's public key Y_B?** **iii) what is the shared secret key? (15M)** BTL3 **Answer:Page-325 to 329 in William Stallings** ✓ prime *p*, element $g \in Z_p^*$ (5M) $h_A = g^x \bmod p$ $h_B = g^y \bmod p$ ✓ Encryption(5M) ✓ Decryption(5M)

UNIT 3- HASH FUNCTIONS AND DIGITAL SIGNATURES
Authentication requirement – Authentication function – MAC – Hash function – Security of hash function and MAC –MD5 - SHA - HMAC – CMAC - Digital signature and authentication protocols – DSS – EI Gamal – Schnorr
PART * A

1	**What is message authentication?** BTL1 It is a procedure that verifies whether the received message comes from assigned source has not

	been altered. It uses message authentication codes, hash algorithms to authenticate the message
2	**Define the classes of message authentication function.** BTL1 Message encryption: The entire cipher text would be used for authentication. Message Authentication Code: It is a function of message and secret key produce a fixed length value Hash function: Some function that map a message of any length to fixed length which serves as authentication
3	**What are the requirements for message authentication?** BTL1 The requirements for message authentication are ✓ Disclosure ✓ Traffic analaysis ✓ Content modification ✓ Sequence modification ✓ Masquerade ✓ Timing modification ✓ Source repudiation ✓ Destination repudiation
4	**What do you mean by hash function?** BTL1 Hash function accept a variable size message M as input and produces a fixed size hash code H(M) called as message digest as output. It is the variation on the message authentication code
5	**Differentiate MAC and Hash function.** BTL3 MAC: In Message Authentication Code, the secret key shared by sender and receiver. The MAC is appended to the message at the source at a time which the message is assumed or known to be correct. Hash Function: The hash value is appended to the message at the source at time when the message is assumed or known to be correct. The hash function itself not considered to be secret
6	**Give any three hash algorithm.** BTL1 ✓ MD5 (Message Digest version 5) algorithm. ✓ SHA_1 (Secure Hash Algorithm). ✓ RIPEMD_160 algorithm.
7	**What are the requirements of the hash function?** BTL1 ✓ H can be applied to a block of data of any size. ✓ H produces a fixed length output. ✓ H(x) is relatively easy to compute for any given x, making both hardware and software implementations practical.
8	**What do you mean by MAC?** BTL1 MAC is Message Authentication Code. It is a function of message and secret key which produce a fixed length value called as MAC. MAC = $C_k(M)$ Where M = variable length message

	K = secret key shared by sender and receiver. CK(M) = fixed length authenticator.
9	**Differentiate internal and external error control**. BTL1 **Internal error control:** In internal error control, an error detecting code also known as frame check sequence or checksum. **External error control:** In external error control, error detecting codes are appended after encryption.
10	**What is the meet in the middle attack?** BTL1 This is the cryptanalytic attack that attempts to find the value in each of the range and domain of the composition of two functions such that the forward mapping of one through the first function is the same as the inverse image of the other through the second function-quite literally meeting in the middle of the composed function.
11	**What is the role of compression function in hash function?** BTL1 The hash algorithm involves repeated use of a compression function f, that takes two inputs and produce a n-bit output. At the start of hashing the chaining variable has an initial value that is specified as part of the algorithm. The final value of the chaining variable is the hash value usually b>n; hence the term compression.
12	**What is the difference between weak and strong collision resistance?** BTL1

Weak collision resistance	**Strong resistance collision**
For any given block x, it is computationally infeasible to fine y≠x wit H(y)=H(x). It is proportional to 2^n	It is computationally infeasible to find any pair (x,y) such that H(x)=H(y). It is proportional to $2^{n/2}$

13 **Compare MD5, SHA1 and RIPEMD-160 algorithm.**BTL2

	MD5	SHA-1	RIPEMD160
Digest length	128 bits	160 bits	160 bits
Basic unit of proce ssing	512 bits	512 bits	512 bits
No of steps	64(4 rounds of 16)	80(4 rounds of 20)	160(5 pairs rounds of 16)
Maximum message	infinity	2^{64}-1 bits	2^{64}-1 bits

Size			
Primitive logical Function	4	4	5
Additive constants Used	64	4	9
Endianess	Little end ian	Big endian	Little endian

14 **Distinguish between direct and arbitrated digital signature.** BTL 2

Direct digital signature	Arbitrated Digital Signature
✓ The direct digital signature involves only the communicating parties	✓ The arbiter plays a sensitive and crucial role in this digital signature
✓ This may be formed by encrypting the entire message with the sender's private key	✓ Every signed message from a sender x to a receiver y goes first to an arbiter A, who subjects the message and its signature to a number of test to check its origin and content

15 **What are the properties a digital signature should have?** BTL1

- ✓ It must verify the author and the data and time of signature.
- ✓ It must authenticate the contents at the time of signature.
- ✓ It must be verifiable by third parties to resolve disputes.

16 **What are the applications in RC4 algorithm?** BTL1

- ✓ WEP Protocol
- ✓ LAN Networks

17 **How is the security of a MAC function expressed?** BTL1

- ✓ Variable input size
- ✓ Fixed output size
- ✓ Efficiency
- ✓ Preimage resistant (one-way property)
- ✓ Second preimage resistant (weak Collison resistant)
- ✓ Collison Resistant (Strong Collision Resistant)
- ✓ Pseudorandomness

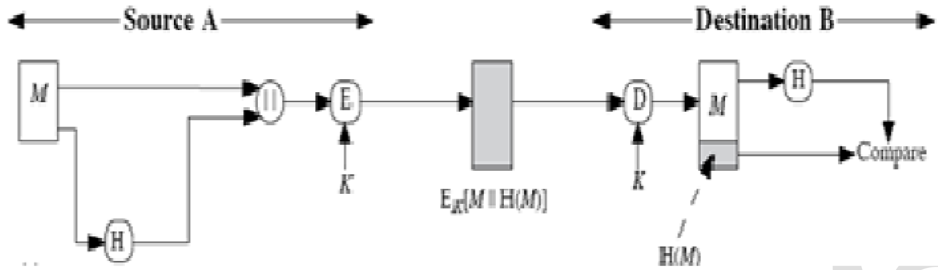
18 **Mention the significance of Signature function in DSS.** BTL1

The signature function also depends on the sender's private key (*PRa*) and a set of parameters known to a group of communicating principals. The signature function is such that only the sender, with knowledge of the private

	key, could have produced the valid signature.
19	**What is Elliptic curve?** BTL1 An elliptic curveis defined by an equation in two variables with coefficients. For cryptography, the variables and coefficients are restricted to elements in a finite field, which results in the definition of a finite abelian group.
20	**What are the two approaches of digital signatures?** BTL1 ✓ It must verify the author and the date and time of the signature. ✓ It must authenticate the contents at the time of the signature. ✓ It must be verifiable by third parties, to resolve disputes.
21	**What are the uses of RC4?** BTL1 ✓ Remarkably Simple And Quite Easy To Explain ✓ RC4 Is Used In The Wifi Protected Access (WPA) Protocol That Are Part Of The Ieee 802.11 Wireless Lan Standard ✓ RC4 Was Kept As A Trade Secret By RSA Security.
22	**What are the security services provided by Digital Signature?** BTL1 ✓ MD5 ✓ SHA
23	**What is Direct Digital Signature?** BTL1 The term **direct digital signature** refers to a digital signature scheme that involves only the communicating parties (source, destination). It is assumed that the destination knows the public key of the source.
24	**What are the requirements of Digital Signature?** BTL1 ✓ The signature must be a bit pattern ✓ The signature must use some information ✓ Signature must be relatively easy to produce the digital signature. ✓ Signature must be relatively easy to recognize and verify the digital signature. ✓ Signature must be computationally infeasible to forge a digital signature. ✓ Signature must be practical to retain a copy of the digital signature in storage.
25	**What is Schnorr Digital Signature Scheme?** BTL1 The Schnorr signature scheme isbased on discrete logarithms [SCHN89, SCHN91]. The Schnorr scheme minimizesthe message-dependent amount of computation required to generate a signature.The main work for signature generation does not depend on the message and can be done during the idle time of the processor.

	PART *B
1	**Explain Hash function. (13M) (AU Nov/Dec 2012)** BTL2 **Answer:Page-351 to 353 in William Stallings** ✓ Authentication function (2M) is a short piece of information used to authenticate a message—in other words, to confirm that the message came from the stated sender (its authenticity) and has not been changed. ✓ Hash Function function (2M) A hash function maps a variable-length data block or message into a fixed-length value called a hashcode.A variation on the message authentication code is the one way hash function. As with MAC, a hash function accepts a variable size message M as input and produces a fixed-size output, referred to as hash code H(M).

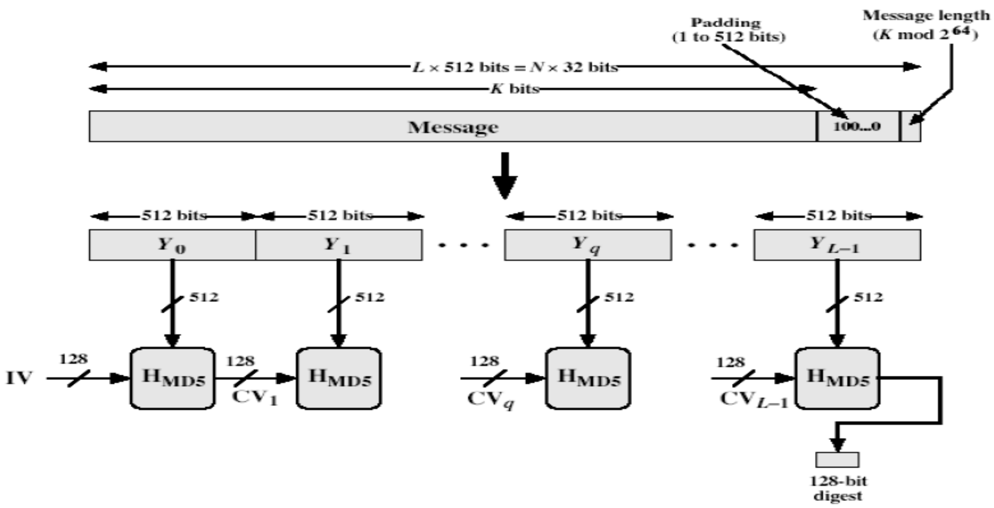
- ✓ Write in detail about MAC(2M)
- ✓ Derive the steps(1 M)
- ✓ Diagrams and cases(2M)



- ✓ Derive the steps(2M)
- ✓ Diagrams and cases(2M)

2 **Explain MD5 algorithm. (13M) (AU May/June 2012, Apr/May 2011)** BTL2
Answer:Page-353 to 355in William Stallings

- ✓ Basic properties of MD5 algorithm(2M)
- ✓ Padding(2M)
- ✓ Append value(1M)
- ✓ Divide input into 512 bit blocks(1M)
- ✓ Initializing chaining variables(2M)
- ✓ Process blocks(2M)

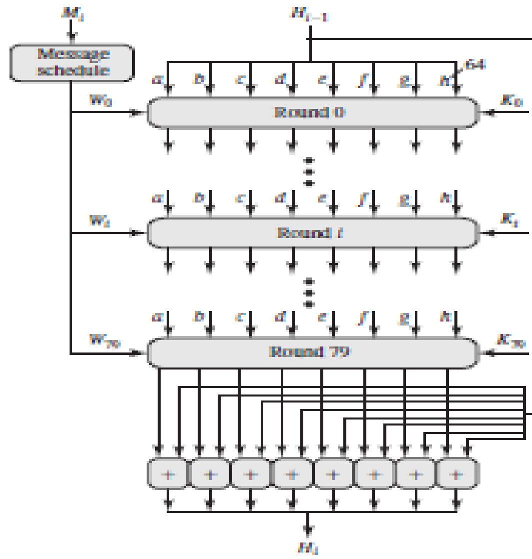


- ✓ Processing of rounds (3M)

3 **Explain Secure Hash algorithm. (13M) (Nov/Dec 2014,April/May 2013)** BTL2
Answer:Page-366 to 368in William Stallings

- ✓ Elaboration of Secure Hash algorithm(3M)
  - SHA was designed by NIST & NSA in 1993, revised 1995 as SHA-1
  - US standard for use with DSA signature scheme
  - standard is FIPS 180-1 1995, also Internet RFC3174
  - ***note:*** the algorithm is SHA, the standard is SHS
  - produces 160-bit hash values

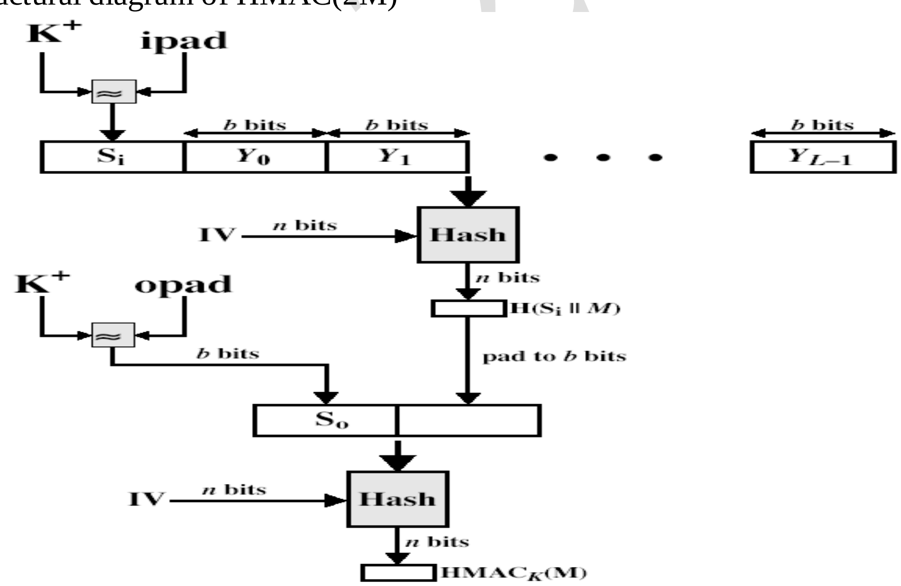
- ✓ Obtain original message(2M)
- ✓ Find same message digest in SHA512(2M)
- ✓ Explain the algorithm with steps(3M)
- ✓ Example with structural diagram(3M)



4 **Explain Hash Based Message Authentication Code and CMAC .(13M)** BTL2

Answer:Page-399 to 401in William Stallings

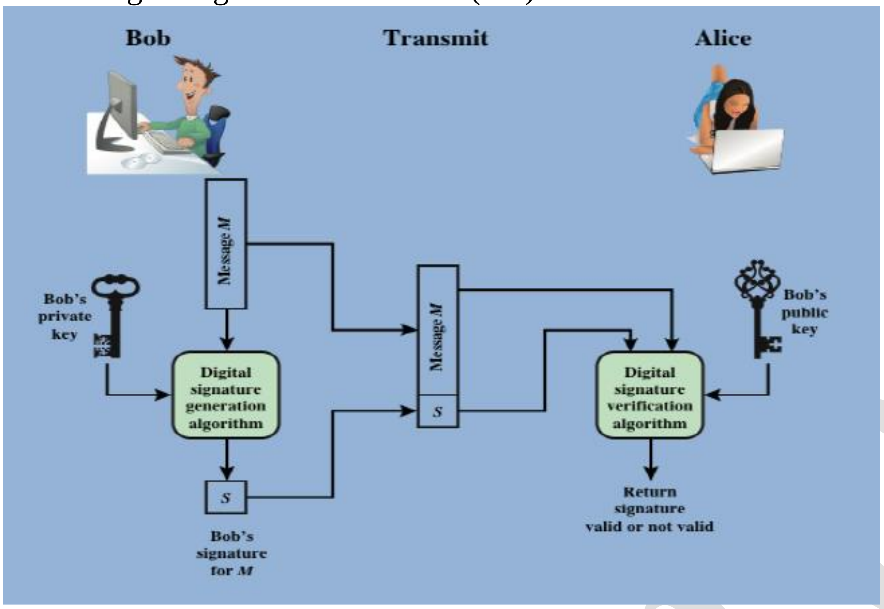
- ✓ Structural diagram of HMAC(2M)

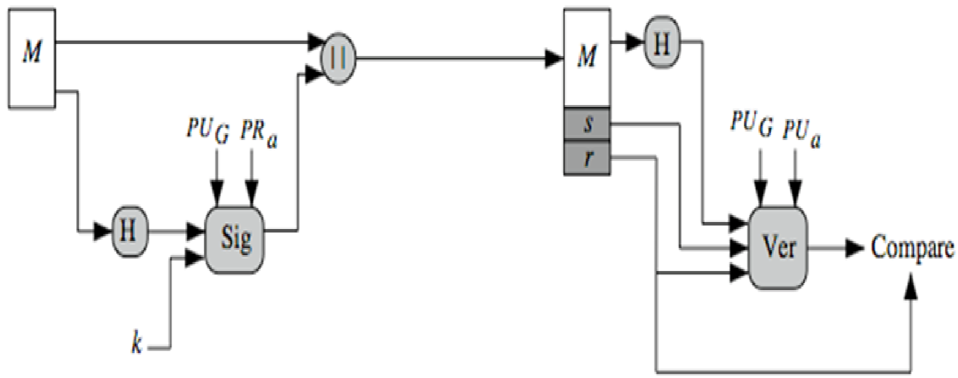


- ✓ Expand all the functions(2M)
- ✓ Explain with steps(1M)
- ✓ Creating length of two phases(3M)
- ✓ Appending (1M)
- ✓ Producing b-bit block(2M)
- ✓ Security of HMAC (2M)

5 **Explain Digital Signatures.(13M) (AU Nov/Dec 2011, May/June 2014)** BTL2

Answer:Page-420 to 422 in William Stallings

	✓ Digital signature mechanism (2M)  ✓ Requirements of Digital signature (3M) ✓ Types of Approaches(2M) ✓ Digital signature types (3M) ✓ Direct digital signature(1M) ✓ Arbitrated digital signature (2M)
6	**Explain Authentication protocol. (13M)** BTL2 **Answer:Page-386 to 389 in William Stallings** ✓ Mutual authentication(3M) ✓ Examples of Replay attack(1M) ✓ Symmetric encryption Approach(3M) ✓ Time stamps(1M) ✓ One say authentication(2M) ✓ Public key encryption approach (3M)
7	**Explain digital signature standard. (13M) (AU May/June 2014)** BTL2 **Answer: Page no.:427 to 429 in William Stallings** ✓ Digital signature algorithm designed to provide digital signature (3M) ✓ Diagrammatical expansion(3M) ✓ Digital signature algorithm(4M) ✓ Diagrammatical expansion of algorithm with various stages (3M)



8 **Explain in detail about EL-GAMAL Algorithm. (13M) (AU Nov/Dec 2013, May/June 2015)** BTL2

Answer:Page-424to 426 in William Stallings

- ✓ Public key crypto system based on concept of Diffie-Hellman key management(1M)
- ✓ Components(2M)
- ✓ El Gamal Key generation and steps to generate private and public keys(3M)
- ✓ El Gamal Encryption(3M)
- ✓ El Gamal Decryption(3M)
- ✓ Proof of Decryption(1M)

PART * C

1 **Explain message authentication requirement and its functions. (15M)** BTL2

Answer:Page-386 to 389in William Stallings

- ✓ Message requirement (3M)
- ✓ Message functions (3M)
- ✓ Security of MAC (3M)
- ✓ Key terms and reviews (3M)
- ✓ Authenticated encryption (3M)

2 **Explain Hash function and its Security. (15M)** BTL2

Answer:Page-351 to 354in William Stallings

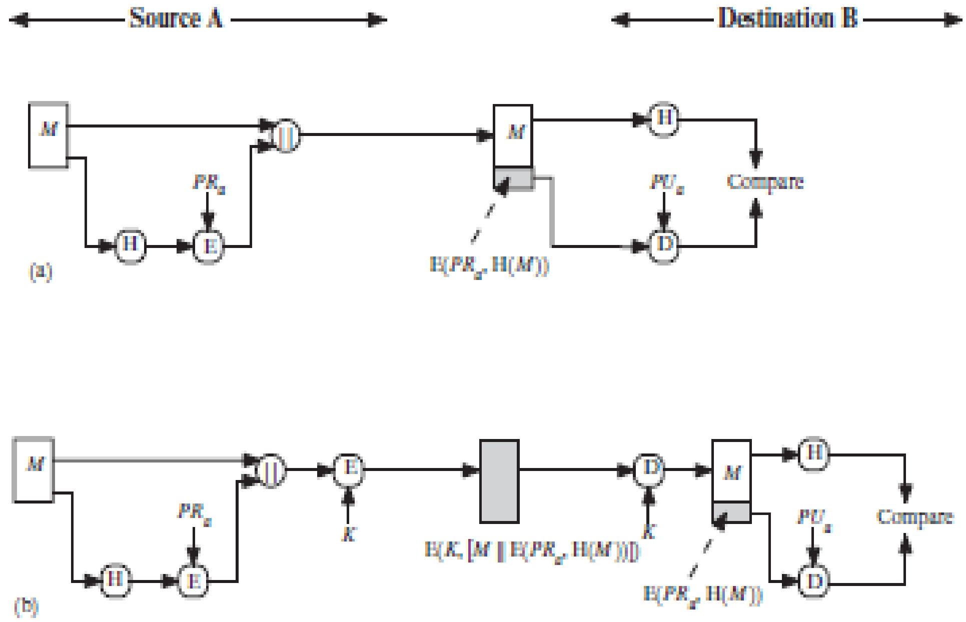
- ✓ Definition (2M)

A **hash function** H accepts a variable-length block of data *M* as input and producesa fixed-size hash value *h* = H(*M*). A "good" hash function has the property that theresults of applying the function to a large set of inputs will

	produce outputs that are evenly distributed and apparently random. ✓ Applications (3M) • Used to create a one-way password file. • Used for intrusion detection and virus detection • Used to construct a pseudorandomfunction (PRF) or a pseudorandom number generator (PRNG). ✓ Simple Hash Functions(3M) ✓ Requirements and Security (3M)

Requirement	Description
Variable input size	H can be applied to a block of data of any size.
Fixed output size	H produces a fixed-length output.
Efficiency	$H(x)$ is relatively easy to compute for any given x, making both hardware and software implementations practical.
Preimage resistant (one-way property)	For any given hash value h, it is computationally infeasible to find y such that $H(y) = h$.
Second preimage resistant (weak collision resistant)	For any given block x, it is computationally infeasible to find $y \neq x$ with $H(y) = H(x)$.
Collision resistant (strong collision resistant)	It is computationally infeasible to find any pair (x, y) with $x \neq y$, such that $H(x) = H(y)$.
Pseudorandomness	Output of H meets standard tests for pseudorandomness.

	✓ Cipher block chaining (4M)
3	**Explain Digital Signature and functions.(15M)** BTL2 **Answer:Page-420 to 422in William Stallings** ✓ Explanation (2M) The operation of the digital signature is similar to that of the MAC. In the case of the digital signature, the hash value of a message is encrypted with a user's private key. ✓ Properties (3M) ✓ Attacks and forgeries (2M) ✓ Diagrams (4M)

	 ✓ Requirements (4M)

UNIT-4 SECURITY PRACTICE & SYSTEM SECURITY	
Authentication applications – Kerberos – X.509 Authentication services - Internet Firewalls for Trusted System: Roles of Firewalls – Firewall related terminology- Types of Firewalls - Firewall designs - SET for E-Commerce Transactions. Intruder – Intrusion detection system – Virus and related threats – Countermeasures – Firewalls design principles – Trusted systems – Practical implementation of cryptography and security	
PART * A	
1	**Define Kerberos.** BTL1 Kerberos is an authentication service developed as part of project Athena at MIT. The problem that Kerberos address is, assume an open distributed environment in which users at work stations wish to access services on servers distributed throughout the network.
2	**What is Kerberos? Write its uses.** BTL1 Kerberos is an authentication service developed as a part of project Athena at MIT. Kerberos provides a centralized authentication server whose functions are to authenticate servers.
3	**What are the requirements defined by Kerberos?** BTL1 ✓ Secure ✓ Reliable ✓ Transparent ✓ Scalable
4	**In the content of Kerberos, What is realm?** BTL1 ✓ A full service Kerberos environment consisting of a Kerberos server, a no. of clients, no.of application server requires the following ✓ The Kerberos server must have user ID and hashed password of all participating users in its database. ✓ The Kerberos server must share a secret key with each server. Such an environment is referred to as "Realm".
5	**What is the purpose of X.509 standard?** BTL1 X.509 defines framework for authentication services by the X.500 directory to its users.X.509 defines authentication protocols based on public key certificates.
6	**List the 3 classes of intruder.** BTL1 ✓ Masquerader ✓ Misfeasor ✓ Clandestine user
7	**Define virus. Specify the types of viruses.** BTL1 A virus is a program that can infect other program by modifying them the modification includes a copy of the virus program, which can then go on to infect other program. Types: ✓ Parasitic virus ✓ Memory-resident virus ✓ Boot sector virus ✓ Stealth virus ✓ Polymorphic virus
8	**What is application level gateway?** BTL1

An application level gateway also called a proxy server; act as a relay of application-level traffic. The user contacts the gateway using a TCP/IP application, such as Telnet or FTP, and the gateway asks the user for the name of the remote host to be accessed.

9 **List the design goals of firewalls.** BTL1

- ✓All traffic from inside to outside, and vise versa, must pass through the firewall.
- ✓Only authorized traffic, as defined by the local security policy, will be allowed to pass.
- ✓The firewall itself is immune to penetration

10 **What are the steps involved in SET Transaction?** BTL1

The customer opens an account
The customer receives a certificate
Merchants have their own certificate
The customer places an order.
The merchant is verified.
The order and payment are sent.
The merchant requests payment authorization.
The merchant confirm the order.
The merchant provides the goods or services.
The merchant requests payment.

11 **What is dual signature? Write its purpose.** BTL1

The purpose of the dual signature is to link two messages that intended for two different recipients. To avoid misplacement of orders.

12 **What is the need for authentication applications?** BTL1

- ✓ Security for E-mail
- ✓ Internet protocol security
- ✓ IP address security.

13 **Differentiate public key encryption and conventional encryption.** BTL2

Conventional encryption	Public key encryption
Same algorithm with same key used for encryption and decryption	Same algorithm Is used for encryption and decryption with a pair of keys
Sender and receiver must share the algorithm and key	Sender and receiver have one of the matched pair key
Key must be kept secret.	Any one of the key must be kept secretly.

14 **What is message authentication?** BTL1

Message authentication is a process that verifies whether the recived message comes from assigned source has not been altered.

15 **Specify the requirements for message authentication.** BTL1

- ✓ Disclosure
- ✓ Traffic analysis
- ✓ Masquerade
- ✓ Content modification
- ✓ Sequence modification

	✓ Timing modification ✓ Repudiation.
16	**Specify the four categories of security threats.** BTL1 ✓ Interruption ✓ Interception ✓ Modification ✓ Fabrication
17	**What do you mean by SET? What are the features of SET?** BTL1 SET is an open encryption and security specification designed to protect credit card transaction on the Internet.
18	**Write any 3 hash algorithm.** BTL1 ✓ MD5 algorithm ✓ SHA-I ✓ RIPEMD-160 algorithm.
19	**What is worm?** BTL1 A worm is a program that can relicate itself and send copie s from computer to computer across network connections
20	**What is Bastion host?** BTL1 Bastion host is a system identified by firewall administrator as critical strong point in network security
21	**Write the four general techniques of firewall.** BTL1 ✓ Security control ✓ Direction control ✓ User control ✓ Behavior control
22	**Write the three types of firewall.** BTL1 ✓ Packet filter ✓ Application level gateway ✓ Circuit level gateway
23	**List approaches for intrusion detection.** BTL1 ✓ Statistical anomaly detection ✓ Rule based detection
24	**What is meant by SET? What are the features of SET?** BTL1 Secure Electronic Transaction (SET) is an open encryption and security specification designed to protect credit card transaction on the internet. Features are: ✓ Confidentiality of information ✓ Integrity of data ✓ Cardholder account authentication ✓ Merchant authentication
25	**What is Zombie?** BTL1 Zombie is a program that securely takes over another internet-attached computer and then uses that computer to launch attacks are difficult to trace the Zombie's creator.

PART * B

1 **Explain Authentication applications**. **(13M) (May/June 2015, May/June 2014)** BTL2

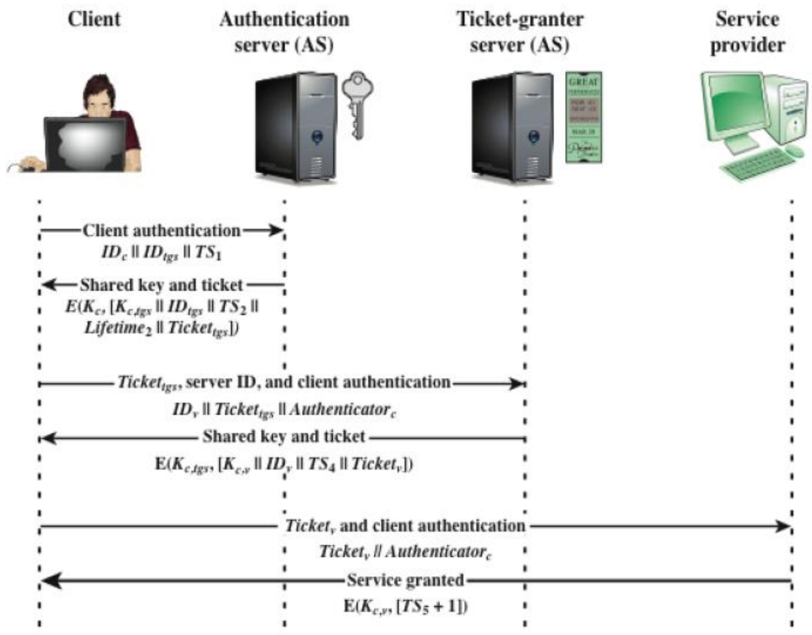
Answer:Page- 476 – William Stallings

- ✓ Kerberos

  It is an authentication service developed as part of project Athena at MIT. The problem that Kerberos address is, assume an open distributed environment in which users at work stations wish to access services on servers distributed throughout the network. It is an authentication protocol (2M)

- ✓ How Kerberos works

  It differs from username authentication methods because instead of authenticating each user to each network service, it uses symmetric encryption and a trusted third party to authenticate users to a suite of network services (2M)



- ✓ Kerberos Message Exchanges (3M)

(1) C → AS $ID_c \parallel ID_{tgs} \parallel TS_1$

(2) AS → C $E(K_c, [K_{c,tgs} \parallel ID_{tgs} \parallel TS_2 \parallel Lifetime_2 \parallel Ticket_{tgs}])$

$$Ticket_{tgs} = E(K_{tgs}, [K_{c,tgs} \parallel ID_C \parallel AD_C \parallel ID_{tgs} \parallel TS_2 \parallel Lifetime_2])$$

(a) Authentication Service Exchange to obtain ticket-granting ticket

(3) C → TGS $ID_v \parallel Ticket_{tgs} \parallel Authenticator_c$

(4) TGS → C $E(K_{c,tgs}, [K_{c,v} \parallel ID_v \parallel TS_4 \parallel Ticket_v])$

$$Ticket_{tgs} = E(K_{tgs}, [K_{c,tgs} \parallel ID_C \parallel AD_C \parallel ID_{tgs} \parallel TS_2 \parallel Lifetime_2])$$

$$Ticket_v = E(K_v, [K_{c,v} \parallel ID_C \parallel AD_C \parallel ID_v \parallel TS_4 \parallel Lifetime_4])$$

$$Authenticator_c = E(K_{c,tgs}, [ID_C \parallel AD_C \parallel TS_3])$$

(b) Ticket-Granting Service Exchange to obtain service-granting ticket

(5) C → V $Ticket_v \parallel Authenticator_c$

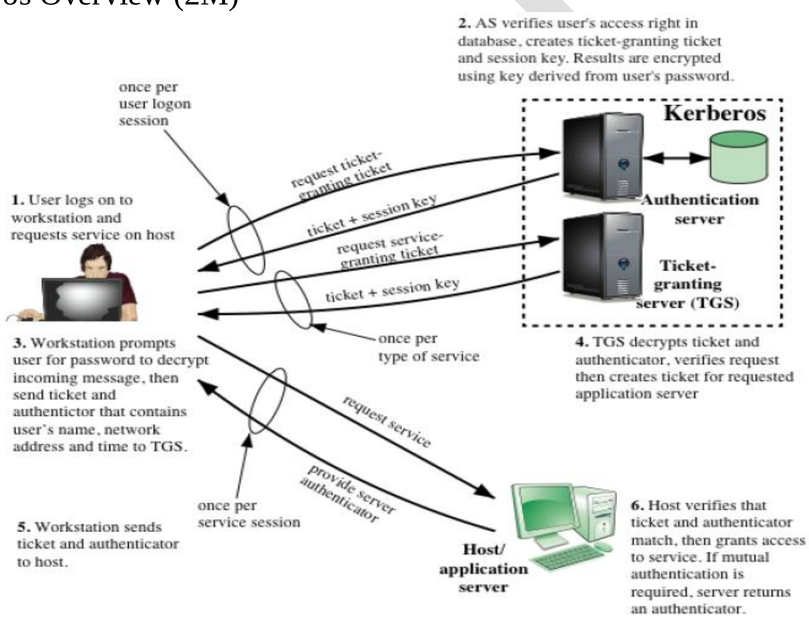
(6) V → C $E(K_{c,v}, [TS_5 + 1])$ (for mutual authentication)

$$Ticket_v = E(K_v, [K_{c,v} \parallel ID_C \parallel AD_C \parallel ID_v \parallel TS_4 \parallel Lifetime_4])$$

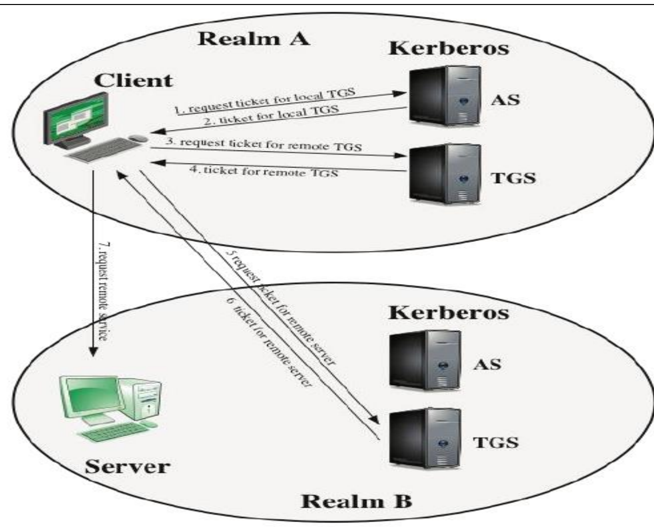
$$Authenticator_c = E(K_{c,v}, [ID_C \parallel AD_C \parallel TS_5])$$

(c) Client/Server Authentication Exchange to obtain service

✓ Kerberos Overview (2M)



✓ Kerberos Realm- A full-service Kerberos environment consisting of a Kerberos server, a number of clients, and a number of application servers. (2M)



- ✓ Difference between Kerberos 4 and 5 (1M)
- ✓ Kerberos Version 5 Message Exchanges (1M)

(1) C → AS $Options \| ID_c \| Realm_c \| ID_{tgs} \| Times \| Nonce_1$

(2) AS → C $Realm_c \| ID_C \| Ticket_{tgs} \| E(K_c, [K_{c,tgs} \| Times \| Nonce_1 \| Realm_{tgs} \| ID_{tgs}])$

$Ticket_{tgs} = E(K_{tgs}, [Flags \| K_{c,tgs} \| Realm_c \| ID_C \| AD_C \| Times])$

(a) Authentication Service Exchange to obtain ticket-granting ticket

(3) C → TGS $Options \| ID_v \| Times \| \| Nonce_2 \| \; Ticket_{tgs} \| Authenticator_c$

(4) TGS → C $Realm_c \| ID_C \| Ticket_v \| E(K_{c,tgs}, [K_{c,v} \| Times \| Nonce_2 \| Realm_v \| ID_v])$

$Ticket_{tgs} = E(K_{tgs}, [Flags \| K_{c,tgs} \| Realm_c \| ID_C \| AD_C \| Times])$

$Ticket_v = E(K_v, [Flags \| K_{c,v} \| Realm_c \| ID_C \| AD_C \| Times])$

$Authenticator_c = E(K_{c,tgs}, [ID_C \| Realm_c \| TS_1])$

(b) Ticket-Granting Service Exchange to obtain service-granting ticket

(5) C → V $Options \| Ticket_v \| Authenticator_c$

(6) V → C $E_{K_{c,v}} [\, TS_2 \| Subkey \| Seq\# \,]$

$Ticket_v = E(K_v, [Flags \| K_{c,v} \| Realm_c \| ID_C \| AD_C \| Times])$

$Authenticator_c = E(K_{c,v}, [ID_C \| Realm_c \| TS_2 \| Subkey \| Seq\#])$

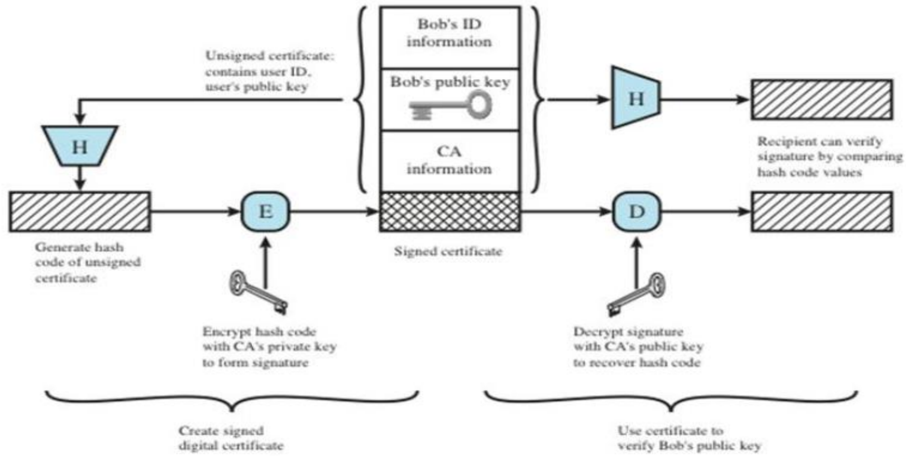
2 **Explain in detail about X.509. (13M) (May/June 2013)** BTL2

Answer:Page- 453 – William Stallings

- ✓ X 509Authentication service defines the structure of digital certificates
  X.509 defines framework for authentication services by the X.500 directory to its users.X.509 defines authentication protocols based on public key certificates. (2M)

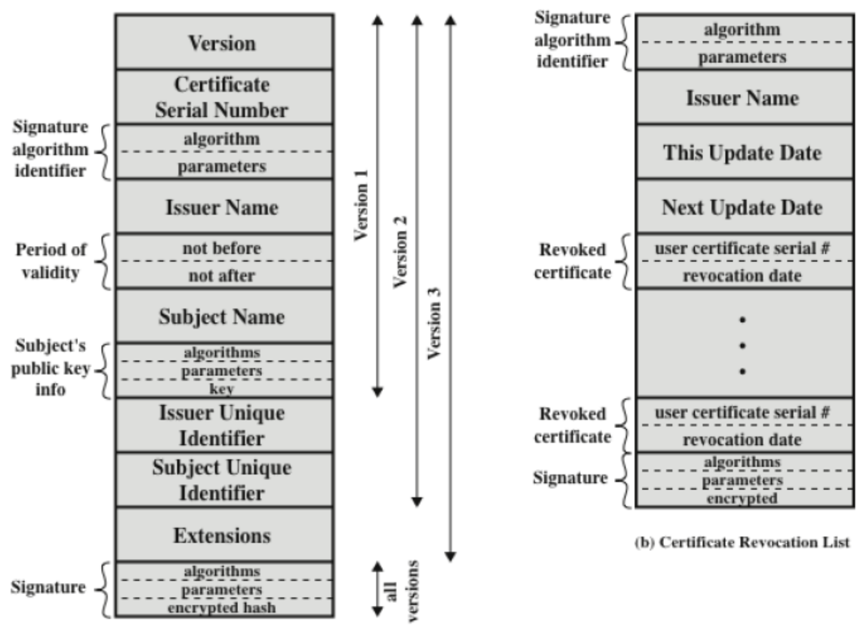
- ✓ X.509 Framework- Was initially issued in 1988 with the latest revision in 2000 .Based on the use of public-key cryptography and digital signatures .Does not dictate the use of a specific algorithm but recommends RSA.Does not dictate a specific hash algorithm (2M)

- ✓ Public Key Certificate Use



(3M)

✓ X.509 Format



(a) X.509 Certificate

(b) Certificate Revocation List

(3M)

✓ Obtaining Certificate (2M)

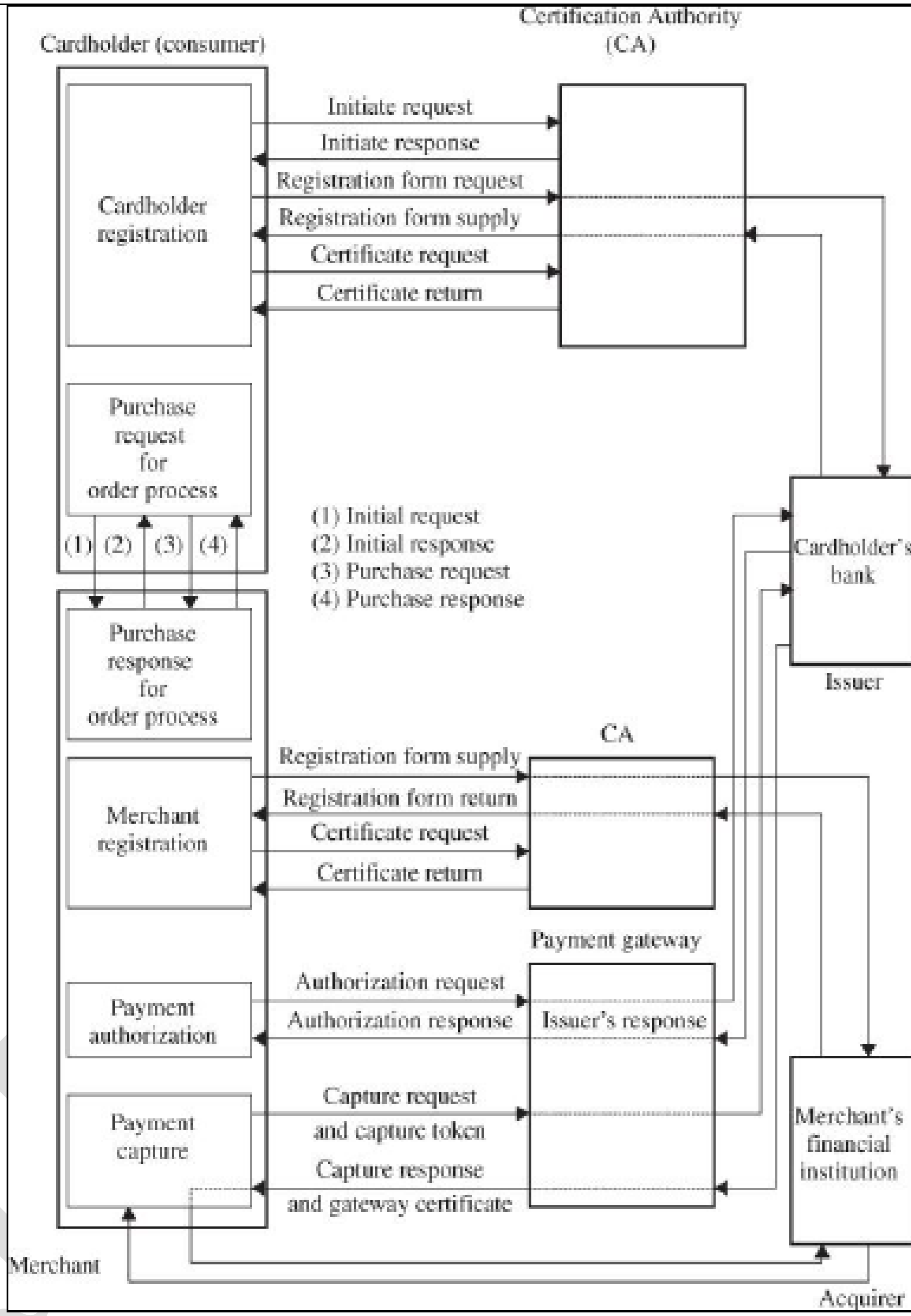
✓ Certificate Revocation (1M)

3 **Explain Secure Electronic Transaction. (13M) (Apr/May 2011, Nov/Dec 2011, Nov/Dec 2012)** BTL2

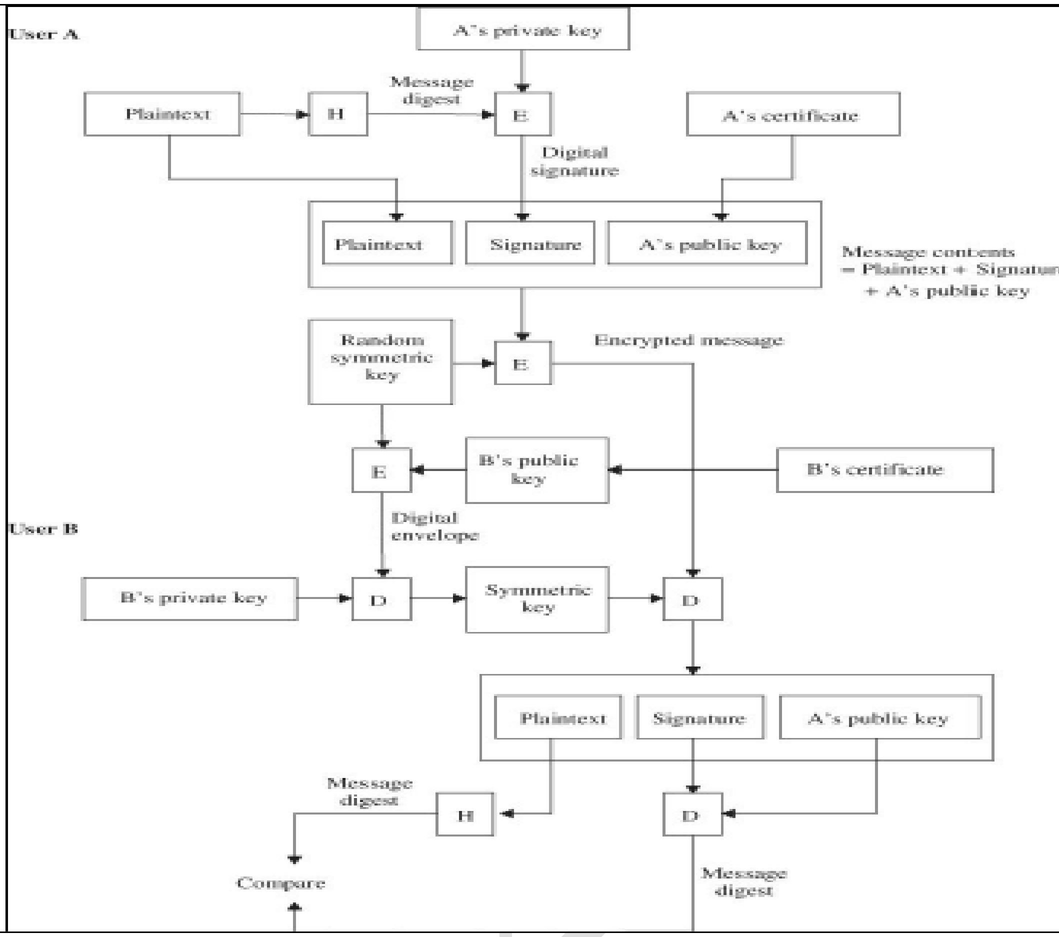
Answer:Page- 627 – William Stallings

SET(2M)

- ✓ Set of security protocol and formats enable user to employ existing infrastructure
  Secure Electronic Transaction (SET) is an open encryption and security specification designed to protect credit card transaction on the internet (2M)
- ✓ Services provided by SET (1M)
- ✓ Key features (1M)
- ✓ Business Requirements for SET (1M)
- ✓ SET System Participants (2M)
- ✓ Processing (3M)



- ✓ Encryption / Decryption (3M)



4 **Explain about Firewall and types of Firewall and Design of Firewall. (13M) (Apr/May 2011, Nov/Dec 2011, May/June 2012, Nov/Dec 2012, Nov/Dec 2013, May/June 2015)** BTL2

Answer:Page- 630 – William Stallings

- ✓ Firewall (1M)

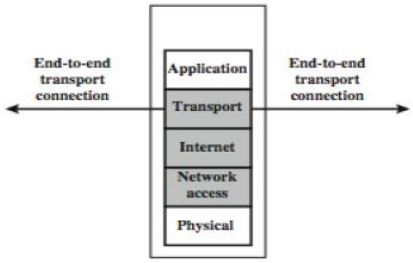
A **choke point** of control and monitoring,interconnects networks with differing trust,imposes restrictions on network services,only authorized traffic is allowed,auditing and controlling access ,can implement alarms for abnormal behavior

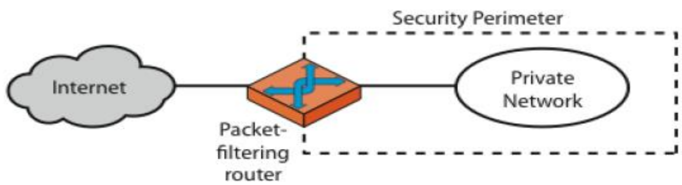
- ✓ Types of firewall

(i) Packet filtering router firewall

Protecting internal users from the external network threats is to implement this type of security (1M)

- ✓ Diagram(2M)



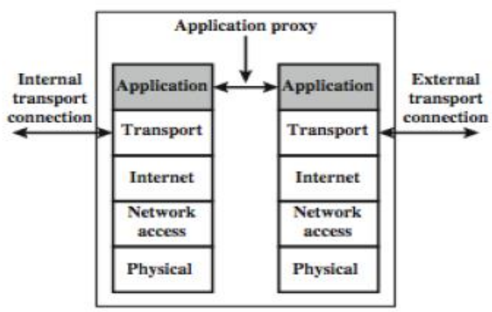


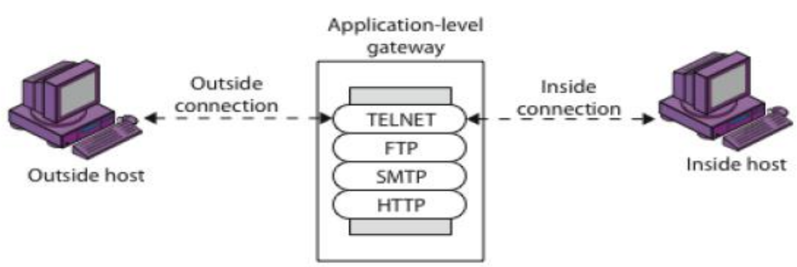
- ✓ Advantages and Disadvantages(1M)

(ii) Application Level Gateway

Have application specific gateway / proxy,has full access to protocol,user requests service from proxy ,proxy validates request as legal,then actions request and returns result to user,can log / audit traffic at application level (1M)

- ✓ Diagram(2M)



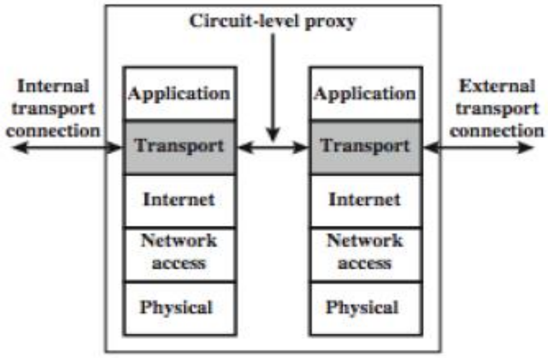


- ✓ Advantages and Disadvantages(1M)

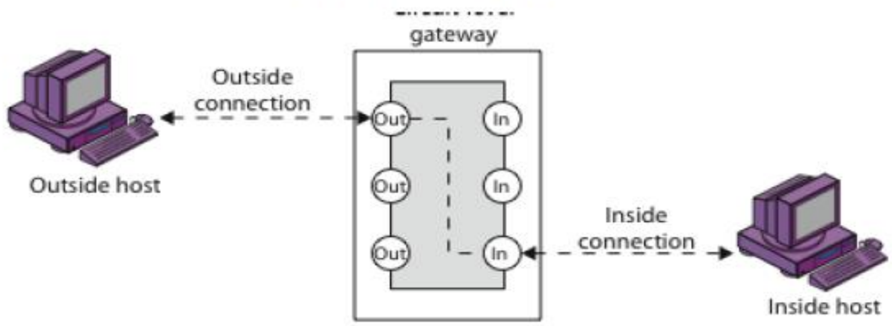
(iii) Circuit Level Gateway- relays two TCP connections,imposes security by limiting which such connections are allowed ,once created usually relays traffic without examining contents.(1M)

- ✓ Diagram(2M)

<table>
<tr><td></td><td>
✓ Advantages and Disadvantages(1M)

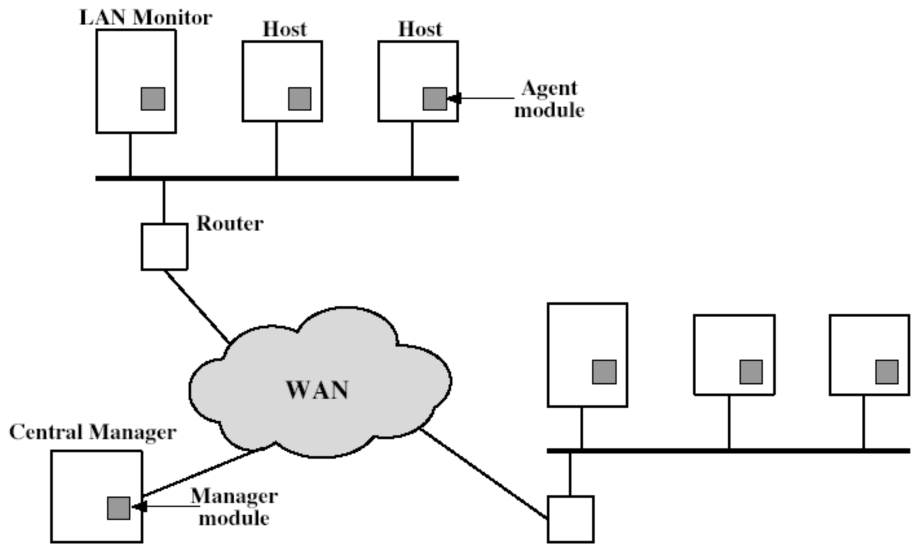


(e) Circuit-level proxy firewall



</td></tr>
<tr><td>5</td><td>
Explain in detail about Intrusion detection system. (13M) (Nov/Dec 2011, May/June 2014) BTL2
Answer:Page- 645 – William Stallings

✓ Intrusion Detection Systems look for attack signatures, which are specific patterns that usually indicate malicious or suspicious intent. (1M)
✓ Statistical anomaly detection
Involves the collection of data relating to the behavior of legitimate users over a period of time (2M)
✓ Rule based detection
Involves as a set of rules can be used to decide given behavior of an intruder (2M)
✓ Distributed intrusion detection
System should detect a substantial percentage of intrusion while keeping the false alarm rate at acceptable level. (2M)
✓ Rule based penetration identification (2M)
✓ Architecture for distribution intrusion detection – diagram (2M)
</td></tr>
</table>

	 ✓ LAN Monitor agent module Operates same as a host agent module except that is analyzes LAN traffic and reports the results to the central manager. (1M) ✓ Honey Pot Relatively recent innovation in intrusion detection technology (1M)
6	**Explain about Malicious software viruses. (13M) (May/June 2012, Nov/Dec 2012, May/June 2013, Nov/Dec 2013, May/June 2014, May/June 2015)** BTL2 **Answer:Page- 645 & 650 – William Stallings** ✓ Malicious programs Overall taxonomy of software threats (1M) ✓ Virus It is a program that can infect other programs by modify them (1M) ✓ Four phases Dormant phase Propagation phase Triggering phase Execution phase (1M) ✓ Virus structure Virus can be postpeneled to an executable program (1M) ✓ Types of virus Macro virus E mail virus Morris virus Worm (1M) ✓ Macro virus Platform independent virus infect the documents and easily spread (2M) ✓ E mail virus It spreads through mails, use of MS embedded in attachment (2M) ✓ Worm It seeks out more machines to infect and every machine that is infected serves as a launch is automatic padeling for attacks on other machines (2M) ✓ Virus counter measures (2M)

7. **Explain about Various types of Configurations or Firewall Designs in Firewall. (13M)** BTL2

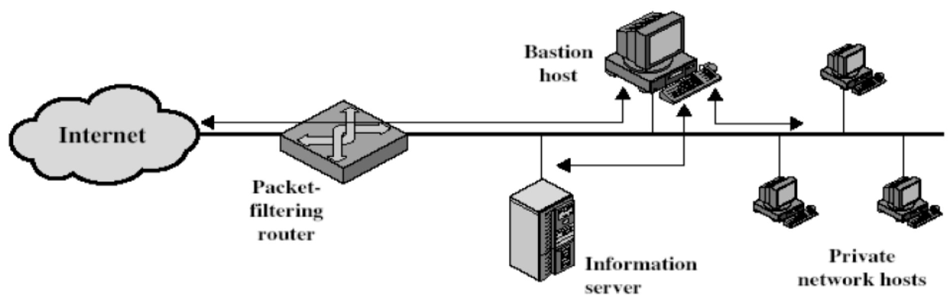
Answer:Page- 630 – William Stallings

The three basic firewall designs are considered: **a single-homed bastion host, a dual-homed bastion host, and a screened subnet firewall**.(1M)

(i) **Screened Host Firewall (Single-Homed Bastion Host)**

Uses a single-homed bastion host plus a packet-filtering router. Single-homed bastion hosts can be configured as either circuit-level or application-level gateways. When using either of these two gateways, each of which is called a *proxy server*, the bastion host can hide the configuration of the internal network.(1M)

✓ Diagram(2M)

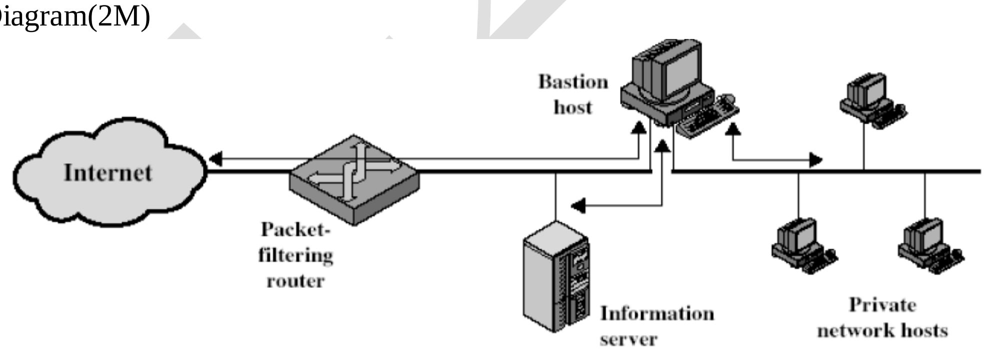


✓ Advantages and Disadvantages(1M)

(ii) Screened Host Firewall (Dual-Homed Bastion Host)

The configuration of the screened host firewall using a dual-homed bastion host adds significant security, compared with a single-homed bastion host. Dual-homed bastion host has two network interfaces. (1M)

✓ Diagram(2M)

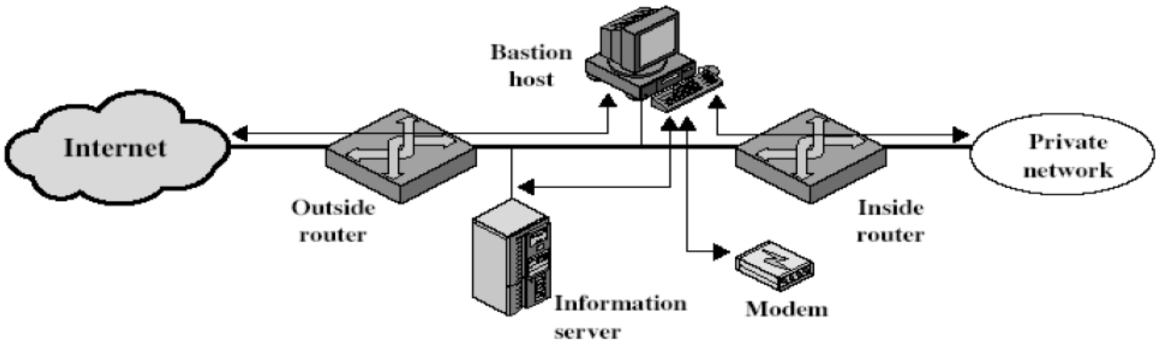


✓ Advantages and Disadvantages(1M)

(iii) **Screened Subnet Firewall**

The third implementation of a firewall is the screened subnet, which is also known as a *DMZ*. This firewall is the most secure one among the three implementations, simply because it uses a bastion host to support both circuit- and application-level gateways. All publicly accessible devices, including modem and server, are placed inside the DMZ. (1M)

✓ Diagram(2M)



✓ Advantages and Disadvantages(1M)

PART * C

1 **Explain Authentication applications. (15M)** BTL2

Answer:Page- 468 – William Stallings

✓ Kerberos

It is an authentication service developed as part of project Athena at MIT. The problem that Kerberos address is, assume an open distributed environment in which users at work stations wish to access services on servers distributed throughout the network. It is an authentication protocol (3M)

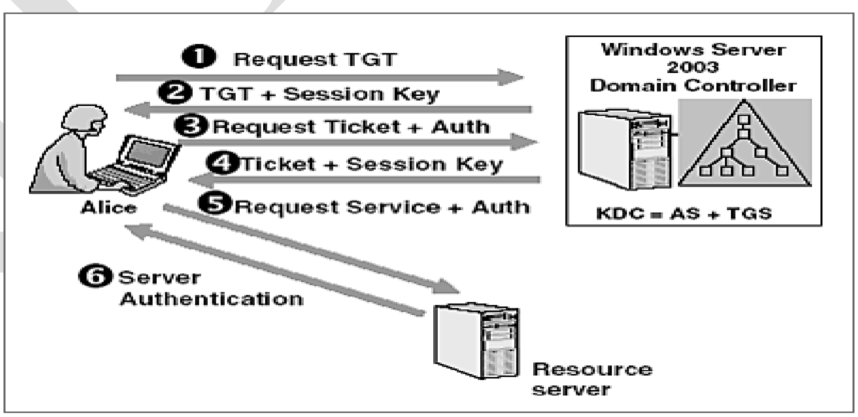
✓ How Kerberos works

It differs from username authentication methods because instead of authenticating each user to each network service, it uses symmetric encryption and a trusted third party to authenticate users to a suite of network services (3M)

✓ Steps with protocol (5M)

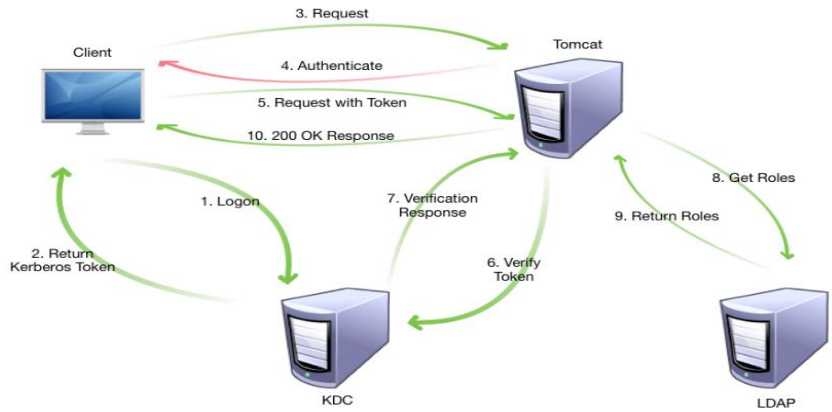
User client logon
Client authentication
Client service authentication
Client service request

✓ Diagram



(2M)

✓ Explanation of working methodology with diagram

<table>
<tr><td></td><td>

(2M)</td></tr>
<tr><td>2</td><td>Explain Internet Firewall and its related terminology. (15M) BTL2
Answer:Page- CHAPTER 22 – William Stallings
✓ Need for firewall
It is a mechanism that protects and isolates internal network (3M)
✓ Characteristics
Service control
Direction control
User control
Behavior control (3M)
✓ Types of firewall
Packet filter
Application level gateway
Circuit level gateway (3M)
✓ Firewall
The host is a system identified by the firewall administrator as a critical strong point in the network security (3M)
✓ Firewall location and configuration
The first type of firewall is a screened host which uses a single homes bastion host plus a packet filtering router. It uses two or more network interfaces
It is a network architecture that uses single firewall with 3 network interface.(3M)</td></tr>
</table>

UNIT 5- E-MAIL, IP & WEB SECURITY

E-mail Security: Security Services for E-mail-attacks possible through E-mail - establishing keys privacy-authentication of the source-Message Integrity-Non-repudiation-Pretty Good Privacy-S/MIME. IP Security: Overview of IPSec - IP and IPv6-Authentication Header-Encapsulation Security Payload (ESP)-Internet Key Exchange (Phases of IKE, ISAKMP/IKE Encoding). Web Security: SSL/TLS Basic Protocol-computing the keys- client authentication-PKI as deployed by SSL Attacks fixed in v3- Exportability-Encoding-Secure Electronic Transaction (SET).

PART * A

1 **Define key Identifier -** BTL1

PGP assigns a key ID to each public key that is very high probability unique with a user ID. It is also required for the PGP digital signature. The key ID associated with each public key consists of its least significant 64bits.

2 **List the limitations of SMTP/RFC 822? –** BTL1

- SMTP cannot transmit executable files or binary objects.
- It cannot transmit text data containing national language characters.
- SMTP servers may reject mail message over certain size.
- SMTP gateways cause problems while transmitting ASCII and EBCDIC.
- SMTP gateways to X.400 E-mail network cannot handle non textual data included in X.400 messages.

3 **Define S/MIME.** BTL1

Secure/Multipurpose Internet Mail Extension(S/MIME) is a security enhancement to the MIME Internet E-mail format standard, based on technology from RSA Data Security.

4 **What are the different between SSL version 3 and TLS?** BTL2

SSL	**TLS**
In SSL the minor version is 0 and major version is 3	In TLS, the major version is 3 and the minor version is 1
SSL use HMAC alg., except that the padding bytes concatenation	TLS makes use of the same alg
SSL supports 12 various alert codes	TLS supports all of the alert codes defined in SSL3 with the exception of no certificate

5 **What are the services provided by PGP services?** BTL1

- Digital signature
- Message encryption
- Compression
- E-mail compatibility
- Segmentation

6 **Why E-mail compatibility function in PGP needed?** BTL2

Electronic mail systems only permit the use of blocks consisting of ASCII text. To accommodate this restriction PGP provides the service converting the row 8-bit binary stream

	to a stream of printable ASCII characters. The scheme used for this purpose is Radix-64 conversion
7	**Name any cryptographic keys used in PGP.** BTL1 ✓ One-time session conventional keys. ✓ Public keys. ✓ Private keys. ✓ Pass phrase based conventional keys.
8	**Define S/MIME .**BTL1 Secure / Multipurpose Internet Mail Extension(S/MIME) is a security enhancement to the MIME internet E-mail format standard, based on technology from RSA Data security.
9	**What are the services provided by PGP services?** BTL1 ✓ Digital signature ✓ Compression ✓ Segmentation ✓ Message encryption ✓ E-mail compatibility
10	**Name any cryptographic keys used in PGP.** BTL1 ✓ One time session conventional keys ✓ Public keys ✓ Private keys ✓ Pass phrase based conventional keys.
11	**What is security association?** BTL1 A security association (SA) is the establishment of shared security attributes between two network entities to support secure communication.
12	**What does Internet key management in IPSec?** BTL1 Internet key exchange (IKE) is a key management protocol standard used in conjunction with the Internet Protocol Security (IPSec) standard protocol. It provides security for Virtual Private Networks (VPNs) negotiations and network access to random hosts.
13	**List out the IKE hybrid protocol dependence.** BTL1 ✓ ISAKMP - Internet Security Association and Key Management Protocols. ✓ Oakley
14	**What does IKE hybrid protocol mean?** BTL2 Internet Key Exchange (IKE) is a key management protocol standard used in conjunction with the internet protocol security (IPSec) standard protocol. It provides security for Virtual Private Networks (VPNs) negotiations and network access to random hosts.
15	**What are the two security services provided by IPSec?** BTL1 ✓ Authentication Header (AH) ✓ Encapsulating Security Payload (ESP).
16	**What are the fields available in AH header?** BTL1 ✓ Next header ✓ Payload length ✓ Reserved ✓ Security parameter ✓ Sequence number Integrity check value

17	**What is virtual private network?** BTL1 VPN means virtual private network, a secure tunnel between two devices.
18	**What is ESP?** BTL1 ESP-encapsulating security payload provides authentication, integrity and confidentiality, which protect against data tempering and provide message content protection
19	**What is Behavior-Blocking Software (BBS)?** BTL1 BBS integrates with the OS of a host computer and monitors program behavior in real time for malicious actions.
20	**List password selection strategies.** BTL1 ✓ User education ✓ Reactive password checking ✓ Computer-generated password. ✓ Proactive password checking.

Part * B	
1	**Explain about Email Security. (13M)** BTL2 **Answer:Page- 591 – William Stallings** ✓ Modes of Operation Authentication Confidentiality Compression e-mail compatibility (2M) ✓ Tunnel mode It provides the protection to the entire IP Packet (1M) ✓ Transport mode It provides protection primarily for upper layer protocols (1M) ✓ Internet key exchange protocol Manual Automated (2M) ✓ Security Association It provides a framework for internet key management and provides the specific protocol support including formats (1M) ✓ Contents of SAD ✓ It represent a specification of security services offered to traffic carried through a in-directional channel from one node to another (1M) ✓ Authentication Header ✓ It is used to provide connectionless integrity and data origin authentication for IP

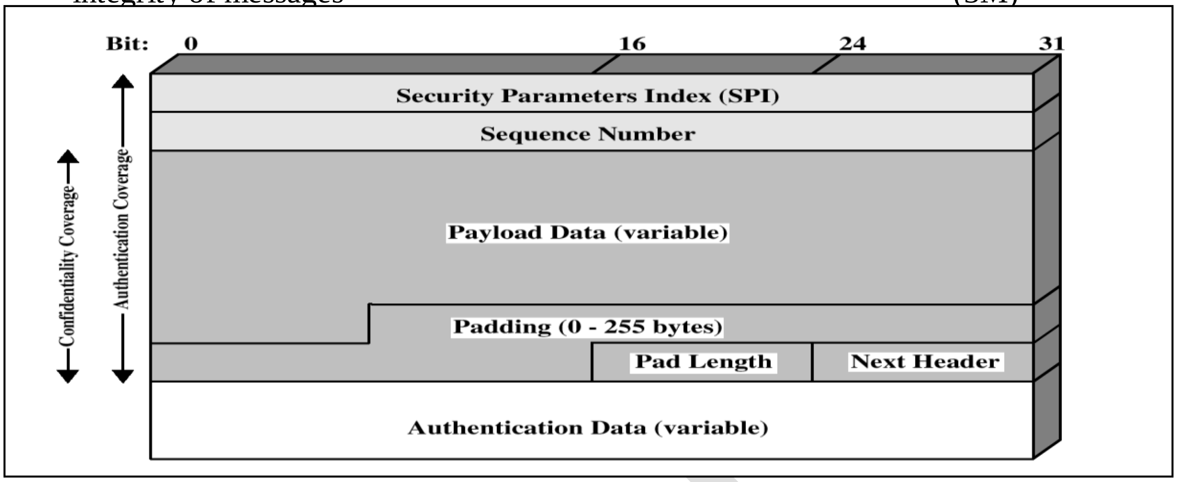
	datagrams (1M) ✓ Authentication Header fields (1M) Access control Connectionless integrity Data origin authentication Confidentiality ✓ Anti Replay Attacks It is a sub protocol of IPsec that is part of Internet engineering task force. The main goal is to avoid hackers injecting or making changes in packets that travel from a source to destination (1M) ✓ Values in sliding window (2M)
2	**Explain in detail about IPSEC. (13M)** BTL2 **Answer:Page- 640 – William Stallings** ✓ IP v4 Specifies an IPv4 address or range of addresses that are authorized senders for a domain (2M) ✓ IP v6 Specifies an IPv6 address or range of addresses that are authorized senders for a domain. (2M) ✓ AH tunnel modes It authenticates the entire inner IP packet selected portion of outer IP header (1M) ✓ IP header An IP header is header information at the beginning of an IP packet which contains information about IP version, source IP address, destination IP address, time-to-live (2M) ✓ New IP header (1M) ✓ TCP header TCP is the primary transport protocol used to provide reliable, full-duplex connections. The most common use of TCP is to exchange TCP data encapsulated in an IP datagram. (2M) ✓ Original data It refers to any data object that hasn't undergone thorough processing, either manually or through automated computer software. (2M) ✓ Original IP header (1M)

3

Explain Encapsulating security payload. (13M) BTL2

Answer:Page- 651 – William Stallings

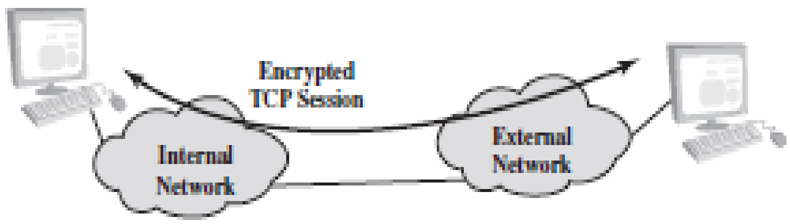
- ✓ ESP consists of an encapsulating header and trailer used to provide encryption or combined encryption/ authentication. The current specification is RFC 4303, IP Encapsulating Security Payload (ESP).The purpose is to provide confidentiality and integrity of messages (3M)



- ✓ ESP Transport mode (1M)

  Transport mode ESP is used to encrypt and optionally authenticate the data carried by IP

- ✓ Operation of ESP Transport mode (4M)

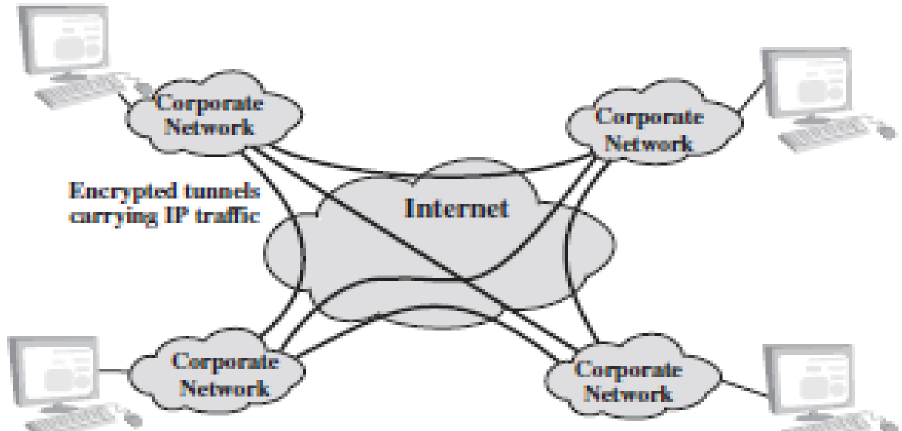
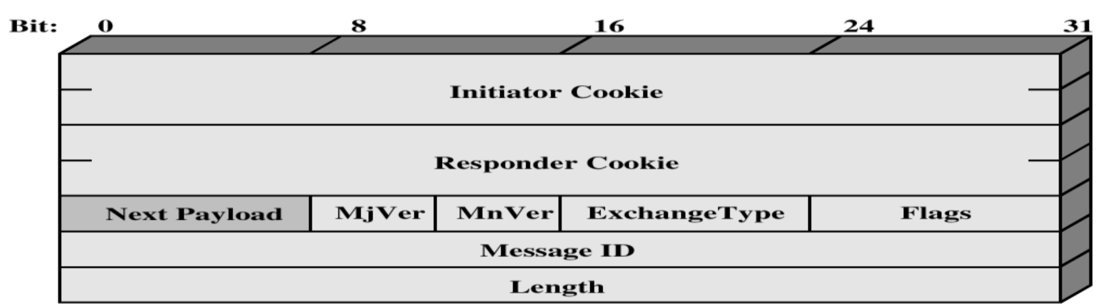
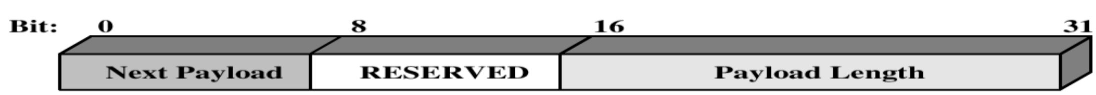


(a) Transport-level security

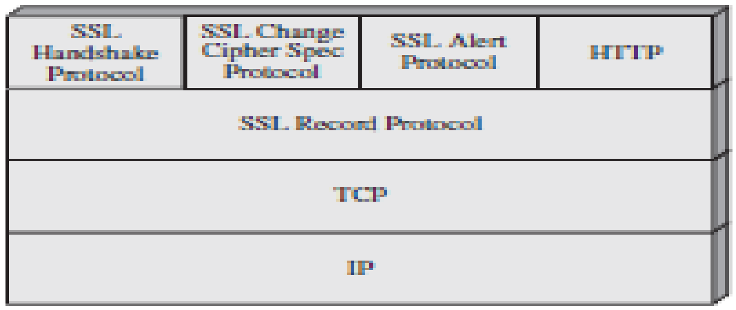
- ✓ ESP tunnel mode

  Tunnel mode ESP is used to encrypt an entire IP packet. For this mode, the ESP header is prefixed to the packet and then the packet plus the ESP trailer is encrypted. This method can be used to counter traffic analysis (1M)

- ✓ Operation of ESP tunnel mode (4M)

	 (b) A virtual private network via tunnel mode
4	**Explain Internet security Association and Key Management Protocol. (13M)** BTL2 **Answer:Page- 663 – William Stallings** ✓ Procedures and formats for establishing maintaining and deleting Security Association information (1M) ✓ IP Seckey management (2M) ✓ Initiator cookie (1M) ✓ Responder cookie (1M) ✓ Major and minor version (3M) ✓ Message ID (1M) ✓ Length (1M) ✓ Payloads (2M)  (a) ISAKMP Header  (b) Generic Payload Header ✓ Exchange types (1M)
5	**Explain about WEB security. (13M) (Apr/May 2011, Nov/Dec 2011, Nov/Dec 13, May/June 2015)** BTL2 **Answer:Page- 510 – William Stallings** ✓ Secure socket layer

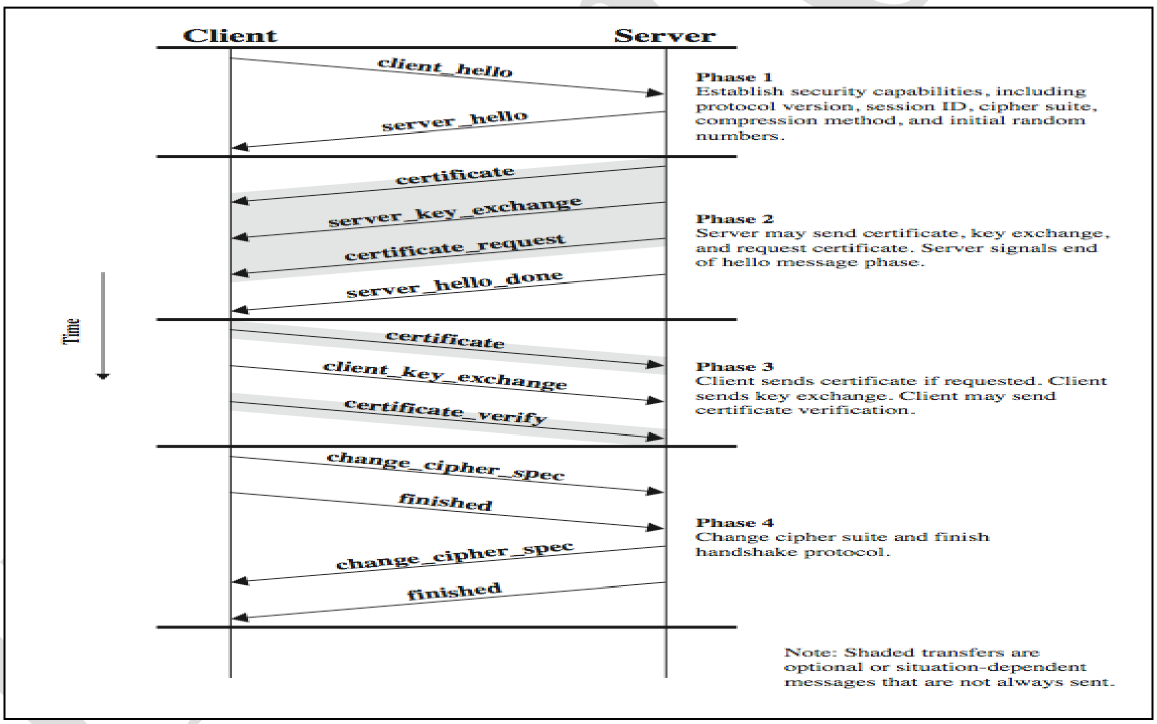
It is the standard security technology for establishing an encrypted link between a web server and a browser. This link ensures that all data passed between the web server and browsers remain private and integral. (2M)



- ✓ How SSL works

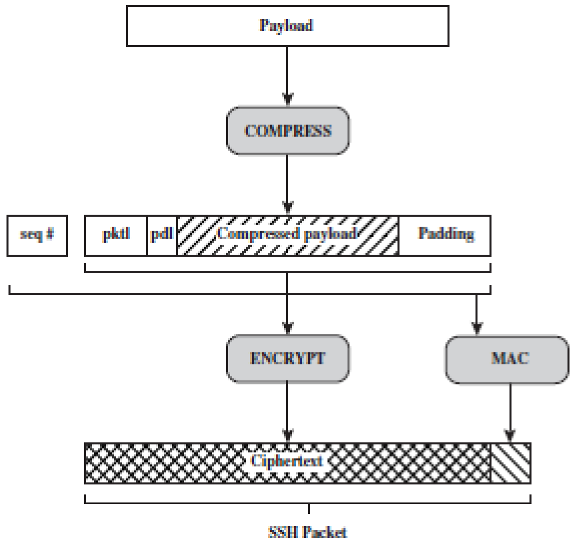
After connection is made, the session key is used to encrypt all transmitted data. Browser connecte to a web serer secured with SSL and request the server identity. Server sends a copy of its SSL certificate (2M)

- ✓ Handshake protocol (2M)

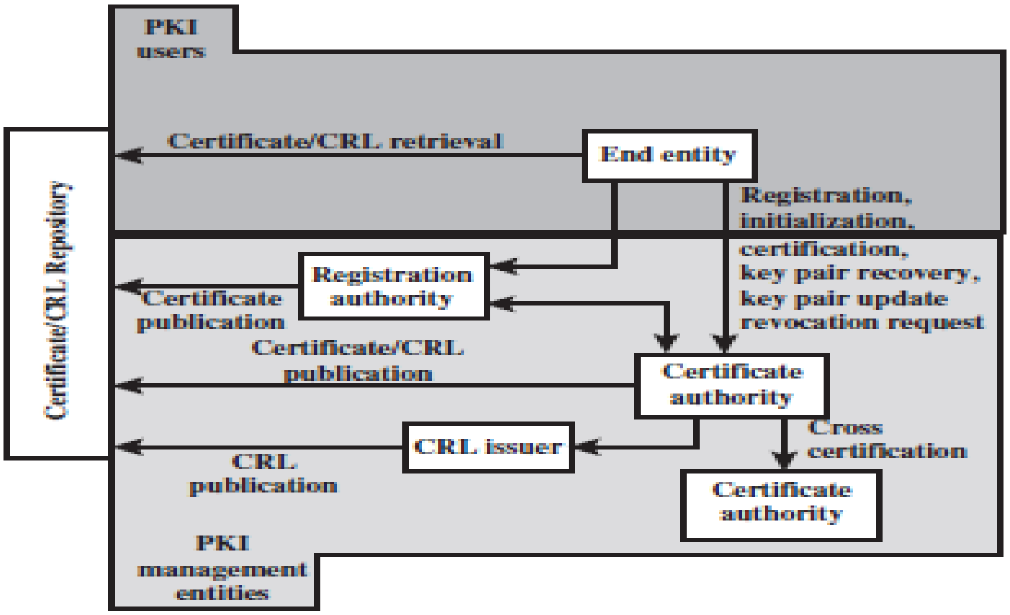


- ✓ Change cipher spec protocol (1M)
- ✓ Record protocol (1M)
- ✓ Alert protocol (1M)
- ✓ Fatal alerts (2M)
- ✓ Transport layer security (2M)

Definition
Architecture
Parameter
Architecture Diagram

	 pktl = packet length pdl = padding length
6	**Explain public key infrastructure. (13M) (Nov/Dec 2013)** BTL2 **Answer:Page- 515 – William Stallings** ✓ It is a model for creating, distributing and revoking certificates based on X.509. A set of policies, processes, server platforms, software and workstations used for the purpose of administering certificates and public-private key pairs, including the ability to issue, maintain, and revoke public key certificates (1M) ✓ End entity A generic term used to denote end users, devices (e.g., servers, routers), or any other entity that can be identified in the subject field of a public-key certificate. End entities typically consume and/or support PKIrelated services (1M) ✓ Certification authority The issuer of certificates and (usually) certificate revocation lists (CRLs). It may also support a variety of administrative functions, although these are often delegated to one or more Registration Authorities. (2M) ✓ Registration authority An optional component that can assume a number of administrative functions from the CA. The RA is often associated with the end entity registration process but can assist in a number of other areas as well. (2M) ✓ CRI issuer An optional component that a CA can delegate to publish CRLs (1M) ✓ Repository A generic term used to denote any method for storing certificates and CRLs so that they can be retrieved by end entities. (1M)

✓ PKI Architecture – Diagram (2M)



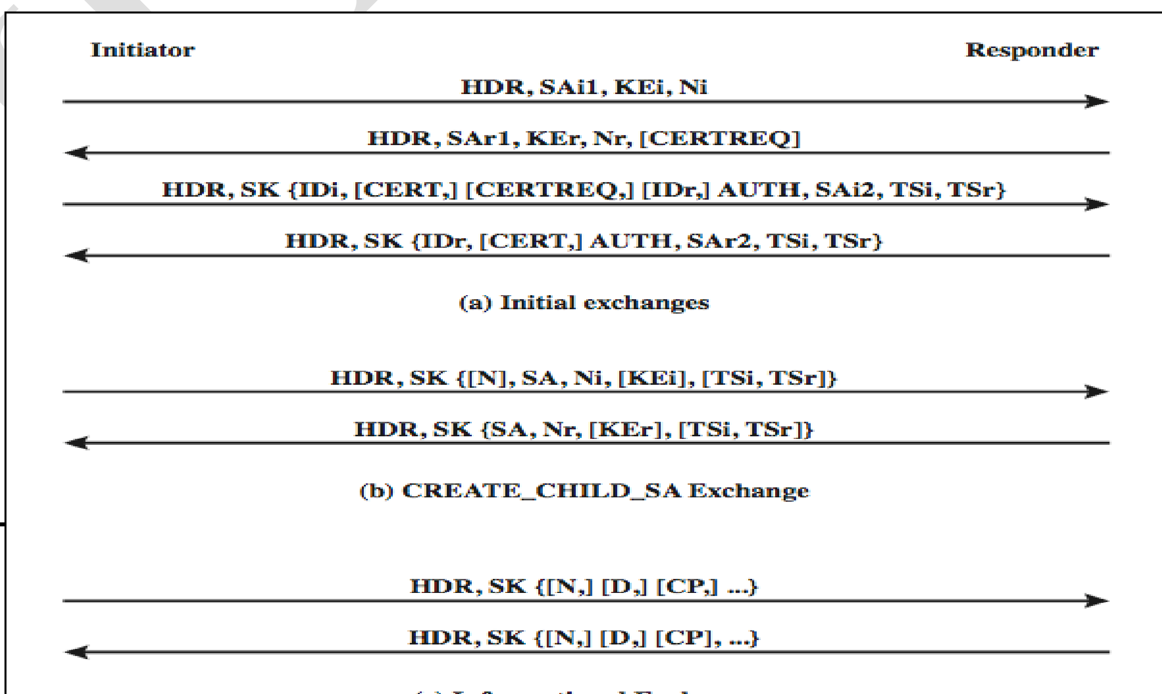
✓ PKI management functions (2M)

- Registration
- Initialization
- Certification
- Key pair recovery
- Key pair update
- Revocation request
- Cross certification

✓ PKI management protocols (1M)

	PART * C
1	**Explain E-mail security. (15M)** BTL2 **Answer:Page- 591 – William Stallings** ✓ Security Services for E-mail (2M) ✓ Possible Attacks through E-mail (2M) ✓ Establishing Keys privacy (2M) ✓ Authentication of source (2M) ✓ Message Integrity (2M)

	✓ NonRepudiation (1M) ✓ PGP (2M) ✓ S/MIME (2M)
2	**Explain IP Security. (15M)** BTL2 **Answer:Page- 639 – William Stallings** ✓ Security policy (3M) Security Parameters Index (SPI) IP Destination Address Security Protocol Identifier ✓ Encapsulating security payload (3M) Diagram Format Algorithm ✓ Internet key exchange (3M) Manual Automated OKDP ISAKMP ✓ Cryptographic suites (3M) ESP encryption ESP integrity IKE encryption IKE PRF IKE Integrity IKE DH group ✓ Diagrams (3M)



3 **Explain Web Security. (15M)** BTL2

Answer:Page- 510 – William Stallings

- ✓ Secure socket layer (3M)

  It is designed to make use of TCP to provide a reliable end-to-end secure service.
  Connection
  Session

- ✓ Protocols and its working (3M)

  Confidentiality
  Message Integrity
  fragmentation
  compression
  message authentication code

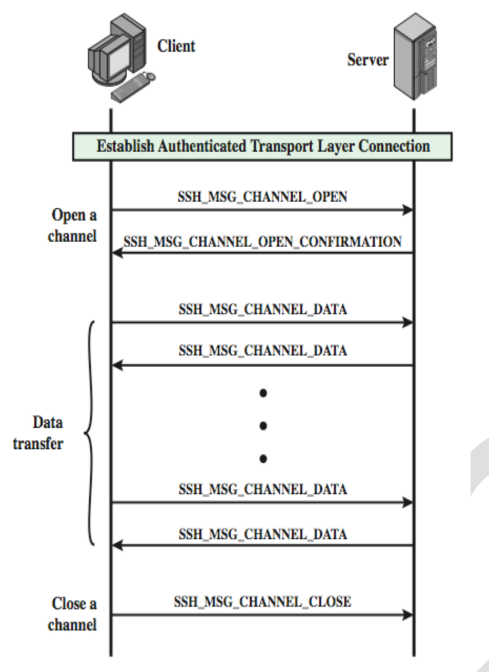
- ✓ differentiation of SSL and TSL (4M)

BASIS FOR COMPARISON	SSL	TLS
Cryptography secret	Uses message digest of the pre-master secret for creating master secret.	Uses a pseudorandom function to create master secret.
Record protocol	Uses MAC (Message Authentication Code)	Uses HMAC (Hashed MAC)
Alert protocol	The "No certificate" alert message is included.	It eliminates alert description (No certificate) and adds a dozen other values.
Message authentication	Ad hoc	Standard
key material authentication	Ad hoc	Pseudorandom function

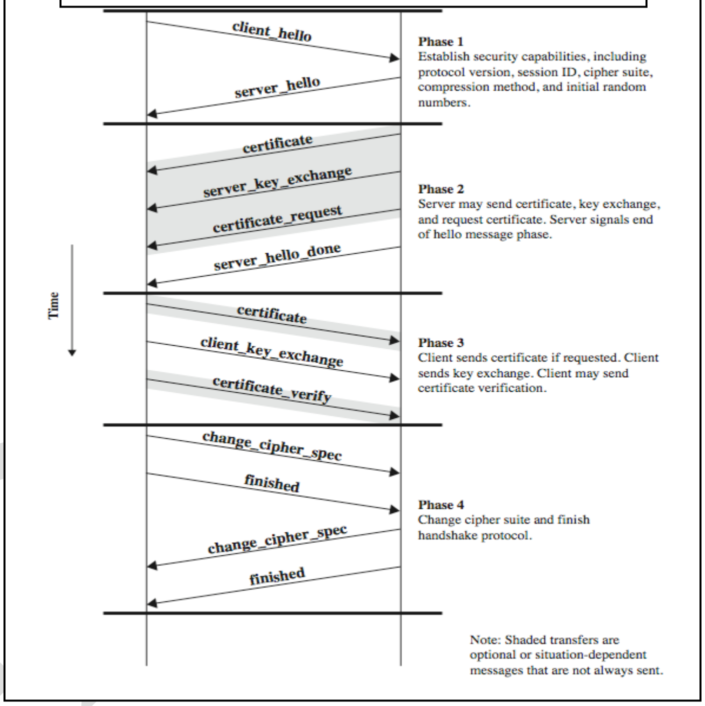
Certificate verify	Complex	Simple
Finished	Ad hoc	Pseudorandom function

✓ Diagrams (5M)

SSH Protocol Exchange



SSL Handshake Protocol



CS6702 GRAPH THEORY AND APPLICATION L T P C

3 0 0 3

OBJECTIVES:

The student should be made to:

- Be familiar with the most fundamental Graph Theory topics and results.
- Be exposed to the techniques of proofs and analysis.

UNIT I INTRODUCTION 9

Graphs – Introduction – Isomorphism – Sub graphs – Walks, Paths, Circuits –Contentedness – Components – Euler graphs – Hamiltonian paths and circuits – Trees – Properties of trees – Distance and centers in tree – Rooted and binary trees.

UNIT II TREES, CONNECTIVITY & PLANARITY 9

Spanning trees – Fundamental circuits – Spanning trees in a weighted graph – cut sets – Properties of cut set – All cut sets – Fundamental circuits and cut sets – Connectivity and separability – Network flows – 1-Isomorphism – 2-Isomorphism – Combinational and geometric graphs – Planer graphs – Different representation of a planer graph.

UNIT III MATRICES, COLOURING AND DIRECTED GRAPH 8

Chromatic number – Chromatic partitioning – Chromatic polynomial – Matching – Covering – Four color problem – Directed graphs – Types of directed graphs – Digraphs and binary relations – Directed paths and connectedness – Euler graphs.

UNIT IV PERMUTATIONS & COMBINATIONS 9

Fundamental principles of counting - Permutations and combinations - Binomial theorem - combinations with repetition - Combinatorial numbers - Principle of inclusion and exclusion - Derangement - Arrangements with forbidden positions.

UNIT V GENERATING FUNCTIONS 10

Generating functions - Partitions of integers - Exponential generating function – Summation operator - Recurrence relations - First order and second order – Non-homogeneous recurrence relations - Method of generating functions. **TOTAL: 45 PERIODS**

OUTCOMES:

Upon Completion of the course, the students should be able to:

- Write precise and accurate mathematical definitions of objects in graph theory.
- Use mathematical definitions to identify and construct examples and to distinguish examples from non-examples.

- Validate and critically assess a mathematical proof.
- Use a combination of theoretical knowledge and independent mathematical thinking in creative investigation of questions in graph theory.
- Reason from definitions to construct mathematical proofs.

TEXT BOOKS:

- **Narsingh Deo, "Graph Theory: With Application to Engineering and Computer Science"**, Prentice Hall of India, 2003.
- **Grimaldi R.P. "Discrete and Combinatorial Mathematics: An Applied Introduction",** Addison Wesley, 1994.

REFERENCES:

- **Clark J. and Holton D.A, "A First Look at Graph Theory",** Allied Publishers, 1995.
- **Mott J.L., Kandel A. and Baker T.P. "Discrete Mathematics for Computer Scientists and Mathematicians"** , Prentice Hall of India, 1996.
- **Liu C.L., "Elements of Discrete Mathematics"**, Mc Graw Hill, 1985.
- **Rosen K.H., "Discrete Mathematics and Its Applications"**, Mc Graw Hill, 2007.

Subject code:CS6702 **Year \ Semester: IV \ 07**

Subject Name: GRAPH THEORY AND APPLICATION Subject handler: J.Arokia Mary.

	UNIT I – Introduction
	Graphs – Introduction – Isomorphism – Sub graphs – Walks, Paths, Circuits –Connectedness – Components – Euler graphs – Hamiltonian paths and circuits – Trees – Properties of trees – Distance and centers in tree – Rooted and binary trees.
	PART * A
Q.No	**Questions**
1.	**Define Graph.** BTL1 A graph $G = (V, E)$consists of a set of objects $V = \{v_1, v_2, v_3,...\}$ called vertices and other set $E = \{e_1, e_2, e_3, ...\}$ whose elements are called edges. The set $V(G)$ is called the vertex set of 'G'and $E(G)$ is the edge set of *'G'*.
2	**Define Euler graph.** BTL 1 A path in a graph '*G'* is called Euler path if it includes every edges exactly once. Since the path contains every edge exactly once, it is also called **Euler trail or Euler path.** A **closed Euler path** is called **Euler circuit.** A graph which contains an Eulerian circuit is called an **Euler or Eulerian Graph.**
3	**Show that an Euler graph is connected except for any isolated vertices the graph may have. (APR/MAY 2017)** BTL 2 Since an isolated vertices are present in Euler graph and every vertices must be even. i.e., every vertex is connected in an Euler graph. So an Euler graph is connected except for any isolated vertices.
4	**Can there be a path longer than a Hamiltonian path (if any) in a simple connected undirected graph? Why? (APR/MAY 2017)** BTL 4 No, there is no path longer than a Hamiltonian path. Hamiltonian path in a simple, connected, undirected graph is the longest path as it includes all the vertices.
5	**Define Walk. (NOV/ DEC 2016) (APR/ MAY 2018)** BTL 1 Let '*G'* be a graph, a walk in '*G'* is an alternating sequence of vertices and edges, starting at a vertex and ending with another vertex and involving '*n'* edges. The length of a walk is its number of edges.
6	**Define path. (APR/ MAY 2018)** BTL 1 If no vertex of the walk occurs more than once, then the walk is called a path. It may also called open walk.

7	**Define Circuit in a graph.** BTL1 If no edges in the walk is repeated, then the walk is called a trail. A closed trail is called a circuit.
8\	**What is meant by eccentricity? (NOV/ DEC 2016)** BTL 2 The **eccentricity** *E(v)* of a vertex *v* in a graph '*G*' is the distance from *v* to the vertex farthest from 'v 'in 'G'; that is, $E(v) = \max_{v_i \in G} d(v, v_i)$. A vertex with minimum eccentricity in graph '*G*' is called a **Centre** of '*G*'.
9	**Write any two properties of tress.** BTL 1 • There is one and only one path between every pair of vertices in a tree. • A tree with 'n' vertices has '$n-1$' edges.
10	**Determine the number of vertices for a graph G, which has 15 edges and each vertex has degree 6. Is the graph G be a simple graph? (NOV/DEC 2017, 2018)** BTL 3 We know that "The sum of degree of all the vertices in a graph' G', is even". No. edges = 15 Degree of each vertex = 6 $\sum_{i=1}^{n} d(v_i) = 2E.$ $\therefore (6)(v) = 2(15)$ $v = 5.$
11	**Suppose G is a finite cycle free connected graph with at least one edge. Show that G has at least two vertices of degree 1. (NOV/DEC 2017)** BTL 3 Let '*G*' be a finite cycle free connected graph of '*p*' vertices so that the number of edges $q = p - 1,$ we know that the sum of degree of all vertices is twice the number of edges. That is, sum of degree of all vertices = $2q = 2(p-1) = 2p - 2.$ This total degree are distributed among the '*p*' vertices. $\therefore$ There must be at least two vertices of degree less than 2. $\because$ the graph is free from isolated vertices no vertex can be of zero degree. $\therefore$ at least two vertices must be of degree one each. Hence there are at least two pendent vertices in a graph.
12	**State the properties of binary tree. (APR/ MAY 2018)** BTL 1 • The number of vertices '*n*' in a binary tree is always odd. • Let '*p*' be the number of pendant vertices in a binary tree' *T*', then $p = \frac{n+1}{2}$
13	**Define complete graph.** BTL 1

	A simple graph is called a complete graph where every pair of distinct vertices are adjacent. If '*G* ' has '*n*' vertices then the complete graph will be denoted by k_n.
14	**Define Bipartite graph.** BTL 1 A graph '*G'* with '*V'* vertices whose set vertices can be portioned into two sets 'V_1' and 'V_2' is such a way that each edge joins a vertex in 'V_1' to a vertex in 'V_2' and no edge joins either two vertices in ' V_1 'or two vertices in 'V_2'.
15	**Explain isomorphism between graphs.** BTL 1 Two graph *G* and *G'* are isomorphic if there is a function $f: v(G) \rightarrow v(G')$ from the vertices of *G* to the vertices of *G'* such that i. *f* is one to one ii. *f* is onto and **iii.** For each pair of vertices *u* and *v* of *G* $[u, v] \in E(G) \leftrightarrow [f(u), f(v)] \epsilon E(G')$ Any function *f* with the above three properties is called an isomorphism from *G* to G' **.**
16	**State handshaking theorem.** BTL 1 For any graph 'G' with '*E'* edges and '*V'* vertices $v_1, v_2, \ldots$ Each edge contributes two degree in a graph. (i.e)., $\sum_{i=1}^{n} d(v_i) = 2E.$
17	**Show that the sum of degree of all vertices in a graph G, is even.** BTL 3 Each edge contribute two degree in a graph. Also, each edge contributes one degree to each of the vertices on which it is incident. Hence if there are '*N'* edges in 'G', then $2N = d(v_1) + d(v_2) + \ldots + d(v_N)$. Thus '*2N'* is always even**.**
18	**Determine the sequence (5, 4, 3, 2, 1) is graphic.** BTL 5 No, It cannot form a graphic since (5+4+3+2+1=15) sum of degree is odd, which contradict the statement 'The sum of degree of all vertices in a graph is even'.
19	**"A complete graph be a regular graph" - Justify.** BTL 4 A graph in which all vertices are of equal degree is called a regular graph. If the degree of each vertex is '*r'*, then the graph is called a regular graph of degree '*r'*. Yes, a complete graph is always a regular, but converse need not true.
20	**What is the degree sequence of K_n, where n is a positive integer? Explain your answer.** BTL 4 Each of the '*n'* vertices are adjacent to each of the other '*n-1'* vertices, so the degree sequence is $n-1, n-1, \ldots, n-1$ (n terms).
21	**Write few problems solved by the application of graph theory.** BTL 4 • Konigsberg bridge problem.

	• Utilities problem. • Electrical network problems. • Seating problem.
22	**Define** i. **Self- loop** ii. **Parallel edges** iii. **Simple graph.** BTL 1 An edge having the same vertex as its end vertices is called a **self-loop**. More than one edge associated a given pair of vertices called **parallel edges**. A graph that has neither self-loop nor parallel edges is called **simple graph**.
23	**Define Connected graph.** BTL 1 A graph '*G*' is said to be connected if there is at least one path between every pair of vertices in '*G*'. Otherwise, '*G*' is disconnected.
24	**Define** i. **Tree.** ii. **Rooted tree.** BTL 1 A **tree** is a connected graph without any circuits. A tree in which one vertex (called the root) is distinguished from all the other is called a **rooted tree**.
25	**Define Rooted binary tree.** BTL 1 There is exactly one vertex of degree two (root) and each of remaining vertex of degree one or three.
	PART * B
1	
	A graph G is disconnected if and only if its vertex set V can be partitioned into non-empty, disjoint subsets V_1 and V_2 such that there exist no edge in G whose one end vertex is in V_1 and the other in V_2. (8 M) BTL 5 **Answer: Page: 1.51- Dr. G. Balaji** **Connected graph:** At least one path between every pair of vertices (1 M) **Walk:** An alternating sequence of vertices and edges, starting at a vertex and ending with another vertex and involving '*n*' edges. (1 M) **Path:** no vertex of the walk occurs more than once. (1 M) **Bipartite graph:** Set of vertices can be portioned into two sets. (1 M) **Disconnected graph:** the vertices of the graph is partitioned. **Components:** The connected subgraphs of a graph *G*. (3M)
2	
	List few properties of Trees and prove them and Explain eccentricity from root. (16M) (NOV/ DEC 2016) (APR/ MAY 2017) BTL 2

	Answer: Page: 1.95, 1.97 & 1.102- Dr. G. Balaji **Tree:** A connected acyclic graph. (3 M) **Properties:** ● Exactly one path between every pair of vertices in tree. ● A tree with '*n*' vertices has '*n-1*' edges. ● In any tree with (2 or more vertices) there are at least 2 pendent vertices. ● Minimally connected graph. ● *'G'* is cycle and has' *n-1'* edges. ● *'G'* is connected and has' *n-1'* edges. ● *'G'* is connected and having no cycle. (7M) **Eccentricity:** $E(v) = \max_{v_i \in G} d(v, v_i)$. (1M) **Binary tree:** Exactly one vertex of degree two (root) remaining vertex of degree one or three. (1 M) Give an example. (5 M)
3	**Show that the maximum number of edges in a simple graph with *n* vertices is $\frac{n(n-1)}{2}$.** **(8M) (NOV/ DEC 2016)** BTL 5 **Answer: Page: 1.15 - Dr. G. Balaji** **Simple graph:** Neither self-loop nor parallel edges. (1 M) **Loops:** Same vertex as its end vertices. (1 M) **Parallel edges:**More than one edge associated a given pair of vertices.(1 M) **Degree: N**umber of edges incident on it. (1 M) **Fundamental theorem of Graph theory statement:** $\sum_{i=1}^{n} d(v_i) = 2E.$ (1 M) **Fundamental theorem of Graph theory proof:** $2E = \{d(v_1) + d(v_2) + \ldots + d(v_n)\}$. Thus '*2E'* is always even**.** (1 M) **The degree of the simple graph with *n* vertices:** 2*E = n +n + … +n (n times)* *2E = n(n-1)* $\Rightarrow E = \frac{n(n-1)}{2}$. (2 M)
4	**Prove that if a graph has exactly two vertices of odd degree, there must be path joining these two vertices.(8M) (NOV/ DEC 2016)** BTL 5 **Answer: Page : 1.88 - Dr. G. Balaji** **Tree:** A connected graph without cycle. (1 M) **Connected graph:**At least one path between every pair. (1 M) **Walk:**An alternating sequence of vertices and edges (1 M) **Path:** An open walk. (1 M) **Degree:**The number of edges incident to the vertex. **Odd degree:** Odd number of edges incident on a vertex. **Even degree:** Even number of edges incident on a vertex. (1 M)

	Components: The connected subgraphs of a graph '*G'*. (1 M) If a graph has exactly two vertices of odd degree, there must be path joining these two vertices in the same components. (2 M)
5	**Prove that any two simple connected graph with n vertices, all of degree two are isomorphic. (8M) (NOV/ DEC 2016)** BTL 5 **Answer: Page: 1.43 - Dr. G. Balaji** **Simple graph:**Neither self-loop nor parallel edges. (1 M) **Connected graph:**At least one path between every pair of vertices (1 M) **Handshaking statement:**,$\sum_{i=1}^{n} d(v_i) = 2E.$ (1 M) **Isomorphism:** One-one correspondence between vertices and edges such that incidence preserved . *(all 2-regular graphs are isomorphic to each other).* (1 M) **Regular graph:** All vertices are of equal degree. (1 M) **2- Regular graph:**All vertices are of degree 2 is called cyclic. (1 M) **Any two simple connected graph with n vertices:** $\sum_{i=1}^{n} d(v_i) = 2\|E\|.$ $\Rightarrow 2 + 2 + 2 + \cdots + 2(n \text{ times}) = 2E.$ $\Rightarrow n = \|E\|$. (2 M)
6	**State and Prove the Necessary and Sufficient condition for existence of Euler Graph. (16 M)** BTL 1 **Answer: Page: 1.58 - Dr. G. Balaji** **Euler Path:**Contains each edge of the graph exactly once. (1 M) **Eulerian Circuit or Eulerian Cycle:**Includes each edge of '*G'* exactly once. (1 M) **Eulerian graph or Euler graph:** Containing an Eulerian circuit or cycle. (1 M) **Necessary and Sufficient condition:** A connected graph is Euler graph if and only if each of its vertices is of even degree. (3 M) Explain the necessary and sufficient condition (10M)
7	**State and Prove Ore's Theorem.(12 M)** BTL 1 **Answer: Page: 1.75 - Dr. G. Balaji** **Hamiltonian Path :** Includes each vertex of 'G' exactly once. (1 M) **Hamiltonian circuit or cycle:** Includes each vertex of '*G'* exactly once. (1 M) **Hamiltonian Graph:** Containing a Hamiltonian circuit. (2 M) **Ore's Theorem statement:** If G is a simple graph with number of vertices 'n' (≥ 3) and if *deg(u) +deg(v)* $\geq n$ for every pair of non- adjacent vetices u and v, then G is Hamiltonian.(3M) Contradiction to our hypothesis: $\deg(u) + \deg(v) = \|S\| + \|T\| = \|S \cup T\| \leq n-1$ (5 M)
8	**The figure 1 represents a floor plan with the doors between the rooms and the outside indicated. The real estate agent would like to tour the house, starting and ending outside, by going through each door exactly once. What is the fewest number of doors that should be added, and where should they be placed in order to make this tour possible? Give**

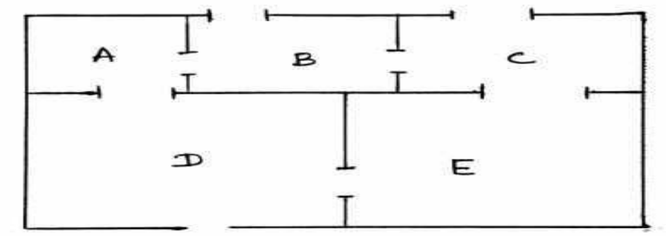


Fig. (1).

reason for your answer. (NOV/ DEC 2017) (8 M) BTL 4

Answer: Page: 55- Class Work Note.

Let the rooms be vertices and the doors be edges between these vertices, construct the tour corresponding to an Eulerian circuit. (3 M)

From the given graph draw an Eulerian circuit. (1 M)

Tour: If no edges in the walk is repeated and end vertices are same. (1 M)

Euler Path: Contains each edge of the graph exactly once (1 M)

Eulerian Circuit or Eulerian Cycle: Includes each edge of *G* exactly once.

Eulerian graph or Euler graph: Containing an Eulerian circuit. (1 M)

Open walk: Path is an open walk.

Closed Walk: Circuit is a closed walk. (1 M)

9 **Nine member of committee have their dinner in round table. If the member sits near to the same neighbor more than once, how many days can this arrangement possible? Write all possible arrangement. (NOV/ DEC 2017) (8 M)** BTL 4

Answer: Page: 1.14- Dr. G. Balaji & Pg. No : 56 - Class Work Note

Simple graph: without loops and parallel edges.A simple graph contains two vertices of same degree. (1 M)

Degree: The number of edges incident to it . (1 M)

Degree of simple graph with *n* vertices: The degree of each vertices is $\leq n-1$.'v' is the vertex with degree '$n-1$' then 'v' has '$n-1$' adjacent vertices. (3 M)

The solutions are

i. 1 2 3 4 5 6 7 8 9 1

ii. 1 3 5 2 7 4 9 6 8 1

iii. 1 5 7 3 9 2 8 4 6 1

iv. 1 7 9 5 8 3 6 2 4 1 (3 M)

10 **Prove that in any tree, there are atleast two pendent vertices. (8M) (NOV/ DEC 2016)** BTL 5

Answer: Page: 1.95 - Dr. G. Balaji

Tree: connected acyclic graph.

A tree is a path then it is an open walk. (2 M)

Handshaking statement: $\sum_{i=1}^{n} d(v_i) = 2E.$ (1 M)

The degree of a tree for *n* vertices : The sum of degrees of the vertices $=2n-2$. since the no. Of edges of '*n*' vertices is '*n-1*'. (2 M)

The total degrees($(2n-4)$ should be shared by the $(n-2)$ vertices such that their degrees are not less than 2. (3 M)

11 **Prove that the number of vertices of odd degree in a graph is always even. (8M) (APR/**

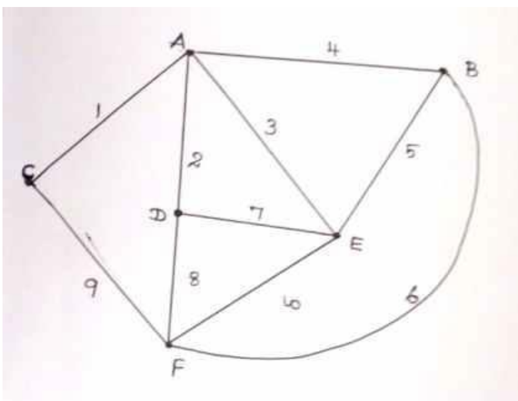
	MAY 2018) BTL 5 **Answer: Page: 1.13 - Dr. G. Balaji** **Handshaking statement:** $\sum_{i=1}^{n} d(v_i) = 2E.$ (2 M) Prove the Handshaking Theorem (2 M) ✓ $\sum_{even} d(v_j) + \sum_{odd} d(v_k) = even$ (2 M) ✓ $\sum_{odd} d(v_k)$ =even. (2 M)
12	**Prove that a connected graph G is an Euler graph if and only if it can be decomposed into circuits. (APR/ MAY 2018) (8 M)** BTL 5 **Answer: Page: 1.60 - Dr. G. Balaji** **Connected graph:**At least one path between every pair of vertices. (1 M) **Euler Path:** Contains each edge of the graph exactly once. (1 M) **Eulerian Circuit or Eulerian Cycle:** Includes each edge of 'G' exactly once. **Eulerian graph or Euler graph:** Containing an Eulerian circuit. (1 M) A connected graph is Euler graph with even degree. (1 M) **Edge disjoint circuits:** There is no edge common in circuits. (1 M) 'G' is a union of edge disjoint circuits.There are at least two edges incident at 'V_1', All vertices in the remaining graph must also be of even degree (1 M) Prove that it can decompose into circuits. (2 M)
13	**State and prove Dirac's theorem. (12 M) (APR/ MAY 2018)** BTL 1 **Answer: Page: 1.77 - Dr. G. Balaji** **Hamiltonian Path :** Includes each vertex of 'G' exactly once. (2 M) **Hamiltonian circuit or cycle:** Includes each vertex of 'G' exactly once, except the starting and ending vertices. (2 M) **Hamiltonian Graph:** Containing a Hamiltonian circuit. (2 M) **Dirac's theorem statement:**A simple graph 'G' has a Hamiltonian circuits if the degree of every vertex at least $\frac{n}{2}$, where' n 'is the number of vertices in G. (2 M) Contradiction to our hypothesis: $d(u) + d(v) < n$, $d(u) + d(v) = n$. (4 M)
14	**The maximum number of edges in a simple disconnected graph G with n vertices and k components is $\frac{(n-k)(n-k+1)}{2}$. (8 M)** BTL 5 **Answer: Pg.no: 1.52- Dr. G. Balaji** **Connected graph:**At least one path between every pair of vertices. (1 M) **Components:** The connected subgraphs of a graph 'G'. (1M) $\varepsilon(G) \leq \frac{n_i(n_i-1)}{2}$ (3M) Here, $n_i \leq n - k + 1$, Prove$\in (G) \leq \frac{(n-k)(n-k+1)}{2}$. (3M)

15

Define

i. Walk
ii. Euler Path
iii. Hamiltonian Path
iv. Subgraph
v. Circuit
vi. Complete graph

From the given graph draw the following:



vii. Walk of length 6
viii. Is this an Euler graph? Give reason
ix. Is there a Hamiltonian path for this graph? Give reasons
x. Find atleast two complete subgraphs. (April/May 2017)(16 M) BTL 1

Answer: Page: 1.4 - 1.47- Dr. G. Balaji

Walk: An alternating sequence of vertices and edges. (1M)

Euler Path: Contains each edge of the graph exactly once. (2M)

Hamiltonian Path : Includes each vertex of G exactly once. (2M)

Subgraph : A subgraph (V_1, E_1) where $V_1 \subseteq V$ and $E_1 \subseteq E$. (2M)
Cycle: If no edges in the walk is repeated. (2M)
Complete graph : Every vertex are adjacent to every other vertex. (1 M)
Walk of length 6: A 1 C 9 F 8 D 7 E 10 F 6 B (the number of the edges in the graph) (2M)

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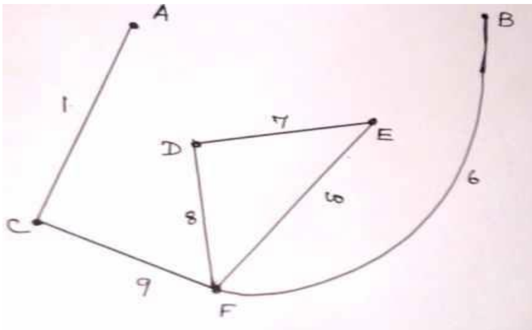
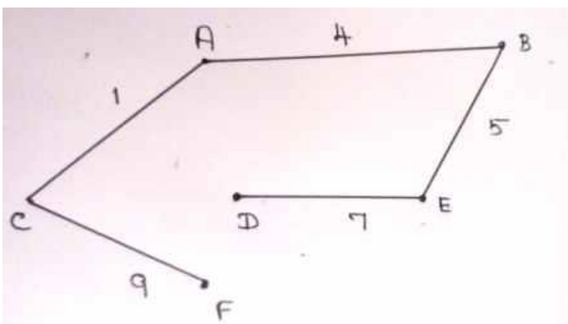


Given graph is not Euler graph- since it does not contain Euler circuit. (2M)

Yes, the given graph has Hamiltonian path. (2M)



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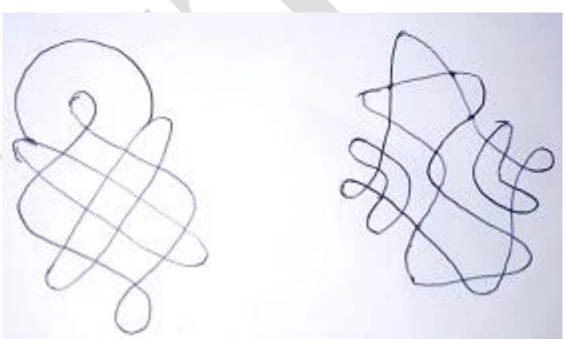
Can the kolams showns in figure be drawn without lifting your hands and not overdrawing any part of the kolam? Substantiate you answers with graph theory knowledge. If not possible, make it possible by adding some curves. (April/May 2018)(16 M) BTL 5



Answer: Page: 1.4 - 1.47- Dr. G. Balaji
Euler Path: Contains each edge of the graph exactly once. (4 M)
Eulerian Circuit or Eulerian Cycle: Includes each edge of '*G'* exactly once.
Eulerian graph or Euler graph: Containing an Eulerian circuit. (4 M)
A connected graph is Euler graph with even degree. (8M)
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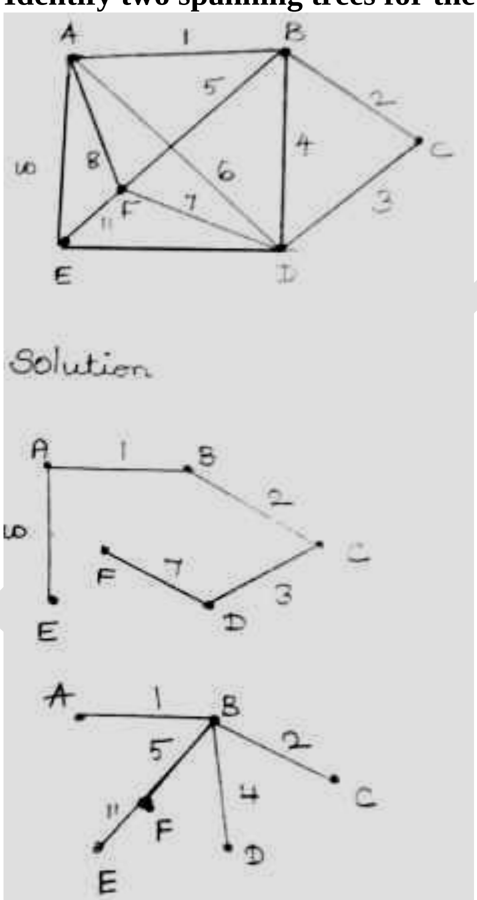
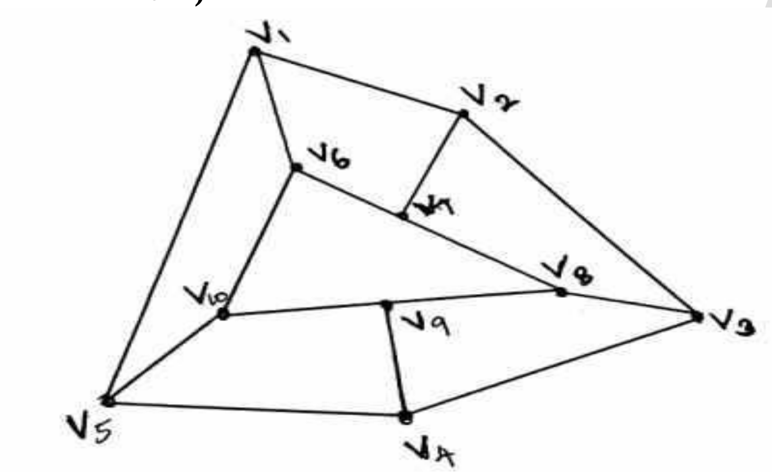
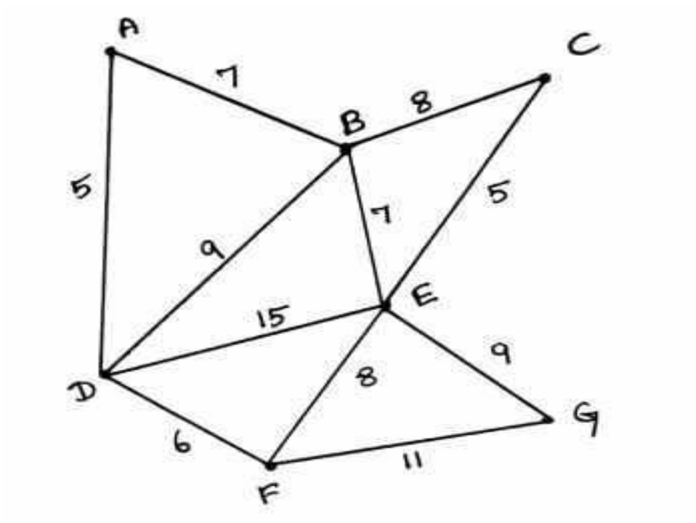
	UNIT II – TREES , CONNECTIVITY & PLANARITY
	Spanning trees – Fundamental circuits – Spanning trees in a weighted graph – cut sets – Properties of cut set – All cut sets – Fundamental circuits and cut sets – Connectivity and separability – Network flows – 1-Isomorphism – 2-Isomorphism – Combinational and geometric graphs – Planer graphs – Different representation of a planer graph.
	PART * A
Q.No.	**Questions**
1.	**Define Planar Graph. (APR/MAY 2017)** BTL 1 A graph is said to be planar if there exists a geometric representation of the graph which can be drawn on a plane such that no two edges intersect at a point other than a vertex.
2	**Define Spanning tree.** BTL 1 A tree T is said to be a spanning tree of a connected graph G if T is a subgraph of G and T contains all vertices (maximal tree subgraph).
3	**Identify two spanning trees for the following graph: (APR/MAY 2017)** BTL5 
4	**Define 1- isomorphic.** BTL1 A graph G_1 was 1- isomorphic to graph G_2 if the block of were G_1 isomorphic to the

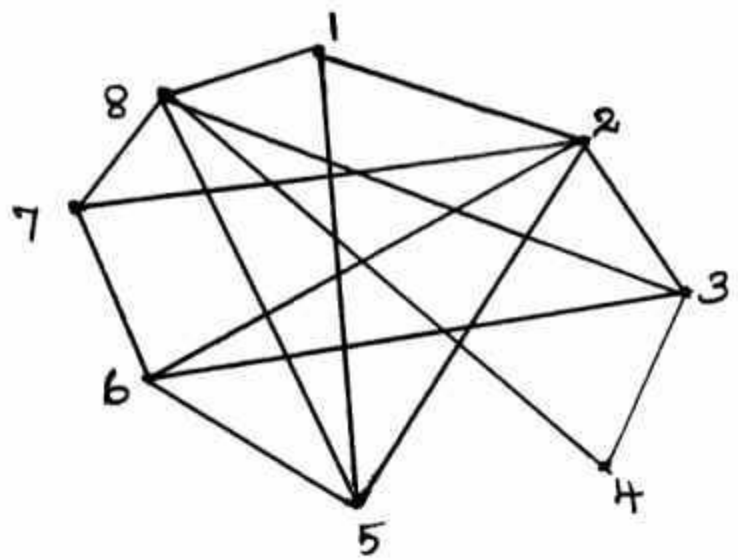
	blocks of G_2. Two graphs G_1 and G_2 are said to be 1-isomorphic if they become isomorphic to each other under repeated application of the following operation. O***peration1*** :"Split " a cut-vertex into two vertices to produce two disjoint subgraphs.
5	**Define 2- isomorphic.** BTL 1 Two graphs G_1 and G_2 are said to be 2-isomorphic if they become isomorphic after undergoing *operation 1* or *operation 2*, or both operations any number of times. ***Operation 1*** : *"Split"* a cut-vertex into two vertices to produce two disjoint subgraphs. ***Operation 2****: "Split"* the vertex x into x_1 and x_2 and the vertex y into y_1 and y_2 such that G is split into g_1 and g_2. Let vertices x_1 and y_1 go with g_1 and vertices x_2 and y_2 go with g_2. Now rejoin the graphs g_1 and g_2 by merging x_1 with y_2 and x_2 with y_1 .
6	**Define the terms: Rank and Nullity.** BTL 1 Rank refers to the number of branches in spanning tree. Nullity refers to the number of chords in G.
7	**What are the applications of planar graph? (NOV/DEC 2017)** BTL 4 ● To eliminate the distinction between finite and infinite regions, a planar graph is often embedded in the surface of sphere. This is done by stereographic projection. ● Euler's formula states that if a finite, connected, planar graph is drawn in the plane without any edge intersections, and v is the number of vertices , e is the number of edges and f is the number of faces then $v-e+f=2$.
8	**In a tree, every vertex is a cut- vertex. Justify the claim. (NOV/DEC 2017)** BTL4 In a tree , every vertex are connected by an unique path so that if we remove a vertex (not end vertices) it disconnect the tree therefore every vertex is a cut-vertex .
9	**A simple planar graph to which no edge can be added without destroying its planarity (while keeping the graph simple) is a maximal planar graph. Prove that every region in a maximal planar graph is a triangle. (NOV/DEC 2017)** BTL 5 Let G is a maximal planar graph. for any planar graph $q \leq 3p-6$. Since G is maximal planar no more edges can be added and so q must be maximum therefore $q=3p-6$ and we know that 'If all faces of the planar graph are triangles $2q=3r$ $\Rightarrow 2q = 3(2-p+q)$. Hence, every region is a maximal planar graph is a triangle.
10	**Define vertex connectivity.** BTL1 The connectivity (or vertex connectivity) $k(G)$ of a connected graph G is the minimum number of vertices whose removal disconnects G.
11	**Define edge connectivity.** BTL 1 Each cut-set of a connected graph G consists of certain number of edges. The number of edges in the smallest cut-set is defined as the edge connectivity of G.
12	**Give the relation between vertex connectivity and edge connectivity. (NOV/ DEC 2017)** BTL4 For any graph G, $k \leq \lambda \leq \delta$. Where, k is vertex connectivity, δ is the minimum degree of the graph and λ is edge connectivity.
13	**Define fundamental circuit in a graph. (APR/ MAY 2018)** BTL 1 Adding just one edge to a spanning tree will create a cycle; such a cycle is called a fundamental cycle (or fundamental circuit).
14	**State Kuratowski's theorem. (APR/ MAY 2018).** BTL 1

	A necessary and sufficient condition for a graph G to be planar is that G does not contain k_5 or $k_{3,3}$ or any graph homeomorphic to them, as a subgraph.
15	**Define cut- set.** BTL 1 A cut set of a connected graph G is a set of edges whose removal makes the remaining graph disconnected is called a cut- set.
16	**Define Kruskal's algorithm.** BTL 1 Start with no nodes or edges in the spanning tree, repeatedly add the cheapest edge that does not create cycle.
17	**Define Prim's algorithm.** BTL 1 Start with any one edge in the spanning tree, and repeatedly add the cheapest edge, and the edge it leads to, for which the edge is not already in the spanning tree.
18	**Define weighted graph.** BTL 1 A weighted graph is a graph for which each edge has an associated real number, called the weight of the edge. The sum of the weights of all of the edges is the total weight of the graph.
19	**Write the properties of the cut set.** BTL 1 ● Every cut-set in a connected graph G must contain at least one branch of every spanning tree of G. ● In a connected graph G, any minimal set of edges containing at least one branch of every spanning tree of G is a cut-set. ● Every circuit has an even number of edges in common with any cut set.
20	**Define separable and non-separable graph.** BTL 1 A connected graph is said to be separable graph if its vertex connectivity is one. All other connected graphs are called non-separable graph.
21	**Define max-flow and min-cut theorem.** BTL 1 The maximum flow between two vertices *a* and *b* in a flow network is equal to the minimum of the capacities of all cut-sets with respect to *a* and *b*. The max. Flow between two vertices = min. of the capacities of all cut-sets.
22	**Define component of graph.** BTL 1 A separable graph consists of two or more non separable subgraphs. Each of the largest non-separable is called a block (or components)
23	**Define minimum spanning tree.** BTL 1 In a weighted graph, a minimum spanning tree is a spanning tree that has minimum weight from all other spanning trees of the same graph.
24	**Prove that a Hamilton path is a spanning tree.** BTL 5 Let T be a Hamilton path of a graph G. clearly T contains all the vertices of G, which traverses through every vertex only once. Therefore T is a connected, circuit less graph having all the vertices of G. Hence T is a spanning tree.
25	**Define shortest spanning tree.** BTL 1 If G is a weighted graph, then the weight of a spanning tree T of G is defined as the sum of the weights of all branches in T. A spanning tree with the smallest weight in a weighted graph is called a shortest spanning tree.
26	**What is network flows.** BTL 1 A flow network is a graph where each edge has a capacity and each edge receives a flow. The amount of flow on an edge cannot exceed the capacity of the edge.

	Part*B
1	**A farm has six walled plots full of water. The graph representation of it is given below. Use the concept of spanning tree, cut sets appropriately to determine the following.** **1. How many walls will have to be broken so that all the water can be drained out?** **2. If only one plot was full of water and this had to be drained into all other plots, then how many walls need to be broken? (8M)(APR/ MAY 2017)** BTL4  **Answer: Page : 2.43 - Dr. G. Balaji and Page:65 - Class Work Notes** **Spanning tree:** Maximal tree sub graph. **Minimum spanning tree:** Smallest weight in a weighted graph. (3M) **1.** n =10 & e = 15, (15-10+1=6)-breaking six walls will drain the water out.(2M) **2.** If only one plot was full of water, if this hard to be drained into all other plots, then we need to be broken 5 walls. (3M)
2	**Show that a Hamiltonian path is a spanning tree with an example. (8M)(APR/ MAY 2017)** BTL 5 **Answer: Page : 2.5 - Dr. G. Balaji** T contains all the vertices of G. (2M) Traverses through every vertex. (2M) T connected, circuit-less graph. (2M) Give an example. (2M)
3	**State the Euler's formula relating the no. of vertices, edges and faces of a planar connected graph. Give two conditions for testing for planarity of a given graph. Give a sample graph that is planar and another that is non-planar. (16M)(APR/ MAY 2017)** BTL2 **Answer: Page : 2.47-2.49 - Dr. G. Balaji** **Planar:** Some geometric representation which can be drawn on a plane such that no two of its edges intersect. (4M) A connected planer graph with n vertices and 'e' edge has e-n+2 regions. By induction hypothesis, we have $R-1=(e-1)-n+2$ $\Rightarrow R=e-n+2.$ (8M)

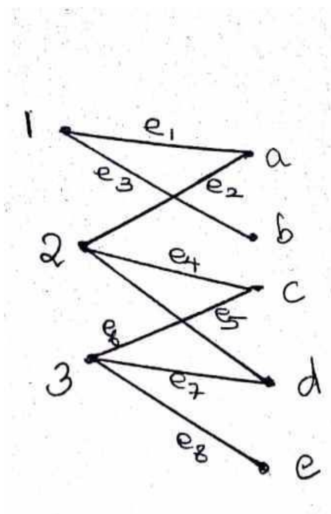
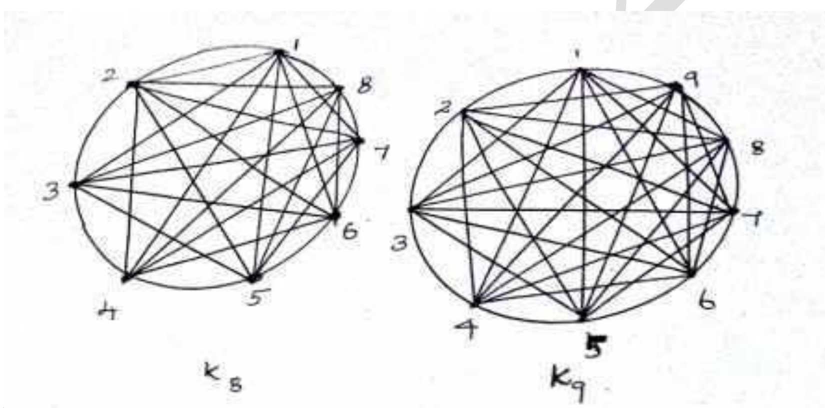
	Any simple, connected planar graph with *R regions, n* vertices, and *e* edges (*e* > *2)*, the following inequalities must hold: $e \geq \frac{3}{2}R$ $e \leq 3n-6$ The spherical embedding of every planer 3-connected graph is unique. (4M)
4	**Explain max-flow min –cut theorem. (NOV/ DEC 2016) (APR/ MAY 2018)** **Using it calculate the maximum flow between the nodes D and E in the graph. the number on a line represent the capacity. (16M)(APR/ MAY 2017)** BTL2  **Answer:Page : 2.39 - Dr. G. Balaji and Page: 75 - Class work note.** **Explain:** The maximum flow possible between two vertices a and b in a network is equal to the minimum of the capacity of all cut sets with respect to a and b'. (4M) For all cut-sets with respect to *a* and *b* , the flow rate cannot exceed the minimum of their capacities. (8M) **Cut-set:**A set of edges whose removal makes the remaining graph disconnected Draw all kinds of graph, Minimum capacity = Maximum flow = 12 units. (4M)
5	**Explain about Fundamental cut set and Fundamental circuit in a graph. (8M) (NOV/ DEC 2016)** BTL 2 **Answer: Page : 2.20 - Dr. G. Balaji** **Spanning tree T**: Maximal tree subgraph. (2M) **Explain:** A fundamental circuit contains exactly one chord of the spanning tree it is referred to as the fundamental circuit corresponding to the chord. (4M) Write the corresponding fundamental circuit and fundamental cut-set. (2M)
6	**Prove that every connected graph has atleast one spanning tree. (8M)(NOV/ DEC 2016)** BTL5 **Answer: Page : 2.2 - Dr. G. Balaji** **Connected graph:**At least one path between every pair. **Spanning tree:**Maximal tree subgraph. (3M) **Explain:**Generalize the connected graph has at least one spanning tree. (5M)
7	**Explain Planar graph and Prove that K_5 and $K_{3,3}$ are non –planar.(8M) (NOV/ DEC 2016)** BTL2 **Answer: Page : 2.30 - Dr. A. Singaravelu**

	Planar Graph: Some geometric representation which can be drawn on a plane such that no two of its edges intersect. (2M) $K_{3,3}$, a complete bipartite graph . $2e \geq 4f$ $2(e) \geq 4(e-n+2) \Rightarrow 18 \geq 20$ using Euler's formula. (2M) $\Rightarrow\Leftarrow$ K_5, a complete graph with 5 vertices. (2M) $e \leq 3n-6$ $10 \leq (3\times5)-6 \Rightarrow 10 \leq 9$ using Euler's formula. $\Rightarrow\Leftarrow$. (2M) Hence K_5 and $K_{3,3}$ are non –planar.
8	**Show that starting from any spanning tree of a graph G, every other spanning tree of G can be obtained by successive cyclic interchanges.(8M) (NOV/ DEC 2017)** BTL3 **Answer: Page : 2.5 - S. Sathya & M. Umamaheswari** **Cyclic interchange:** Generation of one spanning tree from another, through the addition of a chord and deletion of an appropriate branch. (2M) **Explain**: Minimum number of cyclic interchanges in going from one spanning tree to another. (4M) The distance is a metric on the set of spanning trees of a graph. (2M)
9	**Prove that the ring sum of any two cut- sets in a graph is either a third cut-set or an edge disjoint union of cut-sets. (8M)(NOV/ DEC 2017)** BTL5 **Answer:Page : 2.24 - Dr. G. Balaji** $V_1 \cup V_2 = V \ \& V_1 \cap V_2 = \phi,$ $V_3 \cup V_4 = V \ \& V_3 \cup V_4 = \phi,$ (4M) **Explain:** The ring sum $V_1 \oplus V_2$ and the ring sum $S_1 \oplus S_2$. $S_1 \oplus S_2$. is an edge(4M)
10	**Show by drawing the graphs, that two graphs with the same rank and the same nullity need not be 2- isomorphic. (8M)(NOV/ DEC 2017)** BTL 5 **Answer:Page : 2.39 - Dr. G. Balaji** **Rank & Nullity:**Rank refers to the number of branches in spanning tree. Nullity refers to the number of chords in G Draw two graph with same rank and same nullity. (3M) **2-isomorphic**:after undergoing *operation 1* or *operation 2*, or both operations any number of times. ***Operation 1*** : *"Split"* a cut-vertex into two vertices to produce two disjoint subgraphs. ***Operation 2****: "Split"* the vertex *x* into x_1 and x_2 and the vertex *y* into y_1 and y_2 such that *G* is split into g_1 and g_2. Let vertices x_1 and y_1 go with g_1 and vertices x_2 and y_2 go with g_2. Now rejoin the graphs g_1 and g_2 by merging x_1 with y_2 and x_2 with y_1 . (2M) Using the graphs show that when two graph have same rank and nullity need not be 2-isomorphic. (3M)
11	**State Kuratowski's theorem and use it in order to prove the given graph is non-planar.(8M) (NOV/ DEC 2017)** BTL2

	 **Answer:Page : 82 - Class Work Note.** **Kuratowski's theorem:** G does not contain k_5 or $k_{3,3}$ or any graph homeomorphic to them, as a subgraph. (3M) **Planar:**Some geometric representation which can be drawn on a plane such that no two of its edges intersect. (2M) The given graph is not isomorphic, it gives that the graph is non-planar. (3M)
12	**Prove that every connected graph has atleast one spanning tree.(8M) (NOV/ DEC - 2016)** BTL5 **Answer:Page : 2.2 - Dr. G. Balaji** **Explain:**If G has no circuits, then G is a tree and G itself is a spanning tree of G.(4M) If G has circuits, delete an edge from each cycle, then it become circuit free connected graph. (4M)
13	**Define 2- isomorphism and prove that the rank and nullity of a graph is invariant under 2- isomorphism.(16M) (APR/ MAY 2018)** BTL 1 **Answer:Page : 2.37 - Dr. G. Balaji** **2-isomorphic**:after undergoing *operation 1* or *operation 2*, or both operations any number of times. ***Operation 1*** : *"Split"* a cut-vertex into two vertices to produce two disjoint subgraphs. ***Operation 2****: "Split"* the vertex x into x_1 and x_2 and the vertex y into y_1 and y_2 such that G is split into g_1 and g_2. Let vertices x_1 and y_1 go with g_1 and vertices x_2 and y_2 go with g_2. Now rejoin the graphs g_1 and g_2 by merging x_1 with y_2 and x_2 with y_1 . (2M) The maximum flow possible between two vertices a and b in a network is equal to the minimum of the capacities of all cut sets with respect to a and b . (8M) If $G_1$and G_2 are two 1- isomorphic graphs, the rank of G_1 equals the rank of G_2 and the nullity of G_1 equals the nullity of G_2. (6M)
14	**Prove that every circuit has an even number of edges in common with a cut – set. (8M)(APR/ MAY 2018).** BTL5 **Answer:Page : 2.24 - Dr. G. Balaji** **Cut-set:**A set of edges whose removal makes the remaining graph disconnected.(2M)

	S be the cut set. (2M) Consider the Γ circuit in G. (2M) $N(S \cap \Gamma) = 0$ an even number. (2M)
15	**Explain spanning trees in a weighted graph.(16M)** BTL2 **Answer:Page : 2.11-2.18 - Dr. G. Balaji** Let the graph be the sum of the weights of all the branches. (2M) Draw any weighted graph. (2M) **Explain:** A spanning tree is a shortest spanning tree if and only if there exists no other spanning tree at a distance of one from the tree whose weight is smaller than that of the tree. (8M) **Kruskal's Algorithm:**Start with no nodes or edges in the spanning tree, repeatedly add the cheapest edge that does not create cycle. (2M) **Prim's Algorithm:**Start with any one edge in the spanning tree, and repeatedly add the cheapest edge, and the edge it leads to, for which the edge is not already in the spanning tree. (2M)

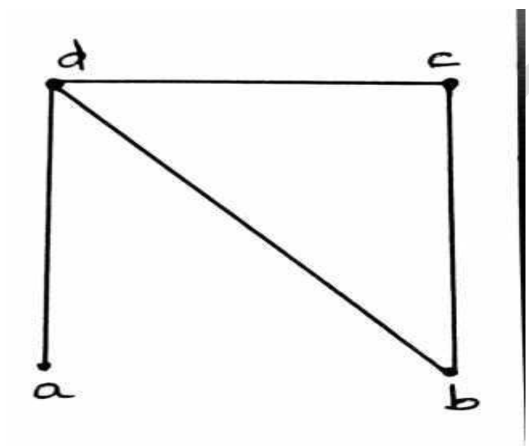
	UNIT III MATRICES, COLOURING AND DIRECTED GRAPH
	Chromatic number – Chromatic partitioning – Chromatic polynomial – Matching – Covering – Four color problem – Directed graphs – Types of directed graphs – Digraphs and binary relations – Directed paths and connectedness – Euler graphs.
	PART * A
Q.No.	**Questions**
1.	**Define Matching.** BTL1 Let G be a graph with edge set E. A subset M of E is said to be a matching in G if its edges are non-adjacent and non-loop.
2	**Define maximal matching.** BTL1 A matching *M* in a graph G is said to be a maximal matching if there does not exist another matching *M'* such that $\lvert M' \rvert > \lvert M \rvert$.
3	**Does the following graph have a maximal matching? Give reason. (APR/ MAY 2017)** BTL 4

	 From the definition of maximal matching we have '**A matching M in a graph G is said to be a maximal matching if there does not exist another matching M' such that** $\lvert M'\rvert > \lvert M\rvert$**'.** Here we have $\boldsymbol{M_1 = \{e_1, e_4. e_7\}}$, $\boldsymbol{M_2 = \{e_3, e_4. e_8\}}$.
4	**Draw k_8 and k_9 and show that thickness of k_8 is 2 while thickness of k_9 is 3. (APR/ MAY 2017)** BTL5  The thickness of a graph G is the minimum no. of planar graphs in which the edges can be partitioned. (i.e),if there exists a collection of K planar graphs, all having the same set of vertices, such that the union of these planar graph is G, then the thickness of G is at most K,
5	**Define saturate.** BTL1 A matching *M* is said to saturate a vertex *v* if *v* is an end vertex of some edge in M. we also say that the vertex *v* is M – saturated.
6	**Define Perfect Matching.** BTL1 A matching *M* to be perfect every vertex of the graph must be an end vertex of some

	edge in *M*.
7	**Define Dominating set. (NOV/DEC 2016).** BTL1 A dominating set in a graph *G* is a set of vertices that dominates every vertex *v* in *G* in the following sense: Either *v* is included in the dominating set or is adjacent to one or more vertices included in the dominating set.
8	**Define Independent set. (NOV/DEC 2016)** BTL1 A set of vertices in a graph is said to be an independent set of vertices or simply independent set if no two vertices in the set are adjacent.
9	**Define Chromatic Polynomials.** BTL1 Let $\boldsymbol{G}$ be a simple graph and $\boldsymbol{\lambda}$ be the number of colours given. By colouring $\boldsymbol{G}$ with $\boldsymbol{\lambda}$ colours means colouring $\boldsymbol{G}$ using all the $\boldsymbol{\lambda}$colours or less number of colours. For example the complete graph's chromatic polynomial is $\boldsymbol{P_n}(\lambda) = \lambda(\lambda - \mathbf{1})(\lambda - \mathbf{2})\ldots(\lambda - \boldsymbol{n} + \mathbf{1})$.
10	**Define Chromatic number.** BTL1 The minimum colours require to colour $\boldsymbol{G}$ is called chromatic number. It is denoted by $\boldsymbol{\psi}(\boldsymbol{G})$ or $\boldsymbol{\chi}(\boldsymbol{G})$.
11	**Define minimal dominating set. (NOV/DEC 2016)** BTL1 A minimal dominating set is a dominating set from which no vertex can be removed without destroying its dominance property.
12	**Define maximal independent set. (NOV/DEC 2016)** BTL 1 A maximal independent set is an independent set to which no other vertex can be added without destroying its independent property.
13	**Define maximum independent set.** BTL 1 An independent set S of G is said to be maximum if G has no independent set *s'* such that $\|s'\| > \|s\|$.
14	**Find the chromatic number of a complete graph of *n* vertices. (NOV/DEC 2016)** BTL5 The chromatic polynomial of a complete graph of *n* vertices is calculated by $\boldsymbol{P_n}(\lambda) = \lambda(\lambda - \mathbf{1})(\lambda - \mathbf{2})\ldots(\lambda - \boldsymbol{n} + \mathbf{1})$ with λ colors.
15	**Define minimal covering. (APR/ MAY 2018)** BTL 1 1) A vertex covering is said to be a minimal vertex covering if there is no vertex covering *K'* such that $\|K'\| < \|K\|$. 2) A edge covering *L* is said to be a minimal vertex covering if there does not exist another edge coving *L'* such that $\|L'\| < \|L\|$.
16	**Let a graph G is 2- chromatic, then prove that it is bipartite.(APR/ MAY 2018**). BTL5

	Let a graph *G* is 2- chromatic. Every vertex in G are colored using only 2 colors where no adjacent vertices are receive the same color. From the definition of bipartite, we know that the vertex set of *G* is split into two disjoint subsets. Hence if *G* is 2- chromatic then it is bipartite.
17	**Define Digraph.** BTL 1 Let V be a non-empty set and A be a sub set of $V \times V$, then the ordered pair $D = (V, A)$ is called directed graph (or digraph).
18	**Prove that a graph of n vertices is a complete graph then its chromatic polynomial is $P_n(\lambda) = \lambda(\lambda - 1)(\lambda - 2)...(\lambda - n + 1)$. (NOV/DEC 2017)** BTL5 In a complete graph of *n* vertices K_n, every vertex is adjacent to every other vertex. So the color used for one vertex cannot be used for another. Thus the first vertex can be colored in λ ways, the next in (λ -1) ways and so on. Therefore we have a chromatic polynomial for complete graph is $P_n(\lambda) = \lambda(\lambda - 1)(\lambda - 2)...(\lambda - n + 1)$
19	**Define the two types of connectedness in digraphs. Give examples. (NOV/DEC 2017)** BTL1 1) A directed graph is **strongly connected** if there is a path from *a* to *b* and a path from *b* to *a* where $a \,\&\, b \in V$. 2) A directed graph is **weakly connected** if there is a path between every two vertices in the underlying undirected graph, which is the undirected graph obtained by ignoring the directions of the edges of the directed graph.
20	**Define covering.** BTL1 A vertex and an edge are said to cover each other if they are incident on each other. A set of edges is said to cover *G* if every vertex in *G* is incident on atleast one edge in *g*. A set of edges that covers a graph *G* is said to be an edge covering a covering subgraph or simply covering.
21	**Define chromatic number.** BTL1 The chromatic number of a graph *G* is the minimum number of colors needed to color the vertices so that no two adjacent vertices share the same color.
22	**Define adjacency matrix.** BTL1 Let *G* be a simple graph , then the adjacency matrix $A = [a_{ij}]_{n\times n}$ is defined by $a_{ij} = \begin{cases} 1 & when \quad v_i \quad is \quad adjacent \quad to \quad v_j \\ 0 & \qquad\qquad otherwise \end{cases}$.
23	**Define incidence matrix.** BTL1 Let *G* be a simple graph , then the incidence matrix $B = [b_{ij}]_{n\times m}$ is defined by

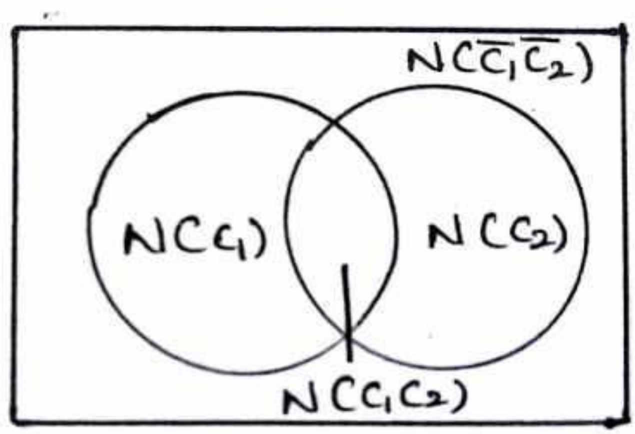
	$b_{ij} = \begin{cases} 1 & when \quad v_i \quad is \quad incident \quad with \quad e_j \\ 0 & otherwise \end{cases}$.
24	**Define underlying graphs.** BTL1 Let D be a digraph. The graph G having the same vertex set *V* in which corresponding to each are in D there is an edge is called the underlying graph of the digraph.
25	**Define in-degree and out-degree.** BTL1 The number of arcs incident into a vertex *v* is called its in-degree and denoted by $d^-(v)$, the number of arcs incident out of the vertex *v* is called its out-degree and its denoted by $d^+(v)$.
	Part-B
1	**Describe the steps to find Adjacency Matrix and Incidence Matrix for a Directed Graph.(8 M) (APR/ MAY 2017)** BTL2 **Answer: Page: 97 - Class Work Note.** **Adjacency Matrix:** $a_{ij} = \begin{cases} 1 & when \quad v_i \quad is \quad adjacent \quad to \quad v_j \\ 0 & otherwise \end{cases}$. (2M) I**ncidence Matrix:** $b_{ij} = \begin{cases} 1 & when \quad v_i \quad is \quad incident \quad with \quad e_j \\ 0 & otherwise \end{cases}$. (2M) **Explain:** Adjacency and Incidence on any directed graph. (4M)
2	**Write a note on Chromatic Polynomials and their applications. (8M)(APR/ MAY 2017)** BTL4 **Answer: Page : 3.7 - Dr. G. Balaji** **Chromatic Polynomials :**A polynomial which gives the number of different ways the graph can be properly coloured using minimum colors. (2M) **Explain:** A graph of n vertices is a complete graph iff its chromatic polynomial is $P_n(\lambda) = \lambda(\lambda - 1)(\lambda - 2)...(\lambda - n + 1).$ (4M) Applications of chromatic polynomial. (2M)
3	**Explain the types of Directed Graph with suitable example.(16M) (NOV/DEC-2016) (APR/ MAY 2018)** BTL2 **Answer: Page : 3.41 - Dr. G. Balaji** **Directed graph :** All the edges of graph directed. (2M) **Simple Digraph:** A digraph without self loop and parallel arcs. (1M) **Asymmetric digraph**: A digraph having atmost one arc between a pair of vertices and with or without loop. (2M) **Oriented graph:** A digraph without parallel arcs. (1M) **Symmetric digraph:** For each arc (*u*,*v*) there is also an arc (*v*,*u*). (2M) **Regular digraph :** Same equal in-degrees and out-degree. (2M) **Complete digraph**

	• **A complete symmetric digraph:** Exactly one arc directed from every vertex to every other vertex. (2M) • **A complete asymmetric digraph:** Exactly one arc between every pair of vertices. (2M) **Balanced digraph:** $d^-(v) = d^+(v)$ **.** (2M)
4	**State and prove five – color theorem. (16M)(NOV/ DEC 2017) (APR/ MAY 2018)** BTL1 **Answer: Page : 3.35 - Dr. G. Balaji** **Statement:** The vertices of every planar graph can be properly coloured with five colors. (3M) **Explain:** If the degree of *v* is less than 4, we can assign a proper colour to v and obtain a proper colouring. (7M) The interchanging will paint the vertices with same colour. (6M)
5	**Obtain the chromatic polynomial of the graph in given figure using the theorem.** $P_n(\lambda)$ **of G =** $P_n(\lambda)$ **of** $G' + P_n(\lambda)$ **of** ***G'*****. (8M) (NOV/ DEC 2017)** BTL4  **Answer: Page : 3.8 - Dr. G. Balaji** **Explain:** Different colours = number of ways of properly colouring G'. (2M) Same colours = number of ways of properly colouring G''. (2M) Give reason on the given graph using this theorem. (4M)
6	**Define the following and give one example to each:** 1. **Complete Matching** 2. **Minimal covering** 3. **Balances digraph** 4. **Strongly connected Digraph** 5. **Fragment in a digraph. (12M)(NOV/ DEC 2017)** BTL1 **Answer: Page : 3.30, 3.31, 3.48- Dr. G. Balaji and Page:3.39 - Dr. A. Singaravelu** **Complete Matching:** Largest maximal matching. (3M) **Minimal covering:** No vertex incident with vertex covering. (3M) **Balanced Digraph:** In-degree of every vertex is equal to out-degree of the

	corresponding vertex. (3M) **Strongly connected Digraph:** A path from *a* to *b* and a path from *b* to *a* where $a \,\&\, b \in V$. **Fragment in a digraph:** At least one directed path from every vertex to every other vertex.(3M)
7	**Prove that a digraph G is Euler digraph if and only if G is connected and is balanced. Draw an example Euler digraph of 6 vertices.(12M) (NOV/ DEC 2017)** BTL5 **Answer: Page : 3.39 - Dr. A. Singaravelu** **Explain:** The in-degree of every vertex is equal to out-degree of the corresponding vertex, then such a graph is said to be balanced digraph . (7M) With 6 vertices draw an Euler digraph. (5M)
8	**1. Prove that a covering G of a graph is minimal iff G contains no paths of length three or more.** **2. Prove that a graph of n vertices is a complete graph iff its chromatic polynomial is** $P_n(\lambda) = \lambda(\lambda-1)(\lambda-2)\ldots(\lambda-n+1)$. **3. Prove that every tree with two or more vertices is 2-chromatic. (16M)(NOV/DEC-2016)** BTL5 **Answer: Page 3.34,3.7,3.2: - Dr. G. Balaji** **Explain the following:** 1. From Star graph no edge can be removed with out uncovering a vertex. (5M) 2. n^{th} vertex can be coloured by $\lambda-(n-1)$ ways. (5M) 3. There is one and only one path between any two vertices in a tree, no two adjacent vertices will have the same colour. (6M)
9	**Define chromatic number. Prove that a graph with at least one edge is 2- chromatic if and only if it has no circuits of odd length.(16M) (APR/ MAY 2018)** BTL1 **Answer: Page :3.3- Dr. G. Balaji** **Chromatic number :** Minimum no. of colours required to colour the graph. (3M) **Explain :** G has no odd circuit , the end vertices of every edge will be coloured with different colours. (8M) G is 2- chromatic , so, it cannot have a circuit of odd circuit. (5M)
10	**If G is a tree with n vertices, then prove that its chromatic polynomial is $P_n(\lambda) = \lambda(\lambda-1)^{n-1}$. (8M)(APR/ MAY 2018)** BTL5 **Answer:Page :3.8 - Dr. G. Balaji** **Tree:** *n* - vertex graph with *n-1* edges. (2M) **Explain:** n^{th} vertex can be coloured by $\lambda-1$ ways. (6M)
11	**Explain chromatic number with necessary proof. (16M)** BTL2 **Answer: Page :3.1 - Dr. G. Balaji** **Chromatic number:** Minimum number of colors require to colour graph. (4M) **Explain:** A graph with at least one edge is 2- chromatic if and only if it has no circuits of odd length. (6M) Every bipartite graph with two or more vertices is 2-chromatic. **(**6M)
12	**Explain chromatic partitioning in detail.(6M)** BTL2 **Answer: Page : 3.6 - Dr. G. Balaji**

	Partition: All vertices into the smallest possible number of disjoint.(3M) **Explain:** Chromatic Partitioning are independent set.(3M)
13	**Write in detail about matching in a graph. (8M)** BTL2 **Answer: Page : 3.29- Dr. G. Balaji** **Matching** in a graph is a subset of edges in which no two edges are adjacent. (3M) **Explain:** Every maximum matching is definitely maximal, but the converse is not true. (3M) **Perfect:** A matching is said to be perfect if it has half of the cardinality of vertices .(2M)
14	**Explain four color problems with theorem proof. (8M)** BTL2 **Answer: Page : 3.32 - Dr. G. Balaji** **Explain:** A graph can color with only four colors. (4M) Give reason with suitable example. (4M)
15	**Explain Euler digraphs with theorem proof. (16M)** BTL2 **Answer: Page : 3.50 - Dr. G. Balaji** **Euler Trail:** A closed directed trail containing all the edges in a digraph. (2M) **Euler digraph:** A digraph containing an Eulerian trail. (2M) **Explain:** 'A weak digraph *D* is Eulerian if and only if every vertex of *D* has equal in degree and out degree'. (10M) Give an example. (2M)

	UNIT IV PERMUTATIONS & COMBINATIONS
	Fundamental principles of counting - Permutations and combinations - Binomial theorem - combinations with repetition - Combinatorial numbers - Principle of inclusion and exclusion - Derangements - Arrangements with forbidden positions.
	PART * A
Q.No.	**Questions**
1.	**State the rule of Sum (APR/ MAY 2017).** BTL1 If a set S is the union of disjoint non-empty subsets $A_1, A_2, ..., A_n,$ then $\|S\| = \|A_1\| + \|A_2\| + ... + \|A_n\|$ where the events are mutually exclusive events. That is the principle for determining the number of ways two or more operation can be performed together.
2	**Use venn diagram to represent the following scenario: If S : a set, C_1= condition 2 satisfied by some elements of S, indicate on the diagram- S, N(C_1), N(C_2), N(C_1,C_2) and N($\overline{C_1}$,$\overline{C_2}$) (APR/ MAY 2017)** BTL4

	
3	**Define Permutation with an example.** BTL1 A permutation is an arrangement of a given collection of objects in a definite order taking some of the objects or all the objects. $P(n,r) = \frac{n!}{(n-r)!}$. <u>Example:</u> It is required to seat 6 men and 5 women in a row so that the women occupy the even places. How many such arrangements are possible? <u>Answer:</u> There should be 6 +5 =1 chairs in a row. 5 women can be arranged on these 5 chairs in $5P_5 = 5! = 120$ ways. Again the remaining 6 chairs can be occupied by 6 men in $6P_6 = 6!$= 720 ways. ∴ Total no of arrangements = 120 × 720 = 86400.
4	**In how many different ways can the letters of the word 'LEADING' be arranged in such a way that the vowels always come together. (NOV/DEC 2016)** BTL5 The number of letters in given word is 7, here 1 each are L's , E's, A's, D's, I's, N's & G's. Using permutation formula, The number of different ways of arrangement of the word "LEADING"= 7! = 5040. The word 'LEADING' be arranged in such a way that the vowels always come together = $\frac{5!}{1!1!1!1!} \times \frac{3!}{1!1!1!}$ =720.
5	**A committee including 3 boys and 4 girls is to be formed from a group of 10 boys and 12 girls. How many different committee can be formed from the group? (NOV/DEC 2016)** BTL5 Using combination formula, The number of possible different committees = $\mathbf{10C_3 \times 12C_4 = 120 \times 495 = 59400}$.
6	**State the Binomial theorem.** BTL1 According to the theorem, it is possible to expand any power of $x + y$ into a sum of the form $(x+y)^n = \binom{n}{0} x^n y^0 + \binom{n}{1} x^{n-1} y^1 + \dots + \binom{n}{k} x^{n-k} y^k + \dots + \binom{n}{n} x^0 y^n$ i.e., $(x+y)^n = \sum_0^n \binom{n}{k} x^{n-k} y^k$.

7	**State the Principle of Inclusion and Exclusion.** BTL1 If A_i are finite subsets of a universal set **S**, then $\left\|\overline{A_1}\cap\overline{A_2}\cap\ldots\cap\overline{A_n}\right\| = \|S\| - \sum_{i=1}^{n}\|A_i\| + \sum_{i,j}^{n}\|A_i\cap A_j\| + \ldots + (-1)^{n-1}\|A_1\cap A_2\cap\ldots\cap A_n\|$.
8	**Define Derangement.** BTL1 A derangement is a permutation of the elements of a set, such that no element appears in its original position. Therefore, $D_n = (n!)\left[1 - \frac{1}{1!} + \frac{1}{2!} - \frac{1}{3!} + \cdots + \frac{(-1)^n}{n!}\right]$.
9	**Write a note on Rook Polynomials.** BTL1 The rook polynomial is a generating polynomial of the number of ways to place non-attacking rooks on a board that looks like a check board; that is no two rooks may be in the same row or column. The coefficient of x^k in the rook polynomial is the number of ways k rooks none of which attacks another, can be arranged in the squares.
10	**THALASSEMIA is a genetic blood disorder. How many way can the letters in THALASSEMIA be arranged so that all three A's together. (NOV/DEC 2017).** BTL5 The number of letters in given word is 11, here 3 are A's , 2 are S's, 1 each are T's , H's, L's, E's, M's & I's. Total number of words in which all three A's together $=\frac{9!}{2!1!1!1!1!1!1!} \times \frac{3!}{3!}$ = 181440.
11	**Determine the number of positive integers $n, 1 \le n \le 100$, that are not divisible by 3 or 7. (NOV/DEC 2017).** BTL5 By Principal of inclusion and exclusion, we have The number of positive integers that are not divisible by 3 or 7 $= 100 - (\frac{100}{3} + \frac{100}{7}) + (\frac{100}{3\times7}) = 57$.
12	**Determine the co-efficient of x^3y^7 in the expansion of $(2x-9y)^{10}$.(NOV/DEC-2017)** BTL5 $(2x-9y)^{10} = \sum_{r=0}^{10} 10C_r (2x)^r(-9y)^{10-r}$ The coefficient of $x^3y^7 = 10C_3(2)^3(-9)^7$
13	**Columba has two dozen each of *n* different colored beads. If she can select 20 beads (with repetitions of colors allowed) in 230230 ways, what is the value of "*n*"? (NOV/DEC-2016)** BTL 5 Given *r* = 20. W. K.T, $C(n+r-1, r) = \frac{(n+r-1)!}{r!(n-1)!}$ $\frac{(n+20-1)!}{20!\,(n-1)!} = 230230$ $\Rightarrow n = 7$.
14	**Find the number of ways in which the letters of the word TRIANGLE can be arranged such that vowels occur together? (APR/ MAY 2018)** BTL5 The number of letters in given word is 8, here 1 each are T's , R's, I's, A's, N's , L's ,G's & E's. Using permutation, we have the number of words in which vowels occurs together

	$\frac{6!}{1!1!1!1!1!1} \times \frac{3!}{1!1!1!} = \mathbf{4320}.$
15	**Find the number of non-negative integral solutions to $x_1 + x_2 + x_3 + x_4 =$ 20. (APR/ MAY 2018)** BTL5 Using combination rule, W. K.T, $C(n+r-1,r) = \frac{(n+r-1)!}{r!(n-1)!}$, Here $n = 4$; $r = 20$. The required number is $C(4+20-1,20) = C(23,20)$ =1771.
16	**State the rule of Product with example. (APR/ MAY 2017)** BTL1 Suppose a certain task or operation can be done in *m* ways and another task independent of the former can be done in *n* ways. Then both of them can be done in *mn* ways. Example: How many 4 – digit number divisible by 5 can be formed using the digit 3, 7, 1, 5, 6? i. Repetitions of the digits are permitted. ii. Repetitions of the digits is not permitted. Answer: i. $5 \times 5 \times 5 \times 1 = 125$ ii. $2 \times 3 \times 4 \times 1 = 24$.
17	**Define Combination with an example.** BTL1 A combination is a selection of objects from a given collection of objects taken some objects or all the objects at a time. The order of selection is immaterial. $C(n,r) = \frac{n!}{(n-r)!r!}$. Example: Find the number of arrangements of all the letters in TALLAHASSEE. How many of these arrangement have no adjacent A's? Answer: The number of letters in given words is 11, Here 3 are A's, 2 each are L's, S's, E's and 1 each are T and H. ∴ The number of arrangements of the letters in the given word is $\frac{11!}{3!2!2!211!1!} = \mathbf{831600}$ If we disregard the A's the remaining 8 letters can be arranged in $\frac{8!}{2!2!2!1!1!} = \mathbf{5040}$ways. There are 9 possible locations for the A's. Therefore, these locations can be chosen in $C(9,3)$ ways. The number of arrangements having no adjacent A's is 5040× $C(9,3)$ = 4,23,360.
18	**Determine the following :** **a)** $\phi(2^n)$, **b)** $\phi(2^n p)$, **c)** $\phi(32)$. **Where p is a prime number.** BTL5 $a)\ \phi(2^n) = 2^n - \frac{2^n}{2} = 2^n - 2^{n-1} = 2^{n-1}$. (Here 2 is the only prime) $b)\phi(2^n p) = 2^n p - \left[\frac{2^n p}{2} + \frac{2^n p}{p}\right] + \left[\frac{2^n p}{2p}\right]$ (Here 2, p are primes) $= 2^n p - 2^{n-1}p - 2^n + 2^{n-1} = 2^{n-1}[\,2p - p - 2 + 1] = 2^{n-1}(p-1)$

	$c)\ \phi(32) = 32 - \left[\frac{32}{2}\right] = 32 - 16 = 16.$ (Here 2 is only distinct prime)
19	**There are eight letters to eight different people to be placed in eight different addressed envelopes. Find the number of ways of doing this so that at least one letter gets to the right person.** BTL 5 The number of ways of placing 8 letters in 8 envelopes is 8! The number of ways of placing 8 letters in 8 envelopes such that no letter is in the right envelope is $\boldsymbol{d_8}$. Therefore, the number of ways of placing 8 letters in 8 envelopes, such that at least one letter is in the right envelop is $\boldsymbol{8! - d_8 \approx (8!) - [(8!) \times e^{-1}]}$ = [(8!) (1-0.3679)] =[40320 × 0.6321] = 25486.
20	**Find the sum of all the coefficients in the expansion of a)** $(\boldsymbol{w + x + y + z})^{\boldsymbol{5}}$; $\boldsymbol{b})\ (\boldsymbol{2s - 3t + 5u + 6v - 11w + 3x + 2y})^{\boldsymbol{10}}$ BTL 5 a) The sum of all the coefficients in the expansion of $(\boldsymbol{w + x + y + z})^{\boldsymbol{5}}$ **is** $(\boldsymbol{1+1+1+1})^{\boldsymbol{5}}$ **= 1024.** b) The sum of all the coefficient in the expansion of $(\boldsymbol{2s - 3t + 5u + 6v - 11w + 3x + 2y})^{\boldsymbol{10}} = (\boldsymbol{2 - 3 + 5 + 6 - 11 + 3 + 2})^{\boldsymbol{10}} = \boldsymbol{1048576}$.
21	**Show that for all positive integers $\boldsymbol{m}$ and $\boldsymbol{n}$, $\boldsymbol{n\binom{m+n}{m} = (m+1)\binom{m+n}{m+1}}$.** BTL5 $\boldsymbol{n\binom{m+n}{m} = \frac{n(m+n)!}{m!\,n!} = \frac{(m+n)!}{m!\,(n-1)!} = (m+1)\frac{(m+n)!}{(m+1)!\,(n-1)!} =}$ $\boldsymbol{= (m+1)\binom{m+n}{m+1}}$.
22	**Find $\boldsymbol{n}$ if (i) $\boldsymbol{P(n,2) = 90, (ii) 2P(n,2) + 50 = P(2n,2)}$.** BTL5 (i) $P(n,2) = 90$ $n(n-1) = 90$ $n^2 - n = 90$ $n^2 - n - 90 = 0$ $(n-10)(n-9) = 0$ $n = 10, n = -9$ $\therefore n = 10$ [$\boldsymbol{n}$>0]

	(ii) $2P(n,2)+50=P(2n,2)$ $2n(n-1)+50=2n(2n-1)$ $2n^2-2n+50=4n^2-2n$ $2n^2-50=0$ $n^2=25$ $n=\pm 5$ $\therefore n=5$.
23	**Determine the coefficient of (i) xyz^2 in $(2x-y-z)^4$ (ii) $w^3x^2yz^2$ in $(2w-x+3y-2z)^8$.** BTL5 (i) By the multinomial theorem, we get the general term in the expansion of $(2x-y-z)^4 = \binom{4}{n_1,n_2,n_3}(2x)^{n_1}(-y)^{n_2}(-z)^{n_3} = \frac{4!}{1!1!2!}(2)(-1)(-1)^2 = -24$. [Here $n_1=1$; $n_2=1$; $n_3=2$]. (ii) By the multinomial theorem, we get the general term in the expansion of $(2w-x+3y-2z)^8$=$\binom{8}{n_1,n_2,n_3,n_4}(2w)^{n_1}(-x)^{n_2}(3y)^{n_3}(-2z)^{n_4} = \frac{8!}{3!2!1!2!}(2)^3(-1)^2(3)^1(-2)^2 = 161280$. [Here $n_1=3$; $n_2=2$; $n_3=1$; $n_4=2$].
24	**Seven books are distributed among seven students for reading. The books are collected and redistributed. In how many ways will each student get to read two different books?** BTL5 The seven books are distributed for the first time in 7! Ways. The second time in D_7 ways. Hence the total number of ways is given by, = $(7!)\left[1-\frac{1}{1!}+\frac{1}{2!}-\frac{1}{3!}+\frac{1}{4!}-\frac{1}{5!}+\frac{1}{6!}-\frac{1}{7!}\right]$= 9344160.
25	**Find r if $(i) 6P_r=360; (ii) 13P_r=156$.** BTL5 (i) $6P_r=360 \implies 6P_r=6\times5\times4\times3 \implies r=4.$ (ii) $13P_r=156 \implies 6P_r=13\times12 \implies r=2.$
	Part*B
1	**In how many ways can the 26 letters of the alphabet be permuted so that none of the patterns car, dog, pun or byte occurs? Use the principle of inclusion and exclusion for this. (8M) (APR/ MAY 2017)** BTL5 **Answer: Page: 4.73- Dr. G. Balaji** $\|s\|=26!$ (2M) $\|A\|=24!;$ $\|B\|=24!;$ $\|C\|=24!;$ (2M) $\|D\|=23!$

	$\lvert A\cap B\rvert = \lvert A\cap C\rvert = \lvert B\cap C\rvert = 22!$ $\lvert A\cap D\rvert = \lvert B\cap D\rvert = \lvert C\cap D\rvert = 21!$. (2M) $\lvert A\cap B\cap C\rvert = 20!$ $\lvert A\cap B\cap D\rvert = \lvert A\cap C\cap D\rvert = \lvert B\cap C\cap D\rvert = 19!$ $\lvert \overline{A}\cap \overline{B}\cap \overline{C}\cap \overline{D}\rvert = 26! - \{(3)(24!)+(23!)\}+\{(3)22!+(3)21!\}-\{20!+(3)19!\}+17!$. (2M)
2	**Out of 100 students in a college, 38 play tennis, 57 play cricket and 31 play hockey, 9 play cricket and hockey, 10 play hockey and tennis, 12 play tennis and cricket** **How many play tennis and cricket but not hockey.(8 M)** BTL5 **Answer: Page: 4.50 – Dr. A. Singaravelu** $\lvert A\cup B\cup C\rvert = \lvert A\rvert+\lvert B\rvert+\lvert C\rvert-\lvert A\cap B\rvert-\lvert A\cap C\rvert-\lvert B\cap C\rvert+\lvert A\cap B\cap C\rvert$. (3M) $\lvert T\rvert = 38$ $\lvert C\rvert = 57$ $\lvert H\rvert = 31$ $\lvert T\cap C\rvert = 12$ (3M) $\lvert T\cap H\rvert = 10$ $\lvert C\cap H\rvert = 9$ $\lvert T\cup C\cup H\rvert = 100$ $\lvert T\cap C\cap H\rvert = 5$ [Use venn diagram] Number of students playing just one game = {No. of students playing Tennis only} +{ No. of students playing Cricket only} +{ No. of students playing Hockey only} = 79. The number of students playing Tennis and Cricket but not Hockey = $\lvert T\cap C\rvert - \lvert T\cap C\cap H\rvert = 12-5=7$. (2M)
3	**i. How many arrangements of the letters in MISSISSIPPI has no consecutive S's?** **ii. A gym coach must select 11 seniors to play on a football team. If he can make his selection in 12,376 ways, how many seniors are eligible to play?** **iii. How many permutations of size 3 can one produce with letters *m, r, a, f* and t?** **iv. Rama has two dozen each of n different colored beads. If she can select 20 beads (with repetitions of colors allowed), in 230,230ways, what is the value of n? (8M) (NOV/DEC-2016)** BTL5 **Answer: Page:4.25, 4.27 – Dr. G. Balaji** **i.** The number of letters in the given word is 11. Here, 4 are S's and I's, 2 P's and one M's. Therefore the number of arrangement of the letters in the given word is 34650. If we disregard the S's, the remaining 7 letters can be arranged in $\frac{7!}{4!2!1!} = 105$ ways. In each of these arrangement, there are 8 possible location for the 4 S's. These location can be chosen in $C(8,4)$ ways. Total arrangement having no consecutive S's is (105)($C(8,4)$)= 7350.

<table>
<tr><td></td><td>(2M)
ii. $C(n,11) = 12376 \Rightarrow \frac{n!}{(n-11)!11!} = 12376,$ The coach was choosing from 17 eligible seniors to get the 11 players. (2M)
iii. Permutations of size 3 out of 5 letters = $5P_3$=60. (2M)
iv. Given r = 20.
W. K.T, $\boldsymbol{C(n+r-1,r)} = \frac{\boldsymbol{(n+r-1)!}}{\boldsymbol{r!(n-1)!}}$
$\frac{\boldsymbol{(n+20-1)!}}{\boldsymbol{20!\,(n-1)!}} = \boldsymbol{230230}$
$\Rightarrow \boldsymbol{n=7}$. (2M)</td></tr>
<tr><td>4</td><td>i. How many arrangements are there of all the vowels adjacent in SOCIOLOGICAL?
ii. Find the value of n for the following: $\boldsymbol{2P(n,2)+50 = P(2n,2)}$
iii. In how many possible ways could a student answer a 10-question true – false test? (8M)(NOV/DEC-2016) BTL5
Answer: Page: 121- Class work note
i. If, in an arrangement, all the vowels are to be adjacent, we treat all the vowels present in the given word (namely A,O,I) as a single letter , say Y , so that we have 2 each of C and L and 1 each of S , G & Y, T
The arrangement be $\frac{7!}{2!2!1!1!1!}$ways.
Here, there are 2 O's & I's and one A can be arranged in $\frac{6!}{3!2!1!}$ways.
Therefore the number of arrangements = $(\frac{7!}{2!2!1!1!1!})(\frac{6!}{3!2!1!})$=(60)(1260) = 75600 of the arrangements of the letters in SOCIOLOGICAL all the vowels are adjacent. (3M)
ii. $2\frac{n!}{(n-2)!}+50=\frac{(2n)!}{(2n-2)!} \Rightarrow 2n(n-1)+50=(2n)(2n-1)$; n=5. (2M)
iii. The number of different ways that 10 questions can be answered =1024. (3M)</td></tr>
<tr><td>5</td><td>A question paper has 3 parts, part A, part B, and part C having 12, 4 and 4 questions respectively. A student has to answer 10 questions from part A and 5 questions from part B and part C put together selecting at least 2 from each one of these two parts. In how many ways the selection of question can be done. (8M) BTL5
Answer: Page :4.29 - Dr. A. Singaravelu
The students can answer the 15 question in the following ways.
Either (1) 10 questions from Part A, 3 question from Part B and 2 questions from Part C.
(2) 10 questions from Part A, 2 questions from Part B and 3 questions from Part C.
The above 2 cases can be done in
$[12C_{10} \times 4C_2 \times 4C_3]+[12C_{10} \times 4C_3 \times 4C_2]ways$ (3M)
$=12C_{10} \times 4C_2 \times 4C_3]$
$=2[66 \times 6 \times 4]$
$=2 \times 1584$
Answer: 3168 ways. (5M)</td></tr>
</table>

<table>
<tr><td>6</td><td>
Find the value of sum if the given program segment is executed.
Main()
{
int inc =0, sum =0;
int i, j, k;
for (i=1;i $\leq$ 10; i++)
for(j=1;j $\leq$ i; j++)
for(k=1; k$\leq$ j; k++)
{
inc = inc +1:
sum = sum + inc;
}
} (NOV/DEC-2017) (8M) BTL4
Answer: Page: 143 – Class work note.
If a set S is the union of disjoint non-empty subsets $A_1, A_2, \ldots, A_n$, then $|S| = |A_1| + |A_2| + \ldots + |A_n|$ where the events are mutually exclusive events. That is the principle for determining the number of ways two or more operation can be performed together. (2M)
Justify that in this give algorithm. (6M)
</td></tr>
<tr><td>7</td><td>
How many integer solutions are possible for $x_1 + x_2 + x_3 + x_4 + x_5 < 40$ where
i. $x_i \geq 0, 1 \leq i \leq 5.$
ii. $x_i \geq -3, 1 \leq i \leq 5$. (8M) (NOV/DEC-2017) BTL5
Answer: Page:4.59 – Dr. G. Balaji
$x_1 + x_2 + x_3 + x_4 + x_5 < 40$
$x_1 + x_2 + x_3 + x_4 + x_5 = 39 - x_6$
$[\because 40 - x_6 \leq 39]$
$\Rightarrow x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 39$
i. $x_i \geq 0, \quad 1 \leq i \leq 5$ (4M)
$(i.e) x_1 \geq 0; x_2 \geq 0; x_3 \geq 0; x_4 \geq 0; x_5 \geq 0;$
$\therefore r = 39; n = 6$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 39, is$
$C(6+39-1, 6-1) = C(44,5)$
</td></tr>
</table>

	$x_i \le -3, \qquad 1 \le i \le 5$ $\Rightarrow x_1 \ge 0 \qquad \Rightarrow x_1 + 3 \ge 0 \qquad \Rightarrow y_1 = x_1 + 3 \ge 0$ $\Rightarrow x_2 \ge 0 \qquad \Rightarrow x_2 + 3 \ge 0 \qquad \Rightarrow y_2 = x_2 + 3 \ge 0$ $\Rightarrow x_3 \ge 0 \qquad \Rightarrow x_3 + 3 \ge 0 \qquad \Rightarrow y_3 = x_3 + 3 \ge 0$ $\Rightarrow x_4 \ge 0 \qquad \Rightarrow x_4 + 3 \ge 0 \qquad \Rightarrow y_4 = x_4 + 3 \ge 0$ $\Rightarrow x_5 \ge 0 \qquad \Rightarrow x_5 + 3 \ge 0 \qquad \Rightarrow y_5 = x_5 + 3 \ge 0$ ii. (4M) $\Rightarrow x_6 \ge 0 \qquad \Rightarrow x_6 + 3 \ge 0 \qquad \Rightarrow y_6 = x_6 + 3 \ge 0$ $(y_1 - 3) + (y_2 - 3) + (y_3 - 3) + (y_4 - 3) + (y_5 - 3) + (y_6 - 3) = 39,$ $y_1 + y_2 + y_3 + y_4 + y_5 + y_6 = 39 + 18 = 57$ $here \qquad r = 57, \quad n = 6$ $\therefore C(6 + 57 - 1, 6 - 1) = C(62,5)$
8	**Find the number of ways of giving 10 identical gift boxes to 6 persons $p_1, p_2, p_3, p_4, p_5, p_6$ such a way that the total number of boxes given to $p_1 \& p_2$ together does not exceed 4. (8M) (NOV/DEC-2017)** BTL1 **Answer: Page: 4.52 – Dr. G. Balaji** Out of the 10 boxes, suppose r boxes are given to P_1 and P_2 together. Then$0 \le i \le r$. The number of ways of giving r boxes to P_1 and P_2 is $C(2 + r - 1, r) = C(r + 1, r) = r + 1.$ (2M) The number of ways in which the remaining $(10 - r)$ boxes can be given P_3, P_4, P_5, P_6 is $C\big(4 + (10 - r) - 1, (10 - r)\big) = C(13 - r, 10 - r)$ $= C(13 - r, 3)$ Consequently, the number of ways in which r boxes may be given to P_1 and P_2 and $10-r$ boxes to $(r - 1) \times C(13 - r, 3)$ (3M) Since $0 \le r \le 4$, the total number of ways in which the boxes may be given, by the sum rule $\sum_{r=0}^{4} (r+1) \times C(13 - r, 3)$. (3M)
9	**Using the principle of inclusion and exclusion find the number of prime numbers not exceeding 100. (8M) (APR/ MAY 2018)** BTL5 **Answer: Page: 4.58 – Dr. A. Singaravelu** To find the number of primes not exceeding 100, first note that composite integer not exceeding 100 must have a prime factor not exceeding 10. The primes not exceeding 100 are 2,3,5 and 7 and the number that are divisible by none of 2, 3, 5 or7. Let P_1be the property that an integer is divisible by 2 Let P_2be the property that an integer is divisible by 3 Let P_3be the property that an integer is divisible by 5 Let P_4be the property that an integer is divisible by 7 (2M)

The number of primes not exceeding 100 = 4+ $N(\bar{p}_1\bar{p}_2\bar{p}_3\bar{p}_4)$ (2M)

Now,

$N(\bar{p}_1\bar{p}_2\bar{p}_3\bar{p}_4)$ = 99 - $N(P_1) - N(P_2) - N(P_3) - N(P_4) + N(P_1, P_2) + N(P_1, P_3) + N(P_1, P_4) + N(P_2, P_3) + N(P_2, P_4) + N(P_3, P_1) - N(P_1, P_2, P_3) - N(P_1, P_2, P_4) - N(P_1, P_3, P_4) - N(P_2, P_3, P_4) + N(P_1, P_2, P_3, P_4)$

$N(\bar{p}_1\bar{p}_2\bar{p}_3\bar{p}_4)$ = 99 - $\left\lfloor\frac{100}{2}\right\rfloor - \left\lfloor\frac{100}{3}\right\rfloor - \left\lfloor\frac{100}{5}\right\rfloor - \left\lfloor\frac{100}{7}\right\rfloor + \left\lfloor\frac{100}{(2)(3)}\right\rfloor + \left\lfloor\frac{100}{(2)(5)}\right\rfloor + \left\lfloor\frac{100}{(2)(7)}\right\rfloor + \left\lfloor\frac{100}{(3)(5)}\right\rfloor + \left\lfloor\frac{100}{(3)(7)}\right\rfloor + \left\lfloor\frac{100}{(5)(7)}\right\rfloor - \left\lfloor\frac{100}{(2)(3)(5)}\right\rfloor - \left\lfloor\frac{100}{(2)(3)(7)}\right\rfloor - \left\lfloor\frac{100}{(3)(5)(7)}\right\rfloor - \left\lfloor\frac{100}{(2)(5)(7)}\right\rfloor + \left\lfloor\frac{100}{(2)(3)(5)(7)}\right\rfloor$.

$N(\bar{p}_1\bar{p}_2\bar{p}_3\bar{p}_4)$ = 99-50-33-20-14+16+10+7+6+4+2-3-1-0+0 =21. (2M)

Hence There are (4+21)=25 primes. (2M)

10

1. **Columba has two dozen each of *n* different coloured beads. If she can select 20 beads (with repetitions of colours allowed) in 230,230 ways, what is the value of *n*?**
2. **In how many ways can 10 identical pen's be distributed among 5 children in the following cases:**
   i. **There are no restrictions.**
   ii. **Each child gets at least one pen.**
   iii. **The youngest child gets atleast two pens. (8M)** BTL 5

Answer: Page: 4.52 – Dr. G. Balaji

1. $C(n+r-1) = \dfrac{(n+r-1)!}{r!(n-1)!}$.

$$\frac{(n+20-1)!}{20!(n-1)!} = 230{,}230 .$$

$$\frac{(n+19)!}{20!(n-1)!} = 230{,}230 .$$

n=*7***.** (4M)

2.

i. The required number is $C(5+10-1,10) = C(14,10) = 1001.$

ii. First we distribute one pen to each child.

Then there remain 5 pen to be distributed. The number of ways of distributing these 5 pen to 5 children is the required number.

$$\therefore C(5+5-1,5) = C(9,5) = 126.$$

iii. First we give two pen to the youngest child. Then there remain 8 pen to be distributed. The number of ways of distributed these 8 pen to 5 children is the required number.

$$\therefore C(5+8-1,8) = C(12,8) = 495.$$

11

A survey of 500 television watchers produced the following information. 285 watch hockey games. 195 watch foot ball games. 115 watch basketball games. 70 watch football and hockey games. 50 watch hockey and basketball games and 30 watch football and hockey and basketball games and 30 watch football and basketball games. 50 do not watch any of the three games. How many people watch exactly one of the three games? (8M) BTL5

Answer: Page: 4.56 – Dr. A. Singaravelu

Using Venn diagram,

$$n(H) = 285$$
$$n(F) = 195$$
$$n(B) = 115$$
$$n(H \cap F) = 70$$
$$n(H \cap B) = 50$$
$$n(F \cap B) = 30$$

Let x be the number television watcher who watch all three games.

Given 50 members does not watch any of the three games. (2M)

Hence $(165 + x) + (95 + x) + (35 + x) + (70 - x) + (50 - x) + (30 - x) + x = 500.$

$x = 55$. (3M)

Number of students who watches exactly one game is $=165 + x + 95 + x + 35 + x = 460.$ (3M)

12 **Five professors P_1, P_2, P_3, P_4, P_5 are to be made class advisors for five sections C_1, C_2, C_3, C_4, C_5 one professor foe each section. P_1 and P_2 do not wish to become the class advisors for C_1 or C_2, P_3 & P_4 for C_4 or C_5 & P_5 for C_3 or C_4 or C_5. In how many ways can the professors be assigned the work (without displacing any professor)? (8M) (APR/ MAY 2018)** BTL 5

Answer: Page: 4.104 – Dr. G. Balaji

The situation can be represented by the board shown in which the rows respectively represent the Professors P_1, P_2, P_3, P_4, P_5 and the columns respectively represent the sections C_1, C_2, C_3, C_4, C_5 and the shaded squares together represent the forbidden places involved.

Objects : P_1, P_2, P_3, P_4, P_5 $(m = 5)$

Places: C_1, C_2, C_3, C_4, C_5 $(n = 5)$

For the board C made up of the shaded squares, the rook Polynomial is given by

$r(C, x) = 1 + 11x + 40x^2 + 56x^3 + 28x^4 + 4x^5$. (3M)

Thus, here $r_1 = 11,\ r_2 = 40,\ r_3 = 56,\ r_4 = 28,\ r_5 = 4$

$\overline{N} = S_0 - S_1 + S_2 - S_3 + S_4 - S_5$. (3M)

$$S_0 = n! = 5! = 120$$
$$S_1 = (5-1)!\, r_1 = 264.$$
$$S_2 = (5-2)!\, r_2 = 240.$$
$$S_3 = (5-3)!\, r_3 = 112.$$
$$S_4 = (5-4)!\, r_4 = 28.$$
$$S_5 = (5-1)!\, r_5 = 4$$

Accordingly, the number of ways in which the work can be assigned is

$$\overline{N} = 120 - 264 + 240 - 112 + 28 - 4 = 8.$$

Answer: 8. (2M)

13 **Explain the fundamental principle of counting. (8M)** BTL 2

Answer: Page: 4.1 – Dr. G. Balaji.

If a set S is the union of disjoint non-empty subsets $A_1, A_2, \ldots, A_n$, then

	$\lvert S\rvert = \lvert A_1\rvert + \lvert A_2\rvert + \dots + \lvert A_n\rvert$ where the events are mutually exclusive events. That is the principle for determining the number of ways two or more operation can be performed together. (3M) Suppose a certain task or operation can be done in *m* ways and another task independent of the former can be done in *n* ways. Then both of them can be done in *mn* ways. (3M) Explain with suitable example explain it. (2M)
14	**In how many ways can the integers 1, 2, 3 … 10 be arranged in a line so that no even integer is in its natural position. (8M)** BTL 5 **Answer: Page: 4.52 – Dr. A. Singaravelu** Let A_1 be the set of all permutations of the given integers where 2 is in its natural place, A_2be the set of all permutations in which 4 is in its natural place, and so on. Then, the number of permutations where no even integer is in its natural places is$\lvert\overline{A_1}\cap\overline{A_2}\cap\overline{A_3}\cap\overline{A_4}\cap\overline{A_5}\rvert$. This is given by $\lvert\overline{A_1}\cap\overline{A_2}\cap\overline{A_3}\cap\overline{A_4}\cap\overline{A_5}\rvert = \lvert S\rvert - S_1 + S_2 - S_3 + S_4 - S_5$ We note that $\lvert S\rvert = 10!$ $\lvert A_1\rvert = \lvert A_2\rvert = \lvert A_3\rvert = \lvert A_4\rvert = \lvert A_5\rvert = 9!$ So that $S_1 = \sum\lvert A_I\rvert = 5\times 9! = C(5,1)\times 9!$ $S_2 = \sum\lvert A_I\cap A_j\rvert = C(5,2)\times 8!$ $S_3 = C(5,3)\times 7!$ $S_4 = C(5,4)\times 6!$ $S_5 = C(5,5)\times 5!$ (5M) $\lvert\overline{A_1}\cap\overline{A_2}\cap\overline{A_3}\cap\overline{A_4}\cap\overline{A_5}\rvert = 10! - C(5,1)\times 9! + C(5,2)\times 8! - C(5,3)\times 7! + C(5,4)\times 6! - C(5,5)\times 5!$=2170680. (3M)
15	**1) Explain Derangements.** **2) A committee of 12 is to be selected from 10 men and 10 women. In how many can the selection be carried out if (a) there are no restrictions? (b) There must be six men and six women? (c) There must be an even number of women? (d) There must be more women than men? (e) There must be at least eight men? (8M)** BTL2 **Answer: Page: 4.83 – Dr. G. Balaji** 1) A derangement is a permutation of the elements of a set, such that no element appears in its original position. Therefore, $\boldsymbol{D_n = (n!)\left[1 - \frac{1}{1!} + \frac{1}{2!} - \frac{1}{3!} + \cdots + \frac{(-1)^n}{n!}\right]}$ (4M) Write any two example. 2) (a) A committee of 12 is to be selected from 10 men and 10 women with no restriction = $\binom{20}{12} = 125970.$ (b) A committee of 12 is to be selected from 10 men and 10 women with there must be 6 men and 6 women = $\binom{10}{6}\binom{10}{6} = 44100.$ (c) A committee of 12 is to be selected from 10 men and 10 women with there must be an even number of women = $\sum\binom{10}{12-2i}\binom{10}{2i} = \binom{10}{10}\binom{10}{2} + \binom{10}{8}\binom{10}{4} + \binom{10}{6}\binom{10}{6} + \binom{10}{4}\binom{10}{8} + \binom{10}{2}\binom{10}{10} = 63090$ (d) A committee of 12 is to be selected from 10 men and 10 women with there must be more women than men $\sum\binom{10}{i}\binom{10}{12-i} = \binom{10}{7}\binom{10}{5} + \binom{10}{8}\binom{10}{4} + \binom{10}{9}\binom{10}{3} +$

	$\binom{10}{10}\binom{10}{2} = 40935.$ (e) A committee of 12 is to be selected from 10 men and 10 women with there must be at least eight men $\sum \binom{10}{i}\binom{10}{12-i} = \binom{10}{8}\binom{10}{4} + \binom{10}{9}\binom{10}{3} + \binom{10}{10}\binom{10}{2} = 10695$ (4M)

	UNIT V GENERATING FUNCTIONS
.	Generating functions - Partitions of integers - Exponential generating function – Summation operator - Recurrence relations - First order and second order – Non-homogeneous recurrence relations - Method of generating functions.
Q.No	Part * A
1.	**Find the generating function of the sequence $\{a_n\}$ where $a_n = \frac{1}{(n+1)!}$, $n = 0, 1, 2, \ldots$** BTL 5 $G(x) = \sum_{n=0}^{\infty} a_n x^n.$ $= \sum_{n=0}^{\infty} x^n \frac{1}{(n+1)!} = .\frac{1}{x}\sum_{n=0}^{\infty} \frac{x^{n+1}}{(n+1)!} = \frac{1}{x}\left[\frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots\right]$ $= \frac{1}{x}[e^x - 1]$.
2	**Define Generating function. (NOV/ DEC 2016)** BTL 1 A generating function describes an infinite sequence of numbers (a_0) by treating them like the co-efficient of a series expansion. The sum of this infinite series is the generating function. Unlike an ordinary series, this formal series is allowed to diverge, meaning that the generating function is not always a true function and the 'variable' is actually an indeterminate.
3	**Define Recurrence relation. (NOV/ DEC 2016)** BTL 1 A recurrence relation is an equation that recursively defines a sequence or multidimensional array of values, once one or more initial terms are given: each further term of the sequence or array is defined as a function of the proceeding terms. However "difference equation" is frequently used to refer to any recurrence relation.
4	**Solve the Recurrence relation (APR/ MAY 2017).** BTL 5 The characteristic equation is $-1 = 0 \therefore r = 1$.

	$\boldsymbol{a_n{}^{(h)} = c.1^n = c}$ The particular solution is Let $\boldsymbol{a_n = (A_0n^2 + A_1n + A_2)n}$ $\therefore \boldsymbol{\{A_0(n+1)^3 + A_1(n+1)^2 + A_2(n+1)\} - \{A_0n^3 + A_1n^2 + A_2n\} = 3n^2 - n}$ Solve the equation, we get $\boldsymbol{A_0 = 1, A_1 = -2, A_2 = 1}$ $\therefore$ $\boldsymbol{a_n{}^{(p)} = n^3 - 2n^2 + n}$=$\boldsymbol{n(n-1)^2}$ $\therefore$the general solution is $\boldsymbol{a_n{}^{(h)}}$ + $\boldsymbol{a_n{}^{(p)}}$= $\boldsymbol{c}$+$\boldsymbol{n(n-1)^2}$ Given that $\boldsymbol{a_0 = 3. \therefore c = 3}$ Hence the require solution is $\boldsymbol{a_n}$= $\boldsymbol{3}$ + $\boldsymbol{n(n-1)^2}$.
5	**Find the Generating function of the numeric function $\boldsymbol{a_r = 2^r, r \geq 0}$.** BTL 5 $\boldsymbol{G(x) = 2^0 + 2x + 2^2x^2 + 2^3x^3 + \cdots = 1 + 2x + (2x)^2 + \ \ldots = (1-2x)^{-1}}$
6	**Find the generating functions of the sequence 1, 1, 0, 1, 1, 1, …** BTL 5 $(1-x)^{-1} = 1 + x + x^2 + \ldots$ $(1-x)^{-1} - x^2 = 1 + x + 0x^2 + x^3 + x^4 + \ldots.$ is generating function of the sequence 1, 1, $f(x) = (1-x)^{-1} - x^2$ 0, 1, 1, ,1, …
7	**Find the unique solution of the recurrence relation $\boldsymbol{6a_n - 7a_{n-1} = 0, n \geq 1}$. $\boldsymbol{a_3 = 343}$. (NOV/DEC 2017)** BTL 5 Given, $\boldsymbol{6a_n - 7a_{n-1} = 0}$ In general,$\boldsymbol{a_n = \left[\frac{7}{6}\right]^i a_{n-i}}$ For $\boldsymbol{n - i = 3, a_n = \left[\frac{7^n}{6^{n-3}}\right]}$.
8	**Find the recurrence relation of the Fibonacci sequence.(APR/ MAY 2018)** BTL 5 The Fibonacci sequence is 0, 1, 1, 2, 3, 5, 8, 13,… The recurrence relation is $F_n - F_{n-1} - F_{n-2} = 0, n \geq 2$ with initial conditions are $F_0 = 0$ and $F_1 = 1$
9	**Find the number of solution of equation$\boldsymbol{x_1 + x_2 + x_3 = 100}$, if $\boldsymbol{x_1, x_2, x_3}$ are non negative integers.(APR/ MAY 2018)** BTL 5 The number of solutions= coefficient of x^{100}in $(1-x)^{-3}$ =$((3 + 100 - 1)C_2$ = 5151
10	**What is exponential generating function?** BTL 1

	For a sequence $a_0, a_1, a_3, \ldots$ of real numbers. $f(x) = a_0 + a_1 x + a_2 \frac{x^2}{2!} + \ \ldots = \sum_{i=0}^{\infty} a_i \frac{x^i}{i!}$ is called the exponential generating function for the given sequence.
11	**What is partitions of integer?** BTL 1 Partitioning a positive $\boldsymbol{n}$ into positive summands and seeking the number of such partitions without regard to order is called Partitions of integer. Example: $\boldsymbol{P(5) = 4+1 = 3+2 = 3+1+1 = 2+2+1 = 2+1+1+1 = 1+1+1+1+1.}$
12	**Define summation operator.** BTL 1 Generating function for a sequence $\boldsymbol{a_0, a_0+a_1, a_0+a_1+a_3}, \ldots$ for $\boldsymbol{(x) = a_0 + a_1 x + a_2 x^2} + \cdots$consider the function$\frac{\boldsymbol{f(x)}}{\boldsymbol{(1-x)}}$, $\frac{\boldsymbol{f(x)}}{\boldsymbol{(1-x)}} = \boldsymbol{f(x)} \frac{\boldsymbol{1}}{\boldsymbol{(1-x)}} = [\boldsymbol{a_0 + a_1 x + a_2 x^2} + \cdots][\boldsymbol{1 + x + x^2 + x^3} + \cdots]$ $= \boldsymbol{a_0 + (a_0 + a_1)x + (a_0 + a_1 + a_3)x^2} + \cdots$ So $\frac{\boldsymbol{f(x)}}{\boldsymbol{(1-x)}}$ generates the sequence of sums $\boldsymbol{a_0, a_0+a_1, a_0+a_1+a_3}, \ldots$. $\frac{\boldsymbol{1}}{\boldsymbol{(1-x)}}$ is called the summation operator.
13	**Define recursive sequence.** BTL 1 A recursive sequence, also known as a recurrence sequence, is a sequence of number indexed by an integer and generated by solving a recurrence equation.
14	**Find a closed form for the generating function of 0, 0, 1, 1, …** BTL 5 W.K.T $\frac{1}{1-x} = \sum_{n=0}^{\infty} x^n$ generates the sequence (1, 1, 1,…) $\frac{x^2}{1-x} = \sum_{n=0}^{\infty} x^{n+2}$ generates the sequence (0, 0, 1, 1,…).
15	**List some application of Generating function.** BTL 4 • For solving recurrence relation. • For proving some of the combinatorial identities. • For finding asymptotic formulae for terms of sequence.
16	**What the co-efficient of $\boldsymbol{17x}$ in the expansion of $\boldsymbol{(1 + x^5 + x^7)^{20}}$.** BTL 5 The only way to form $\boldsymbol{17x}$ term is together two $\boldsymbol{5x}$ and one$\boldsymbol{7x}$. Since there are

	$\mathbf{20C_2} =$ 190 ways to choose two $\mathbf{5x}$ from the 20 multiplicands and 18 ways to choose one $\mathbf{7x}$ from the remaining 18 multiplicands, the answer is 3420.
17	**Define Catalan number.** BTL1 In combinatorial mathematics, the catalan numbers form a sequence of natural numbers that occur in various counting problems, often involving recursively – defined objects.
18	**State the properties of generating functions.** BTL 1 • The number of partitions of n into odd summands equals number of partitions of n into distinct summands. • The number of partitions of a positive integer n, where no summands appear more than twice equal number of partitions of a n is a multiple of 3.
19	**The number of bacteria in a culture is 1000 (approximately, and this number increases 250% every two hours. Use a recurrence relation to determine the number of bacteria present after one day.** BTL5 The number increase by $a_n \times \frac{250}{100}$ in the next two hours. Thus, after *2n+2* hours, the number is $a_{n+1} = a_n + a_n \times \frac{250}{100}$ $a_{12} = 1000 \times (3.5)^{12} = 3379220508$ This is the number of bacteria affected files after one day .
20	**Write note on iteration.** BTL 1 Start with the recurrence and keep applying the recurrence equation until we get a pattern. The result is a guess at the closed form.
21	**Briefly explain substitution.** BTL 2 Guess the solution; prove it using induction. The result here is a proven closed form. Its often different to come up the guess so, in practice, iteration and substitution are used hand-in-hand.
22	**What is the meant by master Theorem?** BTL 1 Plugging into a formula that gives an approximate bound on the solution. The result here is only a bound on the closed form. It is not an exact solution.
23	**If we have a recurrence relation for a sequence, is it possible to express the sequence in a way that does not use recursion?** BTL2 Sometime. When we able to do so, we can find the closed form of the recurrence. It is an algebraic formula .
24	**Define is integer partition.** BTL 2

	A partition of a positive integer , is called inter partition is the way of writing n as a sum of positive integer.
25	**How can representation of partition.** BTL 3 There are two common diagrammatic methods to represent partitions: as Ferrers diagrams, and as Young diagram.
	Part * B
1	**If a_n is count of number of ways a sequence of 1s and 2s will sum to n for $n > 0$, eg: $a_3 = 3$.** **i. 1, 1, 1** **ii. 1, 2 and** **iii. 2, 1 sum up to 3,** **Find and Solve a sequence relation for a_n. (8 M) (APR/ MAY 2017)** BTL5 **Answer: Page: 5.21 – Dr. A. Singaravelu** Partitioning a positive integer n into positive summands and the number of such partitions without regard to order is called partitions of integer. (2M) P(1)=1 P(2) = 2=1+1 . . . P(7) = (1, 1, 1, 1, 1, 1 ,1) = 7!/7=1 P(7) =(1, 1, 1, 1,1, 2) = 6!/5!/1! = 6 P(7) = (1, 1, 1, 2, 2) = 5!/3!/2!=10 P(7) = (1, 2, 2, 2) = 4!/3!/1!= 4. (2M) $f_n = \frac{1}{\sqrt{5}}\left(\frac{1+\sqrt{5}}{2}\right)^n - \frac{1}{\sqrt{5}}\left(\frac{1-\sqrt{5}}{2}\right)^n.$ (4M)
2	**What are Ferrers diagrams? Describe how they are used to** **i. Represent integer partition** **ii. Conjugate diagram or dual partitions** **iii. Self – Conjugates** **iv. Representing bisections of two partition.(8M)(APR/MAY 2017)** BTL2 **Answer: Page: 5.26 – Dr. G. Balaji**

	Two Ferrers graphs are said to be transpositions or conjugates of each other if either of these can be obtained from the other by interchanging the rows and columns. (4M) The partition of 20 that corresponds to the transposition is 20=5+4+4+3+3+1. This partition is the conjugate of the given partition. (4M)
3	**Write a short note on summation operator.(8M) (NOV/DEC-2016)** BTL 2 **Answer: Page:5.42- Dr. G. Balaji** Generating function for a sequence $a_0, a_0+a_1, a_0+a_1+a_3, \ldots$ for $(x) = a_0 + a_1x+a_2x^2+\cdots$consider the function$\frac{f(x)}{(1-x)}$. (2M) $\frac{f(x)}{(1-x)} = f(x)\frac{1}{(1-x)} = [a_0+a_1x+a_2x^2+\cdots][1+x+x^2+x^3+\cdots].$ (2M) $= a_0+(a_0+a_1)x+(a_0+a_1+a_3)x^2+\cdots$ So $\frac{f(x)}{(1-x)}$ generates the sequence of sums $a_0, a_0+a_1, a_0+a_1+a_3, \ldots$. $\frac{1}{(1-x)}$ is called the summation operator. (2M) Give an example. (2M)
4	**The Population of Mumbai city is 6,000,000 at the end of the year 2015. The number of immigrants is 20000n at the end of end of year n, the population of the city increases at the rate of 5% per year. Use a recurrence relation to determine the population of the city at end of 2025.(8M) (NOV/DEC-2016)** BTL5 **Answer: Page:5.44 – Dr. A. Singaravelu** $a_{n+1} = a_n + \frac{5}{100}a_n + 20{,}000n$. (3M) $a_n^{(h)} = A(1.05)^n$. (3M)

	$a_{10} = 10{,}804{,}525$. (2M)
5	**Discuss about Exponential Generating function with an example. (NOV/DEC-2016) (8M)** BTL 2 **Answer: Page: 5.29 – Dr. G. Balaji** For a sequence $a_0, a_1, a_3, \ldots$ of real numbers. $f(x) = a_0 + a_1 x + a_2 \frac{x^2}{2!} + \ldots = \sum_{i=0}^{\infty} a_i \frac{x^i}{i!}$ is called the exponential generating function for the given sequence.. (4M) *f(x)* is the exponential generating function for the sequence $\langle a_r (r!) \rangle$. (2M) $xE'(x)$ is the exponential generating function for the sequence $\langle r\, a_r \rangle$. (2M)
6	**Find the unique solution of the recurrence relation $6a_n - 7a_{n-1} = 0, n \geq 1$, $a_3 = 343$. (8M)(NOV/DEC-2016)** BTL 5 **Answer: Page: 5.4 – Dr. G. Balaji** $\boldsymbol{6a_n - 7a_{n-1} = 0}$. (2M) $\boldsymbol{a_n = \left[\frac{7}{6}\right]^i a_{n-i}}$. (2M) For $n - i = 3, a_n = \left[\frac{7^n}{6^{n-3}}\right]$. (4M)
7	**Two cases of soft drinks, 24 bottles of one type and 24 bottles of another, are distributed among five surveyors who are conducting taste tests. In how many ways can the 48 bottles be distributed so that each surveyor gets at least two bottles of each type? And in how many ways can they be distributed so that each surveyor gets at least two bottles of one type and three of other type? Use generating function. (8M) (NOV/DEC-2017)** BTL 5 **Answer: Page: 123 – Class work note.** A generating function describes an infinite sequence of numbers ($\boldsymbol{a_0}$) by treating them like the co-efficient of a series expansion. (2M) Apply the given values in it. (3M) Explain the Generating function. (3M)
8	**Find all partitions of integer 6 and find the number of partitions with distinct summands. (8M) (NOV/DEC-2017)** BTL 5 **Answer: Page: 5.22- Dr. G. Balaji** $\prod_{r=1}^{\infty} \frac{1}{(1-x^r)} = 1 + x + 2x^2 + 3x^3 + \ldots.$ (5M)

	p(n) = 11. (3M)
9	**A person invests $1,00,000 at 12% interest compounded annually.** • **Find the amount at the end of 1st, 2nd, 3rd year.** • **Write the general explicit formula.** • **How long will it take to double the investment? Use recurrence relation. (8M)(NOV/DEC-2017)** BTL 5 **Answer: Page: 5.29 – Dr. A. Singaravelu** $a_n = 1.12\, a_{n-1}$. (2M) $a_n = (1.12)^n a_0$. (3M) $n = \frac{\log 2}{\log 1.12} = 6.12\, years$. (3M)
10	**Derive an explicit formula for the Fibonacci sequence using recurrence relation. (8M) (NOV/DEC-2017)** BTL 3 **Answer: Page: 5.21 – Dr. A. Singaravelu** $f_n - f_{n-1} - f_{n-2} = 0$. (3M) $f_n = \frac{1}{\sqrt{5}}\left(\frac{1+\sqrt{5}}{2}\right)^n - \frac{1}{\sqrt{5}}\left(\frac{1-\sqrt{5}}{2}\right)^n$. (5M)
11	1. **Obtain the fractional de-composition and identify the sequence having the expression $\frac{3-5z}{1-2z-3z^2}$ as a generating function.** 2. **Find the generating function of the sequence 1, 4, 9, 16, …** 3. **Find the number of distinct summands of the integer 6. (16M)(APR/ MAY 2018)** BTL 5

Answer: Page: 5.58 – Dr. A. Singaravelu & Page: 5.3, 5.22 – Dr. G. Balaji

G(x)= $\sum_{n=0}^{\infty}(3x)^n + 2\sum_{n=0}^{\infty}(-1)^n x^{\infty}$.
(6M)

$f(x) = \frac{1+x}{(1-x)^3}$.
(5M)

$\prod_{r=1}^{\infty}\frac{1}{(1-x^r)}$ = $1+x+2x^2+3x^3+\ldots$ (5M)

12

Solve the recurrence relation $a_n - 6a_{n-1} + 8a_{n-2} = 3^n$, where $n \geq 2$ **(8M) (APR/ MAY2018)** BTL 5

Answer: Page: 5.43 – Dr. A. Singaravelu

$a_n^{(h)} = \alpha_1(2)^n + \alpha_2(4)^n$. (3M)

$a_n^{(p)} = 9(3)^n$. (3M)

a_n =($a_n^{(h)} = \alpha_1(2)^n + \alpha_2(4)^n$)+($a_n^{(p)} = 9(3)^n$). (2M)

13

Find and solve a recurrence relation for the number of binary sequences of length $n \geq 1$ **that have no consecutive 0's. (8M)** BTL 5

Answer: Page: 5.66 – Dr. G. Balaji

All the binary sequence of a given length must end with 1 or 0. (2M)

A= $\frac{\sqrt{5}+3}{2\sqrt{5}}$, B= $\frac{\sqrt{5}-3}{2\sqrt{5}}$.
(3M)

$$\frac{1}{2\sqrt{5}}\{(\sqrt{5}+3)\left(\frac{1+\sqrt{5}}{2}\right)^n + (\sqrt{5}-3)\left(\frac{1-\sqrt{5}}{2}\right)^n\}$$. (3M)

14	**Explain generating function.(8M)** BTL 2 **Answer: Page: 5.1 – Dr. G. Balaji** A generating function describes an infinite sequence of numbers (a_0) by treating them like the co-efficient of a series expansion. (3M) The sum of this infinite series is the generating function. Unlike an ordinary series, this formal series is allowed to diverge, meaning that the generating function is not always a true function and the 'variable' is actually an indeterminate. (5M)
15	**Explain the procedure for solving recurrence relation. (8M)** BTL 2 **Answer: Page: 5.45 – Dr. G. Balaji.** A sequence may be defined by indicating a relation connecting its general term. (3M) Explain that how to get general solution. (6M)

CS6703 GRID AND CLOUD COMPUTING L T P C

3 0 0 3

OBJECTIVES:

- Understand how Grid computing helps in solving large scale scientific problems.
- Gain knowledge on the concept of virtualization fundamental to cloud computing.
- Learn how to program the grid and the cloud.
- Understand the security issues in the grid and the cloud environment.

UNIT I INTRODUCTION 9

Evolution of Distributed computing: Scalable computing over the Internet – Technologies for network based systems – clusters of cooperative computers - Grid computing Infrastructures – cloud computing - service oriented architecture – Introduction to Grid Architecture and standards – Elements of Grid – Overview of Grid Architecture.

UNIT II GRID SERVICES 9

Introduction to Open Grid Services Architecture (OGSA) – Motivation – Functionality Requirements – Practical & Detailed view of OGSA/OGSI – Data intensive grid service models – OGSA services.

UNIT III VIRTUALIZATION 9

Cloud deployment models: public, private, hybrid, community – Categories of cloud computing: Everything as a service: Infrastructure, platform, software - Pros and Cons of cloud computing – Implementation levels of virtualization – virtualization structure – virtualization of CPU, Memory and I/O devices – virtual clusters and Resource Management – Virtualization for data center automation.

UNIT IV PROGRAMMING MODEL 9

Open source grid middleware packages – Globus Toolkit (GT4) Architecture , Configuration – Usage of Globus – Main components and Programming model - Introduction to Hadoop Framework - Mapreduce, Input splitting, map and reduce functions, specifying input and output parameters, configuring and running a job – Design of Hadoop file system, HDFS concepts, command line and java interface, dataflow of File read & File write.

UNIT V SECURITY 9

Trust models for Grid security environment – Authentication and Authorization methods – Grid security infrastructure – Cloud Infrastructure security: network, host and application level – aspects of data security, provider data and its security, Identity and access management architecture, IAM practices in the cloud, SaaS, PaaS, IaaS availability in the cloud, Key privacy issues in the cloud.

TOTAL: 45 PERIODS

OUTCOMES:

At the end of the course, the student should be able to:

- Apply grid computing techniques to solve large scale scientific problems.
- Apply the concept of virtualization.
- Use the grid and cloud tool kits.
- Apply the security models in the grid and the cloud environment.

TEXT BOOK:

1. Kai Hwang, Geoffery C. Fox and Jack J. Dongarra, "Distributed and Cloud Computing: Clusters, Grids, Clouds and the Future of Internet", First Edition, Morgan Kaufman Publisher, an Imprint of Elsevier, 2012.

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1. Jason Venner, "Pro Hadoop- Build Scalable, Distributed Applications in the Cloud", A Press, 2009

2. Tom White, "Hadoop The Definitive Guide", First Edition. O'Reilly, 2009.

3. Bart Jacob (Editor), "Introduction to Grid Computing", IBM Red Books, Vervante, 2005

4. Ian Foster, Carl Kesselman, "The Grid: Blueprint for a New Computing Infrastructure", 2nd Edition, Morgan Kaufmann.

5. Frederic Magoules and Jie Pan, "Introduction to Grid Computing" CRC Press, 2009.

6. Daniel Minoli, "A Networking Approach to Grid Computing", John Wiley Publication, 2005.

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Subject Code: CS6703 **Year/Semester: IV /07**
Subject Name: GRID AND CLOUD COMPUTING **Subject Handler: M.SUGANYA**

UNIT -1- INTRODUCTION	
Evolution of Distributed Computing: Scalable computing over the Internet-Technologies for network based systems-Clusters of cooperative computers-Grid computing Infrastructures-Cloud Computing-Service Oriented Architecture-Introduction to Grid Architecture and Standards-Elements of Grid-Overview of Grid Architecture	
PART A	
Q.NO	**QUESTIONS**
1.	**Illustrate the evolutionary trend towards parallel distributed and cloud computing.** BTL 3 The evolutionary trends emphasize the extension of the Internet to everyday objects. Instead of using a centralized computer to solve computational problems, a parallel and distributed computing system uses multiple computers to solve large-scale problems over the Internet. Some of the evolutionary modern computing techniques are ➢ Cloud Computing ➢ Ubiquitous Computing ➢ High-performance Computing ➢ High Throughput Computing ➢ Internet of Things
2.	**List and explain in brief the three new computing paradigms**. BTL 1 ➢ Infrastructure as a Service(Iaas) ➢ Platform as a Service(Paas) ➢ Software as a Service(Saas) Iaas-instant computing infrastructure,provisioned over the internet Paas-Third party providers delivers hardware and software tools Saas-use cloud based application over the internet
3.	**Describe the applications of high performance and high throughput systems**. **April/May 2017** BTL 1 Applications of High-Performance Computing: ➢ Weather predictors ➢ Manufacturing process ➢ Chemical reactors ➢ Earth Observation ➢ Military Sensors Applications of High Throughput Computing ➢ Geostatistical simulations and analysis ➢ 2D/3D hydrodynamic modeling ➢ Ecological modeling

4.	**Define cyber physical systems**. BTL 1 ➢ A cyber-physical system (CPS) is the result of interaction between computational processes and the physical world. ➢ A CPS integrates cyber (heterogeneous, asynchronous) with physical (concurrent and information-dense) objects. ➢ A CPS merges the “3C” technologies of computation, communication, and control into an intelligent closed feedback system between the physical world and the information world
5.	**Analyze the working of GPUs**. BTL 4 ➢ A GPU stands for graphics processing unit, a coprocessor or accelerator mounted on a computer’s graphics card or video card ➢ Both multi-core CPU and many-core GPU processors can handle multiple instruction threads at different magnitudes. ➢ GPU offloads the CPU from all data-intensive calculations and from tedious graphics tasks in video editing applications.
6.	**Classify the primitive operations of virtual machines**. BTL 3 ➢ A virtual machine runs a dedicated operating system on shared physical hardware and reffered as host ➢ Each Virtual machine shares hardware resources of host machine(including CPU,RAM,Storage,Network) to run independent operating systems
7.	**List out the cluster design.** BTL 1 There are 3 types of clusters Designs are ➢ Fail-over, ➢ Load-balancing ➢ HIGH Performance Computing
8.	**Differentiate compute grid and data grid.** BTL 4 ➢ Compute Grid is a computation, optionally split it into multiple parts, and execute them on different grid nodes in parallel. ➢ Computation will perform faster than data grid ➢ Data Grids is distribution of data across the grid ➢ Data grid performance is slow
9.	**Examine the reasons to adapt the cloud for upgraded internet applications and web services.** BTL 3 ➢ Increases Performance ➢ Security ➢ Flexibility

10. **Discuss on SOA.** BTL 2

- SOA: A service-oriented architecture (SOA) is a software design where services are provided to the other components by application components, through a communication protocol over a network.
- The basic principles of service-oriented architecture are independent of vendors, products and technologies

Four properties of SOA

- It logically represents a business activity with a specified outcome.
- It is self-contained.
- It is a black box for its consumers.
- It may consist of other underlying services

11. **Differentiate grid computing versus cloud computing. Nov/Dec 2018** BTL 2

Grid Computing	Cloud Computing
Application Oriented	Service Oriented
Less Scalable	Very Scalable
Follow queuing pattern	Follow usage pattern
It is part of cloud computing	It is an independent concept

12. **Formulate the features of MPI ,Mapreduce and Hadoop. Nov/Dec 2016** BTL 6

MPI Features:

- High performance, scalability, and portability.

Mapreduce Features:

- Process large amounts of data –Flexibilty in data processing,Easily scalable,Fault tolerant

13. **Summarize the technologies available in grid standards.** BTL 5

National Institute of Standards and Technology, Smart Grid Cloud Computing for Smart Grid applications are also introduced in terms of efficiency, security and usability

14. **Discuss on OGSA**. BTL 2

- Open Grid Services Architecture (OGSA) is a set of standards defining the way in which information is shared among diverse components of large, heterogeneous grid systems
- describes a service-oriented architecture for a grid computing environment for business and scientific use

15. **Where OGSI and OGSA-DAI is utilized?** BTL 1

Reuse – The **OSGI** component model makes it very easy to use many third party components in an application

OGSA-DAI has contributed to projects and organisations around the world, in sectors including medical research, geographical information systems, meteorology, transport, computer-aided design, engineering and astronomy

16. **Analyze the features of grid FTP.** BTL 4

GridFTP is an extension of the File Transfer Protocol (FTP) for grid computing

	It is more reliable and high performance file transfer, GridFTP integrates with the Grid Security Infrastructure, which provides authentication and encryption to file transfers, with user-specified levels of confidentiality and data integrity, also for cross-server transfers
17.	**Define WSRF.** BTL 1 ➢ The Web Services Resource Framework (WSRF) defines a generic and open framework for modeling and accessing stateful resources using Web Services. ➢ This describe views on the state, to support management of the state through properties associated with the Web Service, ➢ To describe how these mechanisms are extensible to groups of Web Services.
18.	**Describe the standards related to web service**. BTL 2 XML SOAP WSDL UDDI
19.	**Summarize the elements of grid.** BTL 5 Grid computing relies on complete computer systems, this means accessing devices such as desktop computers that have on-board CPUs, storage and power supplies. All of the elements of your grid require connectivity, usually in the form of internet connectivity, possibly through an Ethernet connection. Middleware: This software enables you to donate your idle computer time to projects like BOINC, UNICORE,
20.	**Generalize the layers in grid architecture**. BTL 6 ➢ Application Layer ➢ Collective Layer ➢ Resource Layer ➢ Connectivity Layer ➢ Fabric Layer
21	**What is QOS?** BTL1 ➢ Grid computing system is the ability to provide the quality of service requirements necessary for the end-user community. ➢ QOS provided by the grid like performance, availability, management aspects.
22	**Discuss business on demand.** BTL2 ➢ Business On Demand is not just about utility computing as it has a much broader set of ideas about the transformation of business practices, process transformation, and technology implementations.

	➢ The essential characteristics of on-demand businesses are responsiveness to the dynamics of business, adapting to variable cost structures, focusing on core business competency, and resiliency for consistent availability.
23	**List the properties of Cloud Computing. Nov/Dec 2016** BTL1 There are six key properties of cloud computing: Cloud computing is ➢ user-centric ➢ task-centric ➢ powerful ➢ accessible ➢ intelligent ➢ programmable
24	**What is meant by resource broker?** BTL1 Resource broker provides pairing services between the service requester and the service provider. This pairing enables the selection of best available resources from the service provider for the execution of a specific task.
25	**Define – Distributed Computing.** BTL2 Distributed computing is a field of computer science that studies distributed systems. A distributed system is a software system in which components located on networked computers communicate and coordinate their actions by passing messages. The components interact with each other in order to achieve a common goal.
	PART B
1	**i)Identify and explain in detail about evolutionary trend of computer technology**. **(7M)** BTL 1 **Answer**: **Page.1-2 Bhushan** **Evolution Trend: (2M)** Evolutionary trends emphasize - Internet extension. Parallel and distributed computing system - solve large-scale problems. **Modern Techniques(5M)** ➢ Cloud Computing ➢ Ubiquitous Computing ➢ High-performance Computing ➢ High Throughput Computing ➢ Internet of Things **ii) Explain the three paradigms in detail. (6M)** BTL 1 **Answer**:**page-3-7 Bhushan** **Service Models (4M)** ➢ Iaas(Infrastructure as a Service) ➢ Paas(Platform as a Service)

	➢ Saas (Software as a Service) Iaas - Instant computing infrastructure,provisioned - internet Paas - Third party providers delivers hardware- software tools Saas - Use cloud based application – internet
2	**i) Summarize in detail about the degrees of parallelism. (8M) Nov/Dec 2018** BTL 2 **Answer**:**page-6 Bhushan** **Degree of Parallelism (2M)** ➢ DOP – metric - how many operations simultaneously executed by a computer. **Parallelism(6M)** ➢ Program – running on parallel computer - utilize different numbers of processors - different times. ➢ Number of processors - execute a program - degree of parallelism. ➢ Plot DOP - function time for given program - parallelism profile. **ii) Discuss the application of high performance and high throughput system. (April/May 2017) (4M)** BTL 2 **Answer** :**page - 1-3,1-4 Bhushan** **Application List (4M)** **Applications of High-Performance Computing:** ➢ Weather predictors ➢ Manufacturing process ➢ Chemical reactors ➢ Earth Observation ➢ Military Sensors **Applications of High Throughput Computing** ➢ Geostatistical simulations and analysis ➢ 2D/3D hydrodynamic modeling ➢ Ecological modeling
3	**i)Demonstrate in detail about internet of things and cyber physical systems**. **(7m)** BTL 3 **Answer**:**page -10 Bhushan** **IOT(4M)** **Internet of Things :** ➢ Radio frequency Identification(RFID) - Global Positioning System(GPS) ➢ Iot - network connection - computers,sendors - human-centric devices ➢ Iot objects - devices interconnected- network interact intelligently **CPS(3M)** **Cyber Physical System:** ➢ CPS- interaction between computational processes -physical world. ➢ CPS integrates cyber (heterogeneous, asynchronous) - physical (concurrent and informationdense) objects. ➢ CPS - merges "3C" technologies- computation, communication - control **ii)Examine the memory ,storage and wide area networking technology in network based system. (6M)** BTL 3 **Answer:page- 8 Bhushan**

	Network Based System: **Memory Technology(2M)** Faster processor speed - larger memory capacity result - wider gap - processors memory. **Disks and Storage Technology(2M)** Rapid growth of flash memory - solid-state drives (SSDs) - impacts future HPC , HTC systems. Power increases linearly - clock frequency - quadratically - voltage applied on chips **System-Area Interconnects(2M)** SAN- connects servers - network storage -disk arrays. Network attached storage (NAS) - connects client hosts - disk arrays. **Wide-Area Networking:** High-bandwidth networking increases - capability building –massively for distributed systems.
4	**Define and examine in detail about the multi core CPUs and multithreading technologies**. **(13M) Nov/Dec 2018** BTL 1 **Answer**: **page - 3-5 Bhushan** **Explanation(8M)** **Diagram(3M)** **CPU Technologies (2M)** ➢ Multicore CPUs - increase tens cores - hundreds or more ➢ DLP - forementioned memory wall problem. **Multicore CPU and Many-Core GPU Architectures (4M)** ➢ Triggered development many-core GPUs - hundreds or more thin cores. ➢ The GPU - applied large clusters - build supercomputers in MPPs. **Multithreading Technology (4M)** ➢ Only instructions ➢ Fine-grain multithreading switches - execution of instructions - different threads per cycle. ➢ Course-grain multithreading executes many instructions - same thread - few cycles before switching to another thread. ➢ The multicore CMP executes instructions - different threads completely.
5	**Analyze in detail about the GPU programming model. (13M)** BTL 4 **Answer**: **page – 22 Bhushan** **GPU(2M)** ➢ A GPU -graphics coprocessor - accelerator mounted on computer's graphics card or video card. ➢ A GPU offloads - CPU from tedious graphics tasks, video editing applications. **Programming Model (8M)** ➢ A modern GPU chip - built with hundreds of processing cores. ➢ GPUs - throughput architecture that exploits massive parallelism ➢ NVIDIA GPU - upgraded to 128 cores on single chip. GPU - handle eight threads of instructions. ➢ GPUs - designed to handle large numbers of floating point operations in parallel. **Diagram(3M)**

6 **i)Evaluate virtual machine and virtualization middleware in network based system? (8M)** BTL 5

Answer:page - 3-1,3-20 Bhushan Virtual Machine (2M)

- Virtual machines (VMs) - novel solutions to underutilized resources - application inflexibility - software manageability - security concerns in existing physical machines.

Middleware(4M)

- Large clusters, grids, and clouds - large amounts of computing, storage, and networking resources - virtualized manner.
- The VM - virtual resources managed by a guest - OS run a specific application.
- VMs host platform - deploy a middleware layer called a virtual machine monitor (VMM).
- The VMM called a hypervisor - privileged mode.

Diagram (2M)

ii)Explain the convergence of technologies in detail. (5M) BTL 5

Answer:page - 3-11 Bhushan

Convergence (5M)

- Information technology and media - sectors originally operated largely independent of one another
- Technical side - ability of any infrastructure - transport any type of data,
- Functional side - consumers integrate in a seamless way - functions of computation, entertainment.

PART C

1 **Illustarte the architecture of virtual machine and brief about the operations. (15M) 'Nov/Dec 2016** BTL 2

Answer:page - 3-11 Bhushan

VM(2M)

- Virtual machines (VMs) -underutilized resources, application inflexibility, software manageability, and security concerns - existing physical machines.

Operations(8M)

- Build large clusters, grids, and clouds - need to access large amounts of computing, storage, and networking resources - virtualized manner.
- Aggregate the resources - offer a single system image.
- The VM - virtual resources managed by a guest OS - run a specific application.
- VMs and host platform-deploy a middleware layer called a virtual machine monitor (VMM).
- The VMM - hypervisor in privileged mode.

VM Operations (5M)

VM Primitive Operations:

VMM provides the VM abstraction - guest OS.

- First, the VMs - multiplexed between hardware machines
- Second, a VM - suspended stored in stable storage
- Third, a suspended VM - resumed or provisioned to new hardware platform

- Finally, a VM - migrated from one hardware platform to another

2

i)Write a short note on: Clusters of Cooperative Computers. (7M) BTL1
Answer:page - 3-28 Bhushan
Clusters(2M)
Cluster Architecture

- Cluster – connected to internet via a virtual private network(VPN) gateway.

Hardware, Software and Middleware Support
Special cluster middleware supports – create SSi or high availability(HA)
Both sequential and parallel application - clusters facilitate cluster resources.

Major Cluster Design Issues:
Cluster wide OS for complete resource sharing

ii)Service Oriented Architecture (8M) 'Nov/Dec 2016 BTL 1
Answer:**page -37 Bhushan**
SOA (2M)

- In grids/web services, Java, and CORBA- an entity, a service, a Java object, and a CORBA - distributed object - variety of languages.
- Architectures build on the traditional seven Open Systems Interconnection (OSI) layers - base networking abstractions

Explanation (4M)

- A service-oriented architecture - a collection of services.
- Services communicate with each other.
- The communication involve simple data passing - two or more services coordinating some activity.

Diagram(2M)

3

Brief the interaction between the GPU and CPU in performing parallel execution of Operations (15M) 'April/May 2017 BTL 4
Answer:**page – 32 Bhushan**
GPU (2M)

- A GPU - graphics coprocessor or accelerator mounted on a computer's graphics card or video card.
- A GPU offloads the CPU from tedious graphics - tasks in video editing applications.

Comparison (8M)

- A modern GPU chip - hundreds of processing cores. GPUs have a throughput architecture - exploits massive parallelism - executing many concurrent threads slowly
- NVIDIA GPU - 128 cores on a single chip- each core on a GPU - handle eight threads of instructions.

Diagram(5M)

UNIT II GRID SERVICES	
Introduction to Open Grid Services Architecture (OGSA)-Motivation-Functionality Requirements-Practical & Detailed view of OGSA/OGSI-Data Intensive grid service models-OGSA services.	
PART A	
1	**Define OGSA. April/May 2017** BTL 1 Open Grid Services Architecture (OGSA) is a set of standards defining the way in which information is shared among diverse components of large, heterogeneous grid systems describes a service-oriented architecture for a grid computing environment for business and scientific use.
2	**Illustrate the relationship between resources and service.** BTL 3 A service can be defined as a self-contained, independently developed, deployed, managed, and maintained software implementation supporting specific business-relevant functionality for an enterprise as a whole and is "integratable" by design. A resource can be defined as a directly-accessible, independently-developed, deployed, managed and maintained software artifact supporting specific data.
3	**List the major goals of OGSA.** BTL 1 ➢ To manage the resources across distributed heterogeneous platform ➢ To support QOS oriented service level agreements ➢ To define a standard to achieve interoperability
4	**Summarize on the goals of GGF.** BTL 2 The Global Grid Forum has started an initiative to propose a standard architecture for grid computing to improve interoperability security, resource sharing, capability, policy management and grid manageability called OGSA and OGSI.
5.	**What is WSRF? Nov/Dec 2018** BTL 1 The Web Services Resource Framework (WSRF) defines a generic and open framework for modeling and accessing stateful resources using Web Services.T his includes mechanisms to describe views on the state, to support management of the state through properties associated with the Web Service.
6.	**Define grid infrastructure.** BTL1 Grid infrastructure is a complex combination of a number of capabilities and resources identified for the specific problem and environment being addressed. It forms the core foundations for successful grid applications.
7	**Summarize on grid service migration using GSH and GSR.** BTL 5 Grid service migration is a mechanism for creating new services and specifying assertions regarding the lifetime of a service. ➢ A GSH is a globally unique name that distinguishes a specific grid service instance from all others. ➢ The OGSA employs a "handle-resolution" mechanism for mapping from a GSH to a GSR. The GSH must be globally defined for a particular.
8	**Analyze the OGSA security model at various protection levels.** BTL 4 ➢ The OGSA supports security enforcement at various levels.

	➢ The grid works in a heterogeneous distributed environment, which is essentially open to the general public. ➢ At the security policy and user levels, apply a service or endpoint policy, resource mapping rules, authorized access of critical resources, and privacy protection.
9	**Discuss the strategies of data replication.** BTL 2 Replication strategies determine when and where to create a replica of the data. The factors to consider include data demand, network conditions, and transfer cost. The strategies of replication can be classified into method types: ➢ Dynamic and Static. ➢ Dynamic strategies can adjust locations and number of data replicas according to changes in conditions.
10	**List the model for organizing the data grid.** BTL 1 ➢ Monadic model ➢ Hierarchical model ➢ Federation model ➢ Hybrid model
11	**Differentiate parallel data transfer versus striped data transfer.** BTL 2 Parallel data transfer opens multiple data streams for passing subdivided segments of a file simultaneously. Striped data transfer-a data object is partitioned into a number of sections.
12	**Give the basic services of OGSA.** BTL 2 ➢ Infrastructure Service ➢ Execution Management Services ➢ Data Management Services ➢ Resource Management Services ➢ Security Services ➢ Information Services ➢ Self-Management Services
13	**Define WSRF.** BTL 1 ➢ The Web Services Resource Framework (WSRF) defines a generic and open framework for modeling and accessing stateful resources using Web Services. ➢ This includes mechanisms to describe views on the state, to support management of the state through properties associated with the Web Service
14	**Point out the objectives of OGSA.** BTL 4 ➢ To manage the resources across distributed heterogeneous platform ➢ To support QOS oriented service level agreements
15	**Deduce the fundamental requirements for describing Web services based on the OGSI.** BTL 5 There are two fundamental requirements for describing Web services based on the OGSI: ➢ The ability to describe interface inheritance—a basic concept with most of the distributed object systems. ➢ The ability to describe additional information elements with the interface definitions.

16	**Define grid service instance.** BTL 1 A grid service instance is a service that conforms to a set of conventions, expressed as WSDL interfaces, extensions, and behaviours, for such purposes as lifetime management, discovery of characteristics, and notification.
17	**Name the concepts involved in the components of OGSI.** BTL 1 ➢ Stateful Web Services ➢ Extension of Web Service Interfaces ➢ Asynchronous notification of state change ➢ Reference to instances of services
18	**Illustrate the Two approaches to the implementation of argument demarshaling functions in a grid service hosting environment.** BTL 3 ➢ OGSI does not dictate a particular service-provider-side implementation architecture. ➢ A container implementation may provide a range of functionality beyond simple argument demarshaling.
19	**Analyze the functional requirements of OGSA.** BTL 4 Various functional requirements are: ➢ Discovery and bokering ➢ Metering and auditing ➢ Data sharing and management ➢ Deployment ➢ Virtual organizations ➢ Application Monitoring
20	**Formulate the motivations that drive OGSA standards.** BTL 6 ➢ The OGSA developed within the OGSA Working Group of the Global Grid Forum, is a service-oriented architecture that aims to define a common, standard, and open architecture for grid-based applications. ➢ "Open" refers to both the process to develop standards and the standards themselves.
21	**What is meant by grid infrastructure?** BTL 1 Grid infrastructure is a complex combination of a number of capabilities and resources identified for the specific problem and environment being addressed. It forms the core foundations for successful grid applications.
22	**List the layers available in OGSA architectural organizations.** BTL 1 ➢ Native platform services and transport mechanisms. ➢ OGSA hosting environment. ➢ OGSA transport and security. ➢ OGSA infrastructure (OGSI). ➢ OGSA basic services (meta-OS and domain services).
23	**Discuss the role of the grid computing organization.** BTL 2 ➢ Organizations developing grid standards and best practices guidelines. Organizations developing grid computing toolkits, frameworks and middleware solutions. ➢ Organizations building and using grid - based solutions to solve their computing, data, and network requirements.

	➢ Organizations working to adopt grid concepts into commercial products, via utility computing and business on demand computing.
24	**Define WSDL.** BTL 1 WSDL is an XML Info set based document, which provides a model and XML format for describe web services. This enables services to be described and enables the client to consume these services in a standard way without knowing much on the lower level protocol exchange binding including SOAP and HTTP.
25	**Mention the fundamental components of SOAP specification.** BTL 2 ➢ An envelope that defines a framework for describing message structure. ➢ A set of encoding rules for expressing instances of application defined data types. ➢ A convention for representing remote procedure (RPC) and responses. A set of rules for using SOAP with HTTP. x Message exchange patterns (MEP) such as request-response, one-way and peer-to-peer conversations.
	PART B
1	**i)Define OGSA and describe the grid service architecture in detail. (7M) Nov/Dec 2018** BTL 1 **Answer**: **Page - 2-2 Bhushan** **Definition(2M)** ➢ OGSA - open source grid service - standard jointly developed by academia - IT industry - working group in the Global Grid Forum (GGF). ➢ Standard specifically developed for emerging grid - cloud service communities. **Explanation (3M)** **OGSA Framework** Globus Toolkit - grid technology solution – scientific, technical computing - web services for business - network applications **Diagram (2M)** **ii)Examine the grid service migration using GSH and GSR. (6M) (April/May 2017)** BTL 1 **Answer**: **Page -2-4 Bhushan** **GSR(3M)** ➢ Creating new services - specifying assertions - lifetime of a service. ➢ OGSA model - a standard interface - a factor to implement reference. **GSH(3M)** **Grid Service Handle** ➢ GSH - globally unique name - distinguishes specific grid service instance ➢ OGSA employs "handle-resolution" mechanism - mapping GSH to GSR. ➢ GSH - globally defined for particular instance.
2	**i)Summarize the OGSA security model implemented at various protection models. (7M) (April/May 2017)** BTL 2 **Answer:Page - 2-6 Bhushan** **Defintion(2M)** OGSA - security enforcement levels - Grid works heterogeneously in distributed environment - open to general public. **Explanation(5M)** ➢ Security policy and user levels - apply service endpoint policy - resource mapping rules - authorized access critical resources - privacy protection.

	➢ Public Key Infrastructure (PKI) service level - OGSA demands security binding - security protocol stack and bridging of certificate authorities (CAs) ➢ Trust models -secure logging practiced in grid platforms. **ii) Discuss how a GSH resolves to different GSR for migrated service instance. (6M)** BTL 2 **Answer: Page 2-6 Bhushan** **GSR(3M)** ➢ Creating new services - specifying assertions regarding lifetime of service. ➢ OGSA models standard interface -factor to implement reference. ➢ Service address former services - reference of services. ➢ Dynamically created grid service instance - associated with specified lifetime. **GSH(3M)** ➢ GSH - globally unique name distinguishes specific grid service instance. ➢ OGSA employs a "handle-resolution" mechanism mapping GSH to GSR. ➢ GSH - globally defined for instance.
3	**i)Demonstrate the service models of data intensive grid.(Nov/Dec 2016) (5M)** BTL 3 **Answer: Page - 1-12 Bhushan** **List and Expanation(5M)** ➢ Applications grid normally grouped into two categories: computation-intensive and data-intensive. ➢ Grid system - designed to discover, transfer, and manipulate - massive data sets. ➢ Transferring massive data sets - time-consuming task. ➢ Efficient data management demands low-cost storage - high-speed data movement. **ii)Illustrate the architectural models for building a data grid. (8M)** BTL 3 **Answer: Page - 1-15 Bhushan** **Types list(4M)** There are four access models for organizing a data grid ➢ Monadic model ➢ Hierarchical model ➢ Federation model ➢ Hybrid model **Diagram(4M)**
4	**i)Analyze the set of services for the building blocks of OGSA based grid. (5M)** BTL 4 **Answer: Page - 2-2 Bhushan** **Explanation(5M)** ➢ Deliver seamless QOS ➢ Open published interfaces - provide interoperability diverse resources ➢ Exploit industry standard integration technologies ➢ Develop standards - achieve interoperabilty **ii) Explain the services provided by OGSA architecture. (8M) (Nov/Dec 2016)** BTL 4 **Answer**: **Page - 2-8 Bhushan**

	List and Explanation(6M) ➢ Infrastructure Services ➢ Execution Management Services ➢ Data Management Services ➢ Resource Management Services ➢ Security Services ➢ Information Services ➢ Self-Management Services **Diagram(2M)**
5	**Describe in detail about the practical view of OGSA and OGSI. (13M)** BTL 1 **Answer: Page - 2-10 Bhushan** **Definition (2M)** Defined set of interfaces - systems built on open standards as WSDL. **Explanation (8M)** Manage resources - distributed heterogeneous platforms. QoS –Oriented Service Level Agreements(SLAs) - Topology of grid complex - interaction between grid resources - invariably dynamic –authorization,access control,delegation **Diagram(2M)**
6	**i)Examine the client side programming patterns for grid services. (7M)** BTL 3 **Answer**: **Page - 2-14 Bhushan** **Explanation(6M)** OGSI exploits component of the web services framework: use of WSDL multiple protocol bindings - encoding styles - messaging styles web services. Web services Invocation Framework(WSIF) and Java API for XML RPC (JAX – RPC) - infrastructure software that provide capability **Diagram(1M)** **ii)Demonstrate in detail about the conceptual hosting environment for grid service. (6M)** BTL – 3 **Answer: Page - 2-14 Bhushan** **Explanation(6M)** ➢ OGSI - service-provider-side implementation architecture. ➢ Container implementation - range of functionality- simple argument demarshaling.
PART C	
1	**Explain the data intensive grid service models with suitable diagrams. (15M) 'Nov/Dec 2016** BTL 1 **Answer: Page:2-14 in Bhushan** **Definition(2M)** ➢ Applications grid - grouped into two categories: computation-intensive and data-intensive. ➢ Grid system designed to discover, transfer, and manipulate - massive data sets. **Explanation(10M)** ➢ Transferring massive data sets - time-consuming task. ➢ Efficient data management demands low-cost storage - high-speed data movement. **Diagram(3M)**

2	**Write a neat sketch, Discuss the OGSA framework. (15M) 'Nov/Dec 2016** BTL2 **Answer**: **Page - 2-4 in Bhushan** **Definition(2M)** **OGSA Framework** **Explantion(10M)** ➢ OGSA - creation, termination, management - invocation of stateful transisent grid services - standard interfaces conventions ➢ OGSA framework specifies physical environment - security infrastructure - profile resource provisioning -virtual domains and execution environments - API access tools **Diagram(3M)**
3	**Write a detailed note on OGSA security models. (15M) 'April/May 2017** BTL 1 **Answer**: **Page: 2-6 Bhushan** **Definition(2M)** OGSA supports security enforcement levels. Grid works in heterogeneous distributed environment - open to general public **Diagram(3M)** **Explanation(10M)** **OGSA Service Models** ➢ Security policy, user levels -apply a service or endpoint policy, resource mapping rules, authorized access - critical resources, and privacy protection. ➢ Public Key Infrastructure (PKI) service level - OGSA demands security binding - security protocol stack - bridging certificate authorities (CAs) - use of multiple trusted intermediaries ➢ Trust models and secure logging - practiced in grid platforms.

UNIT 3-VIRTUALIZATION	
Cloud Deployment models: public, private, hybrid, community-Categories of cloud computing: Everything as a service: Infrastructure, Platform, Software-Pros and Cons of cloud computing-Implementation levels of virtualization-virtualization structure-virtualization of CPU, Memory and I/O devices-Virtual Clusters and resource Management-Virtualization for Data centre Automation.	
PART A	
1	**Define public private and hybrid clouds. Nov/Dec 2016** BTL 1 ➢ Public: Accessible, via the internet to anyone who pays E.g., Google App Engine, Amazon Web Service. ➢ Private: Accessible via an internet to the members of owing organization E.g., NASA cloud for climate modeling. ➢ Hybrid: A private cloud might buy computing resources from a public cloud.
2	**Differentiate centralized and distributed computing.** BTL 2 Centralized computing: This is a computing paradigm by which all computer resources are centralized in one physical system. Distributed computing: a distributed system consists of multiple autonomous computers, each having its own private memory, communicating through a computer network.
3	**List the design objective of cloud**. BTL 1 Make cloud systems scalable by design so that they can exploit the elasticity of the cloud, as well as maintaining and also improving scalability during system evolution.
4	**Define IaaS.** BTL 1 ➢ This model allows users to use virtualized IT resources for computing, storage, and networking. In short, the service is performed by rented cloud infrastructure. ➢ The user can deploy and run his applications over his chosen OS environment. ➢ The user does not manage or control the underlying cloud infrastructure, but has control over the OS, storage, deployed applications, and possibly select networking components.
5	**Generalize on PaaS and SaaS. April/May 2017** BTL 6 Platform as a Service(PaaS) To be able to develop,deploy and manage the execution of applications using provisioned resources demands a cloud platform with proper software environment. Software as a Service(SaaS): This refers to browser –initiated application software over thousands of cloud customers. Services and tools offered by Paas are utilized in construction of applications and management.

6	**Show the levels of virtualization implementation.** BTL 3 ➢ After virtualization, different user applications managed by their own operating systems (guest OS) can run on the same hardware, independent of the host OS. ➢ This is often done by adding additional software, called a virtualization layer. This virtualization layer is known as hypervisor or virtual machine monitor (VMM). ➢ The VMs are shown in the upper boxes, where applications run with their own guest OS over the virtualized CPU, memory, and I/O resources.
7	**Discuss the design requirements of VMM.** BTL 2 There are three requirements for a VMM. ➢ First, a VMM should provide an environment for pro-grams which is essentially identical to the original machine. ➢ Second, programs run in this environment should show, at worst, only minor decreases in speed. ➢ Third, a VMM should be in complete control of the system resources.
8	**Analyze the advantages and disadvantages of Grid Computing.** BTL 4 Advantages ➢ Can solve larger, more complex problems in a shorter time. ➢ Easier to collaborate with other organizations. ➢ Make better use of existing hardware. Disadvantages ➢ Grid software and standards are still evolving. ➢ Learning curve to get started. ➢ Non-interactive job submission.
9	**How does the virtualization support the Linux platform?** BTL 5 The Xen hypervisor has been applied to virtualize x86-based machines to run Linux or other guest OS.
10	**Compare binary translation with full virtualization.** BTL 4 Full virtualization: With full virtualization, noncritical instructions run on the hardware directly while critical instructions are discovered and replaced with traps into the VMM to be emulated by software. Binary translation: VMware puts the VMM at Ring 0 and the guest OS at Ring 1. The VMM scans the instruction stream and identifies the privileged, control- and behavior-sensitive instructions.
11	**Demonstrate the need of virtualization need of multi- core processor.** BTL 3 ➢ Virtualizing a multi-core processor is relatively more complicated than virtualizing a unicore processor. ➢ Though multicore processors are claimed to have higher performance by integrating multiple processor cores in a single chip, muti-core virtualization has

	raised some new challenges to computer architects, compiler constructors, system designers, and application programmers.
12	**Discuss the design issues of virtual clusters. Nov/Dec 2018** BTL 2 Three critical design issues of virtual clusters: ➢ Live migration of VMs, ➢ Memory and file migrations, ➢ Dynamic deployment of virtual clusters.
13	**List the properties of Virtual clusters when virtual machines are dynamically allocated.** BTL 1 The virtual cluster nodes can be either physical or virtual machines. Multiple VMs running with different OSes can be deployed on the same physical node
14	**Define GSR**. BTL 1 Grid service instances are made accessible to client applications through the use of a grid service handle and a grid service references(GSR)
15	**Describe the resource managers of eucalyptus for virtual network.** BTL 2 CM(Cloud Manager) GM (Group Manager) IM (Instance Manager) Works like AWS APIs
16	**How the data storage is classified in virtual environment?** BTL 3 Four main Layers are: ➢ Storage Device ➢ Block aggregation Layer ➢ File/Record Layer ➢ Application Layer
17	**Formulate the side effects of server virtualization.** BTL 6 ➢ Creation of more high-density areas and hot spots ➢ Potentially detrimental effect on power usage effectiveness (PUE) ➢ Dynamic IT load swings ➢ Lower redundancy requirements
18	**Where OS level virtualization is needed?** BTL 1 ➢ An abstraction layer between traditional OS and user applications ➢ OS-level virtualization is commonly used in creating virtual hosting environments to allocate hardware resources among a large number of mutually distrusting users
19	**Discuss on the support of middleware for virtualization.** BTL 5 ➢ Library-level virtualization is also known as user-level Application Binary Interface (ABI) or API emulation. ➢ This type of virtualization can create execution environments for running alien programs on a platform rather than creating a VM to run the entire operating system.
20	**Compare Full virtualization and Para virtualization.** BTL 4 Para virtualization: Virtualization in which the guest operating system is aware that it is a guest and accordingly has drivers that, instead of issuing hardware commands, simply issue commands directly to the host operating system. Full virtualization: Virtualization in which the guest operating system is unaware that

	it is in a virtualized environment, and therefore hardware is virtualized by the host operating system so that the guest can issue commands to what it thinks is actual hardware, but really are just simulated hardware devices created by the host.
21	**Define Cloud services with example.** BTL2 ➢ Any web-based application or service offered via cloud computing is called a cloud. ➢ Cloud services can include anything from calendar and contact applications to word processing and presentations.
22	**Explain cloud provider and cloud broker.** BTL1 Cloud Provider: Is a company that offers some component of cloud computing typically infrastructure as a service, software as a Service or Platform as a Service. It is something referred as CSP. Cloud Broker: It is a third party individual or business that act as an intermediary between the purchase of cloud computing service and sellers of that service.
23	**Define anything-as-a-service.** BTL1 Providing services to the client on the basis on meeting their demands at some pay per use cost such as data storage as a service, network as a service, communication as a service etc. It is generally denoted as anything as a service (XaaS).
24	**List the types of hypervisor.** BTL2 There are two types of hypervisors: ➢ Type 1 (bare-metal) ➢ Type 2 (hosted) Type 1: Hypervisors run directly on the system hardware. They are often referred to as a "native" or "bare metal" or "embedded" hypervisors in vendor literature. Type 2**:** Hypervisors run on a host operating system. When the virtualization movement first began to take off, Type 2 hypervisors were most popular. Administrators could buy the software and install it on a server they already had.
25	**What is the working principle of Cloud Computing? April/May 2017** BTL1 ➢ The cloud is a collection of computers and servers that are publicly accessible via the This hardware is typically owned and operated by a third party on a consolidated basis in one or more data center locations. ➢ The machines can run any combination of operating systems.
	PART B
1	**i)Examine in detail about public private and hybrid cloud. (8M) (Nov/Dec 2016)** BTL 1 **Answer**:**Page:3-30 - Bhushan** **ii)Examine in detail about data center networking Structure (5M) (April/May 2017)** BTL 1 **Answer**:**Page: 3-5 Bhushan** **i) Definition (2M)** ➢ Public: Accessible via internet - anyone who pays E.g., Google App Engine,Amazon Web Service. ➢ Private:Accessible via internet – members owing organization E.g., NASA cloud climate modeling. Hybrid: Private cloud buy computing resources. **Explanation(4M)** Public cloud - publicly accessible cloud environment - owned by a third party cloud

	provider. IT resources on public clouds - provisioned via cloud delivery models -offered to cloud consumers - cost – commercialized. **Diagram(2M)** **ii)Explanation (3M)** ➢ Physical cluster - collection of servers (physical machines) - interconnected -physical network (LAN) ➢ Virtual clusters - VMs installed at distributed servers - physical clusters. ➢ VMs in virtual cluster - interconnected logically - virtual network physical networks. ➢ Virtual cluster - physical machines - VM hosted multiple physical clusters. ➢ Virtual cluster boundaries - distinct boundaries. **Diagram(2M)**
2	**Analyze the uses of** **i)Infrastructure as a service (4M)** **ii)Platform as a service (4M)** **iii)Software as a service(5M) April/May 2017** BTL 4 **Answer:Page:3-7 Bhushan** **Infrastructure as a Service(IaaS)** Allows users - virtualized IT resources for computing, storage, and networking. Service - rented cloud infrastructure. **Platform as a Service(PaaS)** Able to develop, deploy and manage - execution of applications - provisioned resources demands a cloud platform - software environment **Software as a Service(SaaS):** Browser –initiated application software. Services and tools - offered by Paas - construction of applications and management.
3	**i)Discuss the various levels of virtualization implementation. (7M)** **April/May 2017** BTL 2 **Answer:Page:3-7 Bhushan** **ii)Summarize the design requirements and providers of VMM. (6M)** BTL 2 **Answer:Page:3-11 Bhushan** **i)Explanation (7M)** ➢ Instruction set architecture(ISA) level ➢ Hardware level ➢ Operating system level ➢ Library support level ➢ Application level **ii)Explanation(6M)** ➢ First, VMM - provide environment for pro-grams - identical to original machine. ➢ Second, programs run - environment minor decreases in speed. ➢ Third, VMM - complete control of system resources

4	**i)List the advantages and disadvantages of OS extension in virtualization. (6M)** BTL 1 **Answer:Page:3-11 Bhushan** **ii)Identify the support of virtualization Linux platform. (7M)** BTL 1 **Answer: Page :71 Bhushan** **i)Advantages(3M)** ➢ advantage - failover flexibility **Two difficulties**: **(3M)** ➢ Application programs - parallelized use all cores - software explicitly assign tasks - very complex problem. **ii) Virtualization Linux(7M)** ➢ Allows complete client control - virtualized system hardware. ➢ Executes operations directly - hardware resources including CPUs. ➢ Two classes of Hypervisor: Type1 and Type 2. ➢ Hardware Compatibility.
5	**i)Summarize the support of middleware and library for virtualization. (7M)** BTL 2 **Answer: Page:3-23 – Bhushan** **ii)Describe the vCUDA architecture for virtualization of general purpose GPUs (7M)** BTL 2 **Answer**: **page:3-11 in Bhushan** **i)Explanation(4M)** ➢ Applications use APIs - exported user-level libraries - use lengthy system calls - systems provide well-documented APIs - interface becomes another candidate - virtualization. **Diagram(3M)** **ii)Definition(2M)** ➢ CUDA - programming model - library for general-purpose GPUs- high performance of GPUs - compute-intensive applications - host operating systems. **Explanation(4M)** ➢ Difficult to run CUDA applications - hardware-level VMs directly. ➢ vCUDA virtualizes the CUDA library - installed on guest OSes. ➢ CUDA applications run - guest OS - issue a call to CUDA API, ➢ vCUDA intercepts the call - redirects - CUDA API running host OS. **Diagram(1M)**
6	**i) Compose in detail about the classes of VM architecture based on the position of virtualization layer Hypervisor and Xen architecture. (8M)** BTL 6 **Answer: Page:3-16 - Bhushan** **ii)Design the implementation technology of hardware virtualization. (5M)** BTL 6 **Answer: Page:3-16 Bhushan** **i)Explanation(6M)**

	➢ **Hypervisor** supports hardware-level virtualization - bare metal devices - CPU, memory, disk - network interfaces. ➢ Hypervisor software - directly between physical hardware - OS. ➢ Virtualization layer - VMM or hypervisor. ➢ The hypervisor provides hyper calls - guest OSes - applications. **Diagram(2M)** **ii)Hardware-level virtualization(5M)** - top of bare hardware. ➢ Generates virtual hardware environment ➢ Process manages - hardware through virtualization. ➢ Virtualizes a computer's resources - processors, memory, I/O devices. ➢ Intention to upgrade - hardware utilization rate – concurrently.
	PART C
1	**What do you mean by data center automation using virtualization? (15M) April/May 2017 Nov/Dec 2018** BTL 2 **Answer:Page:3-31 - Bhushan** **List(4M)** **Virtualization for Data-Center Automation** ➢ Server Consolidation in Data Centers ➢ Virtual Storage Management ➢ Cloud OS for Virtualized Data Centers ➢ Trust Management in Virtualized Data Centers **Explanation(8M)** Data center automation - managing and automating - workflow and processes - data center facility. Automating bulk of data center operations - management - monitoring - maintenance tasks. **Diagram (3M)**
2	**Discuss how virtualization is implemented in different layers. (15M) April/May 2017** BTL 4 **Answer:Page:3-16 - Bhushan** **Explanation(8M)** Virtualize - portion of a computing environment - organization seeking performance - reliability/availability – scalability – consolidation – agility - a unified management. Implementation Levels of Virtualization **List(4M)** ➢ Instruction level architecture ➢ Hardware level ➢ Operating system level ➢ Library support level ➢ Application level **Diagram (3M)**
3	**List the cloud deployment models and give a detailed note on them. (15M) Nov/Dec 2016** BTL 1 **Answer:Page: 3-4 Bhushan** **Definition &List(4M)** **Infrastructure as a Service(IaaS)** Allows users - virtualized IT resources for computing, storage, and networking. Service - rented cloud infrastructure. **Platform as a Service(PaaS)**

	Able to develop, deploy and manage - execution of applications - provisioned resources demands a cloud platform - software environment **Software as a Service(SaaS):** Browser –initiated application software - Services and tools - offered by Paas - construction of applications and management. **Explanation(8M)** Capability provided to consumer - provider’s applications running - cloud infrastructure. Applications - accessible from various client devices - thin client interface - web browser (e.g., web-based email) - program interface. **Diagram (3m)**

UNIT-4- PROGRAMMING MODEL

Open source grid middleware packages- Globus Toolkit(GT4) Architecture, Configuration- Usage of Globus - Main Components and Programming Model- Introduction to Hadoop Framework- Map reduce, Input Splitting, Map and Reduce functions, Specifying input and output parameters, configuring and running a job-Design of Hadoop file system, HDFS concepts, Command line and java interfaces, dataflow of File read & File write

PART A

1	**Analyze on grid software support and middleware packages.** BTL 4 ➢ The software on the Grid includes programs such as ROOT, a set of object-oriented core libraries used by all the LHC experiments; POOL, a framework that provides storage for event data. ➢ The Grid depends on the computer and communications networks of the underlying internet, novel software allows users to access computers distributed across the network. This software is called "middleware".
2	**Define condor.** BTL 1 Condor is an open-source high-throughput computing software framework for coarse-grained distributed parallelization of computationally intensive tasks. Example: Condor-G
3	**Examine the sequences of events of SGE workflow.** BTL 3 ➢ The user delegates his credentials to a delegation service. ➢ The user submits a job request to GRAM with the delegation identifier as a parameter. ➢ GRAM parses the request, retrieves the user proxy certificate from the delegation service, and then acts on behalf of the user. ➢ GRAM sends a transfer request to the RFT, which applies Grid FTP to bring in the necessary files.
4	**Summarize on Globus toolkit architecture.** BTL 2 ➢ The Globus Toolkit, started in 1995 with funding from DARPA, is an open middleware library for the grid computing communities. ➢ The toolkit addresses common problems and issues related to grid resource discovery, management, communication, security, fault detection, and portability. The library includes a rich set of service implementations.
5	**List the functional modules in GT4 library. Nov/Dec 2016** BTL 1 ➢ Global Resource Allocation Manager ➢ Communication ➢ Grid Security Infrastructure ➢ Monitory and Discovery Service ➢ Health and Status

	➢ Global Access of Secondary Storage ➢ Grid File Transfer
6	**Evaluate how data's are managed using GT4.** BTL 5 Data management tools are concerned with the location, transfer, and management of distributed data. ➢ GridFTP ➢ RFT ➢ RLS
7	**Define Globus client Interaction.** BTL 1 There are strong interactions between provider programs and user code. GT4 makes heavy use of industry-standard web service protocols and mechanisms in service Description, discovery, access, authentication, authorization, and the like. GT4 makes extensive use of Java, C, and Python to write user code.
8	**Analyze the need of MDS services in distributed system.** BTL 4 ➢ The Monitoring and Discovery System (MDS) is a suite of web services to monitor and determine resources and services on Grids. ➢ Allows users to discover what resources are considered part of a Virtual Organization. ➢ It offers trigger and indexing services.
9	**Illustrate the building blocks in GT4 library**. BTL 3 ➢ The GT4 Library GT4 offers the middle-level core services in grid applications. ➢ The high-level services and tools, such as MPI, Condor-G, and Nirod/G, are developed by third parties for general purpose distributed computing applications. ➢ The local services, such as LSF, TCP, Linux, and Condor, are at the bottom level and are fundamental tools supplied by other developers.
10	**List the security measures in grid.** BTL 1 The necessary security measures are in terms of authentication, authorization, resource protection, secure communication, data confidentiality, data integrity, policy management and network security.
11	**Evaluate why is a Block in HDFS so large?** BTL 5 ➢ HDFS blocks are large compared to disk blocks, and the reason is to minimize the cost of seeks. ➢ If the block is large enough, the time it takes to transfer the data from the disk can be significantly longer than the time to seek to the start of the block.
12	**Differentiate name node with data node in hadoop file system.** BTL 2 ➢ An HDFS cluster has two types of node operating in a master-worker pattern: a **name node** (the master) and a number of **data nodes** (workers). ➢ The name node manages the file system namespace. It maintains the file system tree and the metadata for all the files and directories in the tree. ➢ This information is stored persistently on the local disk in the form of two files: ➢ the namespace image and the edit log. ➢ The name node also knows the data nodes on which all the blocks for a given file are located.
13	**Interpret how file permission is achieved in HDFS.** BTL 2 **For each file system, Hadoop uses a different URI scheme for the file system instance in order to connect with it. For example, you list the files in the local system by using the file URI scheme, as shown here:**

	$ hdfs dfs –ls file:///
14	**Generalize how a name node is not able to serve a request.** BTL 6 The namenode is still a single point of failure (SPOF), since if it did fail, all clients—including MapReduce jobs—would be unable to read, write, or list files, because the namenode is the sole repository of the metadata and the file-to-block mapping.
15	**Analyze how a standby takes over when an active name node is failed.** BTL 4 When a standby name node comes up it reads up to the end of the shared edit log to synchronize its state with the active name node, and then continues to read new entries as they are written by the active name node.
16	**Define failover and fencing.** BTL 1 ➢ The transition from the active name node to the standby is managed by a new entity in the system called the failover controller ➢ The HA implementation goes to great lengths to ensure that the previously active name node is prevented from doing any damage and causing corruption—a method known as fencing.
17	**Generalize how an anatomy of File read is done.** BTL 6 ➢ The client opens the file it wishes to read by calling open () on the File System object, which for HDFS is an instance of Distributed File System. ➢ Distributed File System calls the name node, using RPC, to determine the locations of the blocks for the first few blocks in the file. ➢ The name node returns the addresses of the data nodes that have a copy of that block.

18	**Discuss how a data is read from hadoop URL.** BTL 2
	One of the simplest ways to read a file from a Hadoop files system is by using a java.net. URL object to open a stream to read the data from.
	The general idiom is:
	`InputStream in = null;`
	`try {`
	`    in = new URL("hdfs://host/path").openStream();`
	`    // process in`
	`} finally {`
	`    IOUtils.closeStream(in);`
	`}`

19	**Name the details of file querying system.** BTL 1 Files and directories are like standard SQL tables The following example shows a query on a file system database in a Hadoop distributed file system. `SELECT * FROM hdfs.logs.`AppServerLogs/20104/Jan/01/part0001.txt`;`
20	**Demonstrate how does the name node choose which data nodes to store replicas on?** BTL 3 ➢ The replica placement strategy is that if the writer is on a data node, ➢ the 1st replica is placed on the local machine, otherwise a random data node.

	➢ The 2nd replica is placed on a data node that is on a different rack. ➢ The 3rd replica is placed on a data node which is on the same rack as the first replica.
21	**What are the available input formats?** BTL 1 ➢ Key Value Text Input Format ➢ Text Input Formant ➢ NLine Input Format ➢ Multi File Input Format ➢ Sequence FIle Input Format
22	**Define Block.** BTL 1 ➢ A disk has a block size, which is the minimum amount of data that it can read or write. ➢ File systems for a single disk build on this by dealing with data in blocks, which are an integral multiple of the disk block size. File system blocks are typically a few kilobytes in size.
23	**List two types of nodes that control the job execution process.** BTL 2 A job tracker and a number of task trackers controls the job execution process.
24	**What is meant by FUSE?** BTL 1 ➢ File system in User space (FUSE) allows file systems that are implemented in user space to be integrated as a Unix file system. ➢ Hadoop's Fuse-DFS contribute module allows any Hadoop file system (but typically HDFS) to be mounted as a standard file system.
25	**Define the term Globus Container**. BTL 1 The Globus Container provides a basic runtime environment for hosting the web services needed to execute grid jobs.
	PART B
1	**Describe the relative strength and limitation of open source grid middleware packages. (13M)** BTL 1 **Answer: Page:4-2 - Bhushan** **Advantages(7M)** ➢ Computational resources ➢ Storage resources ➢ Network resources ➢ Scientific instruments **Disadvantages(6M)** ➢ Access to resources ➢ Computing ability
2	**i)List the features in condor kernel and condor G for grid computing**. **(7M)** BTL 1 **Answer:Page:4-7 - Bhushan** **Definition (2M)** **Explanation (2M)** High-throughput computing – ➢ Large amounts of fault-tolerant computational power ➢ Effective utilization of resource Opportunistic computing ➢ Use resource whenever available **Condor G (3M)** Preserve local execution environment -Condor can transfer files

	➢ Automatically send back changed files ➢ Atomic transfer multiple files ➢ Can encrypted over the wire ➢ Remote I/O Socket ➢ Standard Universe - use remote system calls **ii)Describe sun grid engine middleware package in detail. (6M)** BTL 1 **Answer:Page: 71 -Bhushan** **Definition(2M)** ➢ System - offers centralized management - resources allocated to individual jobs. ➢ Enhance efficiency – performance – suspend and resume tools - allow users to halt job - restart without losing work. **Explanation(4M)** ➢ Accepts jobs from users. ➢ Places jobs in computer area. ➢ Sends jobs holding area - host executed. ➢ Manages jobs during execution. ➢ Logs record of execution.
3	**i)Summarize the grid standards and APIs. (8M)** BTL 2 **Answer**: **Page:4-6 - Bhushan** **Explanation(4M)** Open Grid Forum (formally Global Grid Forum) - Object Management Group - well-formed organizations behind standards. **List(2M)** ➢ SAGA (Simple API for Grid Applications), ➢ GSI (Grid Security Infrastructure), ➢ OGSI (Open Grid Service Infrastructure), ➢ WSRE (Web Service Resource Framework). **Diagram (2M)** **ii)Discuss on grid software support and middleware package. (5M)** BTL 2 **Answer:Page:4-2 - Bhushan** **Explanation(5M)** ➢ Grid middleware - layer between hardware and software. ➢ Middleware products - enable sharing - heterogeneous resources - managing virtual organizations - created around the grid. ➢ Middleware - glues allocated resources - specific user applications.
4	**i)Illustrate Globus tool kit architecture in detail. (8M) (Nov/Dec 2016)** BTL 3 **Answer:Page:4-6 - Bhushan** **Definition(2M)** ➢ Open source software libraries - support operational grids - applications on international basis. ➢ Toolkit addresses – issues like grid resource discovery – management – communication – security - fault detection – portability - software provides variety of components - capabilities. **Explanation(4M)** ➢ Library - rich set of service implementations. ➢ Implemented software - supports grid infrastructure management - provides tools - building new web services in Java, C, and Python.

Diagram (2M)

ii)Classify the functional modules in GT4 library. (5M) BTL 3

Answer:Page:4 -7 - Bhushan

List(5M)

- Global Resource Allocation Manager (GRAM)
- Grid Resource Access and Management (HTTP)
- Communication (Nexus) - Unicast - multicast communication
- Grid Security Infrastructure (GSI) - Authentication - security services
- Monitory and Discovery Service(MDS) – Distributed - access structure and state information.
- Health and Status (HBM) - Heartbeat monitoring of system components.
- Global Access of Secondary Storage (GASS) - Grid access data - remote secondary storage.
- Grid File Transfer Grid (FTP) - Inter-node fast file transfer.

5 **i)Explain the concepts involved in resource management using GRAM. (7M)** BTL 4

Answer:Page:80 - Bhushan

Explanation(5M)

- Global Resource Allocation Manager (GRAM)
- Grid Resource Access and Management (HTTP)
- GRAM module supports web services – initiating – monitoring - managing execution - computational jobs on remote computers.
- GRAM - built local resource allocation services.

Diagram(2M)

ii)Classify the GT4 tools used by data management. **(6M)** BTL 4

Answer:Page:4-6 - Bhushan

Definition(2M)

- GT4 tools - used individually - conjunction with other tools - develop interesting solutions - efficient data access.
- **GridFTP** supports reliable – secure - fast memory-to-memory - disk-to-disk data movement - over high-bandwidth WANs.

Explanation(4M)

- **RFT -** provides reliable management - multiple Grid FTP transfers
- **RLS** (Replica Location Service) - scalable system for maintaining - providing access to information - location of replicated files - data sets.
- **OGSA-DAI** (Globus Data Access and Integration) - tools developed by UK e-Science program - provide access - relational XML databases.

6 **i)Evaluate the interaction in the functional module client globus job work flow. (8M) BTL 5**

Answer:Page:4-12 - Bhushan

Definition(2M)

- GRAM parses request - retrieves user proxy certificate - delegation service.
- GRAM sends transfer request - RFT (Reliable File Transfer) - applies Grid FTP - bring necessary files.

Explanation(4M)

- Typical job execution sequence - user delegates his credentials - delegation service. User submits job request - GRAM - delegation identifier as parameter.

Diagram(2M)

ii)Summarize the functional components in CGSP library. (5M) BTL 5

	Answer: Page:4-8 - Bhushan **Listing Components(5M)** ➢ Service container ➢ Security manager ➢ Information center ➢ Data manager ➢ Execution manager ➢ Domain manager ➢ Grid monitor ➢ Portal
7	**i)Generalize the functional components of china grid support platform library. (7M)** BTL 6 **Answer: Page:4-16 - Bhushan** **List (2M)** ➢ Service container ➢ Security manager ➢ Information center ➢ Data manager **Explanation(5M)** ➢ Execution manager ➢ Domain manager ➢ Grid monitor ➢ Portal **ii)Design the functional building blocks in the CGSP library that represents the job executional flow. (6M)** BTL 6 **Answer: Page:4-16 - Bhushan** **Explanation(4M)** ➢ ChinaGrid - constructing public grid service system - research and higher education in China. ➢ CGSP - integrates sorts of heterogeneous resources - educational and research resources - distributed over CERNET in China. **Diagram(2M)**
	PART C
1	**Draw and Explain the Global Toolkit architecture (15M) (Nov/Dec 2016) Nov/Dec 2018** BTL 2 **Answer: Page:4-6 - Bhushan** **Defintion (2M)** ➢ Globus Toolkit - open middleware library - grid computing communities. ➢ Open source software libraries - support many operational grids - applications on international basis. **Explanation(10M)** ➢ Toolkit addresses common problems - issues related to grid resource discovery-management – communication – security - fault detection - portability. ➢ Software provides variety of components – capabilities - rich set of service implementations. **Diagram(3M)**

2	**Give a detailed note on Hadoop framework. (15M) (Nov/Dec 2016)** BTL 4 **Answer: Page:4-19 - Bhushan** **Definition (2M)** ➢ Hadoop - Apache Software Foundation top-level project - holds various Hadoop subprojects - graduated from Apache Incubator. **Explanation(10M)** ➢ Hadood handles processing details - leaving developers free focus on application logic. ➢ Hadoop project - provides supports development - open source software - supplies a framework - development of highly scalable - distributed computing applications. **Diagram(3M)**
3	**Discuss MAPREDUCE with suitable diagrams. (15M) (April/May 2017) Nov/Dec 2018** BTL 3 **Answer: Page:4-22 - Bhushan** **Explanation(10M)** ➢ Web programming model - scalable data processing on large clusters - over large data sets. ➢ Model - applied web-scale search - cloud computing applications. **Diagram(3M)**
4	**Elaborate HDFS concepts with suitable Illustrations. (15M) (April/May2017)** BTL 4 **Answer: Page:4-29 - Bhushan** **Definition (2M)** Hadoop Distributed File System(HDFS) – Map Reduce environment – provides user with sophisticated framework – manage execution of map – reduce tasks – across cluster of machines. **Explanation(10M)** ➢ Location(s) - distributed file system of job input ➢ Location(s) - distributed file system for job output ➢ Input format ➢ Output format ➢ Class containing map function ➢ Class containing reduce function ➢ JAR file(s) containing map - reduce functions - support classes **Diagram(3M)**

UNIT 5- SECURITY	
Trust models for grid security environment-Authentication and Authorization methods-Grid security infrastructure-Cloud Infrastructure security: network, host and application level-aspects of data security, provider data and its security, Identity and access management architecture, IAM practices in the cloud, SaaS, PaaS, IaaS availability in the cloud, Key privacy issues in the cloud	
PART A	
1	**Give the challenges to establish trust among grid sites.** BTL 2 ➢ The first challenge is integration with existing systems and technologies. ➢ The second challenge is interoperability with different "hosting environments." ➢ The third challenge is to construct trust relationships among interacting hosting environments.
2	**Define IDS.** BTL 1 An intrusion detection system (IDS) is a type of security software designed to automatically alert administrators when someone or something is trying to compromise information system through malicious activities or through security policy violations.
3	**Summarize on reputation trust model.** BTL 2 Reputation-based trust model and techniques are used for securing P2P and social networks could be merged to defend data centers and cloud platforms against attacks from the open network.
4	**List various trust models.** BTL 1 ➢ A Generalized Trust Model ➢ Reputation-Based Trust Model ➢ A Fuzzy-Trust Model
5	**Relate Active and Passive attacks.** BTL 3 ➢ Passive attacks steal sensitive data or passwords. ➢ Active attacks manipulate kernel data structures which will cause major damage to cloud servers.
6	**Evaluate the authorization model of grid security.** BTL 5 ➢ The subject-push model ➢ The resource-pulling model

	➢ The authorization agent model .
7	**Define Authentication.** BTL 1 The process of identifying an individual, usually based on a username and password. In security systems, authentication is distinct from authorization , which is the process of giving individuals access to system objects based on their identity.
8	**Formulate the categories of authorization for access control.** BTL 6 ➢ attribute authorities ➢ policy authorities ➢ identity authorities
9	**Discuss on GSI. Nov/Dec 2018** BTL 2 ➢ The major authentication methods in the grid include passwords, PKI, and Kerberos. ➢ The password is the simplest method to identify users, but the most vulnerable one to use. ➢ The PKI is the most popular method supported by GSI.
10	**Differentiate transport level security and message level security Nov/Dec 2016** BTL 4 Transport Level security: means providing security at the transport layer itself. When dealing with security at Transport level, we are concerned about integrity, privacy and authentication of message as it travels along the physical wire. Message Level Security: For Tranport level security, we actually ensure the transport that is being used should be secured but in message level security, we actually secure the message. We encrypt the message before transporting it.
11	**Compose the primary pieces of information of a certificate in GSI authentication**. BTL 6 ➢ A subject name, which identifies the person or object that the certificate represents ➢ The public key belonging to the subject ➢ The identity of a CA that has signed the certificate to certify that the public key and the identity both belong to the subject ➢ The digital signature of the named CA. X.509 provides each entity with a unique identifier.
12	**How will you measure the mutual authentication between two parties?** BTL 5 Mutual authentication is machine-to-machine, when the remote authentication fails Non-technical mutual-authentication also exists to mitigate this problem, requiring the user to complete a challenge, effectively forcing them to notice, and blocking them from authenticating with a false endpoint. Mutual authentication is two types: ➢ Certificate based ➢ User name-password based
13	**Define aspects of Data Security.** BTL 3 Security for ➢ Data in transit ➢ Data at rest ➢ Processing of data including multitenancy ➢ Data Lineage

	➢ Data Provenance
14	**Discuss the risk factors of network level of cloud infrastructure.** BTL 2 ➢ Ensuring data confidentiality and integrity of the organizations data in transit to and from the public cloud provider ➢ Ensuring proper access control (Authentication, Authorization, Auditing) to resources in the public cloud ➢ Ensuring availability of the Internet facing resources of the public cloud used by the organization. ➢ Replacing the established network zones and tiers with domains
15	**Explain the security levels at Host Level.** BTL 1 Host security at PaaS and SaaS Level ➢ Both the PaaS and SaaS hide the host operating system from end users ➢ Host security responsibilities in SaaS and PaaS are transferred to CSP.
16	**Compare SaaS and PaaS Application security.** BTL 4 Application security at the SaaS level ➢ SaaS Providers are responsible for providing application security ➢ Application security at the PaaS level ➢ Security of the PaaS Platform ➢ Security of the customer applications deployed on a PaaS platform.
17	**Show how will you categorize host security in IaaS?** BTL 3 Host security at IaaS Level ➢ Virtualization software security ➢ Hypervisor security ➢ Threats: Blue Pill attack on the hypervisor.
18	**Identify the security Challenges in VMs.** BTL 1 Buffer overflows, DoS attacks, spyware, malware, rootkits, Trojan horses, and worms. In a cloud environment, newer attacks may result from hypervisor malware, guest hopping and hijacking, or VM rootkits, the man-in-the-middle attack for VM migrations.
19	**List out the categories in PaaS application security.** BTL 1 Application security at the PaaS level ➢ Security of the PaaS Platform ➢ Security of the customer applications deployed on a PaaS platform
20	**Point out security issues in cloud.** BTL 4 ➢ Loss of Control ➢ Lack of trust ➢ Multi-tenancy
21	**What is password based authentication?** BTL 2 The authentication is a process of checking authenticity of entities using different methods like password, public key infrastructure(PKI) or Kerberos
22	**Explain the common attacks happen at host level.** BTL 1 ➢ Hijacking of accounts ➢ Stealing the keys like SSH private keys ➢ Attacking unpatched and vulnerable services

	➢ Attcking systems that are not secured ➢ Deploying Trojans embedded viruses in the software
23	**What do you mean by Identity and access management in cloud? Nov/Dec 2016** BTL 2 It is the security framework composed of policy and governance components used for creation ,maintanence and termination of digital indentities with controlled access of shared resources
24	**Define GSI.** BTL1 The Grid Security Infrastructure is a part of Globus toolkit that provides fundamental security services and standards to support grid including authentication,authorization and delegation
25	**List two types of Network level attacks.** BTL1 ➢ Eavesdropping ➢ Port Scanning ➢
	PART B
1	**Examine in detail about trust model for grid security enforcement (13M) (April/May 2017)** BTL 3 **Answer**: **Page - 5-2 - Bhushan** **Explanation(8M)** ➢ Potential security issues- occur in grid environment- qualified security mechanisms. ➢ Issues include- network sniffers- out-of-control access-faulty operation-malicious operation-integration- local security mechanisms-delegation-dynamic resources and services-attack provenance ➢ A Generalized Trust Model ➢ A Reputation-Based Trust Model ➢ A Fuzzy-Trust Model **Diagram(5M)**
2	**i)Define Authentication and Summarize on three authorization models of GSI. (8M)** BTL1 **Answer: Page - 5-4,5-5 - Bhushan** **Definition (2M)** ➢ Authentication methods- grid include passwords-PKI- Kerberos. ➢ Password - method to identify users – but vulnerable to use. **Explanation models(4M)** ➢ PKI - most popular- method supported by GSI. ➢ Authorization Access Control ➢ Three Authorization Models **Diagram(2M)** **ii)Discuss on the trust delegation operations using proxy credentials in GSI**. **(5M)** BTL 1 **Answer**: **Page - 5-7 - Bhushan** **Credentials(5M)** ➢ To reduce - avoid number of times - user enter his passphrase -several grids are used - have agents (local or remote)- request services –on behalf of user- GSI provides - delegation capability -delegation service - provides an interface - allow clients to delegate (and renew) - X.509 proxy certificates service.

	➢ Proxy - a new certificate and private key- Key pair used for proxy- public key embedded in certificate - private key- either be regenerated -for each proxy
3	**i)Define GSI and describe in detail about GSI functional layers.GT4 provides distinct WS and pre-WS authentication and authorization capabilities. (8M)** BTL 1 **Answer**: **Page - 5-7 - Bhushan** **Explanation(4M)** **Transport-Level Security(2M)** ➢ Transport-level security entails - SOAP messages -conveyed over a network - connection protected by TLS. **Message-Level Security(2M)** ➢ GSI provides- message-level security - message protection for SOAP messages - implements WS-Security standard -WS-Secure Conversation specification **Diagram(4M)** **ii)Examine in detail about multiple handshaking in mutual authentication scheme. (5M)** BTL 1 **Answer**: **Page - 5-9 - Bhushan** **Authentication Scheme(5M)** ➢ Mutual authentication - process by two parties - certificates signed by CA -prove to each other -based on the certificate -trust of the CAs - signed each other's certificates ➢ GSI uses - Secure Sockets Layer (SSL) - mutual authentication protocol ➢ Mutually authenticate- the first person (Alice) - establishes a connection-second person (Bob) - start authentication process.
4	**i)Demonstrate the infrastructure security: Network level in cloud. (7M) (Nov/Dec 2016)** BTL 3 **Answer: Page - 5-9 - Bhushan** **Network level in cloud(7M)** ➢ Ensuring data confidentiality - integrity of organizations data - transit to and from - public cloud provider ➢ Ensuring proper access control (Authentication, Authorization, Auditing)- resources in public cloud ➢ Ensuring availability-Internet facing resource - public cloud used by organization ➢ Replacing - established network zones - tiers with domains **ii)Classify the Key privacy issues in the cloud. (6M)** BTL 3 **Answer**: **Page - 5-9 - Bhushan** ➢ Loss of Control **(2M)** ➢ Lack of trust**(2M)** ➢ Multi-tenancy**(2M)**
5	**i)Analyze the infrastructure security of cloud at host level (7M) (Nov/Dec 2016) Nov/Dec 2018** BTL 4 **Answer**: **Page - 5-9- Bhushan** **Host security at PaaS and SaaS Level (4M)** ➢ PaaS and SaaS - hides host operating system - end users ➢ Host security responsibilities- SaaS and PaaS transferred to CSP **Host security at IaaS Level(3M)** ➢ Virtualization software security

	➢ Hypervisor security ➢ Threats: Blue Pill attack on hypervisor **ii)Explain in detail about virtual server security of cloud. (6M)** BTL 4 **Answer: Page - 5-10 - Bhushan** **Cloud Security(6M)** Customer guest OS - virtual server security ➢ Attacks the guest OS: e.g., stealing keys used - access and manage hosts
6	**Explain in detail about application level security in i)SaaS ii)PaaS iii)IaaS (13M)** BTL 4 **Answer**: **Page - 5-12 - Bhushan** **Explanation(12M)** **Application security at the SaaS level(4M)** ➢ SaaS Providers - responsible for providing - application security **Application security at the PaaS level(4M)** ➢ Security of PaaS Platform ➢ Security of customer applications - deployed on PaaS platform **Application security at the IaaS Level(4M)** ➢ Customer applications –treated as black box ➢ IaaS - not responsible for application level security **Diagram(1M)**
7	**i)Compose in detail about the aspects of data security (13M)** BTL 6 **Answer**: **Page - 5-14 - Bhushan** **Definition(2M)** ➢ Data security - weakest link- cloud models- new cloud security standards- apply common API tools - cope with data lock-in problem - network attacks or abuses. **Explanation(8M)** ➢ IaaS model - Amazon - sensitive to external attacks. ➢ Role-based interface tools - alleviate complexity of provisioning system. ➢ Distributed Defense - against DDoS Flooding Attacks ➢ Data and Software Protection Techniques ➢ Data Integrity and Privacy Protection ➢ Data Coloring and Cloud Watermarking ➢ Data Lock-in Problem and Proactive Solutions ➢ Reputation-Guided Protection of Data Centers **Diagram(3M)**
	PART C
1	**Explain Trust models for Grid security Environment (15M) (Nov/Dec 2016)** BTL 2 **Answer**: **Page - 5-2 - Bhushan** **Definition(2M)** **Diagram(3M)** ➢ Potential security issues -occur in grid environment - qualified security mechanisms. **Explanation(10M)**

	➢ Issues include- network sniffers- out-of-control access-faulty operation-malicious operation-integration of local security mechanisms-delegation-dynamic resources and services-attack provenance ➢ A Generalized Trust Model ➢ Reputation-Based Trust Model ➢ A Fuzzy-Trust Model
2	**Write in detail about cloud security infrastructure (15M) (Nov/Dec 2016)** BTL 1 **Answer**: **Page- 5-9 - Bhushan** **Definition(2M)** Lacking trust - service providers and cloud users - hindered universal acceptance - cloud computing - service on demand-trust models -developed to protect - e-commerce and online shopping - provided by eBay and Amazon **Cloud Security Defense Strategies(4M)** ➢ Basic Cloud Security ➢ Security Challenges in VMs ➢ Cloud Defense Methods ➢ Defense with Virtualization ➢ Privacy and Copyright Protection **Distributed Intrusion/Anomaly Detection** ➢ Distributed Defense -DDoS Flooding Attacks **Data and Software Protection Techniques(4M)** ➢ Data Integrity and Privacy Protection ➢ Data Coloring and Cloud Watermarking ➢ Data Lock-in Problem and Proactive Solutions **Reputation-Guided Protection of Data Centers(2M)** ➢ Reputation System Design Options ➢ Reputation Systems for Clouds ➢ Trust Overlay Networks **Diagram(3M)**
3	**Write a detailed note on Identity and access management architecture (15M) (April/May 2017)** BTL 1 **Answer: Page – 140 -Notes** **Definition(2M)** ➢ Improves operational efficiency - regulatory compliance management ➢ IAM - organizations to achieve access cont6rol- operational security **Explanation(10m)** ➢ Cloud use cases - need IAM ➢ Organization employees accessing- SaaS provide identity federation ➢ IT admin access CSP management console - provision resources - access users - usecorporate identity ➢ Developers creating accounts - partner users in PaaS ➢ End users access storage service in cloud ➢ Applications - residing in cloud serviced provider - access storage from another cloud service **Diagram(3M)**

CS6704 RESOURCE MANAGEMENT TECHNIQUES

L T P C

3 0 0 3

OBJECTIVES:

The student should be made to:

- Be familiar with resource management techniques.
- Learn to solve problems in linear programming and Integer programming.
- Be exposed to CPM and PERT.

UNIT I LINEAR PROGRAMMING 9

Principal components of decision problem – Modeling phases – LP Formulation and graphic solution – Resource allocation problems – Simplex method – Sensitivity analysis.

UNIT II DUALITY AND NETWORKS 9

Definition of dual problem – Primal – Dual relation ships – Dual simplex methods – Post optimality analysis – Transportation and assignment model - Shortest route problem.

UNIT III INTEGER PROGRAMMING 9

Cutting plan algorithm – Branch and bound methods, Multistage (Dynamic) programming.

UNIT IV CLASSICAL OPTIMISATION THEORY: 9

Unconstrained external problems, Newton – Ralphson method – Equality constraints – Jacobean methods – Lagrangian method – Kuhn – Tucker conditions – Simple problems.

UNIT V OBJECT SCHEDULING: 9

Network diagram representation – Critical path method – Time charts and resource leveling – PERT.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Completion of the course, the students should be able to:

- Solve optimization problems using simplex method.
- Apply integer programming and linear programming to solve real-life applications.
- Use PERT and CPM for problems in project management

TEXT BOOK:

1. H.A. Taha, “Operation Research”, Prentice Hall of India, 2002.

REFERENCES:

1. Paneer Selvam, ‘Operations Research’, Prentice Hall of India, 2002

2. Anderson ‘Quantitative Methods for Business’, 8th Edition, Thomson Learning, 2002.

3. Winston ‘Operation Research’, Thomson Learning, 2003.

4. Vohra, ‘Quantitative Techniques in Management’, Tata Mc Graw Hill, 2002.

5. Anand Sarma, ‘Operation Research’, Himalaya Publishing House, 2003

Subject Code: CS6704 **Year/Semester: IV/07**

Subject Name: Resource Management Techniques **Subject Handler: Dr. Shenbaga Ezhil**

UNIT I- LINEAR PROGRAMMING *Principal components of decision problem – Modeling phases – LP Formulation and graphic solution – Resource allocation problems – Simplex method – Sensitivity analysis.*	
UNIT-I / PART-A	
1	**What is operations research? (BTL1)** Operations research is the study of **optimization techniques**. OR is the application of **scientific methods, techniques and tools** to problems involving the operations of systems to find optimal solutions. It is applied in decision theory.
2	**List some applications of OR. (May 2018) (BTL1)** ❖ To find **optimal assignment** of various jobs to different machines. ❖ To find the **waiting time** and number of customers waiting in the queue and system in **queuing model.** ❖ To find the **minimum transportation cost** with optimal allocation of goods from different origins to various destinations. ❖ To find **decision** in problems of marketing, finance, production planning and control.
3	**How is an OR model organized? (BTL1)** The first crucial step in any OR model is the definition of the alternatives or the **decision variables** of the problem. Next, the decision variables are used to construct the **objective function and the constraints** of the model. With the three steps completed, the OR model is organized in the following general format: **maximize or minimize objective function subject to constraints**.
4	**List the different techniques used to solve the OR model. (BTL1)** ❖ **Linear programming**: it is designed for models with strict linear objective and constraint functions. ❖ **Integer programming**: in which the variables assume integer values. ❖ **Dynamic programming**: in which the original model can be decomposed into smaller sub-problems. ❖ **Network programming**: in which the problem can be modelled as a network. ❖ **Nonlinear programming**: in which the functions of the model are non-linear.
5	**What are the phases of an OR study? (BTL1)** The principal phases for implementing OR in practice include: ❖ Definition or **formulation** of the problem. ❖ **Construction** of the mathematical model. ❖ **Derive** the solution of the model. ❖ **Validation** of the model. ❖ **Implementation** of the solution.

6	**Give any two Limitations of Linear Programming. (May 2018) (BTL1)** i. The major limitations of linear programming is that it treats all relationships as linear. But it is not true in many real life situations. ii. All the parameters in the linear programming model are assumed to be known constants. But in real life they may not be known completely or they may be probabilistic and they may be liable for changes from time to time.
7	**What is linear programming? (BTL1)** Linear programming (LP) applies to optimization models in which the **objective and constraint functions are strictly linear.** It is a technique used for determining **optimum utilization of limited resources** to meet out the given objectives. The objective is to maximize the profit or minimize the resources (men, machine, materials and money).
8	**What are the basic components for LP model? (BTL1)** The LP model, as in any OR model has three basic components: ❖ **Decision variables** that we seek to determine ❖ **Objective (goal)** that we aim to optimize ❖ **Constraints** that we need to satisfy
9	**What are the requirements for employing LPP technique? (BTL1)** ❖ There must be a **well-defined objective function**. ❖ There must be **alternative courses of action** to choose. ❖ At least some of the **resources** must be in **limited** supply, which give rise to **constraints**. ❖ Both the **objective function and the constraints must be linear** equations or inequalities.
10	**What is the mathematical model of linear programming? (BTL1)** The linear programming involving more than two variables may be expressed as follows: **Maximize or Minimize** $Z = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n$ **Subject to constraints** $a_{11}x_1+a_{12}x_2+ \ldots + a_{1n}x_n \leq$ or $=$ or $\geq b_1$ $a_{21}x_1+a_{22}x_2+ \ldots + a_{2n}x_n \leq$ or $=$ or $\geq b_2$ ……………………………………………. ……………………………………………. $a_{m1}x_1+a_{m2}x_2+ \ldots + a_{mn}x_n \leq$ or $=$ or $\geq b_m$ and the **non-negativity restrictions** $x_1,x_2,\ldots\ _n \geq 0$
11	**What are the properties that LP must satisfy? (BTL1)** Linearity implies that LP must satisfy two properties: ❖ **Proportionality:** requires the contribution of each decision variable in the objective function and its requirements in the constraints to be **directly proportional** to the value of the variable. ❖ **Additivity:** stipulates that the total contribution of all the variables in the objective function and their requirements in the constraints are the **direct sum** of the individual contribution or requirements of each variable.

13	**Define feasible solution and optimal solution to the linear programming problem. (Nov 2016) (BTL1)** A set of variables x1,x2….xn which **satisfies the constraints** of LPP is called a **solution**. Any solution to a Linear Programming Problem which **satisfies the non- negativity restrictions** of LPP's called the **feasible solution**. Any feasible solution which **optimizes the objective function** of the LPP's called the **optimal solution**.
14	**What is Feasible Region in a LPP? (Nov 2017) (BTL3)** In mathematical optimization, a feasible region, feasible set, search space, or solution space is the set of all possible points (sets of values of the choice variables) of an optimization problem that satisfy the problem's constraints, potentially including inequalities, equalities, and integer constraints.
15	**Define slack and slack variable. (BTL1)** **Explain slack variables of LP problem. (May 2017)** In ≤ constraints, the right hand side can be thought of as representing the limit on the availability of a resource, the left hand side represents the usage of this limited resource. The difference between the RHS and LHS of the ≤ constraint yields the **unused or slack** amount of the resource. To convert the ≤ inequality to an equation, a **non-negative slack variable** is added to the LHS of the constraint. For eg: $6x_1 + 4x_2 \leq 24$ is converted to $6x_1 + 4x_2 + s_1 = 24$, $s_1 \geq 0$, $s_1 \rightarrow$ slack variable
16	**Define surplus and surplus variable. (BTL1)** A ≥ constraint normally sets a lower limit on the activities of the LP model. The amount by which the LHS **exceeds the minimum limit represents a surplus**. The conversion from ≥ to = is achieved by subtracting a **non-negative surplus variable** from the LHS of the inequality. For eg: $x_1 + x_2 \geq 800$ is converted to $x_1 + x_2 - S_1 = 800$, $S_1 \geq 0$, $S_1 \rightarrow$ surplus variable.
17	**What are the characteristics of LPP in canonical form? (BTL1)** In matrix notation the canonical form of LPP can be expressed as: Maximize Z = CX (objective function) Subject to AX ≤ b (constraints) And X ≥ 0 (non-negativity restrictions) Where $C = (c_1, c_2, \ldots\ldots\ldots, c_n)$ $A = \begin{bmatrix} a_{11} & a_{12} & \ldots a_{1n} \\ a_{12} & a_{22} & \ldots a_{2n} \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ a_{m1} & a_{m2} & \ldots\ldots a_{mn} \end{bmatrix}, X = \begin{pmatrix} x_1 \\ x_2 \\ . \\ . \\ . \\ x_n \end{pmatrix}, b = \begin{pmatrix} b_1 \\ b_2 \\ . \\ . \\ . \\ b_m \end{pmatrix}$ **Charcteristics:** ❖ The objective function is of maximization type ❖ All constraints are of ≤ type ❖ All variables x_i are non-negative

18 **What is sensitivity analysis? (May 2017, Nov 2017) (BTL1)**

Sensitivity analysis **investigates the changes in the optimal solution** resulting from making changes in parameters of the LP model. Sensitivity analysis is also called **post optimality analysis**.

19 **What are the changes that affect feasibility? (BTL1)**

There are two types of changes that could affect feasibility of the current solution:

- ❖ Changes in **resources availability** (or right side of the constraints or requirement vector b) and
- ❖ Addition of **new constraints**.

20 **What are the characteristics of LPP in standard form? (BTL2)**

The general linear programming problem in the form

Maximize or Minimize $Z = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n$

Subject to constraints

$a_{11}x_1 + a_{12} x_2 + \ldots + a_{1n}x_n = b_1$

$a_{21}x_1 + a_{22} x_2 + \ldots + a_{2n}x_n = b_2$

…………………………………………….

…………………………………………….

$a_{m1}x_1 + a_{m2} x_2 + \ldots + a_{mn}x_n = b_m$

and the non-negativity restrictions $x_1, x_2, \ldots x_n \geq 0$ is known as standard form.

In matrix notation the standard form of LPP can be expressed as:

Maximize Z = CX (objective function)

Subject to constraints AX = b and X ≥ 0

Characteristics:

- ❖ The objective function is of maximization type.
- ❖ All the constraint equation must be of equal type by adding slack or surplus variables
- ❖ RHS of each constraint must be positive type.
- ❖ All variables are non-negative.

21 **List all possible cases that can arise in sensitivity analysis with their actions to obtain new solution. (BTL2)**

Condition resulting from the changes	Recommended action
Current solution remains optimal and feasible	No further action is necessary
Current solution becomes infeasible	Use dual simplex to recover feasibility
Current solution becomes non-optimal	Use primal simplex to recover optimality
Current solution becomes both non-optimal and infeasible	Use the generalized simplex method to obtain a new solution

22 **What are the changes that affect optimality? (BTL3)**

There are two particular situations that could affect optimality of the current solution:

- ❖ Changes in the **original objective coefficients**.
- ❖ Addition of **new economic activity** (variable) to the model.

UNIT-I / PART-B

1 **Explain the types of Models. Also explain the characteristics of a good model along with the principles involved in modeling.(16M) (Nov 2017) (BTL2)**

Modeling

The first thing one has to do to use O.R techniques after formulating a practical problem is to construct a suitable model to represent the practical problem. A model is a reasonably simplified representation of a real-world situation. It is an abstraction of reality. The models can broadly be classified as or types

Types of modeling **(6M)**

- ✓ Iconic Models
- ✓ Mathematical models
- ✓ Analogue models
- ✓ Static models
- ✓ Dynamic models
- ✓ Deterministic models
- ✓ Stochastic models
- ✓ Descriptive models
- ✓ Prescriptive models
- ✓ Analytic models
- ✓ Simulation models

Characteristics of a good modeling: **(4M)**

- ✓ It should be reasonably simple.
- ✓ A good model should be capable of taking into account new changes in the situation affecting its frame significantly with ease. i.e updating the models should be simple and easy as possible.
- ✓ Assumptions made to simplify the model should be as small as possible.
- ✓ Number of variables used should be as small in number as possible.
- ✓ The model should be open to parametric treatment.

Principles of Modeling: **(6M)**

- ✓ Do not build up a complicated model while a simple one will suffice
- ✓ Beware of modeling the problems to fit a technique
- ✓ Deductions must be made carefully
- ✓ Models should be validated prior to implementation
- ✓ A model should neither be pressed to do nor criticized for failing to do that for which it was never intended
- ✓ Beware of overselling the model in cases where assumption made for the construction of the model can be challenged
- ✓ The situation of a model cannot be more accurate than the accuracy of the information that goes into the construction of the model
- ✓ Models are only aids in decision making
- ✓ Model should be as accurate as possible.

2 **Elucidate the procedure for formulating linear programming problems. Explain the advantages and limitations of linear programming .(10M) (Nov 2017) (BTL4)**

Formulation of linear programming is the representation of problem situation in a mathematical form. It involves well defined decision variables, with an objective function and set of constraints.

Objective function (5M)

The objective of the problem is identified and converted into a suitable objective function. The objective function represents the aim or goal of the system (i.e., decision variables) which has to be determined from the problem. Generally, the objective in most cases will be either to maximize resources or profits or, to minimize the cost or time.

For example, assume that a furniture manufacturer produces tables and chairs. If the manufacturer wants to maximize his profits, he has to determine the optimal quantity of tables and chairs to be produced.

Let x_1= Optimal production of tables P_1= Profit from each table sold X_2= Optimal production of chairs P_2= Profit from each chair sold.

Hence, Total profit from tables = $p_1 x_1$

Total profit from chairs = $p_2 x_2$

The objective function is formulated as below, Maximize Z or Z max = $p_1 x_1 + p_2 x_2$Constraints

When the availability of resources is in surplus, there will be no problem in making decisions. But in real life, organizations normally have scarce resources within which the job has to be performed in the most effective way. Therefore, problem situations are within confined limits in which the optimal solution to the problem must be found.

Considering the previous example of furniture manufacturer, let w be the amount of wood available to produce tables and chairs. Each unit of table consumes w_1 unit of wood and each unit of chair consumes w_2 units of wood.

For the constraint of raw material availability, the mathematical expression is,

$w_1 x_1 + w_2 x_2 \leq w$

In addition to raw material, if other resources such as labor, machinery and time are also considered as constraint equations.

Non-negativity constraint (5M)

Negative values of physical quantities are impossible, like producing negative number of chairs, tables, etc., so it is necessary to include the element of non-negativity as a constraint i.e., $x_1, x_2 \geq 0$

A general representation of LP model is given as follows:

Maximize or Minimize, $Z = p_1 x_1 + p_2 x_2 \ldots\ldots\ldots\ldots p_n x_n$

Subject to constraints,

$w_{11} x_1 + w_{12} x_2 + \ldots\ldots\ldots\ldots w_{1n} x_n \leq$ or = or $\geq w_1$………………(i) $w_{21} x_1 + w_{22} x_2 \ldots\ldots\ldots\ldots w_{2n} x_n \leq$or = or $\geq w_2$………………(ii) $w_{m1} x_1 + w_{m2} x_2 + \ldots\ldots\ldots\ldots w_{mn} x_n \leq$ or = $\geq w_m$……………(iii)

Non-negativity constraint,

$x_i \geq$ o (where i = 1,2,3 ......n)

3 **Solve the following LPP by graphical method:(12M)(BTL1)(May2018)**

Max $Z = 3x_1 + 2x_2$

subject to

$-2x_1 + x_2 \leq 1$

$x_1 \leq 2$

$x_1 + x_2 \leq 3$

and $x_1, x_2 \geq 0$.

Solution: First consider the inequality constraints as equalities.

$-2x_1 + x_2 = 1$ (1)

$x_1 = 2$ (2)

$x_1 + x_2 = 3$ (3)

$x_1 = 0$ (4)

$x_2 = 0$ (5)

From the line $-2x_1 + x_2 = 1$

Put $x1 = 0 \Rightarrow x2 = 1 \Rightarrow (0,1)$

Put $x2 = 0 \Rightarrow -2x1 = 1 \Rightarrow x1 = -0.5 \Rightarrow (-0.5, 0)$ (4M)

So the line (1) passes through the points (0,1) and (-0.5, 0). The points on this line satisfy the equation $-2x_1 + x_2 = 1$. Now origin (0, 0) on substitution, gives $-0 + 0 = 0 < 1$; hence it also satisfies the inequality $-2x_1 + x_2 \leq 1$. Thus all points on the origin side and on this line satisfy the inequality $-2x_1 + x_2 \leq 1$. Similarly interpreting the other constraints, the feasible solution is OABCD. The feasible region is also known as solution space of the LPP. Every point in this area satisfies all the constraints.

Now the aim is to find vertices of the solution space. B is the point of intersection of $x1 = 2$ and $x1 + x2 = 3$. Solving these two equations, $x1 = 2$ and $x2 = 1$. Therefore the vertex B(2,1). Similarly C is the intersection of $-2x1 + x2 = 1$ and $x1 + x2 = 3$. Solving these $C(\frac{2}{3}, \frac{7}{3})$. (4M)

Therefore the vertices solution space are O(0,0), A(2,0), B(2,1), $C(\frac{2}{3}, \frac{7}{3})$ and D(0,1). The value of Z at these vertices are given by ($Z = 3x1 + 2x2$).

Vertex	**Value of Z**
O(0,0)	0
A(2,0)	6
B(2,1)	8
$C(\frac{2}{3}, \frac{7}{3})$	$\frac{20}{3}$
D(0,1)	2

Since the problem is of maximization type, the optimum solution to the LPP is

Maximum $Z = 8$, $x1 = 2$ and $x2 = 1$ (4M)

4 **Solve the following LPP problem using graphical method.(8M) (BTL1)**

Maximize Z = $6x_1+8x_2$

Subject to

$5x_1+10x_2 \leq 60$

$4x_1+4x_2 \leq 60$

x_1 and $x_2 \geq 0$ (May 2017)

Solution:

By converting inequalities to equalities the constraints become

$5x_1+10x_2= 60$-------------------(1)

$4x_1+4x_2 =60$ --------------------(2)

Based on the constraints (1) the coordinates becomes (0,6), (12,0)

Based on the constraints (2) the coordinates becomes (0,15), (15,0) (4M)

Vertex	**Z= 6x1+8x2**
O(0,0)	0
A(12,0)	72
B(15,0)	80
C(0,15)	120
D(0,6)	48

Max Z= 120, x_1= 0, x_2= 15 (4M)

5 **Solve the following linear programming problem using graphical method.(12M) (BTL3)(Nov 2017)**

Maximize Z=$100x_1+80x_2$

Subject to

$5x_1 + 10x_2 \leq 50$

$8x_1 + 2x_2 \geq 16$

$3x_1 - 2x_2 \geq 6$

x_1 and $x_2 \geq 0$ (Nov 2016)

Solution:

Change the inequalities to equalities

$5x1 + 10x2 =50 \rightarrow (1)$

$8x1 + 2x2 = 16 \rightarrow (2)$

$3x1 - 2x2 = 6 \rightarrow (3)$

$x1 = 0$

$x2 = 0$ (4M)

(1)$\Rightarrow$ 5x1 + 10x2 =50

Put x1 = 0 $\Rightarrow$ x2 = 5 (0,5)

	Put x2 = 0 $\Rightarrow$ x1 = 10 (10,0)

(2)$\Rightarrow$ 8x1 + 2x2 = 16

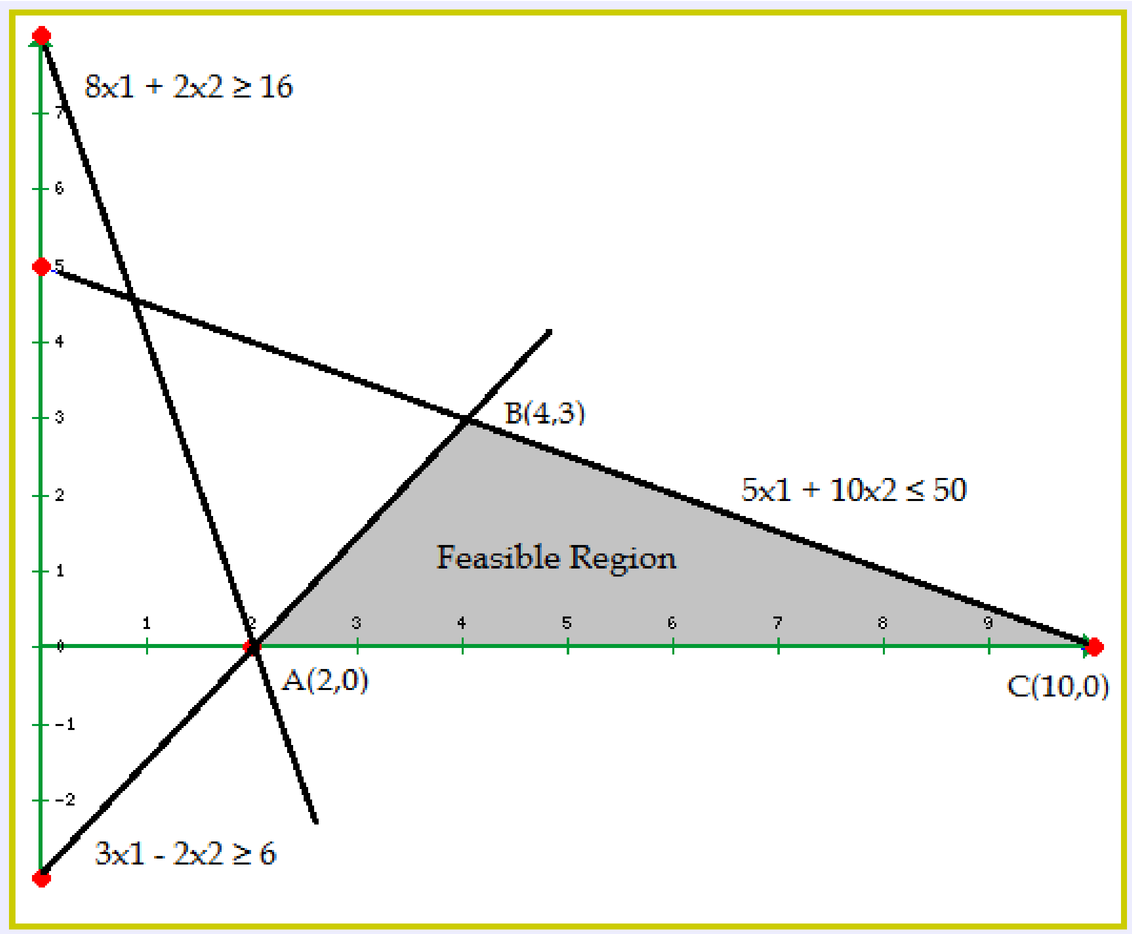
Put x1 = 0 $\Rightarrow$ x2 = 8 (0,8)

Put x2 = 0 $\Rightarrow$ x1 = 2 (2,0)

(3)$\Rightarrow$3x1 - 2x2 = 6

Put x1 = 0 $\Rightarrow$ x2 = -3 (0,-3)

Put x2 = 0 $\Rightarrow$ x1 = 2 (2,0) (4M)



The feasible region is given by region ABC.

Vertex A(2, 0)

Vertex B: Solve 5x1 + 10x2 =50 and 3x1 - 2x2 = 6

$\Rightarrow$x1 = 4 and x2 = 3 Vertex B (4,3)

Vertex C(10,0)

Vertex	Z
A (2, 0)	200
B (4, 3)	640
C (10,0)	1000

The optimal solution is Max Z = 1000, x1 = 10 and x2 = 0 (4M)

6	**A company manufactures two types of printed circuits. The requirements of transistors, resistors and capacitors for each type of printed circuits along with other data are given below:(12M) (BTL4)(May 2018)** **How many circuits of each type should the company produce from the stock to earn maximum profit?**

Components	**Circuit A**	**Circuit B**	**Stock Available**
Transistor	**15**	**10**	**180**
Resistor	**10**	**20**	**200**
Capacitor	**15**	**20**	**210**
Profit	**Rs. 5**	**Rs. 8**	

Solution: Let x1 be the number of type A circuits and x2 be the number of type B circuits to be produced. To produce these units of type A and type B the company requires

Transistors = 15x1 +10x2

Resistor = 10x1 + 20x2

Capacitor = 15x1 + 20x2

Since the availability of these transistors, resistors and capacitors are 180, 200 and 210 respectively, the constraints are

$15x1 + 10x2 \leq 180$

$10x1 + 20x2 \leq 200$

$15x1 + 20x2 \leq 210$

and $x1 \geq 0, x2 \geq 0$ (6M)

Since the profit from type A is Rs. 5 and from type B is Rs. 8 per units, the total profit is 5x1 + 8x2. Therefore the complete formulation of the LPP is

Maximize Z = 5x1 + 8x2

Subject to

$15x1 + 10x2 \leq 180$

$10x1 + 20x2 \leq 200$

$15x1 + 20x2 \leq 210$

and $x1 \geq 0, x2 \geq 0$

By using graphical method the solution space is given with the shaded area OABCD with vertices O(0,0), A(12,0), B(10,3), C(2,9) and D(0,10). The values of Z of these vertices are given by Z=5x1+8x2 (4M)

Vertex	Value of Z
O(0,0)	0
A(12,0)	60
B(10,3)	74
C(2,9)	82
D(0,10)	80

Since the problem is of maximization type, the optimal solution is

Maximize Z = 82, x1 = 2, x2 = 9 (2M)

7 Garden Ltd. Has two products Rose and Lotus. To produce one unit of Rose, 2 units of material X and 4 units of material Y are required. To produce one unit of Lotus, 3 units of material X and 2 units of material Y are required. At least 16 units of each material must be used in order to meet the committed sales of Rose and Lotus Cost per unit of material X and material Y are Rs.2.50 per unit and Rs. 0.25 per unit respectively.

You are required:

i. **To formulate mathematical model**
ii. **To solve it for the minimum cost(Graphically)(12M) (BTL1) (May 2018)**

Solution:

Particular	Rose (Rs.)	Lotus(Rs.)
A Material X B Material Y C Total [A +B]	(Rs. 2.50 X 2) 5.00 (Rs 0.25 X 4) 1.00 ---------- 6.00	(Rs. 2.50 X 3) 7.50 (Rs. 2.50 X 2) 0.50 -------- 8.00

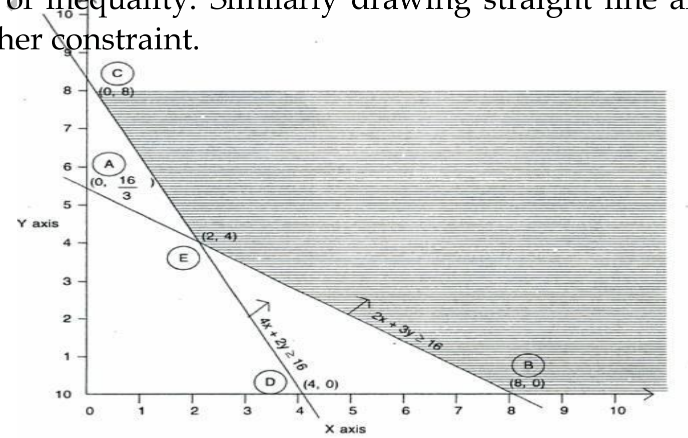
Part (i)

Since the objective is to minimize, the objective function is given by:
Minimize Z = 6x+8y
Subject to constraints:
2x+3y≥16 (Minimum material X constraint)
4x+2y≥16 (Minimum material Y constraint)
X,y≥ 0 (Non negativity constraint)

Part(ii)

Step 1: Finding the vertex for each constraint by treating the constraint of inequality nature as equality.
Constraint (i) in limiting from 2x+3y = 16
When x =0, y = 16/3
When y = 0, x = 16 / 2 = 8
Thus, the vertices are (0,16/3) & (8,0)
Constraint (ii) in limiting from 4x+2y = 16
When x=0, y=16/2 = 8
When y =0, x=16/4=4
Thus, the vertices are(0,8) & (4,0) (6M)

Step 2: Plotting both the co – ordinates of the 1 st constraint on the graph and joining them by straight line and shading the feasible region which are opposite to origin in case of more than type of inequality. Similarly drawing straight line and shading the feasible region for the other constraint.



Step 3: Reading the co-ordinates of the vertices of common shaded feasible region and putting the co-ordinates of each of such vertex in the objective function. Choose those vertices which achieve the most optimal solution (i.e in case of minimization vertices which gives the minimum value of Z).

Set No	Co-ordinates of vertex of common shaded feasible region	Value of Z
1	C(0,8)	Z=64
2	E(2,4)	Z=44
3	B(8,0)	Z=48

Hence the optimal solution is by minimum value of Z with 44 and x = 2, y = 4 (6M)

8 **Obtain all the basic solutions to the following system of linear equations:**

$2x_1 + 6x_2 + 2x_3 + x_4 = 3$,

$6x_1 + 4x_2 + 4x_3 + 6x_4 = 2$

Which of them are basic feasible solutions and which are non-degenerate basic solutions? Is the non-degenerate solution feasible? (6M)(BTL1)(May 2018)

Solution: Since there are 4 variables with 2 equations there are $4C_2 = 6$ different basic solutions, which are given in the following table: (6M)

No.	Basic variables	Non-basic variables	Values of the basic variables given by the constraint equations	Is the solution feasible?	Is the solution non-degenerate?	Is the solution feasible and non-degenerate?
1	x1, x2	x3 = x4 = 0	2x1 + 6x2 = 3 6x1 + 4x2 = 2 ⇒ x1 = 0, x2 = 1/2	Yes	No	No
2	x1, x3	x2 = x4 = 0	2x1+ 2x3 = 3 6x1 + 4x3 = 2 ⇒ x1 = -2, x3 = 7/2	No	Yes	No
3	x1, x4	x2 = x3 = 0	2x1 + x4 = 3 6x1 + 6x4 = 2 ⇒ x1 = 8/3, x4 = -7/3	No	Yes	No
4	x2, x3	x1 = x4 = 0	6x2 + 2x3 = 3 4x2 + 4x3 = 2 ⇒ x2 = ½, x3 = 0	Yes	No	No
5	x2, x4	x1 = x3 = 0	6x2 + x4 = 3 4x2 + 6x4 = 2 ⇒ x2 = ½, x4 = 0	Yes	No	No
6	x3, x4	x1 = x2 = 0	2x3 + x4 = 3 4x3 + 6x4 = 2 ⇒ x3 = 2, x4 = -1	No	Yes	No

9 **Use simplex method to solve the LPP:**

Maximize Z = $4x_1 + 10x_2$

subject to $2x_1 + x_2 \leq 50$, $2x_1$

$+ 5x_2 \leq 100$,

$2x_1 + 3x_2 \leq 90$

and x_1 , $x_2 \geq 0$

(12M)(BTL1)

(Nov2018)

Solution: By introducing the slack variables s1, s2 and s3, the problem in standard form becomes

Maximize Z = 4x1 + 10x2 + 0s1 + 0s2 + 0s3

Subject to

2x1 + x2 + s1 + 0s2 + 0s3 = 50

2x1 + 5x2 + 0s1 + s2+ 0s3 = 100

2x1 + 3x2 + 0s1 + 0s2 + s3 = 90

and x1 , x2, s1, s2, s3 ≥ 0

Since there are 3 equations with 5 variables, the initial basic feasible solution is obtained by equating (5-3)=2 variables to 0. (4M)

Therefore the initial basic feasible solution is s1 = 50, s2 = 100, s3 = 90.

(x1 = 0, x2 = 0, non-basic)

The initial simplex table is given by (4M)

C_j (4 10 0 0 0)

C_B	Y_B	X_B	x1	x2	s1	s2	s3	θ = min X_{Bi}/a_{ir}
0	s1	50	2	1	1	0	0	50
0	s2	100	5	5	0	1	0	20*
0	s3	90	2	3	0	0	1	30
Z_j - C_j		0	-4	-10	0	0	0	

The improved basic feasible solution is given in the following simplex

tableFirst Iteration: (4M)

C_j (4 10 0 0 0)

C_B	Y_B	X_B	x1	x2	s1	s2	s3
0	s1	30	8/5	0	1	-1/5	0
10	x2	20	2/5	1	0	1/5	0
0	s3	30	4/5	0	0	-3/5	1
Z_j - C_j		200	0	0	0	2	0

Since all Z_j - $C_j \geq 0$, the current basic feasible solution is optimal. Therefore the optimal

10 **Solve the following LPP by simplex method**

Max Z = $4x_1 + x_2 + 3x_3 + 5x_4$

Subject to

$4x_1 - 6x_2 - 5x_3 + 4x_4 \geq -20$

$3x_1 - 2x_2 + 4x_3 + x_4 \leq 10$

$8x_1 - 3x_2 + 3x_3 + 2x_4 \leq 20$

$x_1, x_2, x_3, x_4 \geq 0$ (Nov 2016)(12M) (BTL1).

Solution:

We can convert the first constraint to a 'lesser than' type by multiplying both sides by -1.
So the first constraint becomes:

$-4x_1 + 6x_2 + 5x_3 - 4x_4 \leq 20$

Introducing slack variables, we get:

$$-4x_1 + 6x_2 + 5x_3 - 4x_4 + s_1 = 20$$
$$3x_1 - 2x_2 + 4x_3 + x_4 + s_2 = 10$$
$$8x_1 - 3x_2 + 3x_3 + 2x_4 + s_3 = 20$$

We can convert the first constraint to a 'lesser than' type by multiplying both sides by -1.
So the first constraint becomes: (2M)

$-4x_1 + 6x_2 + 5x_3 - 4x_4 \leq 20$

Introducing slack variables, we get:

$$-4x_1 + 6x_2 + 5x_3 - 4x_4 + s_1 = 20$$
$$3x_1 - 2x_2 + 4x_3 + x_4 + s_2 = 10$$
$$8x_1 - 3x_2 + 3x_3 + 2x_4 + s_3 = 20 \qquad (4M)$$

Initial basic feasible solution is

$s_1 = 20$, $s_2 = 10$, $s_3 = 20$ (basic) ($x_1 = x_2 = x_3 = x_4 = 0$, non-basic)

Iteration 1: C_j 4 1 3 5 0 0 0

C_B	Y_B	X_B	x_1	x_2	x_3	x_4	s_1	s_2	s_3	Θ
0	s_1	20	-4	6	5	-4	1	0	0	-
0	s_2	10	3	-2	4	1	0	1	0	10
0	s_3	20	8	-3	3	2	0	0	1	10
Zj-Cj		0	-4	-1	-3	-5	0	0	0	

Iteration 2: Drop s_3 and introduce x_4 C_j 4 1 3 5 0 0 0

C_B	Y_B	X_B	x_1	x_2	x_3	x_4	s_1	s_2	s_3	Θ
0	s_1	60	12	0	11	0	1	0	2	-
0	s_2	0	-1	-1/2	5/2	0	0	1	-1/2	-
5	x_4	10	4	-3/2	3/2	1	0	0	1/2	-
Zj-Cj		50	16	-17/2	9/2	0	0	0	5/2	

Clearly, all the ratios involved, either have a negative denominator or result in infinity.
Therefore, it is impossible to proceed further and we conclude that there is NO FEASIBLE solution to the problem. (6M)

11 **A manufacturer makes two components, T and A, in a factory that is divided into two steps. Shop I, which performs the basic assembly operation, must work 5 man-days on each component T but only 2 man-days on each component A. Shop II, which performs finishing operation, must work 3 man- days for each of component T and A it produces. Because of men and machine limitations, Shop I has 180 man-days per week available, while Shop II has 135 man-days per week. If the manufacturer makes a profit of Rs.300 on each component T and Rs.200 on each component A, how many of each should be produced to maximize his profit. Use simplex method. (Nov 2017)**

Solution: (12M)(BTL1)(April2016)

The mathematical form of the given problem will be:

Maximize $Z= 300x_1+200x_2$

Subject to

$5x_1+2x_2\leq 180$

$3x_1+3x_2\leq 135$

And $x_1,x_2\geq 0$

By introducing non-negative slack variables s_1 and s_2 the standard form of LPP becomes

Maximize $Z= 300x_1+200x_2+0s_1+0s_2$

Subject to

$5x_1+2x_2+s_1+0s_2 = 180$

$3x_1+3x_2+0s_1+s_2 = 135$

and $x_1,x_2,s_1,s_2 \geq 0$

The initial basic feasible solution is given by s_1= 180, s_2=135,(x_1=x_2=0, non basic) (2M)

Initial Iteration **(4M)**

		C_j	(300	200	0	0)	
C_B	Y_B	X_B	x_1	x_2	s_1	s_2	⊘
0	s_1	180	(5)	2	1	0	180/5 = 36*
0	s_2	135	3	3	0	1	135/5 = 45
$(Z_j – C_j)$		0	-300	-200	0	0	

Second Iteration Introduce x_1 and drop s_1

		C_j	(300	200	0	0)	
C_B	Y_B	X_B	x_1	x_2	s_1	s_2	⊘
300	x_1	36	1	2/5	1/5	0	36*5/2 = 90
0	s_2	27	0	(9/5)	(-3/5)	1	27*5/9 = 15*
$(Z_j – C_j)$		10,800	0	-80	60	0	

Third Iteration Introduce x_2 and drop s_2

		C_j	(300	200	0	0)
C_B	Y_B	X_B	x_1	x_2	s_1	s_2
300	x_1	30	1	0	1/3	-2/9
200	x_2	15	0	1	-1/3	-1/3
$(Z_j – C_j)$		12,000	0	0	100/3	400/9

Since $(Z_j – C_j) \geq 0$, the current basic feasible solution is optimal.

The optimal solution is **Max Z= 12,000, x_1=30; x_2=15**

So the Maximum profit is Rs.12,000/ **(4M)**

12 **Use simplex method to**
Minimize $Z = x_2 - 3x_3 + 2x_5$
Subject to $3x_2 - x_3 + 2x_5 \leq 7$,
$-2x_2 + 4x_3 \leq 12$,

$-4x_2 + 3x_3 + 8x_5 \leq 10$

and $x_2, x_3, x_5 \geq 0$ (12M) (BTL3) **(May 2017)**

Solution:

Since the objective function is of minimization type, convert it into mazimization type as follows:

Maximize (-Z) = Maximize $Z^* = -x_2 + 3x_3 - 2x_5$

Subject to

$3x_2 - x_3 + 2x_5 \leq 7$

$-2x_2 + 4x_3 \leq 12$

$-4x_2 + 3x_3 + 8x_5 \leq 10$

$x_2, x_3, x_5 \geq 0$

By introducing non-negative slack variables s1, s2 and s3, the standard form of the LPP becomes

Maximize $Z^* = -x2 + 3x3 - 2x5 + 0s1 + 0s2 + 0s3$

Subject to constraints

$3x2 - x3 + 2x5 + s1 + 0s2 + 0s3 = 7$

$-2x2 + 4x3 + 0s1 + s2 + 0s3 = 12$

$-4x2 + 3x3 + 8x5 + 0s1 + 0s2 + s3 = 10$

$x2, x3, x5, s1, s2, s3 \geq 0$

Therefore the initial basic feasible solution is given by s1 = 7, s2 = 12, s3 = 10

(x2 = x3 = x5 = 0, non-basic) (2M)

Initial Iteration:

C_j (-1 3 -2 0 0 0)

C_B	Y_B	X_B	x2	x3	x5	s1	s2	s3	θ
0	s1	7	3	-1	2	1	0	0	-
0	s2	12	-2	(4)	0	0	1	0	$12/4 = 3^*$
0	s3	10	-4	3	8	0	0	1	10/3 = 3.33
$Z_j^* - C_j$		0	1	-3	2	0	0	0	

Since $Z_2^* - C_2 < 0$, the current basic feasible solution is not optimal. The non-basic variable s2 leaves the basis. (4M)

Second Iteration:

C_j (-1 3 2 0 0 0)

C_B	Y_B	X_B	x2	x3	x5	s1	s2	s3
-1	x2	4	1	0	4/5	2/5	1/10	0
3	x3	5	0	1	2/5	1/5	3/10	0
0	s3	11	0	0	10	1	-1/2	1
$Z_j^* - C_j$		11	0	0	12/5	1/5	4/5	0

Since all $(Z_j^* - C_j) \geq 0$, the current basic feasible solution is optimal. Therefore the solution is obtained. (6M)

13 **An automobile manufacturer makes two auto-mobiles and trucks in a factory that is divided into two shops. Shop A, which performs the basic assembly operation, must work 5 man-days on each truck but only 2 man-days on each automobile. Shop B, which performs finishing operation, must work 3 man- days for each truck or automobile that it produces. Because of men and machine limitations, Shop A has 180 man-days per week available, while Shop B has 135 man-days per week. If the manufacturer makes a profit of Rs.300 on each component T and Rs.200 on each automobile, how many of each should be produced to maximize his profit. (12M)(BTL4)(April 2015)**

Solution:

Let x_1 units of trucks and x_2 units of automobiles be manufactured per week to maximize his profit.

Then the mathematical form of the given problem will be:

Maximize $Z = 300x_1+200x_2$

Subject to

$5x_1+2x_2\leq180$

$3x_1+3x_2\leq135$

And $x_1,x_2\geq0$.

By introducing non-negative slack variables s_1 and s_2, the standard form of LPP becomes

Maximize $Z= 300x_1+200x_2+0s_1+0s_2$

Subject $5x_1+2x_2+s_1+0s_2 = 180$

$3x_1+3x_2+0s_1+s_2 = 135$

And $x_1,x_2,s_1,s_2 \geq0$ (4M)

The initial basic feasible solution is given by $s_1= 180$, $s_2=135$,($x_1=x_2=0$, non basic)

Initial Iteration

		C_j	(300	200	0	0)	
C_B	Y_B	X_B	x1	x2	s1	s2	⊘
0	S1	180	(5)	2	1	0	180/5 = 36*
0	S2	135	3	3	0	1	135/5 = 45
$(Z_j – C_j)$		0	-300	-200	0	0	

Second Iteration Introduce x1 and drop s1

		C_j	(300	200	0	0)	
C_B	Y_B	X_B	x1	x2	s1	s2	⊘
300	X1	36	1	2/5	1/5	0	36*5/2 = 90
0	S2	27	0	(9/5)	(-3/5)	1	27*5/9 = 15*
$(Z_j – C_j)$		10,800	0	-80	60	0	

Third Iteration Introduce x2 and drop s2 **(4M)**

		C_j	(300	200	0	0)
C_B	Y_B	X_B	x1	x2	s1	s2
300	x1	30	1	0	1/3	-2/9
200	x2	15	0	1	-1/3	-1/3
$(Z_j – C_j)$		12,000	0	0	100/3	400/9

Since $(Z_j – C_j) \geq0$, the current basic feasible solution is optimal.

The optimal solution is **Max Z= 12,000, x_1=30; x_2=15**

So the Maximum profit is Rs.12,000/- **(4M)**

14	**A gear manufacturing company received an order for three specific types of gear for regular supply. The management is considering to devote the available excess capacity to one or more of the three types A, B and C. The available capacity on the machines which might limit output and the number of machine hours required for each unit of the respective gear is also given below: The unit profit would be Rs. 20, Rs. 6 and Rs. 8 respectively for the gears A, B and C. Find how much of each gear the company should produce in order to maximize profit?(12M) (BTL3)(May 2019)**

Machine Type	Available machine hours/week	Productivity in machine hours/ unit		
		Gear A	Gear B	Gear C
Gear Hobbing m/c	250	8	2	3
Gear Shaping m/c	150	4	3	0
Gear Grinding m/c	50	2	-	1

Solution: Let x1, x2 and x3 be the number of units of gear A, B and C produced respectively to maximize the profit. The mathematical formulation of the LPP is given by

Maximize Z = 20x1 + 6x2 + 8x3

Subject to

8x1 + 2x2 + 3x3 ≤ 250

4x1 + 3x2 ≤ 150

2x1 + x3 ≤ 50

And x1, x2, x3 ≥ 0

By introducing non-negative slack variables s1, s2 and s3 the standard form of the LPP becomes

Maximize Z^* = 20x1 + 6x2 + 8x3 + 0s1 + 0s2 + 0s3

Subject to

8x1 + 2x2 + 3x3 s1 + 0s2 + 0s3 = 250

4x1 + 3x2 0s1 + s2 + 0s3 = 150

2x1 + x3 +0s1 + 0s2 + s3 = 50

And x1, x2, x3, s1, s2, s3 ≥ 0

Therefore the initial basic feasible solution is given by s1 = 250, s2 = 150, s3 = 50

(x1 = x2 = x3 = 0, non-basic) (4M)

Initial Iteration:

C_j (20 6 8 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	s1	s2	s3	θ
0	s1	250	8	2	3	1	0	0	250/8
0	s2	150	4	3	0	0	1	0	150/4
0	s3	50	(2)	0	1	0	0	1	50/2*
$Z_j - C_j$		0	-20	-6	-8	0	0	0	

Third Iteration: (4M)

Introduce x3 and drop x1

C_j (20 6 8 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	s1	s2	s3
0	s1	0	-2/3	0	0	1	-2/3	-3
6	x2	50	4/3	1	0	0	1/3	0
8	x3	50	2	0	1	0	0	1
$Z_j - C_j$		700	4	0	0	0	2	8

Since all $Z_j - C_j \geq 0$, the current feasible solution is optimal. Therefore the optimal solution is

Maximize Z = 700, x1 = 0, x2 = 50, x3 = 50

Therefore the company should produce 50 units of gear B, 50 units of gear C and none of gear A in order to have maximum profit of Rs. 700. (4M)

15 **Consider the LPP**

Max $Z = 2x_1 + x_2 + 4x_3 - x_4$

subject to $x_1 + 2x_2 + x_3 - 3x_4 \leq 8$,

$- x_2 + x_3 + 2x_4 \leq 0$,

$2x_1 + 7x_2 - 5x_3 - 10x_4 \leq 21$

and $x_1, x_2, x_3, x_4 \geq 0$.

a) **Solve the LPP.**
b) **Discuss the effect of change of b_2 to 11.**
c) **Discuss the effect of change of b to [3-2,4]. (12M)(BTL1)**

Solution: a) By using regular simplex method, the optimal simplex table is displayed below:

C_j (2 1 4 -1 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	s2	s3
1	x2	0	0	1	-1	-2	0	-1	0
2	x1	8	1	0	3	1	1	2	0
0	s3	5	0	0	-4	2	-2	3	1
$Z_j - C_j$		16	0	0	1	1	1	3	0

Therefore the optimal solution is

Max Z = 16, x1 =8, x2 = x3 = x4 = 0. (3)

b) If b2 is changed to 11 , then b = [8, 11, 21] (4M)

The solution is infeasible. That is the change from b2 from 0 to 11 affects the feasibility of the solution. The changes in the final table reduce to

C_j (2 1 4 -1 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	s2	s3
1	x2	-11	0	1	-1	(-2)	0	-1	0
2	x1	30	1	0	3	1	1	2	0
0	s3	38	0	0	-4	2	-2	3	1
$Z_j - C_j$		49	0	0	1	1	2	3	0

Since the current solution is infeasible, use dual simplex method.

The optimal solution to the new problem is

Max Z = 87/2, x1 = 49/2, x2 = 0 = x3, x4 = 11/2 (5M)

	c) If b is changed from [8, 0, 21] to [3, -2, 4] The solution is infeasible. The change of b from [8, 0, 21] to [3, -2, 4] affects the feasibility of the solution

C_j (2 1 4 -1 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	s2	s3
1	x2	-3	1	1	0	0	0	5/2	½
0	s1	14	-2	0	0	-5	1	-17/2	-3/2
4	x3	-5	1	0	1	2	0	7/2	½
$Z_j - C_j$		-23	3	0	0	9	0	33/2	5/2

Since x3 leaves the basis and all $a_{3j} \geq 0$, the new problem poses no feasible solution.

16 **Consider the LPP**

Max Z = $3x_1 + 4x_2 + x_3 + 7x_4$

subject to $8x_1 + 3x_2 + 4x_3 + x_4 \leq 7$,

$2x_1 + 6x_2 + x_3 + 5x_4 \leq 3$,

$x_1 + 4x_2 + 5x_3 + 2x_4 \leq 8$

and $x_1, x_2, x_3, x_4 \geq 0$

a) **Solve the LPP.**

b) **If a new constraint $2x_1 + 3x_2 + x_3 + 5x_4 \leq 4$ is added to the above LPP, discuss the effect of change in the optimal solution of the original problem.**

c) **If a new constraint $2x_1 + 3x_2 + x_3 + 5x_4 \leq 2$ is added (or) if the upper limit of the above constraint is reduced to 2, discuss the effect of change in the optimum solution of the original problem.(12M) (BTL2)(Nov 2016)**

Solution: a) By introducing the non-negative slack variables s1, s2 and s3 and then solving the problem by simplex method, the optimal simplex table is given by:

C_j (3 4 1 7 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	s2	s3
3	x1	16/19	1	9/38	1/2	0	5/38	-1/38	0
7	x4	5/19	0	21/19	0	1	-1/19	4/19	0
0	s3	126/19	0	59/38	9/2	0	-1/38	-15/38	1
$Z_j - C_j$		83/19	0	169/38	1/2	0	1/38	53/38	0

The optimal solution is

Min Z = 83/19, x1 = 16/19, x2 = 0, x3 = 0, x4 = 5/19

b) Now consider the new constraint $2x_1 + 3x_2 + x_3 + 5x_4 \leq 4$ (4M)

As this constraint is satisfied by the optimal solution, the solution remains feasible and optimal for the modified problem also. Here the constraint $2x_1 + 3x_2 + x_3 + 5x_4 \leq 4$ is redundant.

c) Consider the new constraint $2x_1 + 3x_2 + x_3 + 5x_4 \leq 2$

As this constraint is not satisfied by the current optimal solution, the current solution is no longer optimal for the modified problem. In order to find the new optimal solution, a new row is added. By adding the non-negative slack variable s4 the constraint becomes

$2x_1 + 3x_2 + x_3 + 5x_4 + s_4 = 2$

C_j (3 4 1 7 0 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	s2	s3	s4
3	x1	16/19	1	9/38	1/2	0	5/38	-1/38	0	0
7	x4	5/19	0	21/19	0	1	-1/19	4/19	0	0
0	s3	126/19	0	59/38	9/2	0	-1/38	-15/38	1	0
0	s4	-1	0	-3	0	0	0	-1	0	1
$Z_j - C_j$		83/19	0	169/38	1/2	0	1/38	53/38	0	0

First iteration: (4M)

Drop s4 and introduce s2

C_j (3 4 1 7 0 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	s2	s3	s4
3	x1	33/38	1	12/38	1/2	0	5/38	0	0	-1/38
7	x4	1/19	0	9/19	0	1	-1/19	0	0	4/19
0	s3	267/38	0	52/19	9/2	0	-1/38	0	1	-15/38
0	s2	1	0	3	0	0	0	1	0	-1
$Z_j - C_j$		113/38	0	5/19	1/2	0	1/38	0	0	53/38

The new optimal solution is

Max Z = 113/38, x1 = 33/38, x2 =0, x3 = 0, x4 = 1/19

The additional constraint has decreased the optimum value of the objective function. (4M)

17 **Consider the LPP**

Max Z = $5x_1 + 3x_2$

subject to

$3x_1 + 5x_2 \le 15$,

$5x_1 + 6x_2 \le 10$ and $x_1, x_2 \ge 0$.

a) Solve the LPP.

b) Find how far the component C_1 of C can be increased without affecting the optimality of the solution.(10M) (BTL1)(May 2017)

Solution: a) By introducing the non-negative slack variables s1 and s2 and using regular simplex method, the optimal simplex table is displayed below:

C_j (5 3 0 0)

C_B	Y_B	X_B	x1	x2	s1	s2
0	s1	9	0	7/5	1	-3/5
5	x1	2	1	6/5	0	1/5
$Z_j - C_j$		10	0	3	0	1

The optimal solution is

Max Z = 10, x1 = 2, x2 = 0 (4M)

b) Here $C_1 \in C_B$ i.e., C_1 is the coefficient of the basic variable x1 and C1 =5

$\Rightarrow$ Max $\{0, -5/2, -5\} \le \Delta C_1 \le \infty$

$\Rightarrow 0 \le \Delta C_1 \le \infty$

$\Rightarrow C_1 - 0 \le C_1 \le C_1 + \infty$

$\Rightarrow 5 - 0 \le C_1 \le 5 + \infty$

$\Rightarrow 5 \le C_1 \le \infty$, which is the range over C_1 can increase without destroying the optimality of the solution. (6M)

18 **Consider the LPP**

Max Z= $3x_1 + 5x_2$

subject to

$x_1 \leq 4$,

$3x_1 + 2x_2 \leq 18$

and x_1 , $x_2 \geq 0$.

a) **Solve this LPP.**

b) **If a new variable x_5 is added to this problem with a column $\binom{1}{2}$ and $C_5 = 7$, find the change in the optimal solution.(12M) (BTL1)**

Solution: a) By using simplex method, the optimal solution of the original problem is

C_j (3 5 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4
0	x3	4	1	0	1	0
5	x2	9	3/2	1	0	1/2
$Z_j - C_j$		45	9/2	0	0	5/2

Max Z = 45, x1 =0, x2 = 9 (4M)

b) If a new variable x5 is introduced with a5 = $\binom{1}{2}$ and C5 =7, then

$$\bar{a}_5 = \begin{pmatrix} 1 & 0 \\ 0 & 1/2 \end{pmatrix} \begin{pmatrix} 1 \\ 2 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix} = \bar{a}_5$$

and $Z_5 - C_5 = C_B \bar{a}_5 - C_5 = (0, 5) \binom{1}{1} - 7 = -2$. The optimality of the solution is affected. The change in the optimal table is reduced to

C_j (3 5 0 0 7)

C_B	Y_B	X_B	x1	x2	x3	x4	x5	θ
0	x3	4	1	0	1	0	(1)	4
5	x2	9	3/2	1	0	1/2	1	9
$Z_j - C_j$		45	9/2	0	0	5/2	' 2	

First iteration: Introduce x5 and drop x3 (4M)

C_j (3 5 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	x5
7	X5	4	1	0	1	0	1
5	x2	5	1/2	1	-1	1/2	0
$Z_j - C_j$		53	13/2	0	2	5/2	0

Since all $Z_j - C_j \geq 0$, the current solution is optimal. The optimal solution to the new problem is

Max Z = 53, x1 = 0, x2 = 5, x5 = 4. (4M)

UNIT II DUALITY AND NETWORKS	
Definition of dual problem – Primal – Dual relationships – Dual simplex methods – Post optimality analysis – Transportation and assignment model – Shortest route problem.	
UNIT-II / PART-A	
1	**Define primal and dual problem? (May 2017)** **What is a dual problem in LPP? (Nov 2017)** **(BTL1)** For every linear programming problem there is a **unique linear programming problem associated** with it, involving the **same data and closely related optimal solutions**. The original problem is called the **Primal** problem while the other is called its dual problem. In general the two problems are said to be duals of each other.
2	**Mention the importance of duality. (BTL2)** The importance of duality concept is due to two main reasons: ❖ If the primal contains a large number of constraints and a smaller number of variables, the **computation can be reduced** by converting into the dual problem and solving it. ❖ The interpretation of the dual variables from the cost or economic point of view proves extremely **useful in making future decisions** in the activities being programmed.
3	**What are the characteristics of a primal and dual problem? (BTL1) (Nov 2016)**

Primal Problem	Dual problem
The original (given) problem is called the primal.	The other is called as dual
If primal problem has a finite optimal solution.	Then dual also has a finite optimal solution
Max $Z = CX$ Subject to $AX = b$ $X \geq 0$	Min $W = b^TY$ Subject to $A^TY \geq C^T$ Variables are unrestricted
Min $Z = CX$ Subject to $AX = b$ $X \geq 0$	Max $W = b^TY$ Subject to $A^TY \leq C^T$ Variables are unrestricted

4	**How is a dual problem constructed from the primal? (BTL1)** ❖ A **dual variable** is defined for each primal (constraint) equation. ❖ A **dual constraint** is defined for each primal variable. ❖ The **constraint (column) coefficients** of a primal variable define the LHS coefficients of the dual constraint and its objective coefficient define the RHS. ❖ The **objective coefficients** of the dual equal the RHS of the primal constraint equations.

5	**What do you mean by shadow pricing? (BTL1) (Nov 2016)** For primal and dual feasible solutions, the values of the objective functions, when finite satisfy the following inequality: z = $\sum_{j=1}^{n} cjxj \leq \sum_{i=1}^{m} biyi$ = w The strict equality z = w, holds when both the primal and dual solutions are optimal. Given the primal problem represents a resource allocation model, and z represents profit dollars. Because, b_i represents the number of units available of resource i, the equation z = w can be expressed dimensionally as \$ = $\sum_i (units\ of\ resource\ i) * (\$\ per\ unit\ of\ resource\ i)$ This means that the dual variables, y_i, represent the **worth per unit** of resource i. The variables y_i are referred by the abstract name **dual prices**, other names include **shadow prices and simplex multipliers.**
6	**How can optimal dual solution be obtained? (BTL3)** The **primal and dual** solutions are so **closely related** that the optimal solution of the primal problem directly yields the optimal solution of the dual. **Method 1:** *(Optimal values of dual variables) = (Row vector of original objective coefficients of optimal primal basic variables) x (optimal primal inverse)* **Method 2:** *(Optimal primal z-coefficient of any variable x_j) = (LHS of the jth dual constraint) – (RHS of the jth dual constraint)*
7	**How are the primal and dual objective values related? (BTL2)** In the primal-dual problems, if **one is maximization the other must be minimization**. From this standpoint, the objective values in the two problems are related in the following manner: For any feasible primal and dual solutions, *(Objective value in the maximization problem) ≤ (Objective value in the minimization problem)*
8	**What is dual simplex method? (BTL1) (Nov 2017)** In dual simplex method, LP starts at a **basic solution that is optimal but infeasible**, and successive iterations remain basic and optimal as they **move towards feasibility**. At the **last iteration** the **feasible optimal solution is found.**
9	**What do you mean by Transportation Problem? (BTL1) (Nov 2017)** There are *m* sources and *n* destinations, each represented by a node. The arcs represent the routes linking the sources and destinations. Arc(i,j) joining source i to destination j, carries c_{ij} the transportation cost per unit and the amount shipped x_{ij}. The amount of supply at source *i* is a_i, and the amount of demand at destination *j* is b_j. the objective of the model is to **determine the unknowns x_{ij} that will minimize the total transportation cost while satisfying all the supply and demand restrictions**.
10	**What are the methods used in transportation problem to obtain the initial basic feasible solution. (BTL1)** ❖ **North-west corner rule**: The first assignment is made in the cell occupying the upper left-hand corner of the transportation table. ❖ **Least cost method:** Identify the cell with smallest cost and assign the minimum value. ❖ **Vogel's approximation method**: Find the difference between the smallest and next smallest cost in each row (column) and write them in brackets against the row (column).

11 **How will you overcome degeneracy in a transportation problem?**
What do you understand by degeneracy in a transportation problem? (BTL3) (May 2018)

If the number of occupied cells in a $m \times n$ transportation problem is less than **(m+n-1)** then the problem is said to be degenerate where m is the number of rows and n is the number of columns in the transportation table. To resolve degeneracy, **allocate an extremely small amount** (close to zero) to **one or more empty cells** of the transportation table, so that the **total number of occupied cells becomes (m+n-1)** at independent positions. The small amount is denoted by $\in$.

12 **State the necessary and sufficient conditions for a transportation problem to have a solution. (BTL1) (Nov 2016)**

The necessary and sufficient condition for a transportation problem to have a feasible solution is:

$$\sum_{i=1}^{m} ai = \sum_{j=1}^{n} bj$$

Total supply = Total demand

Problems satisfying this condition are called balanced transportation problems.

13 **What is balanced transportation problem & unbalanced transportation problem? (BTL1)**

When the **sum of supply is equal to demands**, then the problem is said to be **balanced** transportation problem. A transportation problem is said to be **unbalanced** if the total **supply is not equal to the total demand.**

14 **How do you convert an unbalanced transportation problem into a balanced one? (May 2018) (BTL3)**

The unbalanced transportation problem is converted into a balanced one by **adding a dummy row (source) or dummy column (destination) with zero cost vectors** whichever is necessary. The unit transportation cost of the dummy row/ column elements are assigned to zero. Then the problem is solved by the usual procedure.

15 **Write the difference between transportation and assignment problem. (BTL1) (May 2017)**

Transportation Problems	Assignment Problems
Supply at any source may be any positive quantity a_i.	Supply at any source will be 1. ie) $a_i = 1$
Demand at any destination maybe a positive quantity b_j.	Demand at any destination will be 1. ie) $b_j = 1$
One or more source to any number of destinations.	One source to one destination.

16 **What do you understand by Assignment Problem? (BTL1) (Nov 2017)**

An assignment problem is a particular case of a transportation problem in which the objective is **to assign a number of tasks (jobs, origins or sources) to an equal number of facilities (machines, persons or destinations)** where each operator performs **only one operation**, the overall objective is to maximize the total profit or minimize the overall cost of the given assignment.

18 **Give the mathematical formulation of an assignment problem. (BTL1)**

The assignment problem can be expressed as

Maximize $Z = \sum_{i=1}^{n}\sum_{j=1}^{n} cij\ xij$

Where cij is the cost of assigning ith machine to the jth job subject to the constraints

$$x_{ij} = \begin{cases} 1, \textit{if ith machine is assigned to the jth job} \\ 0, \textit{if ith machnie is not assigned to the jth job} \end{cases}$$

i.e) $x_{ij} = 1$ or $0 \Rightarrow x_{ij}(x_{ij} - 1) = 0 \Rightarrow x_{ij}^2 = x_{ij}$

$\sum_{j=1}^{n} xij = 1, i = 1, 2, \ldots, n$ and

$\sum_{i=1}^{n} xij = 1, j = 1, 2, \ldots, n$

19 **Give the difference between transportation problem and assignment problem. (BTL1)**

Transportation Problems	Assignment Problems
Supply at any source may be any positive quantity a_i.	Supply at any source will be 1. ie) $a_i = 1$
Demand at any destination maybe a positive quantity b_j.	Demand at any destination will be 1. ie) $b_j = 1$
One or more source to any number of destinations.	One source to one destination.

20 **How do you identify alternative solution in assignment problem? (BTL1)**

If the final cost matrix contains **more than required number of zeroes** at the independent position. This implies that there is more than one optimal solution with some optimum assignment cost.

21 **Define unbounded assignment problem and what are the rules to recognize it? (BTL3)**

In some LP models, the values of the **variables may be increased indefinitely** without violating any of the constraints, meaning that the **solution space is unbounded** in at least one direction. As a result, the objective value may increase (maximization case) or decrease (minimization case) indefinitely.

The rule for recognizing unboundedness is that if at any **iteration all the constraint coefficients** of any non basic variable are **zero or negative**, then the solution space is unbounded in that direction. The **objective coefficient of that variable is negative** in the case of maximization or positive in the case of minimization, then the objective value is unbounded as well.

22 **What is a travelling salesman problem? (BTL1)**

A salesman normally must visit a number of cities starting from his head quarters. The distance between every pair of cities are assumed to be known. The problem of finding the **shortest distance** if the salesman **starts from his head quarters and passes through each city exactly once and returns to the headquarters** is called Travelling Salesman problem.

23 **Define transshipment model. (BTL2)**

A problem in which available commodity frequently **moves from one or more number of sources** to any number of destinations before reaching its actual destination is called as transshipment problems. The transshipment model recognizes that it may be **cheaper to ship through intermediate or transient nodes** before reaching the final destination.

24 **What are the algorithms that are used to solve shortest-route problem? (BTL1)**

The two algorithms for solving both **cyclic and acyclic** networks:

- Dijikstra's algorithm
- Floyd's algorithm

UNIT-II / PART-B	
1	**Use duality to solve the following LPP.**

Minimize $Z = 2x_1 + 2x_2$
subject to $2x_1 + 4x_2 \geq 1$,
$-x_1 - 2x_2 \leq -1$,
$2x_1 + x_2 \geq 1$
and $x_1, x_2 \geq 0$.
(16M)(BTL1)

Solution: Given primal LPP is Minimize $Z = 2x_1 + 2x_2$
Subject to

$2x_1 + 4x_2 \geq 1$
$x_1 + 2x_2 \geq 1$
$2x_1 + x_2 \geq 1$
and $x_1, x_2 \geq 0$

Its dual problem is Max W = y1 + y2 + y3
Subject to

2y1 + y2 + 2y3 ≤ 2
4y1 + 2y2 + y3 ≤ 2
and y1, y2, y3 ≥ 0

By introducing the non-negative slack variables s1 and s2, the standard form of the dual LPP becomes

Max W = y1 + y2 + y3 + 0s1 + 0s2

Subject to

2y1 + y2 + 2y3 + s1 + 0s2 = 2
4y1 + 2y2 + y3 +0s1 + s2 = 2
and y1, y2, y3, s1, s2 ≥ 0

The initial basic feasible solution is s1 = 2, s2 = 2.

First iteration: (6M)

C_B	b_j Y_B	(1 X_B 1	y1 1	y2 0	y3 0)	s1	s2	θ
0	s1	2	2	'	2	1	0	2/2
0	s2	2	(4)	2	1	0	1	2/4
$W_j - b_j$		0	-1	-1	-1	0	0	

Third iteration: Introduce y2 and drop y1

C_B	b_j Y_B	(1 X_B 1	y1 1	y2 0	y3 0)	s1	s2
1	y3	2/3	0	0	1	2/3	-1/3
1	y2	2/3	2	1	0	-1/3	2/3
$W_j - b_j$		4/3	1	0	0	1/3	1/3

Since all $W_j - b_j \geq 0$, the current basic solution is optimal. The optimal solution to the dual LPP is

Max W = 4/3, y1 =0, y2= 2/3, y3 = 2/3

Here it is observed that the primal variables x1 and x2 respectively correspond to the slack variables s1 and s2 of the dual problem. As seen from the above table, the net evaluations $W_j - b_j$ corresponding to the slack variables s1 and s2 are 1/3 and 1/3 respectively.

Therefore the optimal solution to the original primal LPP is

Min Z = 4/3, x1 = 1/3, x2 = 1/3 (6M)

2 **Prove using duality theory that the following linear program is feasible but has no optimal solution. (12M)(BTL1)(April2012)**

Minimize $Z = x_1 - x_2 + x_3$

subject to $x_1 - x_3 \geq 4$,

$x_1 - x_2 + 2x_3 \geq 3$

and $x_1, x_2, x_3 \geq 0$.

Solution: Given primal LPP is

Min $Z = x_1 - x_2 + x_3$

Subject to

$x_1 - x_3 \geq 4$

$x_1 - x_2 + 2x_3 \geq 3$

and $x_1, x_2, x_3 \geq 0$

Its dual problem is

Max W = 4y1 + 3y2

Subject to

y1 + y2 ≤ 1

0y1 + y2 ≥ 1

-y1 + 2y2 ≤ 1

and y1, y2 ≥ 0

By introducing the slack variables s1, s3 and surplus variable s2 and an artificial variable R1, the standard form of the dual LPP is

Max W = 4y1 + 3y2 + 0s1 + 0s2 + 0s3 – MR1

Subject to

y1 + y2 + s1 + 0s2 + 0s3 = 1

0y1 + y2 + 0s1 – s2 + 0s3 + R1 = 1

-y1 + 2y2 + 0s1 + 0s2 + s3 = 1

and y1, y2, s1, s2, s3, R1 ≥ 0

The initial basic feasible solution is given by s1 =1, R1 = 1, s3 = 1 (basic)

(y1 = y2 = s2 =0, non-basic) (4M)

Initial iteration

b_j (4 3 0 0 -M 0)

C_B	Y_B	X'	y'	y2	s2	s1	R1	s3	θ
0	s1	1	1	1	0	1	0	0	1
-M	R1	1	0	1	-1	0	1	0	1
0	s3	1	-1	(2)	0	0	0	1	½*
$W_j - b_j$		-M	-4	-M-3	M	0	0	0	

Second iteration: Introduce y1 and drop s1

b_j (4 3 0 0 -M 0)

C_B	Y_B	X_B	y1	y2	s2	s1	R1	s3
4	y1	1/(3)	1	0	0	2/3	0	-1/3
-M	R1	1/3	0	0	-1	-1/3	1	-1/3
3	y2	2/3	0	1	0	1/3	0	1/3
$W_j - b_j$		$\frac{10-M}{3}$	0	0	M	$\frac{11+M}{3}$	0	$\frac{M-1}{3}$

Since all $W_j - b_j \geq 0$, and an artificial variable R1 appears in the basis at non-zero level, the dual problem has no optimal basic feasible solution. Therefore there exists no finite optimum solution to the given primal LPP. (8M)

3 **Using dual simplex method solve the LPP. (12M)(BTL1)**

Minimize $Z = 2x_1 + x_2$

subject to $3x_1 + x_2 \geq 3$,

$4x_1 + 3x_2 \geq 6$,

$x_1 + 2x_2 \geq 3$

and $x_1, x_2 \geq 0$. (May 2017)

Solution: After converting the objective function in to maximization type and all the constraints in ≤ type, the given LPP becomes

$$\text{Max } Z^* = -2x_1 - x_2$$

Subject to

$$-3x_1 - x_2 \leq -3$$
$$-4x_1 - 3x_2 \leq -6$$
$$-x_1 - 2x_2 \leq -3$$

and $x_1, x_2 \geq 0$.

By introducing the non-negative slack variables s1, s2 and s3, the LPP becomes

$$\text{Max } Z^* = -2x_1 - x_2 + 0s1 + 0s2 + 0s3$$

Subject to

$$-3x_1 - x_2 + s1 = -3$$
$$-4x_1 - 3x_2 + s2 = -6$$
$$-x_1 - 2x_2 + s3 = -3$$

and $x_1, x_2, s1, s2, s3 \geq 0$. (4M)

The initial basic solution is given by s1 = -3, s2 = -6, s3 = -3 (basic)

(x1 = x2 = 0, non-basic)

Initial iteration

C_j (-2 -1 0 0 0)

C_B	Y_B	X_B	x1	x2	s1	s2	s3
0	s1	-3	-3	-1	1	0	0
0	s2	-6	-4	(-3)	0	1	0
0	s3	-3	-1	-2	0	0	1
$Z_j^* - C_j$		0	2	1	0	0	0

	Since $Z_j^* - C_j \geq 0$ and all $X_{Bi} < 0$, the current solution is not an optimum basic feasible solution. Since X_{B2}=-6 is the most negative, the corresponding basic variable s2 leaves the basis. (4M)

Second iteration: Drop s1 and introduce x1

C_j (-2 -1 0 0 0)

C_B	Y_B	X_B	x1	x2	s1	s2	s3
-2	x1	3/5	1	0	-3/5	1/5	0
-1	x2	6/5	0	1	4/5	-3/5	0
0	s3	0	0	0	1	-1	1
$Z_j^* - C_j$		-12/5	0	0	2/5	1/5	0

Since all $Z_j^* - C_j \geq 0$, and all $X_{Bi} \geq 0$, the current solution is an optimum basic feasible solution. The optimal solution is

Max Z* = -12/5, x1 = 3/5, x2 = 6/5

But Min Z = -Max Z* = -(-12/5) = 12/5

Min Z = 12/5, x1 = 3/5, x2 = 6/5 (4M)

4 **Use dual simplex method to solve the LPP**
(10M)(BTL1)(May 2016)
Maximize Z = $-3x_1 - 2x_2$
Subject to
$x_1 + x_2 \geq 1$
$x_1 + x_2 \leq 7$
$x_1 + 2x_2 \geq 10$
$x_2 \leq 3$
and $x_1, x_2 \geq 0$ (Nov 2016, Nov 2017)

Solution:

The given LPP is Maximize Z = -3x1 – 2x2

Subject to

-x1 - x2 ≤ -1

x1 + x2 ≤ 7

-x1 - 2x2 ≤ -10

0x1 + x2 ≤ 3

and x1, x2 ≥ 0

By introducing the non-negative slack variables s1, s2, s3 and s4, the LPP becomes

Maximize Z = -3x1 – 2x2 + 0s1 + 0s2 + 0s3 + 0s4 (5M)

Subject to

-x1 - x2 + s1 = -1

x1 + x2 + s2 = 7

-x1 - 2x2 + s3 = -10

0x1 + x2 + s4 = 3

and x1, x2, s1, s2, s3, s4 ≥ 0

The initial basic solution is given by

S1 = -1, s2 = 7, s3 = -10, s4 = 3 (basic) (x1 = x2 = 0, non-basic) (5M)

Initial Iteration

		C_j	(-3	-2	0	0	0	0)
C_B	Y_B	X_B	x1	x2	s1	s2	s3	s4
0	s1	-1	-1	-1	1	0	0	0
0	s2	7	1	1	0	1	0	0
0	s3	-10	-1	(2)	0	0	1	0
0	s4	3	0	1	0	0	0	1
$(Z_j - C_j)$		0	3	2	0	0	0	0

First Iteration: Drop s3 and introduce x2

		C_j	(-3	-2	0	0	0	0)
C_B	Y_B	X_B	x1	x2	s1	s2	s3	s4
0	s1	4	- ½	0	1	0	- ½	0
0	s2	2	½	0	0	1	½	0
-2	x2	5	½	1	0	0	- ½	0
0	s4	-2	(- ½)	0	0	0	½	1
$(Z_j - C_j)$		-10	2	0	0	0	1	0

Second Iteration: Drop s4 and introduce x1

		C_j	(-3	-2	0	0	0	0)
C_B	Y_B	X_B	x1	x2	s1	s2	s3	s4
0	s1	2	0	0	1	0	-1	-1
0	s2	0	0	0	0	1	1	1
-2	x2	3	0	1	0	0	0	1
-3	x1	4	1	0	0	0	-1	-2
$(Z_j - C_j)$		-18	0	0	0	0	3	4

Since all $(Z_j - C_j) > 0$ and all $X_{Bi} \geq 0$, the current solution is an optimum basic feasible solution.

Therefore the optimum solution is Max Z = -18, x1 = 4, x2 = 3

5 **Determine basic feasible solution to the following transportation problem using North West Corner rule:((10M) (BTL1)**

Sink

		A	B	C	D	E	Supply
	P	**2**	**1**	**10**	**3**	**7**	**4**
Origin	**Q**	**1**	**4**	**7**	**2**	**1**	**8**
	R	**3**	**9**	**4**	**8**	**12**	**9**
Demand		**3**	**3**	**4**	**5**	**6**	

Solution:

Since ai = bj = 21, the given problem is balanced. Therefore there exists a feasible solution to the transportation problem.

2 **3**	11	10	3	7	4
1	4	7	2	1	8
3	9	4	8	12	9
3	3	4	5	6	

Following North West Corner rule, the first allocation is made in the cell (1,1)

Here x_{11} =min {a1, b1} = min {4,3} = 3

Therefore allocate 3 to cell (1,1) and decrease 4 by 3 ie., 4-3 = 1

As the first column is satisfied cross out the first column and the resulting reduced transportation table is (5M)

11 1	10	3	7	1
4	7	2	1	8
9	4	8	12	9
3	4	5	6	

Finally the initial basic feasible solution is shown in the following table.

2 **3**	11 **1**	10	3	7
1	4 **2**	7 **4**	2 **2**	1
3	9	4	8 **3**	12 **6**

The initial transportation cost = Rs. 2 x 3 + 11 x 1 + 4 x 2 + 7 x 4 + 2 x 2 + 8 x 3 + 12 x 6

Rs. 153/- (5M)

6 **Find the initial basic feasible solution for the following transportation problem by VAM. (BTL1) (10M) (May 2018)**

Sink

		D1	D2	D3	D4	Availability
	S1	11	13	17	14	250
Origin	**S2**	16	18	14	10	300
	S3	21	24	13	10	400
Requirements		200	225	275	250	

Solution:

Since the given problem is balanced. There exists a feasible solution to this problem.

11 **200**	13	17	14	250(2)
16	18	14	10	300(4)
21	24	13	10	400(3)
200 (5)	225 (5)	275 (1)	250 (0)	

First let us find the difference between the smallest and next smallest costs in each row and column write them in brackets against the respective rows and columns.(5M)

The largest of these differences in (5) and is associated with the first two columns of the transportation table. We choose the first column arbitrarily.

In this selected column the cell(1,1) has the minimum unit transportation cost C_{11}= 11

Allocate x_{11}=min{ 250,200}=200 to this cell (1,1) and decrease 250 by 200 and cross out the satisfied column.

The resulting reduced transportation table is

13 **50**	17	14	50(1)
18	14	10	300(4)
24	13	10	400(3)
225 (5)	275 (1)	250 (0)	

The row and column differences are now computed for this reduced transportation model. The largest of these is (5) which is associated with the second column. Since, C_{12}=13 is the minimum cost, we allocate x_{12} = min{50,225} = 50 to the cell (1,2) and decrease 225 by 50 and cross out the satisfied row.

Continuing in this manner, the subsequent reduced transportation tables and the differences for the surviving rows and columns are shown below:

(18) 175	(14)	(10)	300(4)
(24)	(13)	(10)	400(3)
175	275	250	
(6)	(1)	(0)	

(14)	(10) 125	125(4)
(13)	(10)	400(3)
	250	
(1)	(0)	

(13)	(10) 125	400
275	125	

(13) 275	275
275	

Finally the initial basic feasible solution is as shown in the following table.

(11) 200	(13) 50	(17)	(14)
(16)	(18) 175	(14)	(10) 125
(21)	(24)	(13) 275	(10) 125

From this table we see that the number of positive independent allocations is equal to m+n-1 = 3+4-1 =6. This ensures that the solution is non degenerate basic feasible.

Therefore the initial transportation cost = Rs. 11X 200 +13 X 50 + 18 X 175+10X 125+13X 275+10X125

=Rs. 12075/- (5M)

7 **Find the optimal transportation cost of the following matrix using least cost method for finding the critical solution.(16M)** (BTL1)(April2016)

		Market					
		A	**B**	**C**	**D**	**E**	**Available**
	P	**4**	**1**	**2**	**6**	**9**	**100**
Factory	**Q**	**6**	**4**	**3**	**5**	**7**	**120**
	R	**5**	**2**	**6**	**4**	**8**	**120**
Demand		**40**	**50**	**70**	**90**	**90**	

Solution:

Since ∑ai = ∑bj = 340, the given transportation problem is balanced. By using least cost method the initial solution is shown in the table:

4	1 **50**	2 **50**	6	9
6 **10**	4	3 **20**	5	7 **90**
5 **30**	2	6	4 **90**	8

The initial transportation cost

= Rs. 1410

For optimality: Since the number of non-negative independent allocations is (m+n-1) apply MODI method: (5M)

The new basic feasible solution is displayed in the following table:

4 **10**	1 **50**	2 **40**	6	9
6	4	3 **30**	5	7 **90**
5 **30**	2	6	4 **90**	8

The above table satisfies the rim conditions so apply the MODI method.(5M)

4 **10**	1 **50**	2 **40**	6 3 3	9 6 3	u1=0
6 5 1	4 2 2	3 **30**	5 4 1	7 **90**	u2=1
5 **30**	2 2 0	6 3 3	4 **90**	8 7 1	u3=1
v1=4	v2=1	v3=2	v4=3	v5=6	

The optimum allocation schedule is given by x11 = 10, x12 = 50, x13 = 40, x23 = 30, x25 = 90, x31 = 30, x34 = 90 and the optimum transportation cost Rs. 1400/-(6M)

8	**Solve the transportation problem:(10M)** (BTL1) **(May 2017)**

	A	**B**	**C**	**D**	**Supply**
	21	**16**	**25**	**13**	**11**
	17	**18**	**14**	**23**	**13**
	3	**27**	**18**	**41**	**19**
Demand	**6**	**10**	**12**	**15**	

Solution:

∑ai=∑bj=43, the given transportation problem is balanced. There exists basic feasible solution to this problem.

By vogel's approximation method, the initial solution is shown in the following table.

21	16	25	13	(3) -- -- --
7 **6**	18 3	14	23 4	(3) (3) (3) (4)
32	27 7	18 12	41	(9) (9) (9) (9)
(4)	(2)	(4)	(10)	
(15)	(9)	(4)	(18)	
(15)	(9)	(4)	--	
--	(9)	(4)	--	

That is

21	16	25	13 11
17 **6**	18 3	14	23 4
32	27 7	18 12	41

From this table, we see that number of non- negative independent allocations is (m+n-1)= (3+4-1) =6. Hence the solution is non-degenerate basic feasible. The initial transportation cost:

=Rs. 13X11+17X6+18X3+23X4+27X7+18X12 =Rs.796 (5M)

To find optimal solution:

Consider MODI method:

21	16	25	13 11	u1=-10
17 6	18 3	14	23 4	u2=0
32	27 7	18 12	41	u3=9
v1=17	v2=18	v3=9	v4=23	

By finding d_{ij}

21 7 14	16 8 8	25 -1 **26**	13 11	u1=-10
17 6	18 3	14 9 **5**	23 4	u2=0
32 26 **6**	27 7	18 12	41 32 **9**	u3=9
v1=17	v2=18	v3=9	v4=23	

The optimum allocation scheme of minimum transportation cost is

Rs.13*11+17*6+18*3+23*4+27*7+18*12 = Rs. 796/-

9 **Obtain an optimum basic feasible solution to the following transportation problem. (16M)(Nov 2017)** (BTL1)

	To			Available
	7	**3**	**2**	**2**
From	**2**	**1**	**3**	**3**
	3	**4**	**6**	**5**
Demand	**4**	**1**	**5**	**10**

Solution:

The cost matrix of the given assignment problem is
By Vogel's approximation method, the initial solution is as shown in the following pages

7	3	2 2	(1)	(5)	-
2	1 1	3 2	(1)	(1)	(1)
3 4	4	6 1	(1)	(3)	(3)

(1)	(2)	(1)
(1)	-	(1)
(1)	-	(3)

i.e.)

7	3	2 2
2	1 1	3 2
3 4	4	6 1

From this table we see that the number of non- negative allocations is
m+n-1= (3+3-1) = 5. (10M)
Hence the solution is non-degenerate basic feasible therefore the initial transportation cost
= Rs.2*2 + 1*1+ 3*2 +3*4+6*1
= Rs.29/- (6M)

10 **Find the non-degenerate basic feasible solution for the following transportation problem using:**

a) North west corner approach

b) Least cost method

c) Vogel's approximation method.(16M) (BTL3)

	To				Supply
	10	**20**	**5**	**7**	**10**
	13	**9**	**12**	**8**	**20**
From	**4**	**5**	**7**	**9**	**30**
	14	**7**	**1**	**0**	**40**
	3	**12**	**5**	**19**	**50**
Demand	**60**	**60**	**20**	**10**	

Solution:

Since $\sum ai = \sum bj = 150$, the transportation problem is balanced. There exist a basic feasible solution to this problem.

a) The starting solution by NWC rule is shown in the table

10 **10**	20	5	7
13 **20**	9	12	8
4 **30**	5	7	9
14	7 **40**	1	0
3	12 **20**	5 **20**	19 **10**

The initial transportation cost = Rs. 1290/-, as $\in \to 0$ (4M)

b) Least Cost Method:

10	20 **10**	5	7
13	9 **20**	12	8
4 **10**	5 **20**	7	9
14	7 **10**	1 **20**	0 **10**
3 **50**	12	5	19

Since the number of non-negative allocations at independent positions is (m+n-1)=8, the solution is non-degenerate basic feasible.
The initial transportation cost = Rs. 760/- (4M)

c) Vogel's Approximation Method:

10 **10**	20	5	7
13	9 **20**	12	8
4	5 **30**	7	9
14	7 **10**	1 **20**	0 **10**
3 **50**	12 $\in$	5	19

The initial transportation cost = Rs. 670/- as $\in \to 0$ (10M)

11 **The processing time in hours, for the jobs when allocated to the different machines are indicated below. Assign the machines for the jobs so that the total processing time is minimum.(12 M) (BTL1)(Nov 2017)**

		Machines				
		M1	**M2**	**M3**	**M4**	**M5**
Jobs	**J1**	**9**	**22**	**58**	**11**	**19**
	J2	**43**	**78**	**72**	**50**	**63**
	J3	**41**	**28**	**91**	**37**	**45**
	J4	**74**	**42**	**27**	**49**	**39**
	J5	**36**	**11**	**57**	**22**	**25**

Solution: The cost matrix of the given problem is (4M)

9	22	58	11	19
43	78	72	50	63
41	28	91	37	45
74	42	27	49	39
36	11	57	22	25

Since the number of rows is equal to the number of columns in the cost matrix, the given assignment problem is balanced.

Select the smallest cost element in each row and subtract from all elements in corresponding row and get a reduced matrix. (4M)

0	13	49	2	10
0	35	29	7	20
13	0	63	9	17
47	15	0	22	12
25	0	46	11	14

Select the smallest cost element in each column and subtract from all elements in corresponding column. The reduced matrix is

0	13	49	0	0
0	35	29	5	10
13	0	63	7	7
47	15	0	20	2
25	0	46	9	4

Cover all zeros by drawing a minimum number of straight lines (4M)

0	13	49	0	0
0	35	29	5	10
13	0	63	7	7
47	15	0	20	2
25	0	46	9	(4)

The optimal assignment schedule is J1 $\rightarrow$ M4, J2 $\rightarrow$ M1, J3 $\rightarrow$ M2, J4 $\rightarrow$ M3, J5 $\rightarrow$ M5 and the optimum processing time is

= 11 + 43 + 28 + 27 + 25 hours

= 134 hours (4M)

12 **A company has four machines to do three jobs. Each job can be assigned to one and only one machine. The cost of each job on each machine is given in the following table. What are the job assignments which will minimize the cost? (16M)(BTL1)(April 2016)**

		Machines			
		1	**2**	**3**	**4**
	A	**18**	**24**	**28**	**32**
Jobs	**B**	**8**	**13**	**17**	**19**
	C	**10**	**15**	**19**	**22**

Solution: The cost matrix of the given assignment problem is

18	24	28	32
8	13	17	19
10	15	19	22

Since the number of rows is less than the number of columns in the cost matrix, the given assignment problem is unbalanced. To make it balanced, add a dummy job D (row) with 0 cost elements. The balanced cost matrix is given by:c (8M)

18	24	28	32
8	13	17	19
10	15	19	22
0	0	0	0

Now select the smallest cost element in each row (column) and subtract this from all the elements of corresponding row (column), the reduced matrix is given as:

0	6	10	14
0	5	9	11
0	5	9	12
0	0	0	0

Cover the all zeros by drawing minimum number of straight lines. Choose the smallest cost element not covered by these straight lines.

0	6	10	14
0	5	9	11
0	(5)	9	12
0	0	0	0

(0)	1	1	5
	(0)		2
		(0)	3
9	4		(0)

The optimum assignment schedule is given by A $\rightarrow$ 1, B $\rightarrow$ 2, C $\rightarrow$ 3, D $\rightarrow$ 4 and the optimum assignment cost = 18 + 13 + 19 + 0 = 50/- units of cost. (8M)

13 **Solve the following assignment problem for maximization given the profit matrix (profit in rupees)(16M) (BTL1) (Nov 2017, May 2018)**

	P	**Q**	**R**	**S**
A	**51**	**53**	**54**	**50**
B	**47**	**50**	**48**	**50**
C	**49**	**50**	**60**	**61**
D	**63**	**64**	**60**	**60**

The profit matrix of the given assignment problem is

51	53	54	50
47	50	48	50
49	50	60	61
63	64	60	60

Since this is a maximization problem it can be converted it into an equivalent minimization problem by subtracting all the profit elements in the profit matrix from the highest profit element 64 of this profit matrix (5M)

13	11	10	14
17	14	16	14
15	14	4	3
1	0	4	4

Select the smallest cost in each row and subtract this from all the cost elements of the corresponding row

3	1	0	4
3	0	2	0
12	11	1	0
1	0	4	4

Select the smallest cost in each row and subtract this from all the cost elements of the corresponding row (5M)

2	1	0	4
2	0	2	0
11	11	1	0
0	0	4	4

Select the smallest cost in each row and subtract this from all the cost elements of the corresponding row

2	1	(0)	4
2	(0)	2	0
11	11	1	(0)
(0)	0	4	4

Since each row and each column contains exactly one encircle zero the current assignment is optimal.

Therefore the optimum assignment schedule is given by A $\rightarrow$ R,B $\rightarrow$ Q,C $\rightarrow$ S,D $\rightarrow$ P and the optimum profit

= Rs.(54+50+61+63)

= Rs.228/- (6M)

14 **A company has a team of four salesmen and there are four districts where the company wants to start its business. After taking into account the capabilities of salesman and the nature of districts, the company estimates that the profit per day in rupees for each salesman in each district is as below. Find the assignment of salesmen to various districts which will yield maximum profit.(12M)(BTL1)**

Districts

Salesmen		1	2	3	4
	A	16	10	14	11
	B	14	11	15	15
	C	15	15	13	12
	D	13	12	14	15

(16)	10	14	11
14	11	15	15
15	15	13	12
13	12	14	15

Convert to equivalent minimization problem by subtracting all cost elements in the cost matrix by the highest cost element 16. (4M)

0	6	2	5
2	5	1	1
1	1	3	4
3	4	2	1

Get the reduced cost matrix

0	6	2	5
1	4	0	0
0	0	2	3
2	3	1	0

Since each row and each column contains at least one zero, make the assignment in rows and columns having single zero. (4M)

(0)	6	2	5
1	4	(0)	
	(0)	2	3
2	3	1	(0)

The optimum assignment schedule is given by A $\rightarrow$ 1, B $\rightarrow$ 3, C $\rightarrow$ 2, D $\rightarrow$ 4 and the optimum profit

= Rs. (16 + 15 + 15 + 15)

= Rs. 61/-. (4M)

15 **Consider the problem of assigning four sales persons to four different sales regions as shown in the following table such that the total sales is maximized.**

		Sales region			
		1	**2**	**3**	**4**
Salesman	**1**	**10**	**22**	**12**	**14**
	2	**16**	**18**	**22**	**10**
	3	**24**	**20**	**12**	**18**
	4	**16**	**14**	**24**	**20**

The cell entries represent annual sales figures in lakhs of rupees. Find the optimal allocation of the sales persons to different regions. (12M) (BTL2) (Nov 2016)

Solution:

The cost matrix of the given assignment problem is

10	22	12	14
16	18	22	10
24	20	12	18
16	14	24	20

Since this is a maximization problem, it can be converted into an equivalent minimization problem by subtracting all the elements in the matrix from the highest element 24.

Thus the cost matrix of the equivalent minimization problem is

14	2	12	10
8	6	2	14
0	4	12	6
8	10	0	4

Select the smallest cost in each row and subtract this from all the cost elements of the corresponding row. (4M)

12	0	10	8
6	4	0	12
0	4	12	6
8	10	0	4

Select the smallest cost in each column and subtract this from all the cost elements of the corresponding column. (4M)

12	0	10	4
6	4	0	8
0	4	12	2
8	10	0	0

Since each row and column contains at least one zero, assignments are made in rows and columns containing single zeros.

12	(0)	10	4
6	4	(0)	8
(0)	4	12	2
8	10	0	(0)

Since each row and each column contains exactly one encircled zero, the current assignment is optimal.

Therefore the optimum assignment schedule is given by

Salesman 1 → Sales region 2

Salesman 2 → Sales region 3

Salesman 3 → Sales region 1

Salesman 4 → Sales region 4

The maximum annual sales profit is given by

= Rs. (24 + 22 + 22 + 20) lakhs

= Rs. 88 lakhs (4M)

16 **Solve the following travelling salesman problem so as to minimize the cost per cycle.**

To

	A	**B**	**C**	**D**	**E**
A	**-**	**3**	**6**	**2**	**3**
B	**3**	**-**	**5**	**2**	**3**
From C D	**6**	**5**	**-**	**6**	**4**
E	**2**	**2**	**6**	**-**	**6**
	3	**3**	**4**	**6**	**-**

(BTL1)(12M) (April 2019)

Solution: The cost matrix of the given travelling salesman problem is

$$\begin{bmatrix} \infty & 3 & 6 & 2 & 3 \\ 3 & \infty & 5 & 2 & 3 \\ 6 & 5 & \infty & 6 & 4 \\ 2 & 2 & 6 & \infty & 6 \\ 3 & 3 & 4 & 6 & \infty \end{bmatrix}$$

Subtract the smallest cost element in each row (column) from all the elements of the corresponding row (column) we get: (4M)

∞	1	3	0	1
1	∞	2	0	1
2	1	∞	2	0
0	0	3	∞	4
0	0	0	3	∞

Now make assignment in rows and columns having single zeros

∞	1	3	(0)	1
1	∞	2	0	1
2	1	∞	2	(0)
0	(0)	3	∞	4
0	0	(0)	3	∞

Since some rows and columns are without assignments, the current assignment is not optimal. Cover all the zeros by drawing minimum number of straight lines. (4M)

∞	(1)	3	0	1
1	∞	2	0	1
2	1	∞	2	0
0	0	3	∞	4
0	0	0	3	∞

The optimum assignment is given by (4M)

$A \rightarrow D, B \rightarrow C, C \rightarrow E, D \rightarrow B, E \rightarrow A$

$A \rightarrow D \rightarrow B \rightarrow C \rightarrow E \rightarrow A$

UNIT III INTEGER PROGRAMMING

Cutting plan algorithm – Branch and bound methods, Multistage (Dynamic) programming.

UNIT-III/ PART-A

1 **What is integer programming? (BTL1)**

A linear programming problem in which **some or all of the variables** in the optimal solution are **restricted to assume non-negative integer** (or discrete) values is called an Integer Programming Problem (**IPP**) or Integer Linear Programming (**ILP**).

2 **State the general form of an integer programming problem? (BTL1)**

The general Integer Programming Problem is given by Maximize $Z = CX$, Subject to the constraints $AX \leq b$, $X \geq 0$ and some or all variables are integers.

3 **Define All IPP and Mixed IPP. (BTL1)**

List different types of integer programming problem. (May 2017)

Can you provide various types of integer programming? (May 2018)

All (pure) IPP: In a linear programming problem, if **all the variables** in the optimal solution are restricted to assume **non-negative integer** values, then it is called the pure (all) IPP.

Mixed IPP: In a linear programming problem, if only **some of the variables** in the optimal solution are restricted to assume **non-negative integer** values, while the **remaining variables** are free to take any **non-negative values**, then it is called mixed IPP.

4 **Mention some important applications of integer programming problems. (BTL1) (Nov 2016)**

- IPP occur quite frequently in **business and industry**, such as estimation of plant location and size.
- All **transportation, assignment and travelling salesman** problems are IPP, since the decision variables are either zero or one.
- All **sequencing and routing decisions** are IPP as it requires the integer values of the decision variables.
- **Capital budgeting and production scheduling** problem are IPP. In fact, any situation involving decisions of the type either to do a job or not to do can be treated as an IPP.
- All **allocation problems** involving the allocation of goods, men, machines, give rise to IPP since such commodities can be assigned only integer and not fractional values.

5 **State the importance of Integer Programming? (BTL1) (May 2018)**

In linear programming problem, all the decision variables allowed to take any non-negative real values, as it is quite possible and appropriate to have fractional values in many situations. In many situations, like business and industry, these **decision variables make sense only if they have integer values** in the optimal solution. Hence a new procedure has been developed in this direction for the case of LPP subjected to additional restriction that the decision variables must have integer values.

6	**What is the strategy used in integer programming algorithms? (BTL1)** The ILP algorithms are based on exploiting the computational success of LP. The strategy of these algorithms involves three steps. **Step 1:** Relax the solution space of ILP by deleting the integer restriction on all integer variables and replacing any binary variable y with the continuous range $0 \leq y$ 1. The result of the relaxation is a regular LP. **Step 2:** Solve the LP and identify its continuous optimum. **Step 3:** Starting from the continuous optimum point, add special constraints that iteratively modify the LP solution space in a manner that will eventually render an optimum extreme point satisfying the integer requirements.
7	**What are the methods for generating the special constraints in ILP? (BTL2)** **Write down the methods for solving integer linear programming problems. (Nov 2016)** **What do you understand by Cutting Plane Algorithm? (Nov 2017)** The general methods have been developed generating the special constraints and solving integer linear programming problems are: ❖ **Branch and Bound (B&B) Method:** It starts with the continuous optimum, but systematically **partitions the solution space into sub problems** that eliminate parts that contain no feasible integer solution. ❖ **Cutting Plane Method:** This method solves the IPP as ordinary LPP by ignoring the integer restriction and then **introducing additional constraints one after the other to cut (eliminate) certain part of the solution space** until an integral solution is obtained. ❖ **Balas Additive Method:** This method is for solving zero-one integer programming problems.
8	**Write an algorithm for Gomory's Fractional Cut algorithm? (BTL1)** **Step 1:** Convert the minimization IPP into an equivalent maximization IPP and all the coefficients and constraints should be integers. **Step 2:** Find the optimum solution of the resulting maximization LPP by using simplex method. **Step 3:** Test the integrity of the optimum solution. **Step 4:** Rewrite each XBi **Step 5:** Express each of the negative fractions if any, in the kth row of the optimum simplex table as the sum of a negative integer and a non-negative fraction. **Step 6:** Find the fractional cut constraint. **Step 7:** Add fractional cut constraint at the bottom of optimum simplex table obtained in step 2. **Step 8:** Go to step 3 and repeat the procedure until an optimum integer solution is obtained.
9	**What is a fractional cut? (BTL1)** In the cutting plane method, the fractional cut constraints **cut the unused area of the feasible region** in the graphical solution of the problem. i.e. cut that area which has no integer-valued feasible solution. Thus these constraints eliminate all the non-integral solutions without loosing any integer-valued solution. A desired cut which **represents a necessary condition** for obtaining an integer solution is referred to as the **fractional cut** because all its coefficients are fractions.

10 **Write the Gomory's constraint for the all integer programming problem whose simplex table (with non-integer solution) given below: (BTL3) (May 2017)**

		C_j	2	20	-10	0
Basic variable	C_B	X_B	X_1	X_2	X_3	S_1
x_2	20	5/8	0	1	1/5	3/40
x_1	2	5/4	1	0	0	1/4
	$Z = C_B X_B = 15$		0	0	-14	-1

Solution:

Now $x_1 = \frac{5}{4} = 1 + \frac{1}{4} = [X_{B1}] + f_1$

$x_2 = \frac{5}{8} = 0 + \frac{5}{8} = [X_{B2}] + f_2$

$\text{Max}\{f_1, f_2\} = \text{Max}\left\{\frac{1}{4}, \frac{5}{8}\right\} = \frac{5}{8}$

This corresponds to the first row (the source row). From the source row

$$\frac{5}{8} = x_2 + \frac{1}{5}x_3 + \frac{3}{40}s_1$$

Therefore the fractional cut (Gomorian) constraint is given by

$$\frac{1}{5}x_3 + \frac{3}{40}s_1 \geq \frac{5}{8}$$

$$\Rightarrow \quad -\frac{1}{5}x_3 - \frac{3}{40}s_1 \leq -\frac{5}{8}$$

$$\Rightarrow \quad -\frac{1}{5}x_3 - \frac{3}{40}s_1 + s_2 = -\frac{5}{8}$$

Where s_2 is the Gomorian slack

11 **Mention some suggestions that are helpful in computation in ILP. (BTL2)**

The most important factor affecting computation in ILP is the number of integer variables and the feasible range in which they apply. It may be advantageous **to reduce the number of integer variables** in the ILP model as much as possible. The following suggestions may provide helpful:

- ❖ **Approximate** the integer variables by **continuous ones** whenever possible.
- ❖ For the integer variables, **restrict their feasible ranges** as much as possible.
- ❖ **Avoid the use of nonlinearity** in the model.

12 **What is mixed integer problem? (BTL1)(April 2019)**

In the mixed integer programming problem only **some of the variables are integer constrained**, while other variables may take integer or other real values. The problem is first solved as a continuous LPP by ignoring the integer condition. If the values of the integer constrained variables are integers then the current solution is an optimal solution to the given mixed IPP. Otherwise select the source row which corresponds to the largest fractional part f_k among those basic variables which are constrained to be integers. Then construct **Gomorian constraint** from the source row.

13 **What is dynamic programming? (BTL1) (Nov 2017)**

Dynamic programming is the mathematical technique of **optimization using multistage decision process**. It is a process in which a sequence of interrelated decisions has to be made. It provides a systematic procedure for determining the combination of decisions which maximize overall effectiveness.

14	**Specify the need for dynamic programming. (BTL1)** Decision making process consists of selecting a combination of plans from a large number of alternative combinations. This involves lot of computational work and time. Dynamic programming deals with such situations by **dividing the given problem into sub problems or stages**. Only one stage is considered at a time and the various infeasible combinations are eliminated with the objective of reducing the volume of computations. The solution is obtained by **moving from one stage to the next** and is completed when the final stage is reached.
15	**What is forward and backward recursion? (BTL1)** **Forward recursion** is one in which the computation proceed from stage 1 to stage n. The same can be solved by **backward recursion** starting at stage n and ending at stage 1. Both yield the same solution. Although forward appears more logical, DP invariably uses backward recursion. The reason for this preference is that, in general backward recursion may be **more efficient computationally**.
16	**State Bellman's principle of optimality. (BTL2)** An optimal policy (set of decisions) has the property that whatever be the initial state and initial decisions, **the remaining decisions must constitute an optimal policy** for the state resulting from the first decision.
17	**List some characteristics of dynamic programming problems. (BTL1)** The characteristics of dynamic programming problems may be outlined as: ❖ Each problem can be **divided into stages**, with a policy decision required at each stage. ❖ Each stage has **number of states** associated with it. ❖ The effect of the policy decision at each stage is to **transform the current state** into a state associated with the next stage. ❖ The current state of the system is described by **state variables**.
18	**State Markovian property. (BTL1)** For dynamic programming problem, in general, the **knowledge of the current state of the system conveys all of the information about its previous behaviour** necessary for determining the optimal policy hence forth. This is the Markovian property.
19	**Define stage. (BTL1)** A stage may be defined as the **portion** of the problem that possesses a **set of mutually exclusive alternatives** from which the best alternative is to be selected. If we are to take six sequential decisions then we have six stages.
20	**Mention some applications of dynamic programming. (BTL1)** ❖ Used for **production, scheduling and employment** smoothening problems. ❖ Used to determine the **inventory level** and formulating inventory recording. ❖ Applied for **allocating scarce resource** to different alternative uses. ❖ Used to determine the **optimal combination of advertising media**. ❖ Applied in **replacement theory** to determine at which age the equipment is to be replaced for optimal return from the facility.
21	**What are the steps involved in dynamic programming algorithm? (BTL1)** **Step 1:** Identify the decision variables and specify objective function to be optimized. **Step 2:** Decompose the given problem into smaller sub problems. Identify state variables a t each stage. **Step 3:** Write the general recursive relationship for computing the optimal policy. **Step 4:** Write the relation giving the optimal decision function for one stage sub-problem and solve it. **Step 5:** Solve the optimal decision function for 2-stage, 3-stage, ..(n-1)-stage and n-stage problem.

UNIT-III / PART-B	
1	**Find the optimum integer solution to the following LPP.(12M) (BTL1)** **Maximize Z = $x_1 + x_2$** **subject to constraints** **$3x_1 + 2x_2 \le 5$,** **$x_2 \le 2$ and** **$x_1 > 0$, $x_2 \ge 0$ and are integers.**

Solution:

Ignoring the integrality condition and introducing non-negative slack variables x3 and x4, the standard form of the continuous LPP becomes

Maximize $Z = x_1 + x_2 + 0x3 + 0x4$

Subject to

$3x_1 + 2x_2 + x3 + 0x4 = 5$

$0x1 + x_2 + 0x3 + x4 = 2$

and x_1, x_2, x3, x4 ≥ 0

The initial basic feasible solution is given by x3 = 5, x4 = 2, (x1 = x2 = 0, non-basic) (4M)

Initial iteration:

C_j (1 1 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
0	x3	5	(3)	2	1	0	5/3
0	x4	2	0	1	0	1	-
$Z_j - C_j$		0	-1	-1	0	0	

Third iteration:

C_j (1 1 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1
1	x1	0	1	0	0	-1	1
1	x2	2	0	1	0	1	1
0	x3	1	0	0	1	1	-3
$Z_j - C_j$		2	0	0	0	0	1

For the above LPP the feasible regions OABC, the optimum solution is

Max Z = 7/3, x1 = 1/3, x2 = 2

Since this solution is not an integer optimum solution, introduce the secondary Gomorian constant. (4M)

$\frac{x3}{3} + \frac{x4}{3} \ge \frac{1}{3}$

Express this in terms of x1 and x2

$3x1 + 2x2 + x3 = 5 \Rightarrow x3 = 5 - 3x1 - 2x2$

and $x2 + x4 = 2 \Rightarrow x4 = 2 - x2$

Substituting in the Gomory constants

$\frac{1}{3}(5 - 3x1 - 2x2) + \frac{1}{3}(2 - x2) \ge \frac{1}{3}$

$\Rightarrow 5 - 3x1 - 2x2 + 2 - x2 \ge 1$

$\Rightarrow -3x1 - 3x2 + 7 \ge 1 \Rightarrow -3x1 - 3x2 \ge -6$

$\Rightarrow 3x1 + 3x2 \le 6 \Rightarrow x1 + x2 \le 2$

The required optimal integer valued solution is

Max Z = 2, x1 = 0, x2 = 2 (or)

Max Z = 2, x1 = 1, x2 = 1 (4M)

2	**Find the optimum integer solution to the following linear programming problem.**

Maximize Z= x_1+2x_2

Subject to

$2x_2 \le 7$

$x_1+x_2 \le 7$

$2x_1 \le 11$

and $x_1,x_2 \ge 0$ and are integers.(16M) (BTL1) (May 2017)

Solution:
Ignoring the integrality condition and introducing the non-negative slack variables x3,x4 and x5, the standard form of the continuous L.P.P becomes
Maximize Z= $x_1+2x_2+0x_3+0x_4+0x_5$
Subject to
$0x_1+2x_2+x_3+0x_4+0x_5=7$
$x_1+x_2+0x_3+x_4+0x_5=7$
$2x_1+0x_2+0x_3+0x_4+x_5=11$

And $x_i \ge 0$, i=1,2,3,4,5
The initial basic feasible solution is given by
$x_3=7$, $x_4= 7$, $x_5= 11$ (basic)
($x_1=x_2=0$, non basic) (2M)

Initial Iteration:

C_j (2 1 4 -1 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	X5	
0	X3	7	0	(2)	1	0	'	7/2
0	X4	7	1	1	0	1	0	7
0	X5	11	2	0	0	0	1	-
Z_j - C_j		0	-1	-2	0	0	0	

First Iteration: introduce x2 and drop x3

C_j (1 2 4 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	θ
0	X2	7/2	0	1	1/2	0	0	-
0	X4	7/2	(1)	0	-1/2	1	0	7/2
0	X5	11	2	0	0	0	1	11/2
Z_j - C_j		7	-1	0	1	0	0	

Third Iteration: introduce x1 and drop x4

C_j (1 2 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1
0	X2	7/2	0	1	1/2	0	0
0	X1	7/2	1	0	-1/2	1	0
0	X5	4	0	0	1	-2	1
Z_j - C_j		21/2	0	0	1/2	1	0

Since all ($Z_j - C_j$) ≥0, the current basic feasible solution is optimal but non integer. (10M)
Max Z= 21/2= 3+1/2= [XB1]+f1

Max [f1,f2]= Max[1/2,1/2]= ½ which corresponds to both first and second rows. We choose the first row arbitrarily as the source row. From this we have

$7/2= x_2+1/2x_3$

$3+1/2=x_2+1/2x_3$

The fractional cut (Gomorian) construct is given by

$½ x_3 \geq ½$

$\rightarrow -1/2x_3+s1= -1/2$

Where s1 is the Gomorian slack.

C_j (1 2 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	X5	s1
2	X'	' /2	0	1	1/2	0	0	0
1	X1	7/2	1	0	-1/2	1	0	0
0	X5	4	0	0	1	-2	1	0
0	S1	-1/2	0	0	(-1/2)	0	0	1
$Z_j - C_j$		21/2	0	0	1/2	1	0	0

Since s_1= -1/2 the solution is infeasible. To find the feasible optimal solution, we have to use dual simplex method.

Third Iteration: Introduce x3 and drop s1 (4M)

C_B	Y_B	X_B	x1	x2	x3	x4	X5	s1
2	X2	3	0	1	0	0	0	1
1	X1	4	1	0	0	1	0	-1
0	X5	3	0	0	0	-2	1	2
0	X3	1	0	0	1	0	0	-2
$Z_j - C_j$		10	0	0	0	1	0	1

Since all the current solution is feasible integer optimal.

The optimal integer solution is Max Z= 10, x_1= 4, x_2= 3.

3 **Using Gomory's cutting plane method**

Maximize $Z = 2x_1 + 2x_2$

subject to $5x_1 + 3x_2 \leq 8$,

$2x_1 + 4x_2 \leq 8$

and $x_1 , x_2 \geq 0$ and are all integers.(16M) (BTL1)(Nov 2016)

Solution:

Ignore the integrality condition and introducing the non-negative slack variables x3 and x4 the standard form of the continuous LPP becomes

Maximize

$Z = 2x_1 + 2x_2 + 0x3 + 0x4$

Subject to

$5x_1 + 3x_2 + x3 + 0x4 = 8$

$2x_1 + 4x_2 + 0x3 + x4 = 8$

and $x_1 , x_2, x3, x4 \geq 0$

The initial basic feasible solution is given by

x3 =8, x4 = 8 (basic)

(x1 = x2 = 0, non-basic) (4M)

	Initial iteration:

C_j (2 2 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
0	x3	8	(5)	3	1	0	8/5*
0	x4	8	2	4	0	1	8/2
Z_j - C_j		0	-2	-2	0	0	

First Iteration: Introduce x1 drop x3

C_j (2 2 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
2	x1	8/5	1	3/5	1/5	0	8/3
0	x4	24/5	0	(14/5)	-2/5	1	24/14=12/7*
Z_j - C_j		16/5	0	-4/5	2/5	0	

Fourth iteration: Introduce x4 and drop s2

C_j (2 2 0 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1	s2
2	x1	1	1	0	0	0	1	-4/5
2	x2	1	0	1	0	0	-1	1
0	x3	0	0	0	1	0	-2	1
0	x4	2	0	0	0	1	2	-12/5
Z_j - C_j		4	0	0	0	0	0	2/5

The optimal solution to the new problem is

Max Z = 4, x1 = 1, x2 = 1 (12M)

4 **Solve the following IPP.**

Minimize Z= $-2x_1 - 3x_2$

subject to

$2x_1 + 2x_2 \leq 7$,

$x_1 \leq 2$, $x_2 \leq 2$

and x_1 , $x_2 \geq 0$ and are integers. (12M) (BTL3) (Nov 2016)

Solution: Given IPP is

Minimize Z= $-2x_1 - 3x_2$

Subject to

$2x_1 + 2x_2 \leq 7$

$x_1 \leq 2$

$x_2 \leq 2$

x_1 , $x_2 \geq 0$ and integers.

Maximize

$Z^* = 2x_1 + 3x_2$

Subject to

$2x_1 + 2x_2 \leq 7x_1$

≤ 2

$x_2 \leq 2$

$x_1, x_2 \geq 0$ and integers.

Ignoring the integrality condition and introducing the non-negative slack variables x3, x4, x5 the standard form of the continuous LPP becomes. (4M)

Maximize

$Z^* = 2x_1 + 3x_2 + 0x3 + 0x4 + 0x5$

Subject to

$2x_1 + 2x_2 + x3 + 0x4 + 0x5 = 7$

$x_1 + 0x2 + 0x3 + x4 + 0x5 = 2$

$0x1 + x_2 + 0x3 + 0x4 + x5 = 2$

$x_1, x_2, x3, x4, x5 \geq 0$ and integers.

The basic feasible solution is given by x3=7, x4=2, x5=2 (basic)

(x1=x2=0, non-basic)

Initial iteration:

		C_j	(2	3	0	0	0)	
C_B	Y_B	X_B	x1	x2	x3	x4	x5	θ
0	x3	7	2	2	1	0	0	7/2
0	x4	2	1	0	0	1	0	-
0	x5	2	0	(1)	0	0	1	2*
$Z_j^*- C_j$		0	-2	-3	0	0	0	

First Iteration: Introduce x2 and drop x5

		C_j	(2	3	0	0	0)	
C_B	Y_B	X_B	x1	x2	x3	x4	x5	θ
0	x3	3	(2)	0	1	0	-2	3/2*
0	x4	2	1	0	0	1	0	2
3	x2	2	0	1	0	0	1	-
$Z_j^*- C_j$		6	-2	0	0	0	3	

Second iteration: Introduce x1 and drop x3

		C_j	(2	3	0	0	0)
C_B	Y_B	X_B	x1	x2	x3	x4	x5
2	x1	3/2	1	0	1/2	0	-1
0	x4	1/2	0	0	-1/2	1	1
3	x2	2	0	1	0	0	1
$Z_j^*- C_j$		9	0	0	1	0	1

Since all $Z_j^*- C_j \geq 0$, the current basic feasible solution is optimal but non-integer.
To obtain the optimum integer solution, construct a fractional cut constraint

$x1 = 3/2 = 1 + 1/2 = [X_{B1}] + f1$

$x2 = 1/2 = 0 + 1/2 = [X_{B2}] + f2$

Max {f1, f2} = Max {½, ½} = ½ which corresponds to both first and second rows. Select first row arbitrarily as the source row.
Now from the source row,

$3/2 = x1 + 1/2\, x3 - x5$

$1 + 1/2 = x1 + 1/2\, x3 - x5$

Therefore the fractional cut (Gomorian) constraint is given by

$1/2\, x3 \geq 1/2$

$\Rightarrow -1/2\, x3 \leq -1/2$

$\Rightarrow -1/2\, x3 + s1 = -1/2$

s1 → Gomorian constraint
Add this fractional cut at the bottom of the optimum simplex table and using dual simplex method

		C_j	(2	3	0	0	0	0)
C_B	Y_B	X_B	x1	x2	x3	x4	x5	s1
2	x1	3/2	1	0	1/2	0	-1	0
0	x4	1/2	0	0	-1/2	1	1	0
3	x2	2	0	1	0	0	1	0
0	s1	-1/2	0	0	(-1/2)	0	0	1
$Z_j^*- C_j$		9	0	0	1	0	1	0

Since s1 = -1/2, s1 leaves the basis.
Further,

Max $\left\{\frac{Z_j* - C_j}{a_{ik}}\right\}, a_{ik} < 0$= Max $\left\{\frac{1}{-1/2}\right\}$ = -2 which corresponds to x3. So x3 enters the basis. (12M)

Third iteration: Drop s1 and introduce x3

		C_j	(2	3	0	0	0	0)
C_B	Y_B	X_B	x1	x2	x3	x4	x5	s1
2	x1	1	1	0	0	0	-1	1
0	x4	1	0	0	0	1	1	-1
3	x2	2	0	1	0	0	1	0
0	x3	1	0	0	1	0	0	-2
$Z_j^*- C_j$		8	0	0	0	0	1	2

Since all $Z_j^*- C_j \geq 0$ and all $X_{Bi} \geq 0$, the current solution is feasible and integer optimal.
The optimal integer solution is

Max Z* = 8, x1=1, x2=2

Min Z = -Max(-Z) = -Max Z* = -8

Min Z = -8, x1=1, x2=2

5 **Solve the following mixed integer programming problem by Gomory's cutting plane algorithm:**

Maximize $Z = x_1 + x_2$

subject to $3x_1 + 2x_2 \le 5$,

$x_2 \le 2$

and x_1 , $x_2 \ge 0$ and x_1 an integer. (16M) (BTL2) (May 2018)

Solution: Ignoring the integrality condition and introducing the non-negative slack variables x3, x4, the standard form of the continuous LPP becomes

Maximize

$$Z = x_1 + x_2 + 0x3 + 0x4$$

Subject to

$$3x_1 + 2x_2 + x3 + 0x4 = 5$$

$$0x1 + x_2 + 0x3 + x4 = 2$$

and x_1 , x_2 , x3, x4 ≥0 (4M)

The initial basic feasible solution is given by

x3=5, x4=2 (basic) (x1=x2=0, non-basic)

Initial iteration:

C_j (1 1 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
0	x3	5	(3)	2	1	0	5/3
0	x4	2	0	1	0	1	-
Z_j - C_j		0	-1	-1	0	0	

First iteration: Introduce x1 and drop x3

C_j (1 1 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
1	x1	5/3	1	2/3	1/3	0	5/2
0	x4	2	0	(1)	0	1	2
Z_j - C_j		5/3	0	-1/3	1/3	0	

Third iteration: Drop s1 and introduce x3

C_j (1 1 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
1	x1	0	1	0	0	-1	1
1	x2	2	0	1	0	1	0
0	x3	1	0	0	1	1	-3
Z_j - C_j		2	0	0	0	0	1

The required solution is(12M)

Max Z = 2, x1=0, x2=2

6 **Solve the following mixed integer programming problem**

Minimize $Z = x_1 - 3x_2$

subject to $x_1 + x_2 \le 5$,

$-2x_1 + 4x_2 \le 11$

and x_1 , $x_2 \ge 0$ and x_2 is an integer. (12M)(BTL3)(Nov 2019)

Solution:

Given mixed IPP be

Minimize

$Z = x1 - 3x2$

Subject to

$x1 + x2 \le 5$

$-2x1 + 4x2 \le 11$

$x1$, $x2 \ge 0$ and x2 is an integer.

Maximize

$Z^* = -x1 + 3x2$

Subject to

$x1 + x2 \le 5$

$-2x1 + 4x2 \le 11$

$x1$, $x2 \ge 0$ and x2 is an integer.

Ignoring the integrality condition and introducing the non-negative slack variables x3 and x4, the standard form of the continuous LPP becomes (4M)

Maximize

$Z^* = -x1 + 3x2 + 0x3 + 0x4$

Subject to

$x1 + x2 + x3 + 0x4 = 5$

$-2x1 + 4x2 + 0x3 + x4 = 11$

x1 , x2 , x3, x4

The initial basic feasible solution is given by

x3=5, x4=11 (basic)

(x1=x2=0, non-basic)

Initial iteration:

C_j (-1 3 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
0	x3	5	1	1	1	0	5/1
0	x4	11	-2	(4)	0	1	11/4
$Z_j - C_j$		0	1	-3	0	0	

	First Iteration: Introduce x2 and drop x4 Initial iteration: C_j (-1 3 0 0) (table 1 below) Third iteration: Drop s1 and introduce x3 C_j (-1 3 0 0 0) (table 2 below) The optimal integer solution is Max Z* = 17/2, x1=1/2, x2=3 Min Z = -Max Z* = -17/2 Min Z = -17/2, x1=1/2, x2=3 (8M)

First Iteration: Introduce x2 and drop x4

Initial iteration:

C_j (-1 3 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
0	x3	9/4	(3/2)	0	1	-1/4	3/2
3	x2	11/4	-1/2	1	0	1/4	-
Z_j - C_j		33/4	-1/2	0	0	3/4	

Third iteration: Drop s1 and introduce x3

C_j (-1 3 0 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	s1
-1	x1	1/2	1	0	0	-1/2	2
3	x2	3	0	1	0	0	1
0	x3	3/2	0	0	1	1/2	-3
Z_j - C_j		17/2	0	0	0	1/2	1

The optimal integer solution is

Max Z* = 17/2, x1=1/2, x2=3

Min Z = -Max Z* = -17/2

Min Z = -17/2, x1=1/2, x2=3 (8M)

7 **Use branch and bound technique to solve the following:**

Maximize Z = $x_1 + 4x_2$

subject to constraints

$2x_1 + 4x_2 \leq 7$,

$5x_1 + 3x_2 \leq 15$

and x_1, $x_2 \geq 0$ and integers. (12M)(BTL1) (May 2018)

Solution: Ignoring the integrality condition the continuous LPP becomes

Maximize

Z = x1 + 4x2

Subject to

2x1 + 4x2 ≤ 7

5x1 + 3x2 ≤ 15

and x1 , x2 ≥ 0 and integers.

By using the graphical method the solution space in given by the region OABC. The optimum solution of this problem is

Max Z = 7, x1=0, x2=7/2 (4M)

Since x2=7/2, this problem should be branched into two problems.

Sub-problem (1)

Maximize

Z = x1 + 4x2

	Subject to $2x1 + 4x2 \le 7$ $5x1 + 3x2 \le 15$ $x2 \le 1$ and $x1 , x2 \ge 0$ Its solution space is given by the region OABDE and its optimal solution is Max Z = 11/2, x1=3/2, x2=1 Since x1=3/2, this sub-problem is branched again. (4M) Sub-problem (2) Maximize $Z = x1 + 4x2$ Subject to $2x1 + 4x2 \le 7$ $5x1 + 3x2 \le 15$ $x2 \ge 2$ and $x1 , x2 \ge 0$ Its solution space is given by region OABC and FGH and it has no feasible solution. Sub-problem (3) Maximize $Z = x1 + 4x2$ Subject to $2x1 + 4x2 \le 7$ $5x1 + 3x2 \le 15$ $x2 \le 1$ $x1 \le 1$ and $x1 , x2 \ge 0$ Its solution space is given and its optimal solution is Max Z = 5, x1=1, x2=1 (4M)
8	**Use branch and bound to solve the following IPP.** **Max $Z = 3x_1 + 4x_2$** **subject to $7x_1 + 16x_2 \le 52$,** **$3x_1 - 2x_2 \le 18$** **and $x_1 , x_2 \ge 0$ and are all integers.(12M) (BTL1)(Nov 2011)** Solution: Ignoring the integrality condition and introducing the non-negative slack variables x3, x4, the standard form of the continuous LPP becomes Max $Z = 3x_1 + 4x_2 + 0x3 + 0x4$ Subject to $7x_1 + 16x_2 + x3 + 0x4 = 52$ $3x_1 - 2x_2 + 0x3 + x4 = 18$ $x_1 , x_2 , x3, x4 \ge 0$

The initial basic feasible solution is given by x3 = 52, x4 = 18 (basic)

(x1= x2= 0, non-basic) (4M)

Initial Iteration:

C_j (3 4 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
0	x3	52	7	(16)	1	0	52/16
0	x4	18	3	-2	0	1	-
Z_j - C_j		0	-3	-4	0	0	

First Iteration: Introduce x2 and drop x3

C_j (3 4 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	θ
4	x2	13/4	7/16	1	1/16	0	52/7
0	x4	49/2	(31/8)	0	1/8	1	196/31*
Z_j - C_j		13	-5/4	0	1/4	0	

Second Iteration: Introduce x1 and drop x4

C_j (3 4 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4
4	x2	15/31	0	1	-1/12	7/62
3	x1	196/31	1	0	1/3	8/31
Z_j - C_j		648/31	0	0	2/3	19/43

Since all (Zj –Cj) ≥ 0, the current basic solution is optimal, but non-integer.

x2 = 15/31 = 0 + 15/31

x1 = 196/31 = 6 + 10/31

The maximum fractional part is 15/31 which corresponds to x2

0 < x2 < 1 ⇒ x2 ≤ 0 (or) x2 ≥ 1

Applying these two conditions separately in the continuous LPP, the two sub-problems are: (4M)

Sub-problem 1

Max

$Z = 3x_1 + 4x_2$

Subject to

$7x_1 + 16x_2 \leq 52$

$3x_1 - 2x_2 \leq 18$

$x2 \leq 0$

$x_1, x_2 \geq 0$

The optimal solution is given by Max Z= 18, x1=6, x2=0. Since the solution is in integers this sub-problem is fathomed. The lower limit of the objective function is 18.

	Sub-problem 2 Max $Z = 3x_1 + 4x_2$ Subject to $7x_1 + 16x_2 \leq 52$ $3x_1 - 2x_2 \leq 18$ $x2 \geq 1$ $x_1, x_2 \geq 0$ The optimal solution is given by Max Z=19.43, x1=5.14, x2=1 Also in sub-problem (2) since x1=5.14 $\Rightarrow 5 < x1 < 6$ $\Rightarrow x1 \leq 5$ or $x1 \geq 6$ Applying these two conditions separately in sub-problem (2), solve sub-problem (3) and sub-problem (4). Sub-problem 3 The optimal solution is given by Max Z= 19.25, x1 = 5, x2 = 1.063 Sub-problem 4 This sub-problem has no feasible solution. So this sub-problem is fathomed. From the available integer optimal solutions, the best optimal solution is Max Z=19, x1=5, x2=1, which is the required optimal solution.(4M)
9	**Use branch and bound method to solve the following** **Max Z= $2x_1+2x_2$** **Subject to $5x_1+3x_2 \leq 8$** **$x_1+2x_2 \leq 4$** **and $x_1, x_2 \geq 0$ and integer. (16M) (BTL1) (May 2017, Nov 2017)** Maximize Z= $2x_1+2x_2+0x_3+0x_4$ Subject to $5x_1+3x_2+x3+0x4=8$ $x_1+2x_2+0x_3+x_4=4$ and $x_1,x_2,x_3,x_4 \geq 0$ The initial basic feasible solution is given by $x_3=8$, $x_4=4$ (basic) ($x_1=x_2=0$, non basic) Initial Iteration:

		C_j	(2	2	0	0)	
C_B	Y_B	X_B	x1	x2	x3	x4	
0	X3	8	(5)	3	1	0	8/5
0	X4	4	1	2	0	1	4
$Z_j - C_j$		-2	-2	0	0	0	

First Iteration: (introduce x1 and drop x3)(4M)

C_j (2 2 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4	
2	X1	8/5	1	3/5	1/5	0	8/3
0	X4	12/5	0	(7/5)	-1/5	1	12/ 7
Z_j - C_j		16/5	0	-4/5	2/5	0	

Second Iteration: (introduce x2 and drop x4)

C_j (2 2 0 0)

C_B	Y_B	X_B	x1	x2	x3	x4
2	X1	4/7	1	0	2/7	-3/7
2	X2	12/7	0	1	-1/7	5/7
Z_j - C_j		32/7	0	0	2/7	4/7

Max Z= 32/7

x_1= 4/7

x_2= 12/7

In order to obtain the integer optimal solution, we have to branch this problem into two sub- program (4M)

Now from x_2= 12/7 ---→ $1\le x_1\le 2$

$x_1\le1$ or $x_2 \ge2$

Applying these conditions separately in the continuous LPP, we have two sub problem,

Sub – problem (1)

Max Z= $2x_1+2x_2$

Subject to

$5x_1+3x_2 \le8$

$x_1+2x_2 \le4$

$x_2 \le1$

And $x_1,x_2\ge 0$

Its optimal solution is Max Z= 4, x_1=1, x_2=1 (4M)

Sub – problem (2)

Max z= $2x_1+2x_2$

subject to

5x1+3x2 =8

x_1+2x_2= 4

x_2=2

And x1,x2 0

Its optimal solution is z=4, x1= 0, x2= 2. So this problem is also fathomed

Hence from the both sub problems(1), (2) the integer optimal solution is given by Max Z=4

With x_1= 1, x2= 1 or x1=0, x2=0

Hence the Integer optimal solution is

Max Z = 4

With $x_1 = 1$, $x_2 = 1$ or $x_1 = 0$, $x_2 = 2$. (4M)

10 **Solve the following by dynamic programming.**

Min Z = $y_1 + y_2 + \ldots + y_n$

subject to constraints $y_1\, y_2 \ldots\, y_n = b$ and $y_1\, y_2 \ldots\ldots y_n \geq 0$ (or)

Factorize a positive quantity b into n factors in such a way so that their sum is a minimum. (10M)(BTL2)

Solution: To develop the recursive equation:

Let fn(b) be the minimum attainable sum y1 + y2 +.......+ yn when the positive quantity b is factorized into n factors y1, y2, …, yn.

For n=1 (One stage problem)

Here b is factorized into one factor y1=b only

$$f1(b) = \underset{y1 = b}{Min}\{y1\} = b \text{ (trivial case)}$$

For n=2 (Two stage problem) (5M)

Here b is factorized into two factors y1=x and y2=b/x so that y1.y2=b

$$f2(b) = \underset{0 \leq x \leq b}{Min}\{y1+y2\}$$

$$= \underset{0 \leq x \leq b}{Min}\{x + \tfrac{b}{x}\}$$

$$= \underset{0 \leq x \leq b}{Min}\{x + f1\,(b/x)\}$$

For n=3 (Three stage problem)

Here b is factorized into three factors y1=x and y2.y3=b/x so that y1.y2.y3=b

$$f3(b) = \underset{0 \leq x \leq b}{Min}\{y1+y2+y3\}$$

$$= \underset{0 \leq x \leq b}{Min}\{x + f2\,(b/x)\}$$

In general the recursive equation for the n-stage problem is

$$fn(b) = \underset{0 \leq x \leq b}{Min}\{x + f_{n-1}\,(b/x)\} \quad (5M)$$

11 **By dynamic programming technique, solve the problem.**

Min Z = $x_1^2 + x_2^2 + x_3^2$

subject to constraints

$x_1 + x_2 + x_3 \geq 15$

and $x_1, x_2, x_3 \geq 0$.(10M) (BTL1)

Solution: To develop the recursive equation

It is a three stage problem. The decision variables are x1, x2, x3 and the state variables are s1, s2 and s3 are defined as

s3 = x1+x2+x3 ≥15

s2 = x1+x2 = s3-x3

s1 = x1 = s2-x2

	Let fi(si) be the minimum value of Z at the i-th stage where Si = x1+x2+….+xi (i=1,2,3) Now the recursive equations are $f1(s1) = \underset{0 \le x1 \le s1}{Min}\{x1^2\} = s1^2 = (s2-x2)^2 \rightarrow (1)$ $f2(s2) = \underset{0 \le x2 \le s2}{Min}\{x1^2 + x2^2\}$ $= \underset{0 \le x2 \le s2}{Min}\{x2^2 + f1(s1)\} \qquad \rightarrow (2)$ $f3(s3) = \underset{0 \le x3 \le s3}{Min}\{x1^2 + x2^2 + x3^2\}$ $= \underset{0 \le x3 \le s3}{Min}\{x3^2 + f2(s2)\} \qquad \rightarrow (2)$ To solve the recursive equations: (5M) From (1) $f1(s1) = (s2-x2)^2$ From (2) $f2(s2) = \underset{0 \le x2 \le s2}{Min}\{x2^2 + f1(s1)\}$ $= \underset{0 \le x2 \le s2}{Min}\{x2^2 + f1(s2-x2)\}$ $= \underset{0 \le x2 \le s2}{Min}\{2x2^2 - 2s2x2 + s2^2\}$ The function $\{2x2^2 - 2s2x2 + s2^2\}$ will attain minimum when $x2 = s2/2$ $f2(s2) = \underset{0 \le x2 \le s2}{Min}\{2x2^2 - 2s2x2 + s2^2\}$ $= 2(s2/2)^2 - 2s2(s2/2) + s2^2 = s2^2/2$ From (3) $f3(s3) = \underset{0 \le x3 \le s3}{Min}\{x3^2 + f2(s2)\}$ $= \underset{0 \le x3 \le s3}{Min}\{x3^2 + f2(s3-x3)\}$ $= \underset{0 \le x3 \le s3}{Min}\{x3^2 + (s3-x3)^2/2\}$ The function $x3^2 + (s3-x3)^2/2$ will attain its minimum when $x3 = s3/3$ $f3(s3) = \underset{0 \le x3 \le s3}{Min}\{x3^2 + (s3-x3)^2/2\}$ $= (s3/3)^2 + (s3-s3/3)^2/2$ $= s3^2/3$ But $s3 \ge 15$, i.e., minimum s3 =15 Therefore Z is minimum when $x3 = s3/3 = 15/3 = 5$ But $s2 = s3 - x3 = 15 - 5 = 10$ Therefore $x2 = s2/2 = 10/2 = 5$

Also s1 = s2 –x2 = 10 -5 =5

Therefore x1 = s1 = 5

$f3(s3) = s3^2/3 = 15^2/3 = 75 = f3(15)$

Therefore the optimal policy is (5, 5, 5) and Min Z = 75 = f3(15). (5M)

12 **Solve the following LPP using dynamic programming principles.**

Max $Z = 2x_1 + 5x_2$

subject to $2x_1 + x_2 \leq 43$,

$2x_2 \leq 46$

and $x_1, x_2 \geq 0$.(10M) (BTL1)

Solution: The problem consists of two decision variables and two resources (constraints). Hence the problem has two stages and two state variables: Let (B1j, B2j) be the state of the system at stage j (j=1,2) and fj(B1j,B2j) be the optimal (maximum) value of the objective function for stage j=1,2 given the state (B1j,B2j)

Using backward computation procedure

$$F2(B12,B22)= \underset{\substack{0 \leq x2 \leq B12 \\ 0 \leq x2 \leq B22}}{Max} \{5x2\} = \underset{\substack{0 \leq x2 \leq B12 \\ 0 \leq x2 \leq B22/2}}{Max} \{x2\}$$

Since Max{x2} which satisfies 0≤x2≤B12, 0≤x2≤B22/2 is the minimum of B12, B22/2

$x2^* = Max\{x2\} = Min\{B12, B22/2\} \rightarrow (1)$

$f2\ (B12,B22) = 5Min\{B12,B22/2\} \rightarrow (2)$

Also $f1\ (B11,B21) = \underset{0 \leq 2x1 \leq B11}{Max} \{2x1+f2(B11-2x1,B21-0)\}$

From (2)

$F2(B11-2x1,B21)= 5\ Min\ \{B11-2x1,B21/2\}$ (5M)

$F1(B11.B21) = \underset{0 \leq x1 \leq B11/2}{Max} \{2x1+ 5\ Min(B11-2x1,B21/2)\}$

Since it is a two stage problem, at the first stage B11=43, b21=46

$F1(B11,B21) = f1(43,46)$

$= \underset{0 \leq x1 \leq 43/2}{Max} \{2x1+ 5\ Min(43-2x1, 46/2)\}$

$= \underset{0 \leq x1 \leq 43/2}{Max} \{2x1+ 5\ Min(43-2x1, 23)\} \rightarrow (3)$

From (3)

$F1(B11,B21) = Max\ \{2x1 + 5 \left(\begin{matrix} 23, if\ 0 \leq x1 \leq 10 \\ 43-2x1, if\ 10 \leq x1 \leq 43/2 \end{matrix}\right)\}$

$= Max\ \begin{cases} 2x1 + 115, if\ 0 \leq x1 \leq 10 \\ 215 - 8x1, if\ 10 \leq x1 \leq 43/2 \end{cases}$

Since Max of 2x1 +115, 0≤x1≤10 occurs at x1 = 10 and

Max of 215 -8x1, 10≤x1≤43/2 also occurs at x1 =10

F1(B11,B21) = 2(10) +115 = 135

Now

x2 = Min {B11-2x1,B21/2}

= Min {43-2x1,23}

= Min {23,23} = 23

The optimal solution is Max Z = 135, x1=10, x2=23 (5M)

13	**Solve the following LPP using dynamic programming approach:** **Max Z= $3x_1+5x_2$** **Subject to** **$x_1 \le 4$** **$x_2 \le 6$** **$3x_1+2x_2 \le 18$** **and x_1, $x_2 \ge 0$(10M) (BTL1) (Nov 2017)** Here we have two decision variables and three resources (constraints). Hence the problem has two stages and three state variables. Let (B_{1j}, B_{2j},B_{3j}) be the state of the system at stage j(j=1,2)and fi(B_{1j}, B_{2j},B_{3j}) be the optimal (maximum) value of the objective function for stage j=1,2 given the state (B_{1j}, B_{2j},B_{3j}) Using backward computational procedure, we have $f_2(B_{12},B_{22},B_{32})= 0\le x2\le B_{22}\{ 5_{x2}\}=5\ \ 0\le x2\le B_{22}\{x_2\}$ $0\le 2_{x2}\le B_{32}$ $\quad 0\le x_2\le \frac{B32}{2}$ Since Max{x_2} which satisfies$0\le x_2\le B_{12}$, $0\le x_2\le \frac{B22}{2}$ is the minimum of B_{12}, $\frac{B22}{2}$ i.e $\quad$ Max{x_2} = x_2* =Min={B_{22}, }----------------(1) $f_2(B_{12},B_{22},B_{32})$=5 Min{ B_{22}, $\frac{B32}{2}$ }-----------------------(2) Also $f_1(B_{11},B_{21},B_{31}) = 0\le 2x_1\le B_{11}\{3X_1+f2(B_{11}-x_1,B_{21}-0,B_{31}-3x_1)$ $0\le 3x_1\le B_{11}$ From (2) $f_2(B_{11}-x_1, B_{2i},B_{31}-3x_1)$ = 5 Min{B_{21}, $\frac{B31-3x1}{2}$ } $f_1(B_{11},B_{21},B_{31}) = 0\le x_1\le B_{11}$ {$3X_1$+5 Min $\left(B21, \frac{B31-3x}{2}\right)$} $0\le x_1\le \frac{B31}{3}$ Since it is a two stage problem, at the first stage B_{11} = 4, B_{21}=6, B_{31}= 18 $f_1(B_{11},B_{21},B_{31})$ Max = $0\le x_1\le 4$ {$3X_1$+5 Min$\left(6, \frac{18-3x1}{2}\right)$} $0\le x_1\le 6$ Max $0\le x_1\le 4$ {$3X_1$+5 Min$\left(6, \frac{18-3x1}{2}\right)$}--------------------(3) Now, Min (6, $\frac{18-3x1}{2}$) = 6, if $0\le x1\le 2$ $\frac{18-3x1}{2}$, if $2\le x1\le 4$ From (3) Max of $3x_1+30$, $0\le x_1\le 2$ occurs at x_1=2 Now x_2= Min {B_{21}, $\frac{B31-3x1}{2}$ Min {6, $\frac{18-3x1}{2}$ }=Min {6,6}=6 **The optimal solution is Max Z= 36, x_1=2, x_2=6**

14 **A student has to take examination in three courses A, B and C. He has three days available for study. He feels it would be best to devote a whole day to the study of the same course, so that he may study a course for one day, two days or three days or not at all. How should he plan to study so that he maximizes the sum of his grades? His estimates of grades he may get by study are as follows:(16M) (BTL3) (Nov 2016)**

Course/Study days	**A**	**B**	**C**
0	**0**	**1**	**0**
1	**1**	**1**	**1**
2	**1**	**3**	**3**
3	**3**	**4**	**3**

Solution:

Let n1, n2 and n3 be the number of days he should study the courses A, B and C respectively. If f1(n1), f2(n2), f3(n3) be the grades earned by such a study, then the problem becomes:

Max Z = f1(n1) + f2(n2) + f3(n3)

Subject to

n1 + n2 + n3 ≤ 3

n1, n2, n3 ≥ 0 and integers. (6M)

Here

nj are the decision variables and

fj(nj) are the corresponding return functions for j = 1, 2, 3.

Now, the state variables sj can be defined as follows:

s3 = n1 + n2 + n3 ≤ 3

s2 = n1 + n2 = s3 - n3

s1 = n1 = s2 - n2

Thus, state transformation functions are defined as

$s_{j-1} = T_j(s_j, n_j)$, j = 2, 3

The recursive equations applicable here are:

Fi(sj) = $\max_{nj}\{fj(nj) + Fj - 1(sj - 1)\}$, j = 2, 3

F1(s1) = f1(n1)

Where F3(s3) = $\max_{n1,n2,n3}\{f1(n1) + f2(n2) + f3(n3)\}$ for any feasible value of s3.

Then the required solution becomes

$\max_{s3} F3(s3)$

Recursive operations leading to the answer are tabulated as follows:

Stage returns fj(nj)

j \ nj	**0**	**1***	**2**	**3**
1	0	(1)	1	3
2	1	1	3	4
3	0	1	3	3

Stage transformation sj-1, j = 2, 3

j \ nj	**0**	**1**	**2**	**3**
0	0	_	_	_
1	1	0	_	_
2	2	1	0	_
3	3	2	1	0

Recursive operations

s2\n2	f2(n2)	F1(s1) = f1(n1)	f2(n2) + F1(s1)	F2(s2)
	0 1 2 3	0 1 2 3	0* 1 2 3	
0	1 _ _ _	0 _ _ _	1 _ _ _	1
1	(1) 1 _ _	1 0 _ _	2 1 _ _	(2)
2	1 1 3 _	1 1 0 _	2 2 3 _	3
3	1 1 3 4	3 1 1 0	4 2 4 4	4

s3\n3	f3(n3)	F2(s2) = f2(n2)	f3(n3) + F2(s2)	F3(s3)
	0 1 2 3	0 1 2 3	0 1 2* 3	
0	0 _ _ _	1 _ _ _	1 _ _ _	1
1	0 1 _ _	2 1 _ _	2 2 _ _	2
2	0 1 3 _	3 2 1 _	3 3 4 _	4
3	0 1 (3) 3	4 3 (2) 1	4 4 (5) 4	(5)

Proceeding backwards through enclosed type numbers, the optimal policy is obtained as n3 = 2, n2 = 0, n1 = 1 keeping in view n1 + n2 + n3 ≤ 3. The required maximum return is 5.(10M)

UNIT IV CLASSICAL OPTIMISATION THEORY

Unconstrained external problems, Newton – Ralphson method – Equality constraints – Jacobian methods – Lagrangian method – Kuhn – Tucker conditions – Simple problems.

UNIT-IV / PART-A

1 **What is nonlinear programming? (BTL1)**

Nonlinear programming is an extension of linear programming. In real life problems the objective function may be nonlinear but the set of constraints may be linear or nonlinear. Such problems are called as nonlinear problems. A set of nonlinear programming problems include:

- Nonlinear programming problems of general nature.
- Quadratic programming problems.
- Separable programming problems

2 **How do classical optimization problems determine points of maxima and minima? (BTL3)**

Classical optimization theory uses differential calculus to determine points of maxima and minima extrema) for unconstrained and constrained functions. The methods may not be suitable for efficient numerical computations, but the underlying theory provides the basis for most nonlinear programming algorithms.

3 **Examine $f(x) = 6x^5 - 4x^3 + 10$ for extreme points. (BTL3) (Nov 2016)**

The given equation is

$$f(x) = 6x^5 - 4x^3 + 10$$
$$f'(x) = 30x^4 - 12x^2$$

At an extremum $f'(x) = 0$

$$\Rightarrow 30x^4 - 12x^2 = 0$$
$$\Rightarrow 3x^2(10x^2 - 4) = 0$$
$$\Rightarrow x = 0 \text{ or } 10x^2 - 4 = 0$$
$$\Rightarrow x = 0 \text{ or } x = \pm\sqrt{\frac{2}{5}}$$

Therefore x = 0, x = 0.63 and x = -0.63 are the stationary values

$$f''(x) = 120x^3 - 24x$$
$$f''(0) = 0$$

$$f'''(x) = 360x^2 - 24$$
$$f'''(0) = -24 \neq 0$$

x = 0 is an inflection point

$x = 0.63$, $f''(0.63) = 120(0.63)^3 - 24(0.63) = 14.88 > 0$

f(x) attains its maximum at x = 0.63

$x = -0.63$, $f''(-0.63) = 120(-0.63)^3 - 24(-0.63) = -14.88 < 0$

f(x) attains its maximum at x=-0.63

4 **What is an unconstraint problem? (BTL2)**

An extreme point of a function f(X) defines either maximum or minimum of the function. Mathematically, a point $X_0 = (x_1^0, \ldots, x_j^0, \ldots, x_n^0)$ is a maximum if $f(X_0 + h) \leq f(X_0)$ for all $h = (h_1, \ldots, h_j, \ldots, h_n)$ and $|h_j|$ is sufficiently small for all j.

5	**What is the necessary condition for an n variable function to have extrema? (BTL1)** A necessary condition for X_0 to be an extreme point of f(x) is that $\nabla f(X_0) = 0$.

6	**What is the sufficient condition for a function to have extrema? (BTL1)** A sufficient condition for a stationary point X_0 to be an extremum is that Hessian matrix H evaluated at X_0 satisfy the following conditions: ❖ H is positive definite if X_0 is minimum point. ❖ H is negative definite if X_0 is maximum point.
7	**What are the various aspects of non-linear optimization? (BTL1)** ❖ Unconstrained extremum points. ❖ Constrained problems with equality constraints – Lagrangean method. ❖ Constrained problems with inequalities – Kuhn Tucker conditions. ❖ Quadratic programming.
8	**What is Newton-Ralphson method? (BTL1) (May 2018)** The Newton-Ralphson method is an iterative procedure for solving simultaneous nonlinear equations. It is part of gradient methods for optimizing unconstrained functions numerically.
9	**List the types of constrained problems. (BTL1)** There are 2 types of constrained problem ❖ Equality constraints ❖ Inequality constraints
10	**List the methods to solve equality constraints(BTL1)** Equality constraints present two methods. ❖ Jacobian method ❖ Lagrangian method The Lagrangian method can be developed logically from the Jacobian method. It provides an economic interpretation of Lagrangian method.
11	**What is the mathematical form of Lagrangian method? (BTL1)** The form for nonlinear programming: Maximize or minimize $Z = f(X_1, X_2, \ldots, X_j, \ldots, X_n)$ subject to $G_i(X_1, X_2, \ldots, X_j, \ldots, X_n) = b_i$, $i = 1, 2, \ldots, m$, $X_j \geq 0$, $j = 1, 2, \ldots, n$.
12	**Define Lagrangian method. (BTL1)** The Lagrangian method for identifying the stationary points of optimization problem with equality constraints are defined by the procedure which is developed formally as $L(X, \lambda) = f(X) - \lambda g(X)$. The function L is called the Lagrangian function and the parameters λ the Lagrange multipliers.
13	**Mention the steps involved in Lagrangian method. (BTL2)** Step 1: Form the Lagrangian function. Step 2: The first partial derivative of L with respect to X_j is obtained, where j varies from 1 to n, and also with respect to ϕ_i, where i varies from 1 to m. then equate them to 0. Step 3: Solution to equations in step 2 are found. Step 4: The bordered Hessian square matrix $[H^B]$ of size n + m is formed. Step 5: The stationary points $(X_1^*, X_2^*, \ldots, X_j^*, \ldots, X_n^*)$ are tested for maximization/minimization objective function.
14	**What is the condition to be checked for maximization type objective function? (BTL2)** The stationary point will be given the maximum objective function value if the sign of each of the last (n – m) principal minor determinants of the bordered Hessian matrix is the same as that of $(-1)^{m+1}$, ending with the (2m+1)th principal minor determinant.

15	**What is the condition to be checked for minimization type objective function? (BTL2)** The stationary point will be given the minimum objective function value if the sign of each of the last (n – m) principal minor determinants of the bordered Hessian matrix is the same as that of $(-1)^m$, ending with the (2m+1)th principal minor determinant.
16	**What is the mathematical form of constrained optimization problem with inequality constraints? (BTL2)** The inequality constraints can be converted into equations and use the Lagrangian method. The problem is of the form: Maximize Z = f(X) subject to g(X) ≤ 0, where $X = (x_1, x_2, \ldots, x_n)$ and $g = (g_1, g_2, \ldots, g_m)^T$. The functions f(X) and $g_i(X_i)$ are assumed to be twice differentiable.
17	**Define Jacobian matrix and control matrix. (BTL1) (May 2017)** The Jacobian matrix is the matrix of all first order partial derivatives of a vector valued function. When the matrix is a square matrix, both the matrix and its determinant are referred to as Jacobian matrix. J m x m is called the Jacobian matrix. The Jacobian J is assumed nonsingular. This is possible because m equations are independent by definition. If U and V are functions of two independent variables x and y then the following determinant becomes $\begin{vmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{vmatrix}$ is called Jacobian of u and v with respect to x and y, its denoted by $\frac{\partial(u,v)}{\partial(x,y)}$ or J
18	**Mention about sensitivity analysis in the Jacobian method. (BTL1)** The Jacobian method can be used to study the effect of small changes in the right hand side of the constraints on the optimal value of f. This type of investigation is called sensitivity analysis and is similar to what is carried out in linear programming.
19	**What is sensitive coefficient? (BTL1)** The effect of the small change ∂g on the optimum value of f can be studied by evaluating the rate of change of f with respect to g. These rates are usually referred to as sensitivity coefficients.
20	**Define Kuhn Tucker Conditions. (BTL1) (May 2018)** The Karush–Kuhn–Tucker (KKT) conditions (also known as the Kuhn–Tucker conditions) are first order necessary conditions for a solution in nonlinear programming to be optimal, provided that some regularity conditions are satisfied. Allowing inequality constraints, the KKT approach to nonlinear programming generalizes the method of Lagrange multipliers, which allows only equality constraints. The system of equations corresponding to the KKT conditions is usually not solved directly, except in the few special cases where a closed-form solution can be derived analytically. The form for nonlinear programming which is having a maximization objective function with all less than or equal to type constraints: Maximize $Z = f(X_1, X_2, \ldots, X_j, \ldots, X_n)$ subject to $G_i(X_1, X_2, \ldots, X_j, \ldots, X_n) \le b_i$, i = 1, 2, ….., m, $X_j \ge 0$, j = 1, 2, ….., n.

21	**What is the mathematical form of Kuhn Tucker conditions? (BTL1)** The form for nonlinear programming which is having a maximization objective function with all less than or equal to type constraints: Maximize $Z = f(X_1, X_2, \ldots, X_j, \ldots, X_n)$ subject to $G_i(X_1, X_2, \ldots, X_j, \ldots, X_n) \le b_i$, $i = 1, 2, \ldots, m$, $X_j \ge 0$, $j = 1, 2, \ldots, n$.
22	**Write down the Lagrangian function for Kuhn-Tucker method for following non-linear programming with inequality constraints. (BTL1) (Nov 2016)** The Lagrangian function for Kuhn-Tucker method for following non-linear programming with inequality constraints $L(X, S, \lambda) = f(X) - \lambda[h(X) + S^2]$ The necessary conditions are summarized as $\frac{\partial f}{\partial xj} - \lambda \frac{\partial h}{\partial xj} = 0, j = 1, 2, \ldots, n \rightarrow (1)$ $\lambda\, h(X) = 0 \rightarrow (2)$ $h(X) \le 0 \rightarrow (3)$ $\lambda \ge 0 \rightarrow (4)$
23	**Write down the necessary condition for general non linear programming problem by Lagrangean's multiplier method for equal constraints. (BTL1) (May 2017)** The Lagrangean multiplier method can be illustrated by the following simple two variable problem with one constraint, Maximize or minimize = $f(x_1,x_2)$ Subject to $g(x_1,x_2) \le b$ $x_1,x_2 \ge 0$
	UNIT-IV / PART-B
1	**Explain Classical optimization theory concept in detail.(10M) (BTL1)(Nov2017)** Classical optimization theory uses differential calculus to determine points of maxima and minima (extrema) for unconstrained and constrained functions. These methods may not be suitable for efficient numerical computations, but the underlying theory provides the basis for most non-linear programming algorithms. It develops necessary and sufficient conditions for determining unconstrained extrema, the Jacobian and Lagrangian methods for problems with equality constraints and the Kuhn-Tucker conditions for problems with inequality constraints. Theorem 1 A necessary condition for x_0 to be an extreme point of f(x) is that $\nabla f(x_0) = 0$ Proof by Taylor's theorem for $0 < \theta < 1$ $f(x_0 + h) - f(x_0) = \nabla f(x_0)h + \frac{1}{2} h^T H h \mid x_0 + \theta h$ where h is defined earlier. For sufficiently small $\mid h_j \mid$, the reminder term $\frac{1}{2} h^T H h$ is of the order h_j^2 hence, $f(x_0 + h) - f(x_0) = \nabla f(x_0)h + O(h_j^2) \approx \nabla f(x_0)$ It can be shown by contradiction that $\nabla f(x_0)$ must vanish at a minimum point x_0, otherwise if it does not, then for specific j the following condition will be held (5M) $\frac{\partial f(x0)}{\partial xj} < 0$ or $\frac{\partial f(x0)}{\partial xj} > 0$ By selecting h_j with appropriate sign it is always possible to have

	$h_j \dfrac{\partial f(x0)}{\partial xj} < 0$ Selecting all other h_j equal to zero, Taylor's expansion yields $f(x_0 + h) < f(x_0)$ The results contradicts the assumption that x is a minimum point. Consequently $\nabla f(x_0)$ must be equal to zero. The necessary condition is also satisfied for inflection and saddle points, the points obtained fron the solution of $\nabla f(x_0) = 0$. Theorem 2 A sufficient condition for a stationary point X_0 to be an extremum is that the Hessian matrix H evaluated at X_0 satisfy the following conditions. 1. H is positive definite if X_0 is a minimum point 2. H is negative definite if X_0 is a maximum point Proof by Taylor's theorem, for $0<\theta M<1$, $f(X_0+h)-f(X_0)=\nabla f(X_0)h+1/2h^THh \mid_{X0+\theta h}$ Given X_0 is a stationary point, then=$\nabla f(X_0)$ =0 (by theorem 1) thus, $f(X_0+h)-f(X_0)= \frac{1}{2}h^THh \mid_{X0+\theta h}$ if X_0 is a minimum point, then $f(X_0+h)>f(X_0), \quad h\neq 0$ Thus for X_0 to be minimum point it must be true that $\frac{1}{2}h^THh \mid_{X0+\theta h} >0$ Theorem 3 Given Y_0, a stationary point of f(Y), if the first (n-1) derivatives are zero and $f^{(n)}(Y_0) \neq 0$, then 1. Y_0 is an inflection point if n is odd 2. Y_0 is a minimum if n is even & $f^{(n)}(Y_0) >0$ Y_0 is a maximum if n is even & $f^{(n)}(Y_0)<0$ (5M)
2	**What is unconstrained external problem? Explain in detail. (BTL1)(10M)** Unconstrained External Problems There are two types: (i) Maxima and Minima for a function of one variable (ii) Maxima and Minima for a function of two variable Maxima and Minima for a function of one variable Let y=f(x) be a differentiable function in (a,b) we have studied in easier semesters that the necessary condition for y=f(x) to have an extremum is $\frac{dy}{dx}=f'(x)=0 \quad \rightarrow (1)$ Let $x_1,x_2,\ldots\ldots x_n$ be the roots of $f''(x)=0$ Then (i) f(x) is said to have a maximum at x1 if $f''(x_1)< 0$ (ii) f(x) is said to have a manimum at x1 if $f''(x_1)> 0$ (iii) It $f''(x_1)=0$ then x1 gives a point of inflection $(x_1,f(x_1))$ if $f'''(x_1)\neq 0$ Similar conclusions for the other roots $x_2,x_3,\ldots.x_4$ of (1) Facts: If x_0 is a stationary point of f(x) that is $f'(x_0)=0$ then if the first (n-1) derivatives are zero $f^{(n)}(x_0)\neq D$ then (5M) (a) If n is odd, x_0 gives an inflection point $(x_0,f(x_0))$

	(b) If n is even then x0 makes f(x0) a minimum if $f^{(n)}(x_0) >0$ and a maximum if $f^{(n)}(x_0) <0$ Maxima and Minima for a function of two variables Let Z=f(x,y), f(x,y) is said to have a relative maximum point (a,b) if f(a,b) >f(a+h, b+k) for small positive or negative values of h and k. Extremum is a point which is either maximum or minimum. The values of the function f at an extreme point are known as the extreme value of the function f. The minimum point is in the bottom point of the surface from which the surface ascends in every direction. In both these cases the tangent plane to the surface at maximum of minimum point is horizontal. Saddle point is a point where the function which is either maximum or minimum. The function at such a point is maximum in one direction and minimum in another direction. Such a surface looks like the leather seat on the back of a horse. (5M)
3	**Explain in detail about Newton-Ralphson method . (6M) (BTL1) (May 2018)** Newton Raphson method The necessary condition for y=f(x) to have an extremum is f′(x)=0. Solving this equation may be very difficult and we should be satisfied with a reasonably approximate value of the roots of the equation f′(x)=0. There are many numerical methods for solving f′(x)= 0. One standard method studied in earlier semesters in numerical method is Newton Raphson method. If x_0 is an initial approximation of a root of f′(x)=0 chosen properly in the vicinity of the root α of f′(x)=0, a≤ α ≤b. so as to ensure the convergence of the approximations then the Newton Raphson formula is given by $X_k+1=x_k-\frac{f(xk)}{f'(xk)}$, k=0,1,2 (4M) When the successive iterations x_k and x_k+1 are approximately equal within a specified degree of accuracy then the convergence occur. Newton Raphson may be used to determine the extreme value. (2M)
4	**By using the Newton-Raphson's method find the positive root of the quadratic equation 5x2 + 11x – 17 = 0 correct to 3 significant figures.(10M) (BTL1) (May 2018)** Solution $f(x)= 5x^2+11x-17$ f′(x)=10x+11 Choose x1=1 f(x1)=f(1)=5*(1)2+11*(1)-17=5+11-17=-1 f′(x1)=f′(1)=10*(1)+11=21 $x2=x1-\frac{f(x1)}{f'*(x1)}=1-\frac{f(1)}{f'(1)}=1-(-\frac{1}{21})=1+\frac{1}{21}=1.0476$ x2= 1.0476 (5M)

	$f(x2)=f(1.0476)=5*(1.0476)2+11*(1.0476)-17=0.1133$ $f'(x2)=f'(1.0476)=10*(1.0476)+11=10.476+11=21.476$ Checking it by the quadratic formula: x=-11± $x=\frac{-11\pm}{10}\ \sqrt{461}$ Use the + to get the positive root: x=1.0476 So we only need one iteration of the Newton-Raphson method to get it to three significant figures, for what we had then would have rounded to 1.05. (5M)
5	**What are Equality constraints?(6M) (BTL1)** The necessary and sufficient conditions for the problem in n variables and m equality type constraints for the optimization of the negative functions. A general problem with n variables and m equality constraints (n>m) can be expressed as Optimize Z= f(x) $x= (x_1,x_2,.....x_3)$ Subject to $g^i (x)= b_i$; i=1,2,3….m $x \geq 0$ It can be rewritten as $Hi(x)= g^i (x)-b_i=0$ ¥i The Lagrangian function becomes $L(x,\lambda)=f(x)-\sum_{i=1}^{m} \lambda_i h^i(x)$ The necessary conditions for the objective function to hare an optimum are (4M) $\frac{\partial L}{\partial Xj}=\frac{\partial f}{\partial Xj}-\quad i\frac{\partial hi}{\partial xj}=0$ $\frac{\partial L}{\partial \lambda i}=O-h^i$ and $-h^i=0$ where j= 1,2,3…., n i= 1,2,3…., m Assuming that L, f and h^i are differentiable partially with respect to $x_1,x_2,....x_n$ and λ_1, $\lambda_2,......\lambda_m$. (2M)
6	**Using Jacobian method Max Z = 2x1 + 3x2** **Subject to** **x1 + x2 + x3 = 5** **x1 + x2 + x4 = 3** **x1, x2, x3, x4 ≥ 0, (10M) (BTL1) (Nov 2016)** *Solution:* Make the following substitution:

	For each $x_j \geq 0$ substitute $x_j = \omega_j^2$ So, now we have Maximize $z = 2\omega_1^2 + 3\omega_2^2$ Subject to $\omega_1^2 + w_2^2 + w_3^2 = 5$ $\omega_1^2 - w_2^2 + w_4^2 = 3$ Now, let $Y = (\omega_2, w_4) \quad Z = (\omega_1, w_3)$ Now, we have $\nabla_c f = \nabla_z f - \nabla_y f J^{-1} C.$ where $J = \begin{pmatrix} \frac{\partial g_2}{\partial x_2} & \frac{\partial g_2}{\partial x_4} \\ \frac{\partial g_4}{\partial x_2} & \frac{\partial g_4}{\partial x_4} \end{pmatrix} \quad C = \begin{pmatrix} \frac{\partial g_1}{\partial x_1} & \frac{\partial g_1}{\partial x_3} \\ \frac{\partial g_3}{\partial x_1} & \frac{\partial g_3}{\partial x_3} \end{pmatrix}$ So, $\nabla_c f = (4w_1, 0) - (6w_2, 0)\begin{bmatrix} \frac{1}{2\omega_2} & 0 \\ \frac{1}{2w_4} & \frac{1}{2\omega_4} \end{bmatrix} \cdot \begin{bmatrix} 2\omega_1 & 2w_3 \\ 2\omega_1 & 0 \end{bmatrix} = (-2\omega_1, 6w_3)$ $\nabla_c f = 0$ So, we get $\omega_1 = 0$, $\omega_3 = 0$ (5M) Also, we know that $g(x_1) = 0$ and $g(x_2) = 0$ So, we have $\omega_2 = \sqrt{5}$ and $\omega_4 = \sqrt{3}$ Now, the Hessian matrix is $H_c = \begin{bmatrix} -2 & 0 \\ 0 & -6 \end{bmatrix}$ which implies a negative definite. So we have arrived at the required maximum point. So, the required maximum point is: $x_1 = 0$ $x_2 = 5$ (5M)
7	**Explain Lagrangian method with example. (10M)(BTL1) (Nov 2017)** The most common method of solving extremal problems having continuous differentiable objective function as well as constraint functions with respect to the decision variables is the Lagrangian multiplier method. Lagrangian multiplier method can be illustrated by the following simple two variable problems with one constraint.

Maximize or minimize $Z= f(x_1,x_2)$

Subject to $g(x_1,x_2) \le b$

$x_1, x_2 \ge 0$

Step 1:

The constraint is replaced another function $h(x_1,x_2)$such that $H(x_1,x_2)=g(x_1,x_2) - b=0$

The problem now becomes

Maximize or minimize $Z=f(x_1,x_2)$

Subject to $h(x_1,x_2)=0$

$x_1,x_2 \ge 0$ (5M)

Step 2:

The Lagrangian function L can be constructed as

$L(x_1,x_2,\lambda) = f(x_1,x_2)- \lambda h(x_1,x_2)$

Where λ is called the Lagrangian multiplier a constant. (5M)

8 **Use the Lagrangian method to maximize the function**

f (x; y) = xy

subject to the constraint

x + 2y ≤200 (10M) (BTL1)

Solution

$L=xy- \lambda(x+2y-200)$

$$\frac{\partial L}{\partial x} = y- \lambda(1) = 0 \quad \rightarrow(1)$$

$$\frac{\partial L}{\partial y} = x- \lambda(2) = 0 \quad \rightarrow(2)$$

$$\frac{\partial L}{\partial \lambda} = -(x+2y-200) = 0$$

$$x+2y = 200 \quad \rightarrow(3)$$

$$\lambda = y$$

$$2\lambda=x \Rightarrow \lambda=x/2$$

$$X=2y$$

$$x-2y = 0 \quad \rightarrow(4)$$

Solve 3 and 4

$$X=100$$

$$Y=50$$

Consider n-1= 2-1 =1 Principal mirror (5M)

Here f= xy

H= x+2y-200

So, $\Delta 3=\begin{bmatrix} 0 & 1 & 2 \\ 1 & 0 & 0 \\ 2 & 0 & 0 \end{bmatrix} = 0$ (5M)

9 **Solve the non-linear programming problem by Lagrangean multiplier method**

Minimize $z = x_1^2+3x_2^2+5x_3^2$

Subject to constraints

$x_1+x_2+3x_3=2$

$5x_1+2x_2+x_3=5$

$x_1,x_2,x_3 \geq 0$ (10M)

(May 2017) (BTL1)

Solution:

Let $f(X) = x_1^2+3x_2^2+5x_3^2$, $X= (x_1,x_2,x_3)$

$H'(X)= x_1+x_2+3x_3-2$

$H''(X)= 5x_1+2x_2+x_3-5$

$X1,x2,x3 \geq 0$

The Lagrangean function

$L(X,\lambda)= f(X)- \lambda1\ h'(X)- \lambda2h''(X)$

$L= x12+x22+x32- \lambda\ (x1+x2+3x3 -2) - \lambda2(5x1+2x2+x3-5)$

The stationary point (X^*, λ^*) is given by the following necessary conditions:

$\partial L/\partial x1= 2x1- \lambda1-5\ \lambda2=0$-----------------------(1)

$\partial L/\partial x2= 2x2- \lambda1-2\ \lambda2=0$------------------------(2)

$\partial L/\partial x3= 2x2-3\lambda1- \lambda2=0$ --------------------------(3)

$\partial L/\partial \lambda1= -(x1+x2+3x3-2)-0$-------------------------(4)

$\partial L/\partial \lambda2= -(5x1+2x2+x3-5)=0$ -----------------------(5)

from (1)

$x1= (\lambda1+5\ \lambda2)/2$--------------- (6)

from (2)

$x2= (\lambda1+2\ \lambda2)/2$--------------- (7)

from (3)

$x3= (3\lambda1+ \lambda2)/2$--------------- (8)

Using 7,8

$11\lambda+10\ \lambda2=4$ ------------- (9)

$11\ \lambda1+33\ \lambda2=11$--------------(10)

$\lambda2=7/23$

$\lambda1=2/23$

Using bordered hessian matrix n=3, m=2gives n-m=1; For minimization the sign $(-1)^m=(-1)^2$ (8M)

Is + so the solution is

Min = Z= 0.857, x1= 37/46; x2=8/23; x3=13/46 (2M)

10 **Explain Kuhn-Tucker conditions with example. (10M)(BTL1) (Nov 2017, May 2018)**

Maximization Problem:

Maximize Z=f(x)

Subject to

$g(x) \leq b$

$x \geq 0,\ x=(x_1,x_2,\ldots x_n)$ $\rightarrow$(A)

Let $h(x)=g(x)-b$ then $h(x) \leq 0$ from (A)

First the inequality constraint is changed to equality type by introducing a slack variable S in the form of S^2 to ensure the non-negativity.

Thus the constraint can be expressed as $h(x) + S^2 = 0$ then

$$\text{Max } Z=f(x)$$

Subject to

$$S^2=0$$

$$x \geq 0$$

We have now n+1 variables with single inequality constraint. Next construct the Lagrangian function.

$$L(X,S,\lambda)= f(X)-f(X)- \lambda[h(X)+S^2]$$

The necessary conditions for the stationary point are given by

$$\frac{\partial L}{\partial xj}=\frac{\partial f}{\partial xj}- \lambda\frac{\partial h}{\partial xj} =0 \qquad \rightarrow(1)$$

j= 1,2,3 ,…..n

$$\frac{\partial L}{\partial \lambda} = -[h(X) +S^2]=0 \qquad \rightarrow(2)$$

$$\frac{\partial L}{\partial S}= -2S\,\lambda = 0 \qquad \rightarrow(3)$$

From (3) we have

Either $S=0$ or $\lambda =0$

If S=0 then from (2) we have

$$h(X)=0$$

Therefore, either $\lambda =0$ or $h(x)=0$

$$\lambda h(X) =0 \qquad \rightarrow(4)$$

From (2) again we have

$$h(X)= -S^2 = -ve$$

Therefore, $h(X) \leq 0$ $\rightarrow(5)$

If $h(X) <0$ then $\lambda=0$ from (4)

If $\lambda >0$ then $h(X) = 0$

Thus the necessary condition are summarized as

$$\frac{\partial f}{\partial xj}- \lambda \frac{\partial h}{\partial xj} = 0 , j= 1, 2, 3….. n \qquad \rightarrow(I)$$

$$\lambda\, h(x) =0 \qquad \rightarrow(II)$$

$$h(x) \leq 0 \qquad \rightarrow(III)$$

$$\lambda \geq 0 \qquad \rightarrow(IV)$$

Minimization Problem:

Minimize

$$Z= f(x),\ x = (x_1,x_2,x_3……x_n)$$

Subject to

$$g(x) \geq b$$

$$x \geq 0$$

This can be rewritten as

Minimize

Z= f(x)

Subject to

$h(x)= g(x) -b \geq 0$

$x \geq 0$

Introducing slack variable in the form of S^2 we have the problem as

(5M)

Minimize

Z=f(x)

Subject to

$h(x)- S^2=0$

Following the analysis similar to the one used for maximization problem the Kuhn Tucker conditions become

$$\frac{\partial f}{\partial x j} - \lambda \frac{\partial h}{\partial x j} = 0 \text{ , j= 1, 2, 3….. n}$$

$\lambda\, h(X) = 0$

$h(X) \geq 0$

$\lambda \geq 0$

For a single constraint non-linear programming problem the Kuhn Tucker conditions are also sufficient conditions if

(i) f(X) is concave and h(X) is concave in the maximization problem and

Both f(X) and h(X) are concave in the minimization problem. (5M)

11 **Explain the Kuhn-Tucker conditions and solve them in the following Kuhn-Tucker problems(10M)(BTL1)(May 2018)**

a) Max $f(x,y)= xy$ subject to $x+4Y \leq 16$

b) Max $f(x,y)=x^2y$ subject to $2x^2+y^2 \leq 3$

c) Max $f(x,y,z)=xyz$ subject to $x^2 + y^2 \leq 1$ and $x + z \geq 1$.

Solution

a)

$f(x,y)=xy$

$H(x,y)=x+4y-16$

$y- \lambda(1)=0 \quad \rightarrow (1)$

$x- \lambda(4)=0 \quad \rightarrow (2)$

$\lambda(x+4y-16)=0 \quad \rightarrow (3)$

$x+4y-16 \leq 0 \quad \rightarrow (4)$

$\lambda \geq 0 \quad \rightarrow (5)$

By using (3) $\lambda=0$, $x+4y-16=0$

$\lambda=0$; x=0, y=0, which does not satisfy the condition (4)

(1) $\Rightarrow \lambda = y$; $4\lambda = x$

(4) $\Rightarrow 4\lambda + 4\lambda = 16$; $\lambda=2$; x=8; y=2 (5M)

b)

f(x,y) = x^2y

h(x,y) = $2x^2+y^2-3$

$2xy- \lambda(4x) = 0 \quad \rightarrow (1)$

$x^2- \lambda(2y) =0 \quad \rightarrow (2)$

$\lambda (2x^2+y^2-3)=0 \quad \rightarrow (3)$

$\lambda \geq 0$

$\lambda =1/2, x=\pm 1$

(1,1)(-1,1) (5M)

12 **Solve the non-linear programming problem by Kuhn-Tucker conditions.(10M) (BTL2) (Nov 2016)**

Minimize f(x) = $x1^2 + x2^2 + x3^2$

Subject to

g1(X) = 2x1 + x2 – 5 ≤ 0

g2(X) = x1 + x2 – 2 ≤ 0

g3(X) = 1 - x1 ≤ 0

g4(X) = 2 - x2 – 5 ≤ 0

g5(X) = – x3 ≤ 0

Solution:

The Kuhn-Tucker conditions are :

1. $(\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5) \leq 0$
2. $(2x_1, 2x_2, 2x_3) - (\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5)\begin{pmatrix} 2 & 1 & 0 \\ 1 & 0 & 1 \\ -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix} = 0$
3. $\lambda_i g_i = 0$ for i = 1 to 5
4. $g(X) \leq 0$

Also, g(X) ≤ 0 (5M)

Thus, we now have

$\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5 \leq 0$ from the first condition.

From the second condition, we have

$2x_1 - 2\lambda_1 - \lambda_2 + \lambda_3 = 0 \quad \rightarrow$ (i)

$2x_2 - \lambda_1 + \lambda_4 = 0 \quad \rightarrow$ (ii)

$2x_3 - \lambda_2 + \lambda_5 = 0 \quad \rightarrow$ (iii

From the third condition, we have

$\lambda_1(2x_1 + x_2 - 5) = 0 \quad \rightarrow$ (iv)

$\lambda_2(x_1 + x_3 - 2) = 0 \quad \rightarrow$ (v)

	$\lambda_3(1-x_1)=0$ → (vi) $\lambda_4(2-x_2)=0$ → (vii) $\lambda_5 x_3 = 0$ → (viii) From the fourth condition, we have $2x_1 + x_2 \le 5$ → (ix) $x_1 + x_3 \le 2$ → (x) $x_1 \ge 1, x_2 \ge 2, x_3 \ge 0$ → (xi) From (vi), (vii) and (viii), we get $x_1 = 1, x_2 = 2, x_3 = 0$ These values of x satisfy all the other conditions too. So now we determine the remaining values. From (iv), (v) and (viii) we have: $\lambda_1 = \lambda_2 = \lambda_5 = 0$ From (i) and (ii) we have: (5M) $\lambda_3 = -2, \lambda_4 = -4$ Thus, we have all the desired values now. Precisely, f minimizes at $x_1 = 1$, $x_2 = 2$ and $x_3 = 0$
13	**Maximize $f(x)=x_1^2+2x_2^2+10x_3^2+5x_1x_2$** **Subject to** **$g1(x)= x_1+x_2^2+3x_2x_3-5=0$** **$g2(x)= x_1^2+5x_1x_2+x_3^2-75=0$** **Apply Jacobian method to find Ə$f(x)$ in the feasible neighborhood of the feasible point (1,1,1). Assume that the feasible neighborhood is specified by Əg1= -0.1, Əg2=- 0.1. (4M)((BTL3) (May 2017)** If U and V are functions of two independent variables x and y then the following determinant becomes $\begin{vmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{vmatrix}$ is called Jacobian of u and v with respect to x and y, its denoted by $\frac{\partial(u,v)}{\partial(x,y)}$ or J (4M)

UNIT V OBJECT SCHEDULING

Network diagram representation – Critical path method – Time charts and resource leveling – PERT.

UNIT-V / PART-A

1 **What is network? (BTL1)**

A network is defined as a graphical representation of a project’s operation and is composed of all the events and activities in sequence along with their inter relationship and inter dependencies. Project networks can be used to plan, record, and document a schedule and to track actual results against the schedule.

2 **What is Event in a network diagram? (BTL1)**

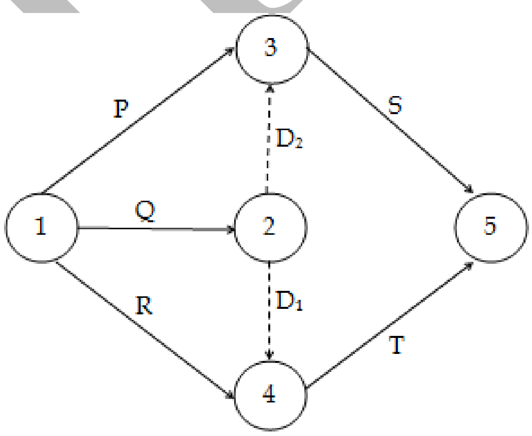
Each activity in the project network begins and ends with an event (a circle or a bubble). The events are numbered (the numbers do not necessarily imply sequence), and a given activity is identified by the numbers associated with its beginning and ending events.

3 **State the rules for network construction. (BTL1) (May 2017)**

The rules for network construction are:

i. Number the start node which has no predecessor activity as 1
ii. Delete all activities emanating from this node 1
iii. Number all resulting start nodes without any predecessor as 2,3…
iv. Delete all activities originating from the start nodes 2,3,…. In step 3.
v. Number all resulting new start nodes without any predecessor next to the last number used in step (3).
vi. Repeat all process until the terminal node without any successor activity is reached and number this terminal node suitably.

4 **If there are five activities P, Q, R, S and T such that P, Q, R have no immediate predecessors but S and T have immediate predecessors P, Q and Q, R respectively. Represent this situation by a network. (BTL1) (Nov 2016)**

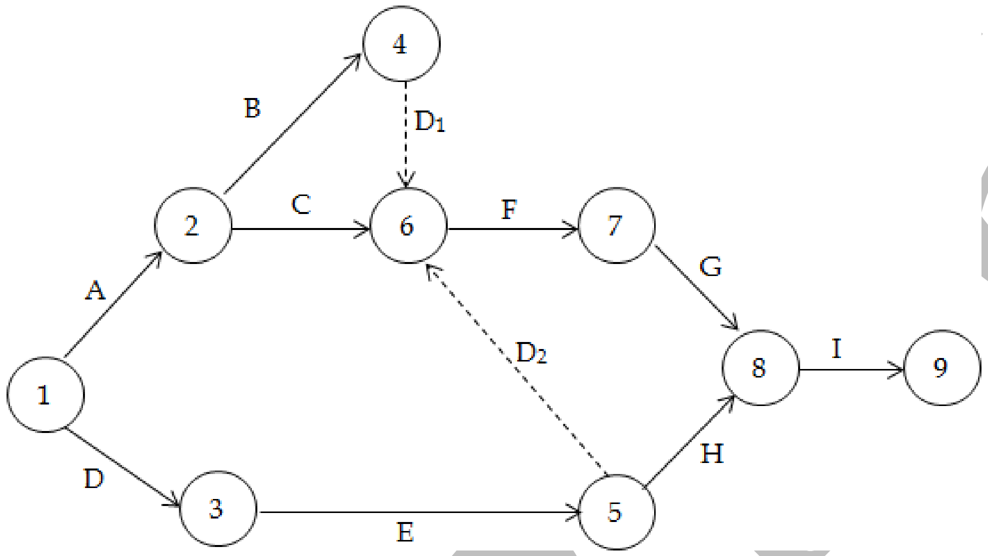


D_1 and D_2 are dummy activities.

5	**Draw the network for the project whose activities and their precedence relationship are as given below: (BTL3)**

Activities	A	B	C	D	E	F	G	H	I
Precedence	-	A	A	-	D	B,C,E	F	E	G,H

Start activities A,D terminal activities I only. Activities B and C starting with same node both the predecessors of the activity F, also the activity E has to be the predecessor of both F and H. Therefore dummy activities are necessary.



D_1 and D_2 are dummy activities.

6	**What are the three main phases of project? (BTL1)** Planning – This phase involves a listing of tasks or jobs that must be performed to complete a project under considerations. Scheduling – This phase involves the laying out of the actual activities of the projects in a logical sequence of time in which they have to be performed. Control – This phase consists of reviewing the progress of the project whether the actual performance is according to the planned schedule and finding the reasons for difference, if any, between the schedule and performance.
7	**What are the two basic planning and controlling techniques in a network analysis? (BTL1)** Critical Path Method (CPM) - This is the unit cost that is only for your reference when comparing one plan to another. Programme Evaluation and Review Technique (PERT) – It takes into account the uncertainty project durations into account.
8	**What is CPM? (BTL1) (Nov 2017)** A project is defined by a **set of activities**. Each activity is defined by its **duration** (time to complete the activity) and its **predecessors.** CPM (Critical Path Method) is used to assist the project manager in scheduling the activities (i.e., when should each activity start). It assumes that activity durations are known with certainty.

9	**Write about PERT. (BTL1) (Nov 2017)** PERT (Program Evaluation and Review Technique) is used to assist in project scheduling similar to CPM. However, PERT assumes that activity durations are random variables (i.e., probabilistic). An event oriented network, Probabilistic nature, it uses three time estimation (i.e optimistic, pessimistic and most likely time).

10	**Define activity & Critical Activities? (BTL1)** An activity is a task or an item of work to be done in a project. It is the element of the project and it may be a process, material handling, procurement cycle etc. In a Network diagram all the activities in any critical path are called critical activities.
11	**Define non critical activities? (BTL1)** Activities which have a provision such that the event if they consume a specified time over and above the estimated time the project will not be delayed are termed as non-critical activities.
12	**Define Dummy Activities & duration? (BTL1)** Dummy activities - When two activities start at a same time, the head event are joined by a dotted arrow known as dummy activity which may be critical or non-critical. Duration - It is the estimated or the actual time required to complete a trade or an activity.
13	**Define total project time & Critical path? (BTL1) (Nov 2016)** Total project time is the time taken to complete a project and just found from the sequence of critical activities. In other words it is the duration of the critical path. Path connecting the first initial node to the very last terminal node of longest duration in any project network is called critical path. It is the sequence of activities which decides the total project duration. It is formed by critical activities and consumes maximum resources and time.
14	**Define Optimistic? (BTL1)** Optimistic time estimate or least time estimate (t_o or a) is the duration of any activity when everything goes on very well during the project. i.e labours are available and come in time, machines are working properly, money is available whenever needed, there is no scarcity of raw material needed etc.,
15	**Define Pessimistic time estimate in PERT. (BTL1) (May 2018)** Pessimistic time estimate or greatest time estimate is denoted by t_p or b is the duration of any activity when almost everything goes against our will and a lot of difficulties are faced while doing a project.
16	**Define most likely time estimation? (BTL1)** Most likely time estimate is the duration of any activity when sometimes thing go on very well, sometimes things go on very bad while doing the project. Two assumptions are, (i) the activity durations are independent. It follows the β – distribution.
17	**What is a parallel critical path? (BTL1)** When critical activities are crashed and the duration is reduced other paths may also become critical such critical paths are called as parallel critical path. When there is more than one critical path in a network, project duration can be reduced only when the duration of critical activity is reduced or the duration of different activities on different critical paths are reduced
18	**What is standard deviation and variance in PERT network? (BTL1)** The expected time of an activity in actual execution is not completely reliable and is likely to vary. If the variability is known we can measure the reliability of the expected time as determined from three estimates. The measure of the variability of possible activity time is given by standard deviation, their probability distribution. Variance of the activity is the square of the standard deviation

19	**What is meant by resource analysis? (BTL1)** Resources are required to carry out the project tasks. They can be equipment, facilities, funding which are required for the completion of a project activity. The lack of resource will therefore be a constraint on the completion of a project activity. Resource scheduling, availability and optimization are considered key to successful project management.
20	**What are the three time estimates used in the context of PERT? How are the expected duration of an activity and its standard deviation calculated? (BTL1)** Optimistic time estimate or least time estimate (t_o or a) Pessimistic time estimate or greatest time estimate (t_p or b) Most likely time estimate (t_m or b) Expected Duration = $(t_e+4t_m+t_p)/6$ Standard deviation = $(t_p-t_o)/6$
21	**Explain the term: Resource smoothing. (BTL2)** Resource smoothing means the uniform distribution of resource allocate on over the project. That is scheduling of activities, within the limits of their float, so that fluctuations in individual resource requirements are minimized.
22	**Define a dummy arrow used in a network and state two purposes for which it is used. (BTL3)** Dummy activity is a hypothetical activity which requires zero time and zero resources for completion. Dummy arrow represents an activity with zero duration. It is represented by dotted line and is inserted in the network to clarify activity pattern under the following situations: i. It is created to make activities with common starting and finishing events distinguishable, and ii. To identify and maintain the proper precedence relationship between activities those are not connected by events.
23	**What are the advantages of CPM and PERT techniques? (BTL1)** It encourages a logical discipline in planning, scheduling and control of projects. It helps to effect considerable reduction of project times and the cost. It helps better utilization of resources like men, machines, materials and money with reference to time. It measures the effect of delays on the project and procedural changes on the overall schedule.
24	**Differentiate between PERT and CPM? (BTL2) (May 2018)** **CPM-**Network is built on the basis of activity, Deterministic nature, one time estimation **PERT-** An event oriented network, Probabilistic nature, three time estimation (i.e optimistic, pessimistic and most likely time).
25	**Mention some advantages of PERT. (BTL1)** ❖ It compels managers to plan their projects critically and analyse all factors affecting the progress of the plan. The process of the network analysis requires that the project planning be conducted on considerable detail from the start to the finish. ❖ It provides the management a tool for forecasting the impact of schedule changes and be prepared to correct such situations. The likely trouble spots are located early enough so as to apply some preventive measures or corrective actions. ❖ A lot of data can be presented in a highly ordered fashion. The task relationships are graphically represented for easier evaluation and individuals in different locations can easily determine their role in the total task requirements. ❖ The PERT time (Te) is based upon 3-way estimate and hence is the most objective time in the light of uncertainties and results in greater degree of accuracy in time forecasting.

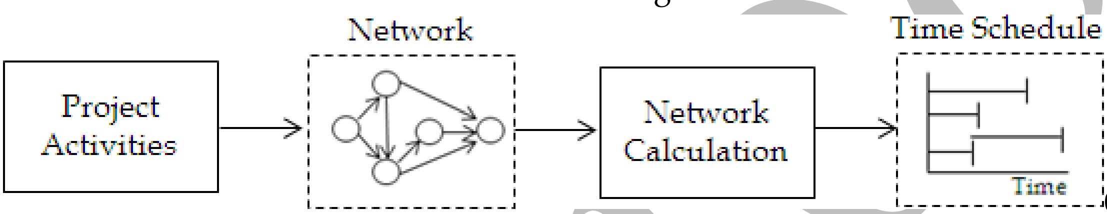
UNIT-V / PART-B

1 **Explain the following: Critical Path Method, PERT**

Explain the difference between PERT and CPM.(10M) (BTL1) (Nov 2017)

CPM and PERT are network based methods designed to assist in the planning, scheduling and control of projects. A project is defined as a collection of interrelated activities, with each activity consuming time and resources. The objective of CPM and PERT is to provide analytic means for scheduling the activities. It defines the activities of the project, their precedence relationships and their time requirements. Next the project is translated into a network. It shows the precedence relationships among the activities. The third step involves specific network computations that form the basis for the development of the time schedule for the project. (4M)

During the execution of the project the schedule may not be realized as planned, causing some of the activities to be expedited or delayed. In this case, it will be necessary to update the schedule to reflect the realities on the ground.



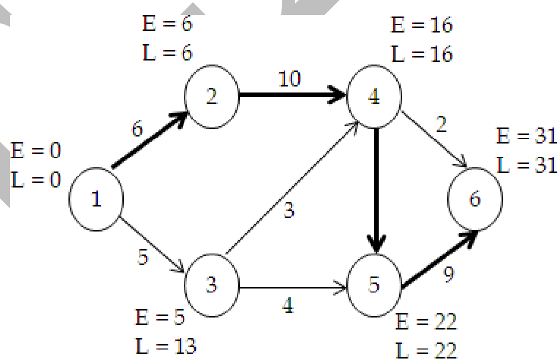
(4M)

The two techniques CPM and PERT which were developed independently, differ in that CPM assumes deterministic activity durations, whereas PERT assumes probabilistic durations. (2M)

2 **Draw the network and determine the critical path and also calculate the floats: (BTL1)**

Jobs	**1-2**	**1-3**	**2-4**	**3-4**	**3-5**	**4-5**	**4-6**	**5-6**
Duration (Days)	**6**	**5**	**10**	**3**	**4**	**6**	**2**	**9**

Solution(16M)



Jobs	Duration (days)	EST	EFT	LST	LFT	TF	FF	IF
1-2	6	0	6	0	6	0	0	0
1-3	5	0	5	8	13	8	0	0
2-4	10	6	16	6	16	0	0	0
3-4	3	5	8	13	16	8	8	0
3-5	4	5	9	18	22	13	13	5
4-5	6	16	22	16	22	0	0	0
4-6	2	16	18	29	31	13	13	13
5-6	9	22	31	22	31	0	0	0

Critical path calculation → 1 – 2 – 4 – 5 – 6

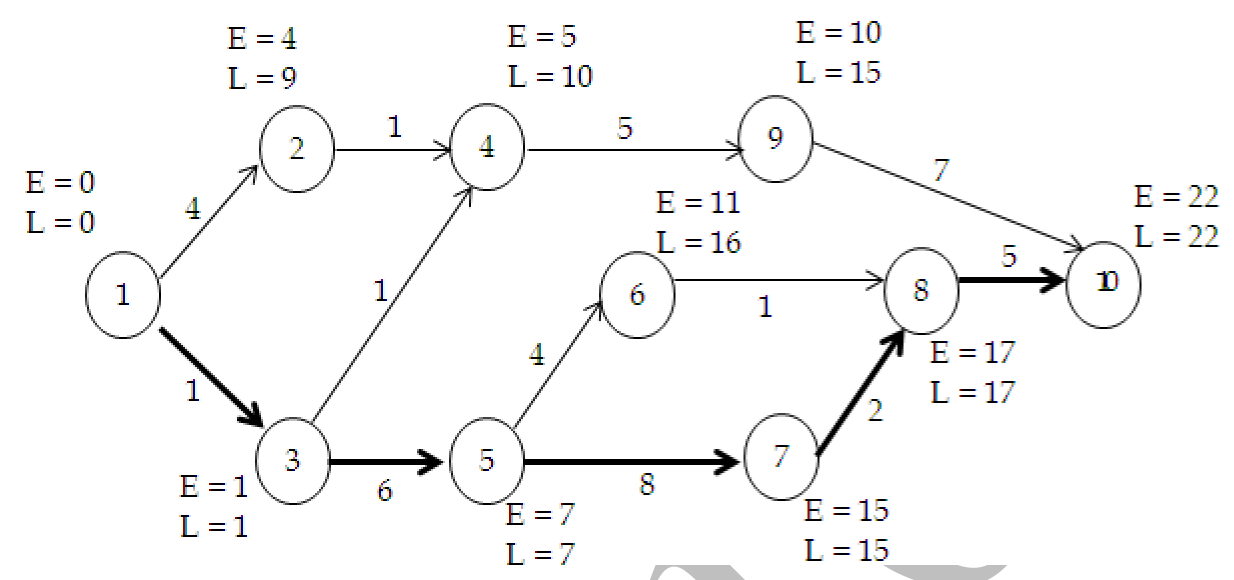
= 6 + 10 + 6 + 9

= 31 days

3 **Construct PERT networks and find the critical path and find all floats. (16M)(BTL1)**

Activity	**1-2**	**1-3**	**2-4**	**3-4**	**3-5**	**4-9**	**5-6**	**5-7**	**6-8**	**7-8**	**8-10**	**9-10**
Time	**4**	**1**	**1**	**1**	**6**	**5**	**4**	**8**	**1**	**2**	**5**	**7**

Solution:



Activity	Time	EST	EFT	LST	LFT	TF	FF	IF
1-2	4	0	4	5	9	5	0	0
1-3	1	0	1	0	1	0	0	0
2-4	1	4	5	9	10	5	0	5
3-4	1	1	2	9	10	8	3	3
3-5	6	1	7	1	7	0	0	0
4-9	5	5	10	10	15	5	0	5
5-6	4	7	11	12	16	5	0	0
5-7	8	7	15	7	15	0	0	0
6-8	1	11	12	16	17	5	5	0
7-8	2	15	17	15	17	0	0	0
8-10	5	17	22	17	22	0	0	0
9-10	7	10	17	17	22	7	7	2

Critical Path → 1 – 3 – 5 – 7 – 8 – 10

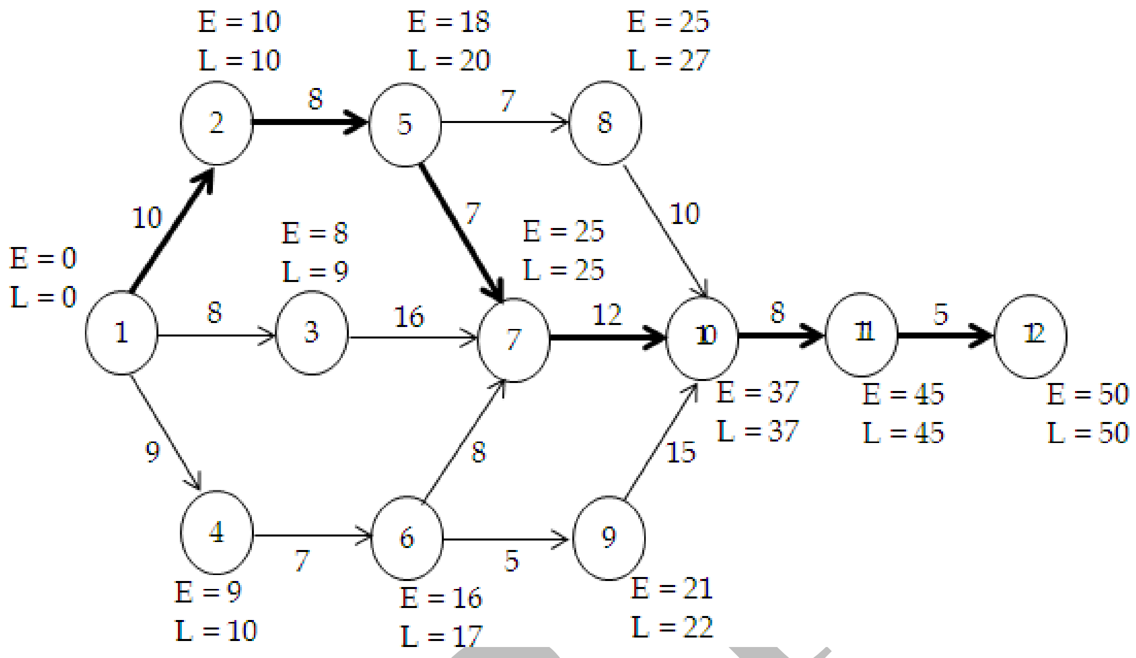
= 1 + 6 + 8 + 8 + 5

= 22

4 **The following table shows the jobs of a project with their duration in days. Draw the network and determine the critical path. Also calculate all the floats. (16M)(BTL1)**

Jobs	**1-2**	**1-3**	**1-4**	**2-5**	**3-7**	**4-6**	**5-7**	**5-8**	**6-7**	**6-9**	**7-10**	**8-10**	**9-10**	**10-11**	**11-12**
Duration	**10**	**8**	**9**	**8**	**16**	**7**	**7**	**7**	**8**	**5**	**12**	**10**	**15**	**8**	**5**

Solution:



Jobs	Duration	EST	EFT	LST	LFT	TF	FF	IF
1-2	10	0	10	0	10	0	0	0
1-3	8	0	8	1	9	1	0	1
1-4	9	0	9	1	10	1	0	1
2-5	8	10	18	12	20	2	0	2
3-7	16	8	24	9	25	1	1	1
4-6	7	9	16	10	17	1	0	1
5-7	7	18	25	18	25	0	0	0
5-8	7	18	25	20	27	2	0	2
6-7	8	16	24	17	25	1	1	1
6-9	5	16	21	17	22	1	0	1
7-10	12	25	37	15	37	10	10	10
8-10	10	25	35	27	37	2	2	2
9-10	15	21	36	12	37	9	9	9
10-11	8	37	45	37	45	0	0	0
11-12	5	45	50	45	50	0	0	0

Critical Path → 1 – 2 – 5 – 7 – 10 – 11 – 12

= 10 + 8 + 7 + 12 + 8 + 5

= 50

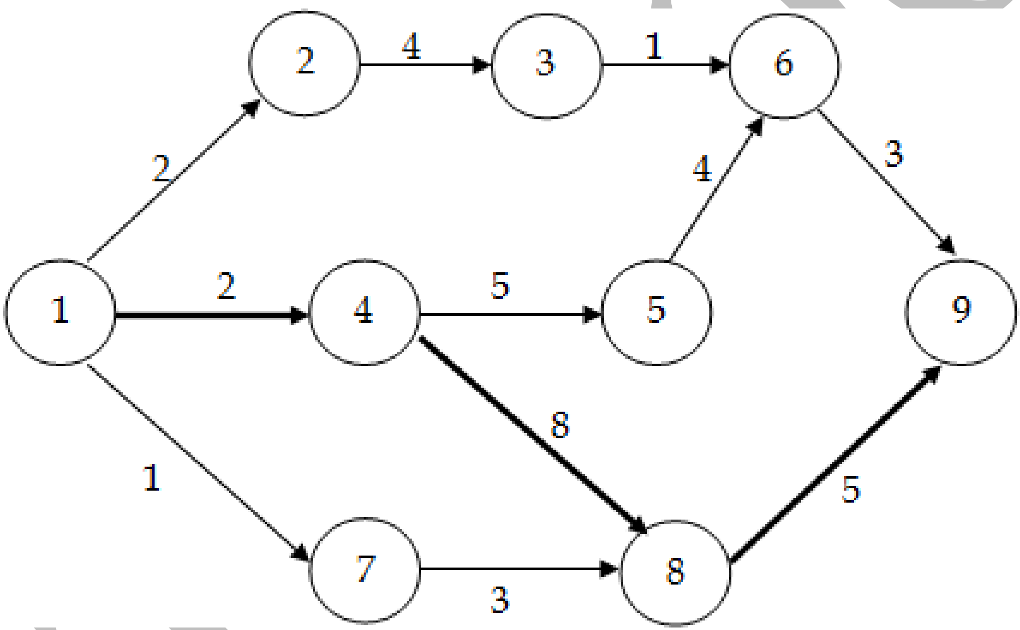
5 **A project schedule has the following characteristics**

(a) Construct a PERT network and find the critical path and the project duration.

(b) Activities 2-3, 4-5, 6-9 each requires one unit of the same key equipment to complete it. Do you think availability of one unit of the equipment in the organization is sufficient for completing the project without delaying it; if so sufficient of these activities? (16M) (BTL1) (May 2017)

Activity	**1-2**	**1-4**	**1-7**	**2-3**	**3-6**	**4-5**	**4-8**	**5-6**	**6-9**	**7-8**	**8-9**
Duration	**2**	**2**	**1**	**4**	**1**	**5**	**8**	**4**	**3**	**3**	**5**

Solution:



Critical Path:

1-4-8-9

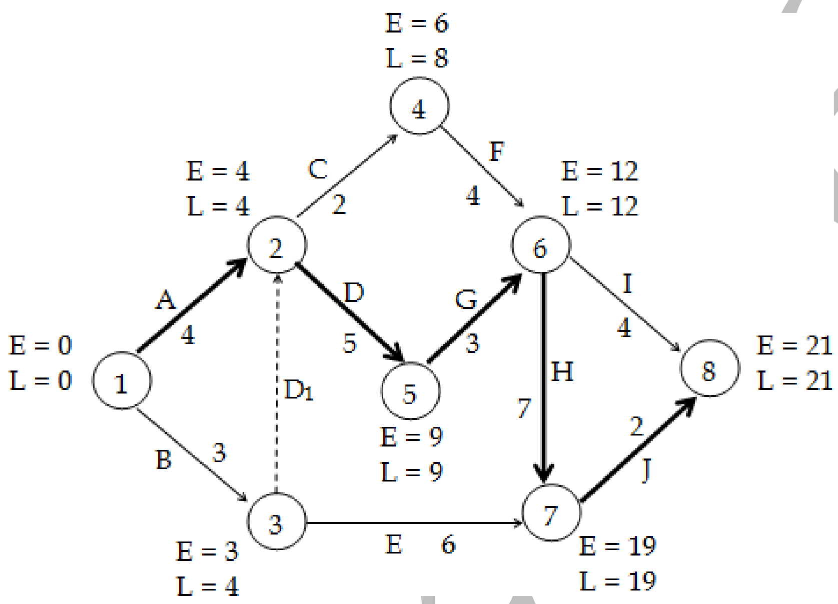
Project duration: 15 time units.

6

A project consists of activities from A to J as shown in the following table. The immediate predecessor(s) and the duration in weeks of each of the activities are given in the same table. Draw the project network and find the critical path and the corresponding project completion time. Also find the total float as well as free float for each of the non-critical activities. (16M)(BTL1) (Nov 2016)

Activity	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Immediate Predecessor(s)	**-**	**-**	**A,B**	**A,B**	**B**	**C**	**D**	**F,G**	**F,G**	**E,H**
Duration (weeks)	**4**	**3**	**2**	**5**	**6**	**4**	**3**	**7**	**4**	**2**

Solution: The project network is as follows:



The critical path is

1 – 2 – 5 – 6 – 7 – 8

The corresponding project completion time

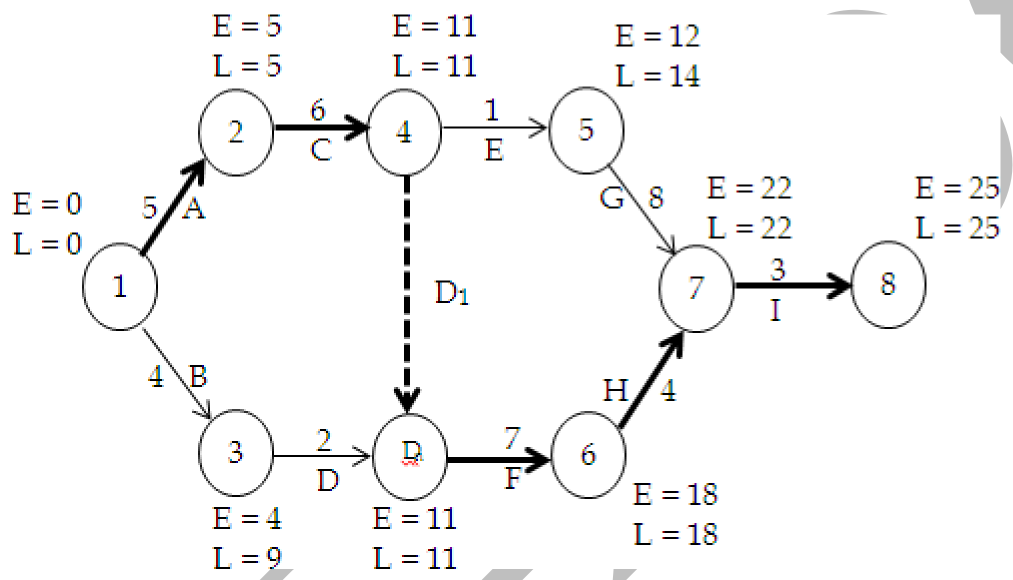
= 21 weeks

Activity (i-j)	Duration (weeks)	Earliest Start ES	Earliest Finish $EF=ES+t_{ij}$	Latest Start $LS=LF-t_{ij}$	Latest Finish LF	Total float TF=LF-EF	Free float FF=TF-slack of head j
1-2 (A)	4	0	4	0	4	0	0
1-3 (B)	**3**	**0**	**3**	**1**	**4**	**1**	**0**
2-4 (C)	**2**	**4**	**6**	**6**	**8**	**2**	**0**
2-5 (D)	5	4	9	4	9	0	0
3-7 (E)	**6**	**3**	**9**	**13**	**19**	**10**	**10**
4-6 (F)	**4**	**6**	**10**	**8**	**12**	**2**	**2**
5-6 (G)	3	9	12	9	12	0	0
6-7 (H)	7	12	19	12	19	0	0
6-8 (I)	**4**	**12**	**16**	**17**	**21**	**5**	**5**
7-8 (J)	2	19	21	19	21	0	0

7 **Draw the network for the following project and compute the earliest and latest times for each event and also find the critical path.(12M) (BTL1)**

Activity	Immediate predecessor	Time (days)
1-2	**-**	**5**
1-3	**-**	**4**
2-4	**1-2**	**6**
3-4	**1-3**	**2**
4-5	**2-4**	**1**
4-6	**2-4 & 3-4**	**7**
5-7	**4-5**	**8**
6-7	**4-6**	**4**
7-8	**6-7&5-7**	**3**

Solution:



Activity	Duration	Earliest		Latest	
		Start	Finish	Start	Finish
1-2	5	0	5	0	5
1-3	4	0	4	5	9
2-4	6	5	11	5	11
3-4	2	4	6	9	11
4-5	1	11	12	13	14
4-6	7	11	18	11	18
5-7	8	12	20	14	22
6-7	4	18	22	18	22
7-8	3	22	25	22	25

Critical path → 1 – 2 – 4 – D_n – 6 – 7 – 8

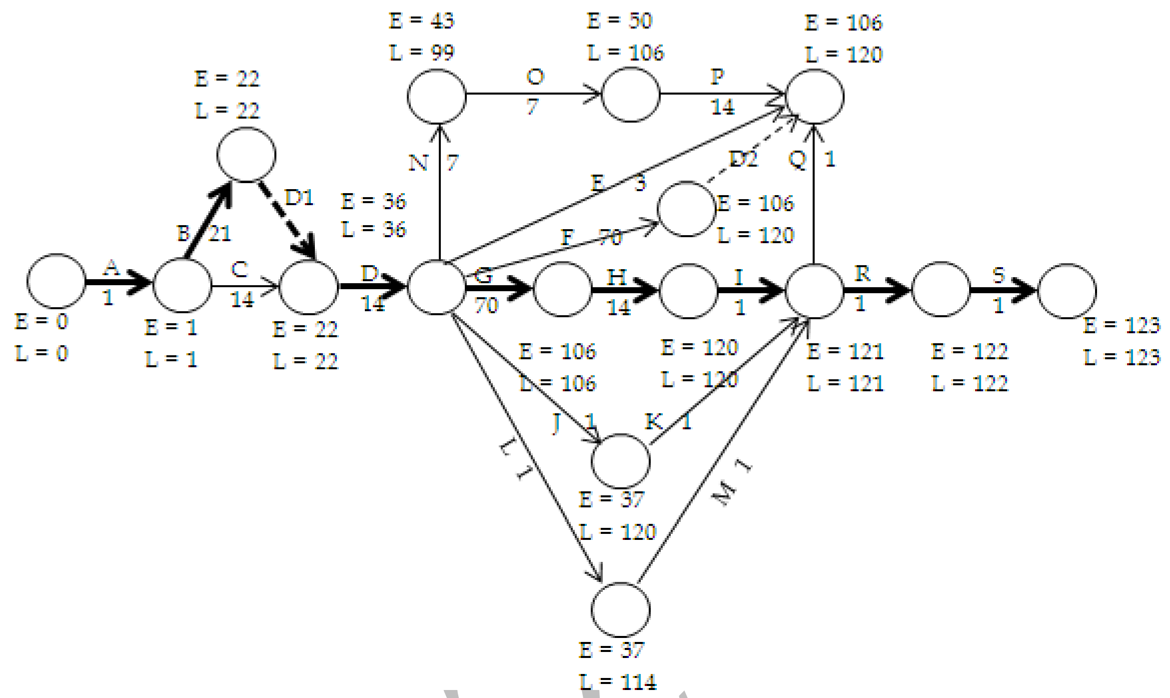
= 5 + 6 + 0 + 7+ 4 + 3

= 25 days

8 **Draw the network model of the problem and carry out the critical path computations. (BTL1)(16M)**

Immediate Predecessor	**A**	**A**	**B,C**	**D**	**D**	**D**	**G**	**H**	**D**
Duration (days)	**21**	**14**	**14**	**3**	**70**	**70**	**14**	**1**	**1**
Immediate Predecessor	**J**	**D**	**L**	**D**	**N**	**O**	**E,F,P**	**Q,I,K**	**M,R**
Duration (days)	**1**	**1**	**7**	**7**	**7**	**14**	**1**	**1**	**1**

Solution



Activity	Duration	Earliest		Latest	
		Start	Finish	Start	Finish
A	1	0	1	0	1
B	21	1	22	1	22
C	14	1	15	8	22
D	14	22	36	22	36
E	3	36	39	117	120
F	70	36	106	50	120
G	70	36	106	36	106
H	14	106	120	106	120
I	1	120	121	120	121
J	1	36	37	119	120
K	1	37	38	120	121
L	1	36	37	113	114
M	7	37	44	114	121
N	7	36	43	92	99
O	7	43	50	99	106
P	14	50	64	106	120
Q	1	121	122	119	120
R	1	121	122	121	122
S	1	122	123	122	123

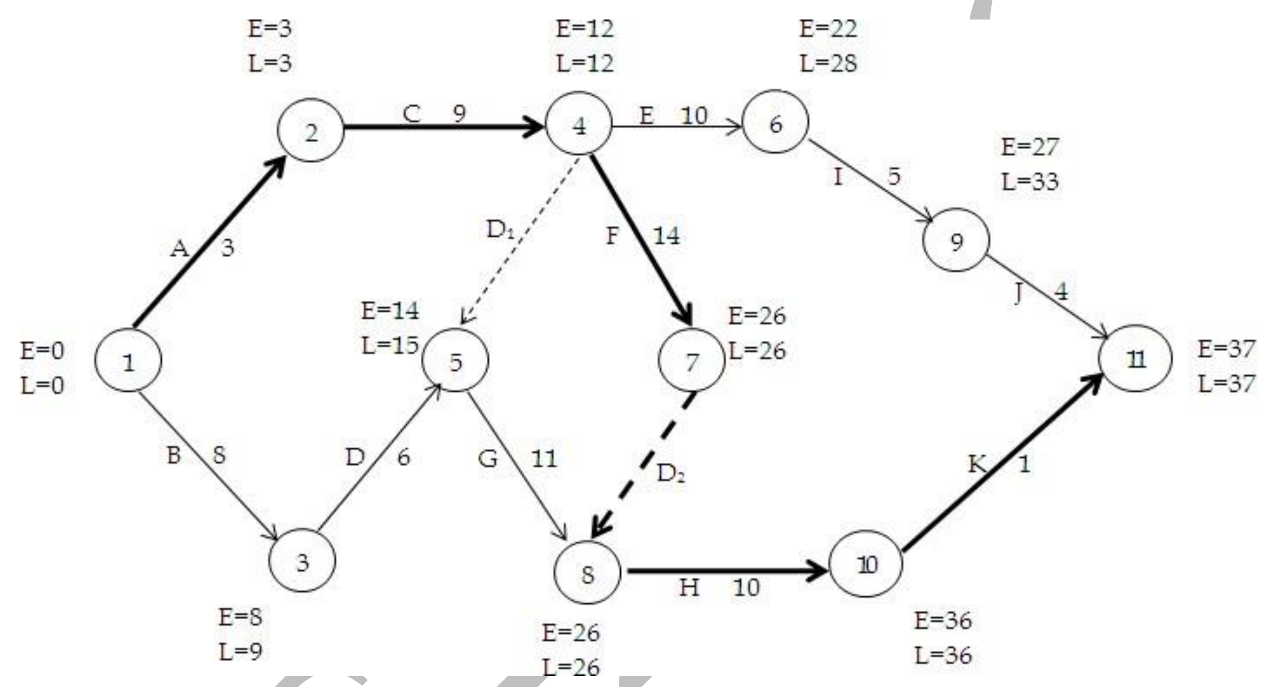
Critical Path → A – B – D1 – D – G – H – I – R – S

= 1 + 21 + 0 + 14 + 70 + 14 + 1 + 1 + 1 = 123 Days

9 **Draw the network from the following activity and find the critical path and total duration of project. (12M)(BTL1) (May 2018)**

Activity	A	B	C	D	E	F	G	H	I	J	K
Immediate Predecessor	-	-	A	B	C	C	C,D	F,G	E	I	H
Duration (weeks)	3	8	9	6	10	14	11	10	5	4	1

Solution:



Critical Path : A – C – F – D_2 – H – K

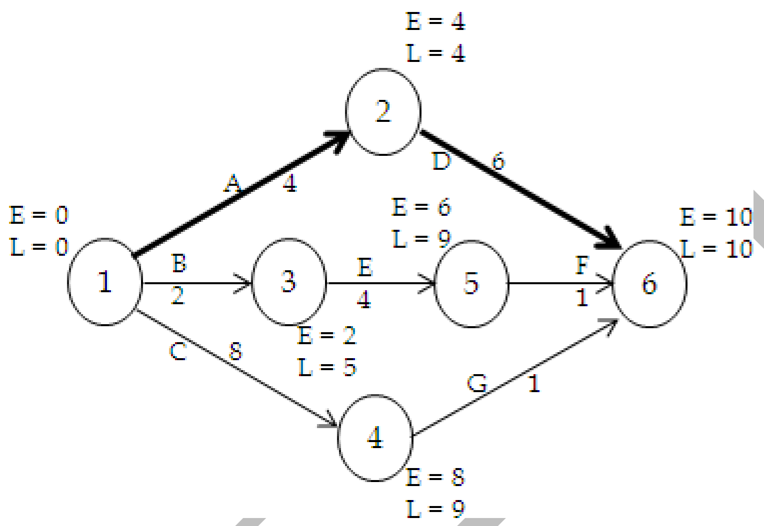
Total duration of the project = 3 + 9 + 14 + 10 + 1 = 37 weeks.

10 **The following information is available. Find the following:**

a) **Draw the network and find the critical path.**
b) **What is the peak requirement of Manpower? On which day(s) will this occur?**
c) **If the minimum labour available on any day is only 10, when can the project be completed. (BTL1)(12M)**

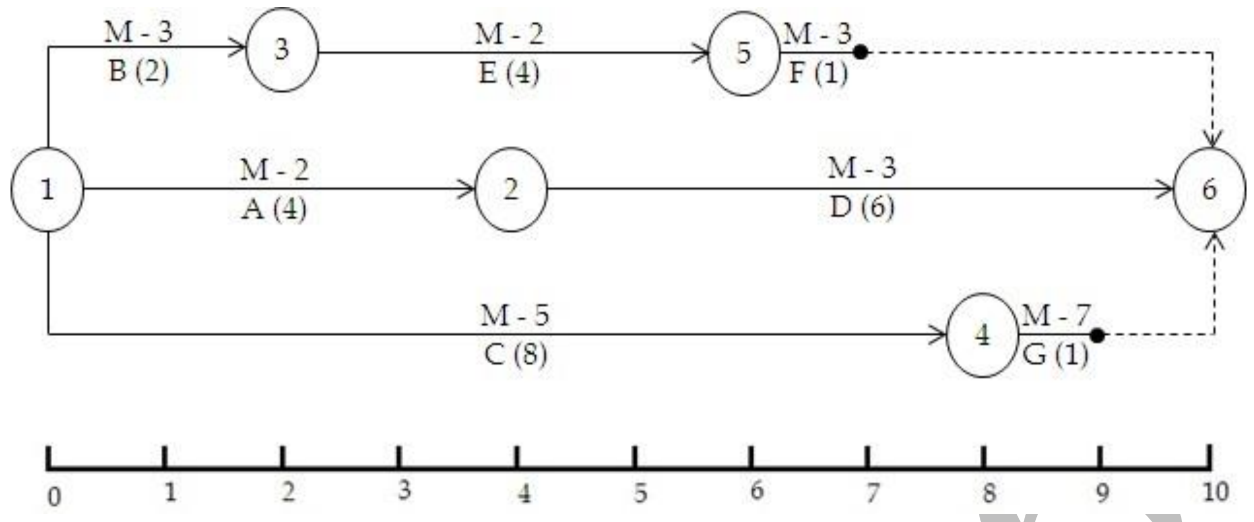
Activity	Number of Days	Number of men required per day
A 1-2	**4**	**2**
B 1-3	**2**	**3**
C 1-4	**8**	**5**
D 2-6	**6**	**3**
E 3-5	**4**	**2**
F 5-6	**1**	**3**
G 4-6	**1**	**8**

Solution



Critical Path → A – D
= 4 + 6
= 10 Days

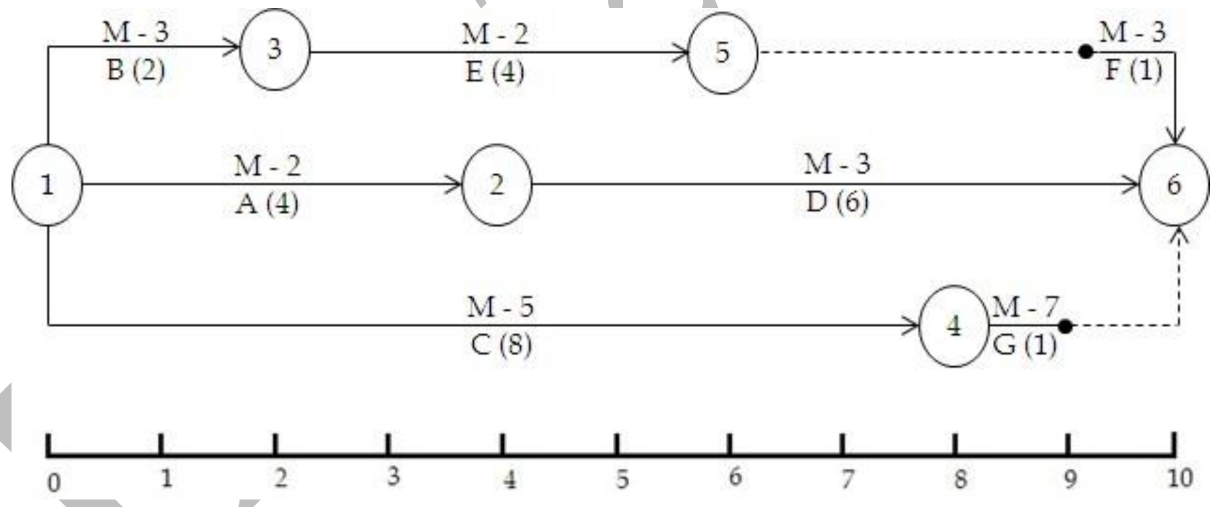
Activity	Duration	EST	EFT	LST	LFT	TF	FF	IF
A 1-2	4	0	4	0	4	0	0	0
B 1-3	2	0	2	3	5	3	0	0
C 1-4	8	0	8	1	9	1	0	0
D 2-6	6	4	10	4	10	0	0	0
E 3-5	4	2	6	5	9	3	0	0
F 5-6	1	6	7	9	10	3	3	0
G 4-6	1	8	9	9	10	1	1	0



M – Number of Men

Day	1	2	3	4	5	6	7	8	9	10
Men Required	10	10	9	9	10	10	11	8	10	3
Men Available	10	10	10	10	10	10	10	10	10	10
(Shortage) / Excess	0	0	1	1	0	0	-1	2	0	7

From the above time scale diagram the peak requirement is 11 men and the same is required on the 7th day.



M – Number of Men

As only 10 men are available on any day, we have to shift Activity F to 10th day. Now the project can be completed in 10 days.

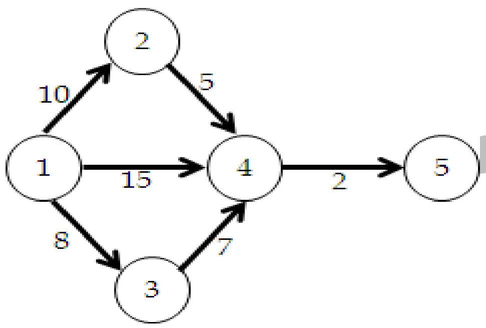
Day	1	2	3	4	5	6	7	8	9	10
Men Required	10	10	9	9	10	10	8	8	10	6
Men Available	10	10	10	10	10	10	10	10	10	10
(Shortage) / Excess	0	0	1	1	0	0	2	2	0	4

11 **A small project consists of jobs as given in the table below. Each job is listed with its normal time and a minimum or crash time (in days). The cost (in Rs. per day) for each job is also given**

a) **What is the normal project length and the minimum project length?**
b) **Determine the minimum crashing cost of schedules ranging from normal length down to, and including, the minimum length schedule. That is, if L = Length of the schedule, find the costs of schedules which are L, L-1, L-2 and so on.**
c) **Overhead costs total Rs.60 per day. What is the optimum length schedule in terms of both crashing and overhead cost? List the schedule duration of each job for your solution. (16M)(BTL1)**

Job (i-j)	**Normal Duration (in days)**	**Minimum (crash) Duration (in days)**	**Cost of Crashing (Rs. per day)**
1-2	**9**	**5**	**20**
1-3	**8**	**5**	**25**
1-4	**15**	**10**	**30**
2-4	**5**	**3**	**10**
3-4	**10**	**6**	**15**
4-5	**2**	**1**	**40**

Solution



Critical Paths are:
1-2-4-5 in 17 days
1-3-4-5 in 17 days
1-4-5 in 17 days
Therefore all paths are critical. Hence the reduction is based on the combination of activities from all paths. The various combinations are:

Nodes	Activities4-5	Cost slope/day	Maximum reduction
1	4-5	40	2 days
2	1-4, 2-4, 3-4	55	4,2,2 therefore 2 days
3	1-3, 1-4, 2-4	65	2,4,2 therefore 2 days
4	1-2, 1-4, 3-4	65	3,4,2 therefore 2 days
5	1-2, 1-3, 1-4	75	3,2,4 therefore 2 days

Step 1: Reduce activity 4-5(since that has the least cost slope) by 2 days. Incremental cost is Rs.40 per day and cumulative cost is Rs.80/.
Step 2: Reduce activities 1-4, 2-4, 3-4 by 2 days. Incremental cost is Rs.55 per day. Total cost is Rs.110 and cumulative cost is Rs. 190/-
Step 3: Combination 3 and 4 are redundant, since activities 2-4 & 3-4 are fully crashed. Hence reduce activities 1-2, 1-3 and 1-4 by 2 days. Incremental cost is Rs.75 per day. Total cost is Rs.150 and cumulative cost is Rs.340/-. No further crashing is possible.
The normal duration of 20 days can be crashed to 14 days. However the optimum duration is 16 days.

Duration	20	19	18	17	16	15	14
Crash cost	0	40	40	55	55	75	75
Cum crash cost	0	40	80	135	190	265	340
Indirect cost	1200	1140	1080	1020	960	900	840
Total cost	1200	1180	1160	1155	1150	1165	1180

12 **Consider the data of a project summarized in the following table:**

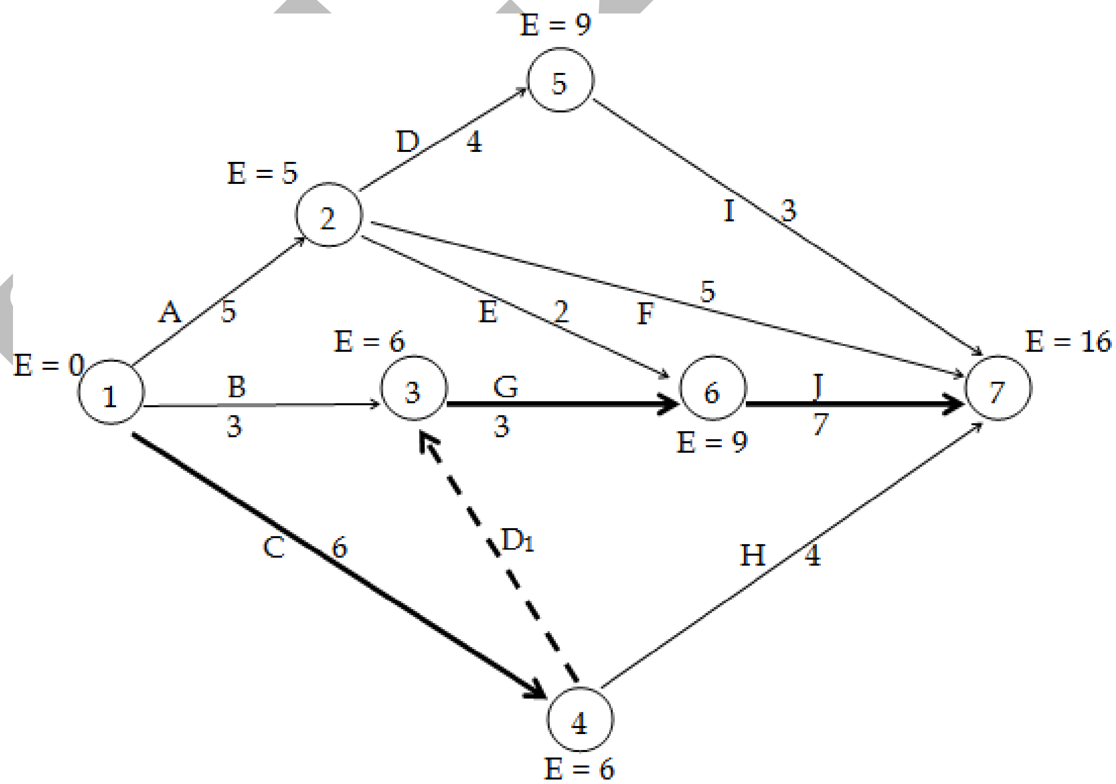
- **i) Construct the project network.**
- **ii) Find the expected duration and the variances of each activity.**
- **iii) Find the critical path and the expected project completion time.**
- **iv) What is the probability of completing the project on or before 35 weeks?**

(12M)(BTL1) (Nov 2016)

Activity	Immediate Predecessor(s)	Duration (weeks)		
		a	m	b
A	_	4	4	10
B	_	1	2	9
C	_	2	5	14
D	A	1	4	7
E	A	1	2	3
F	A	1	5	9
G	B, C	1	2	9
H	C	4	4	4
I	D	2	2	8
J	E, G	6	7	8

Solution:

i) Project Network



ii) Expected duration and variance of each activity

Activity	a (to)	m (tm)	b (tp)	Expected duration te = $\frac{to+4tm+tp}{6}$	Expected Variance $\sigma^2 = \left(\frac{tp-to}{6}\right)^2$
1-2	4	4	10	5	1.00
1-3	1	2	9	3	1.78
1-4	2	5	14	6	4.00
2-5	1	4	7	4	1.00
2-6	1	2	3	2	0.11
2-7	1	5	9	5	1.78
3-6	1	2	9	3	1.78
4-7	4	4	4	4	0.00
5-7	2	2	8	3	1.00
6-7	6	7	8	7	0.11

iii) Critical path and expected project completion time

Critical path

1 – 4 – 3 – 6 – 7

Project completion time

16 weeks

iv) Probability of completing the project on or before 35 weeks

Expected variance of the project length

= Sum of expected variances of all the critical activities

= 4.00 + 1.78 + 0.11

= 5.89 weeks

Standard deviation of the project length

$\sigma_c = \sqrt{5.89}$

= 2.427 weeks

$z = \frac{TS-TE}{\sigma c}$

$= \frac{35-16}{2.427}$

$= \frac{19}{2.427}$

= 7.82

$P(T_S \le 35)$

$= P(z \le 7.82)$

= 0.9999

=99.99 %

13 **The following table indicates the details of a project. The duration are in days. "a" refers to optimistic time, "m" refers to most likely time and "b" refers to pessimistic time duration.**

i. Draw the network

ii. Find the Critical Path

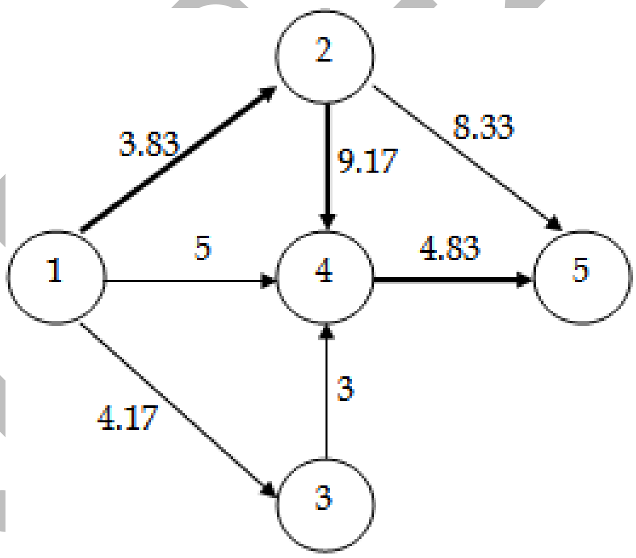
iii. Determine the expected standard deviation of the completion time.

(BTL1) (May 2017,Nov 2017)

Activity	**1-2**	**1-3**	**1-4**	**2-4**	**2-5**	**3-4**	**4-5**
a	**2**	**3**	**4**	**8**	**6**	**2**	**2**
m	**4**	**4**	**5**	**9**	**8**	**3**	**5**
b	**5**	**6**	**6**	**11**	**12**	**4**	**7**

Solution:

Activity	a	m	b	Expected Duraration te	Expected Variance σ2
1-2	2	4	5	3.83	¼
1-3	3	4	6	4.17	¼
1-4	4	5	6	5	1/9
2-4	8	9	11	9.17	¼
2-5	6	8	12	8.33	1
3-4	2	3	4	3	1/9
4-5	2	5	7	4.83	25/36



The critical path is 1-2-4-5

Expected project duration is 17.83 days

Expected variance of the completion time=1/4+1/4+25/36=43/36

Expected standard deviation of completion time=1.09 nearby.

CS6003 ADHOC AND SENSOR NETWORKS L T P C 3 0 0 3

OBJECTIVES:

The student should be made to: □ Understand the design issues in ad hoc and sensor networks. □ Learn the different types of MAC protocols. □ Be familiar with different types of adhoc routing protocols. □ Be expose to the TCP issues in adhoc networks. □ Learn the architecture and protocols of wireless sensor networks.

UNIT I INTRODUCTION 9

Fundamentals of Wireless Communication Technology – The Electromagnetic Spectrum – Radio propagation Mechanisms – Characteristics of the Wireless Channel -mobile ad hoc networks (MANETs) and wireless sensor networks (WSNs) :concepts and architectures. Applications of Ad Hoc and Sensor networks. Design Challenges in Ad hoc and Sensor Networks.

UNIT II MAC PROTOCOLS FOR AD HOC WIRELESS NETWORKS 9

Issues in designing a MAC Protocol- Classification of MAC Protocols- Contention based protocols- Contention based protocols with Reservation Mechanisms- Contention based protocols with Scheduling Mechanisms – Multi channel MAC-IEEE 802.11

UNIT III ROUTING PROTOCOLS AND TRANSPORT LAYER IN AD HOC WIRELESS NETWORKS 9

Issues in designing a routing and Transport Layer protocol for Ad hoc networks- proactive routing, reactive routing (on-demand), hybrid routing- Classification of Transport Layer solutions-TCP over Ad hoc wireless Networks.

UNIT IV WIRELESS SENSOR NETWORKS (WSNS) AND MAC PROTOCOLS 9

Single node architecture: hardware and software components of a sensor node - WSN Network architecture: typical network architectures-data relaying and aggregation strategies -MAC layer protocols: self-organizing, Hybrid TDMA/FDMA and CSMA based MAC- IEEE 802.15.4.

UNIT V WSN ROUTING, LOCALIZATION & QOS 9

Issues in WSN routing – OLSR- Localization – Indoor and Sensor Network Localization-absolute and relative localization, triangulation-QOS in WSN-Energy Efficient Design-Synchronization-Transport Layer issues.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of the course, the student should be able to: Explain the concepts, network architectures and applications of ad hoc and wireless sensor networks

 Analyze the protocol design issues of ad hoc and sensor networks

 Design routing protocols for ad hoc and wireless sensor networks with respect to some protocol design issues

 Evaluate the QoS related performance measurements of ad hoc and sensor networks

TEXT BOOK:

1. C. Siva Ram Murthy, and B. S. Manoj, "Ad Hoc Wireless Networks: Architectures and Protocols ", Prentice Hall Professional Technical Reference, 2008.

.REFERENCES:

1. Carlos De Morais Cordeiro, Dharma Prakash Agrawal “Ad Hoc & Sensor Networks: Theory and Applications”, World Scientific Publishing Company, 2006.

2. Feng Zhao and Leonides Guibas, "Wireless Sensor Networks", Elsevier Publication - 2002.

3. Holger Karl and Andreas Willig “Protocols and Architectures for Wireless Sensor Networks”, Wiley, 2005

4. Kazem Sohraby, Daniel Minoli, & Taieb Znati, “Wireless Sensor Networks-Technology, Protocols, and Applications”, John Wiley, 2007.

5. Anna Hac, “Wireless Sensor Network Designs”, John Wiley, 2003

Subject Name: ADHOC AND SENSOR NETWROKS **Subject Handler: R.DAYANA**

UNIT I INTRODUCTION	
Fundamentals of Wireless Communication Technology – The Electromagnetic Spectrum – Radio propagation Mechanisms – Characteristics of the Wireless Channel -mobile ad hoc networks (MANETs) and wireless sensor networks (WSNs):concepts and architectures. Applications of Ad Hoc and Sensor networks. Design Challenges in Ad hoc and Sensor Networks.	

PART- A

Q.No	Questions
1	**What is an adhoc network? (May 2015) BTL 1** A mobile ad hoc network (MANET) is a continuously self-configuring, infrastructure less network of mobile devices connected without wires. .
2	**What is fading? List the different types of fading? BTL 1** Fading is deviation of the attenuation affecting a signal over certain propagation media. Slow fading & Fast fading.
3	**Why adhoc networks are needed? (May 2012) BTL 2** The network is ad hoc because it does not rely on a preexisting infrastructure, such as routersin wired networks or access points in managed(infrastructure) wireless networks. Instead, each node participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamically on the basis of network connectivity. .
4	**What are the challenging issues in adhoc network maintenance?(May 2013)BTL 1** a. Changing the network topology over time, b. Potentially frequent network partition, c. Every node can be mobile, d. Limited power capacity, e. Limited wireless bandwidth, f. Presence of varying channel quality.
5	**What is hidden terminal problem? BTL 1** Hidden node problem or hidden terminal problem occurs when a node is visible from a wireless access point (AP), but not from other nodes communicating with that AP.
6	**List the transmission impediments of wireless channel. (May 2013) BTL 1** Path loss, interference, blockage are the impediments
7	**State Shannon's theorem. (Nov 2012) BTL 1** The shannon–hartley theorem tells the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise. It is an application of the noisy channel coding theorem to the archetypal case of a continuous-time analog communications channel subject to Gaussian noise.
8	**List the applications of adhoc network. BTL 1** 1) Crisis management services applications. 2) Another application example of a mobile ad-hoc network is bluetooth, which is designed to support a personal area network by eliminating the need of wires between various devices, such as printers and personal digital assistants. 3) In comparison with geographical positioning systems, mobile ad-hoc networks can

	support the built-in geographical location by using an extremely accurate form of triangulation. This feature enables soldiers in a military operation to triangulate its position based on the mobile enabled vehicles or other devices. .
9	**Write the equation for maximum data rate according to Shannon's theorem.(May 2013) BTL 1** The shannon–hartley theorem tells the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise. $$C = B\log_2\left(1+\frac{S}{N}\right)$$
10	**Differentiate an adhoc network and a cellular network with respect to bandwidth usage and cost effectiveness. (Nov 2012) BTL 4** Cellular: high cost and time of deployment, easier to employ bandwidth reservationAdhoc network: quick and cost-effective deployment, bandwidth reservation requires complex medium access control protocols.
11	**Define path loss. BTL 1** Path loss (or path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. Path loss normally includes *propagation losses* caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever-increasing sphere), *absorption losses* (sometimes called penetration losses), when the signal passes through media not transparent to electromagnetic waves, *diffraction losses* when part of the radio wave front is obstructed by an opaque obstacle, and losses caused by other phenomena.
12	**Give the difference between cellular networks and adhoc wireless networks.(April 2016) BTL 1** <table><tr><th>Cellular network</th><th>Ad hoc network</th></tr><tr><td>Fixed infrastructure</td><td>Infra structure –less</td></tr><tr><td>Single –hop wireless</td><td>Multi-hop wireless</td></tr><tr><td>Centralized routing</td><td>Distributed routing</td></tr></table>
13	**List the propagation mechanism experienced by radio wave. BTL 1** 1.Surface modes (ground wave), 2.Direct modes (line-of-sight),3.Ionospheric modes (sky wave), 4.Tropospheric modes, 5. Diffraction, 6.Absorption.
14	**Define Doppler shift. BTL 1** The wavelength of light emitted by a moving object is shifted. This effect is called the Doppler shift. If the object is coming toward you, the light is shifted toward shorter wavelengths, *blue shifted*. If the object is going away from you, the light is shifted toward longer wavelengths, *red shifted*. The amount of shift is bigger if the emitting object is moving faster.
15	**Compare ad-hoc networks and wireless LAN / Differentiate infrastructure and infrastructure less network. (April 2014) & (May 2015) BTL 4** <table><tr><td>wireless LAN</td><td>Ad-hoc networks</td></tr></table>

<table>
<tr><td></td><td><table>
<tr><td>Application domains include mainly civilian and commercial sectors</td><td>Application domain includes emergency and rescue operation</td></tr>
<tr><td>High cost network maintanance</td><td>Self organizing and maintenance property</td></tr>
<tr><td>Mobile host with low complexity</td><td>Mobile host requires intelligence so complex</td></tr>
</table></td></tr>
<tr><td>16</td><td>Define scalability. (April 2014), (May 2015) & (April 2016) BTL 1
Scalability is the ability of a system, network, or process to handle a growing amount of work in a capable manner or its ability to be enlarged to accommodate that growth.</td></tr>
<tr><td>17</td><td>Name the different mobility models of adhoc network. BTL 1
Brownian motion model, Random walk model, Random way point mobility model & Mobility vector model.</td></tr>
<tr><td>18</td><td>What is Wireless sensor network? BTL 1
Wireless Sensor networks consist of individual sensor nodes that are able to interact with their environment by sensing or controlling physical parameters; these nodes have to collaborate to fulfill their tasks as, usually, a single node is incapable of doing so; and they use wireless communication to enable this collaboration. In essence, the nodes without such a network contain at least some computation, wireless communication, and sensing or control functionalities.</td></tr>
<tr><td>19</td><td>List the applications of WSN. BTL 1
Disaster relief applications, Environment control and biodiversity mapping, Intelligent buildings, Facility management, Machine surveillance and preventive maintenance, Precision agriculture, Medicine and health care, Logistics and Telematics.</td></tr>
<tr><td>20</td><td>What are the types of applications? BTL 1
Event detection, Periodic measurements, Function approximation and edge detection and Tracking</td></tr>
<tr><td>21</td><td>Define tracking. BTL 1
The source of an event can be mobile (e.g. an intruder in surveillance scenarios). The WSN can be used to report updates on the event source’s position to the sink(s), potentially with estimates about speed and direction as well. To do so, typically sensor nodes have to cooperate before updates can be reported to the sink. These interactions can be scoped both in time and in space (reporting events only within a given time span, only from certain areas, and so on). These requirements can also change dynamically overtime; sinks have to have a means to inform the sensors of their requirements at runtime. Moreover, these interactions can take place only for one specific request of a sink (so-called “one-shot queries”), or they could be long-lasting relationships between many sensors and many sinks.</td></tr>
<tr><td>22</td><td>What are the characteristics requirement for WSNs? BTL 1
Type of service, quality of service, fault tolerance, life time, scalability, Wide range of densities, programmability and maintainability.</td></tr>
<tr><td>23</td><td>What is the difference between sensor network and MANET? BTL 1
Wireless sensor networks may be considered a subset of Mobile Ad-hoc Networks (MANET). WSN nodes have less power, computation and communication compared to</td></tr>
</table>

	MANET nodes. MANETs have high degree of mobility, while sensor networks are mostly stationary. Frequent node failures in WSN causes changes in the network topology. Routing protocols tend to be complex in MANET, but need to be simple in sensor networks. Low-power operation is even more critical in WSN. MANET is address centric, WSN is data centric.
24	**Write the name of three types of mobility. BTL 1** Node mobility: The wireless sensor nodes themselves can be mobile. Sink mobility: the information sinks can be mobile. Event mobility: In applications like event detection and in particular in tracking applications, the cause of the events or the objects to be tracked can be mobile.
25	**What are the five main components of a basic sensor node? BTL 1** Microcontroller, Memory, Sensors and Actuators, Communication and Power supply.
	PART-B
1	**What are the characteristics and features of adhoc networks?(May 2012) BTL 1** Key Points: Infrastructure based (3m) Contains special nodes called Access points. All nodes coomunicate with Access points Infrastructure less based (3m) Does not have any fixed infrastructure All nodes communicate directly. Applications (4m) Design issues (3m)
2	**How the path loss and fading affects the wireless channel? Explain it. (May 2013) & (May 2015) BTL 1** Key Points: Path loss (7m) Free space propagation model Realistic Loss model Two ray model Fading (6m) Fast fading Slow fading
3	**Explain the two main forms of interference, Doppler shift and nyquist theorem. (May 2013) BTL 1** Keypoints:

	Interference (7m) Adjacent channel interference Co channel interference Inter symbol interefernce Doppler shift(3m) Nyquist's theorem (3m)
4	. **i) Explain the applications areas of adhoc networks. (May 2013) & (April 2016) BTL 1** i)Military applications (5m) Emergency services Commercial applications Education **ii) Explain the characteristics of wireless channels.(May 2012) BTL 1** Path loss (2m) It can be expressed as the ratio of the power of the transmitted signal to the power of the same signal received by the receiver on the given path. Fading (2m) Fading refers to fluctuations in signal strength when received at the receiver . Fast fading Slow fading Interference (2m) Adjacent channel interference Co channel interference Doppler shift (1m) Change /shift in the frequency of the received signal when the transmitter and the receiver are mobile with respect to each other. Blockage(Nyquist theorem c=2xBxlog2L bits/sec, Shannon's theorem C=Bxlog2(1+(S+N))) (1m)
5	**Explain MANET architecture in detail.(May 2012) BTL 1** Architecture with diagram (4m) Enabling Technologies (3m) Communications (2m) MANET operations (4m)
	PART C
1	**(i)Compare cellular network and adhoc wireless network. (May 2015) & (April 2014) BTL 4** **(ii)What are the issues and challenges of adhoc system? BTL 1** i) Difference between Cellular and Adhoc Network (6m) Diagram ii)Design Issues of Ad Hoc Wireless Network (7m) Medium access scheme, Routing, Multicasting, Transport layer protocol, Pricing scheme, QOS provisioning, Self organization, security, Addressing and service discovery, Energy management, Deployment Considerations.
2	**What is MANET? Explain about MANET architecture. (April 2014) BTL 1**

	Manet Architecture (4m) Block Diagram(2m) Enabling Technologies(2m) Communication(2m) MANET operations(3m)
3	**Describe the concepts of adhoc wireless internet.(April 2014) BTL 2** Introduction (3m) Types of Wireless Network (6m) Infrastructure network Adhoc network Applications Of Adhoc network (4m) Military applications Collaborative and distributed computing Emergency operations Wireless mesh networks
2	**How the path loss and fading affects the wireless channel? Explain it. (May 2013) & (Nov/Dec 2018) BTL 3** Key Points: Path loss (7m) Free space propagation model Realistic Loss model Two ray model Fading (6m) Fast fading Slow fading
3	**Explain the two main forms of interference, Doppler shift and nyquist theorem. (May 2013) BTL 2** **Keypoints:** Interference (7m) Adjacent channel interference Co channel interference Inter symbol intereefernce Doppler shift(3m) Nyquist's theorem (3m)
4	. **i) Explain the applications areas of adhoc networks. (May 2013) & (April 2016) BTL 2** i)Military applications (5m) Emergency services Commercial applications Education **ii) Explain the characteristics of wireless channels.(May 2012) BTL 2**

	Path loss (2m) Fading (2m) Interference (2m) Doppler shift (1m) Blockage(Nyquist theorem, Shannon's theorem) (1m)
UNIT II	**MAC PROTOCOLS FOR AD HOC WIRELESS NETWORKS** Issues in designing a MAC Protocol- Classification of MAC Protocols- Contention based protocols-Contention based protocols with Reservation Mechanisms- Contention based protocols with Scheduling Mechanisms – Multi channel MAC-IEEE 802.11
	PART-A
1	**List the design goals of MAC protocol for ad-hoc networks. BTL 1** *The operation of the protocol should be distributed. * The protocol should provide qos support for real-time traffic. *The available bandwidth must be utilized efficiently. *The protocol should ensure fair allocation of bandwidth to nodes. * Control overhead must be kept as low as possible. *The protocol should minimize the effects of hidden and exposed terminal problems. *The protocol must be scalable to large networks..
2	**. List the issues of designing a MAC protocol for adhoc networks. BTL 1** * Bandwidth efficiency is defined at the ratio of the bandwidth used for actual data transmission to the total available bandwidth. The MAC protocol for ad-hoc networks should maximize it. * Quality of service support is essential for time-critical applications. The MAC protocol for ad-hoc networks should consider the constraint of ad-hoc networks. *Synchronization can be achieved by exchange of control packets. .
3	**What are the classifications of MAC protocol? (May2012) BTL 1** Contention-based protocols,Contention-based protocols with reservation mechanisms,Contention-based protocols with scheduling mechanisms.
4	**What are the advantages of directional antennas of MMAC over MACAW? BTL 1** Reduced signal interference, increase system throughput, and Improved channel reuse.
5	**What are the mechanisms used in MAC layer? BTL 1** Contention based protocol with reservation mechanism & Contention based protocol with scheduling mechanism.
6	**What are the differences between HRMA and SRMA? BTL 1** Hop reservation multiple access protocol (HRMA): A multichannel MAC protocol which is based on half-duplex, very slow frequency-hopping spread spectrum (FHSS) radios. It uses a reservation and handshake mechanism to enable a pair of communicating nodes to reserve a frequency hop, thereby guaranteeing collision-free data transmission. It Can be viewed as a time slot reservation protocol where each time slot is assigned a separate frequency channel. Soft reservation multiple access with priority assignment (SRMA/PA):Developed with

the main objective of supporting integrated services of real-time and non-real-time application in ad hoc networks, at the same time maximizing the statistical multiplexing gain. Nodes use a collision-avoidance handshake mechanism and a soft reservation mechanism.

7 **What are the effects of exposed terminal problem in wireless networks? BTL 1**

Wireless networks, the exposed node problem occurs when a node is prevented from sending packets to other nodes due to a neighboring transmitter. Consider an example of 4 nodes eighbou r1, s1, s2, and r2, where the two receivers (r1, r2) are out of range of each other, yet the two transmitters (s1, s2) in the middle are in range of each other. Here, if a transmission between s1 and r1 is taking place, node s2 is prevented from transmitting to r2 as it concludes after carrier sense that it will interfere with the transmission by its eighbour s1. However note that r2 could still receive the transmission of s2 without interference because it is out of range of s1.

8 **List the five phases of FPRP. BTL 1**

A new single channel, time division multiple access (TDMA)-based broadcast scheduling protocol,termed the Five-Phase Reservation Protocol (FPRP), is presented for mobile ad hoc networks The protocol jointly and simultaneously performs the tasks of channel access and node broadcast scheduling. Multiple reservations are possible.

9 **List any two needs of real-time MAC protocol. BTL 1**

It supports bandwidth efficiency. It supports asynchronous mode of operation.

10 **Compare the efficiency of the packet queuing mechanism adopted in MACA and MACAW (Nov2012) BTL 4**

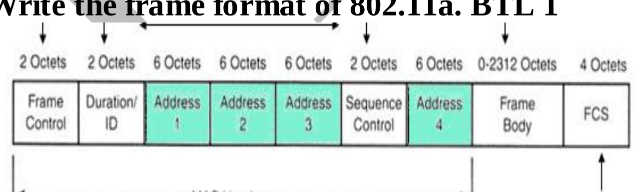
MACA:MACA did not solve hidden & exposed terminal problems.MACA did not provide specifications about parameters like RTS, CTS packet sizes, timers ,initial back off window size.

MACAW:Revisit Hidden Terminal Problem.Data packet still may suffer collision,To recover packet loss at transport layer is too slow,Recover at MAC layer is more fast.Need ACK from destination..

11 **How is directional antenna MACA superior over MACAW? BTL 3**

Solve both hidden and exposed node problems; Increase channel spatial reuse.

12 **Write the frame format of 802.11a. BTL 1**



13 **Differentiate IEEE 802.11 standard and HIPERLAN. (April 2016) BTL 4**

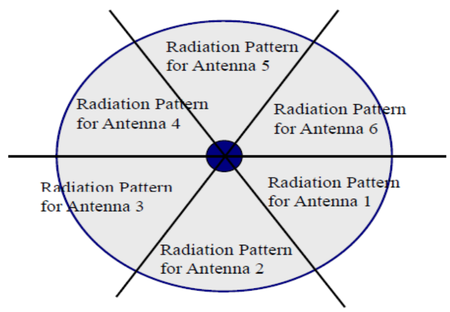
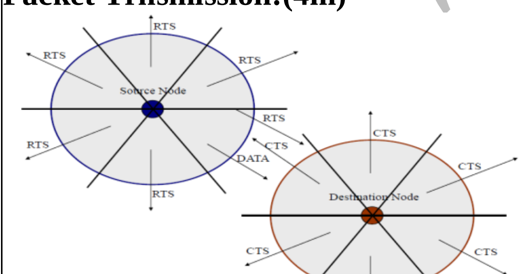
Parameters	802.11	HIPERLAN
Spectrum (GHz)	2.4	5
Max PHY rate (Mbps)	2	54
Max data rate (Mbps)	1.2	32
Connectivity	Connectionless	Connection oriented

14 **What do you mean by contention based protocols? Give the classification of contention based protocol. BTL 1**

	It does not reserve channel in priori, the received packets is contended with shared channel. Sender initiated protocol, receiver initiated protocol.
15	**Why contention based protocol is not suitable for real time traffic?(April 2016) BTL 2** Contention based MAC protocols involve random access based contention for the channel when packets need to be transmitted.They are again suitable for bursty traffic, but there is a possibility of collisions and no delay guarantees can be provided.Hence they are not suitable for delay sensitive or real time traffic.
16	**What do you mean by FAMA? BTL 1** Floor acquisition Multiple Access Protocols (FAMA):Based on a channel access discipline which consists of a carrier-sensing operation and a collision-avoidance dialog between the sender and the intended receiver of a packet.Floor acquisition refers to the process of gaining control of the channel. At any time only one node is assigned to use the channel. Two variations of FAMA: *RTS-CTS exchange with no carrier-sensing uses the ALOHA protocol for transmitting RTS. *RTS-CTS exchange with non-persistent carrier-sensing uses non-persistent CSMA.
17	**What are the issues to be considered while designing a MAC protocol for ad-hoc Networks? (April 2014) BTL 1** Bandwidth efficiency, QOS, synchronization, hidden&exposed terminal, shared broadcast terminal, lack of central coordination, mobility of nodes.
18	**What do you mean by contention based protocols with reservation mechanism? BTL 1** Synchronous protocols: All nodes need to be synchronized. Global time synchronization is difficult to achieve.Asynchronous protocols: These protocols use relative time information for effecting reservations.
19	**What do you mean by contention based protocols with scheduling mechanism? BTL 1** Node scheduling is done in a manner so that all nodes are treated fairly and no node is starved of bandwidth.Scheduling-based schemes are also used for enforcing priorities among flows whose packets are queued at nodes.Some scheduling schemes also consider battery characteristics
20	**What do you mean by D-PRMA? BTL 1** Distributed packet reservation multiple access protocol (D-PRMA):It extends the centralized packet reservation multiple access (PRMA) scheme into a distributed scheme that can be used in ad hoc wireless networks.PRMA was designed in a wireless LAN with a base station.D-PRMA extends PRMA protocol in a wireless LAN.D-PRMA is a TDMA-based scheme. The channel is divided into fixed- and equal-sized framesalong the time axis.
21	**What are the disadvantages of the binary exponential backoff mechanism used in MACA? How are they overcome in MACAW? BTL 1** MACA uses RTS and CTS to overcome hidden node problem and exposed node problem, the binary exponential back off can starve the flows data to send, MACAW introduced multiplicative increase and Linear Decrease (MILD), Upon collision BO multiplied by 1.5,Upon successful transmission it is decreased b1, Per flow fairness is

	implemented, Each flow runs the back off algorithm. Flow with minimum back off value is chosen to send RTS.
22	**What do you mean by BTMA? BTL 1** Busy Tone Multiple Access Protocols (BTMA):The transmission channel is split into two: data channel for data packet transmissions & control channel used to transmit the busy tone signal. If not, it turns on the busy tone signal and starts data transmissions. Otherwise, it reschedules the packet for transmission after some random rescheduling delay. Any other node which senses the carrier on the incoming data channel also transmits the busy tone signal on the control channel, thus, prevent two neighboring nodes from transmitting at the same time.
23	**On what basis MACAW protocol is designed? BTL 3** Congestion at receiver node not at sender node.Congestion is based on location of receiver.Congestion at node must be collective enterprise.Synchronization of information in appropriate time.
	PART-B
1	**Explain MACAW protocol in detail. BTL 2** Solution to Hidden terminal problem (3m) MACAW protocol (5m) Problems with BEB algorithm (5m)
2	**Explain the contention based protocols with scheduling and reservation in detail. (May2012) & (April 2014) BTL 2** Contention based protocols-reservation mechanism: (7m) D-PRMA CATA HRMA SRMA/PA FPRP MACA/PR RTMAC Contention based protocols-Scheduling mechanism: (6m) DPS DWOP DLPS
3	**Explain IEEE 802.11g standard in detail.(May2012) BTL 2** **Physical layers:** (4m) FHSS DSSS IF **Architecture:** (4m) Infrastructure mode Infrastructureless mode **Physical Layer** (2m) **MAC Layer** (3m)
4	**(i) List and explain the issues in designing a MAC protocol for adhoc wireless**

	networks. (April 2016) BTL 1 **Design Issues of MAC protocol** (7m) Bandwidth Efficiency QOS support Synchronization Hidden and Exposed Terminal Problem Error-Prone shared broadcast Channel Lack of central coordination Mobility of nodes **(ii)How packets are transmitted in MACA protocol & how the collision is avoided? Explain. (April 2016) BTL 1** MACA PROTOCOL with diagram (3m) Solution to Hidden terminal Problem (3m)
5	**List the important goals of designing a MAC protocol for adhoc wireless networks. (May 2013) BTL 1** **Design Goals of MAC protocol** (13m) Bandwidth Efficiency QOS support Synchronization Hidden and Exposed Terminal Problem Error-Prone shared broadcast Channel Lack of central coordination Mobility of nodes
6	**Illustrate various steps involved in five phase reservation protocol with its frame format. (Nov 2012& 2018) BTL 3** **Frame structure of FPRP** (5m) **Steps involved in five phase reservation protocol** (8m) 1.Reservation Request phase (RR) 2.Collision Report phase (CR) 3.Reservation Confirmation Phase (RC) 4.Rservation Acknowledgement Phase(RA) 5.Packing and Elimination Phase(P/E)
7	**How is scheduling mechanism achieved in distributed wireless ordering protocol? Explain in detail. BTL 3** DWOP –explanation (2m) Diagram(2m) Receiver participation Mechanism(3m) Perfect FIFO scheduling (3m) Stale Entry Elimination Mechanism(3m)
PART-C	
1	**How the table update mechanism is implemented in distributed priority scheduling? (April 2016) BTL 5** DPS –explanation (4m) Data transmission with table update --- diagram and calculation (3m)

	Multihop Coordination (3m) Calculation of new priority index value. (3m)
2	**What are the advantages and disadvantages of MAC protocol using directional antennas?(April 2014) BTL 1** **MAv protocol using directionalantennas:** (3m) Advantages - Reduced signal interference, increase system throughput, and improved channel reuse **Assumptions:** (2m) **Diagram:** (4m)  Node with 6 antennas ($M = 6$) Figure 6.28. Radiation patterns of directional antennas. **Packet Trnsmission:(4m)**  Figure 6.29. Packet transmission.
3	**Name the three MAC services provided by the IEEE 802.11 that are not provided in the traditional LAN's such as 802.3. (April 2014, Nov/Dec 2018) BTL 1** **MAC layer** (4m) PCF(Point Coordination Function) DCF(Distributed Coordinated Function) **CSMA/CA Mechanism**(2m) **Inter-Frame Spacing** (7m) Short Inter frame spacing PCF inter frame spacing DCF inter frame spacing Exteneded inter frame spacing

UNIT III ROUTING PROTOCOLS AND TRANSPORT LAYER IN AD HOC WIRELESS NETWORKS Issues in designing a routing and Transport Layer protocol for Ad hoc networks- proactive routing, reactive routing (on-demand), hybrid routing- Classification of Transport Layer solutions-TCP over Ad hoc wireless Networks.	
PART-A	
1	**What are the responsibilities of routing protocol? BTL 1** *A procedure for passing reachability information about networks to other routers *****A procedure for receiving reachability information from other routers *****A procedure for determining optimal routes based on the reachability information it has and for recording this information in a route table.
2	**What are the major challenges in designing routing protocols? BTL 1** Need dynamic routing, Frequent topological changes possible, Very different from dynamic routing in the Internet, Potential of network partitions, Routing overhead must be kept minimal, Wireless → low bandwidth, Mobile → low power, Minimize routing state at each node.
3	**List the characteristics of a routing protocol for ad hoc wireless networks. BTL 1** Dynamic topologies: Network topology may change dynamically as the nodes are free to move. Bandwidth-constrained, variable capacity links: Realized throughput of wireless communication is less than the radio's maximum transmission rate. Collision occurs frequently. Energy-constrained operation: Some nodes in the ad hoc network may rely on batteries or other exhaustible means for their energy. Limited physical security: More prone to physical security threats than fixed cable networks.
5	**Based on routing information update mechanism how the routing protocols are classified? BTL 1** Optimized Link State Routing Protocol (OLSR), Destination Sequence Distance Vector (DSDV) Fisheye State Routing (FSR), Fuzzy Sighted Link State(FSLS).
6	**List the advantages and disadvantages of DSDV routing protocols. BTL 1** **Advantages:**Route setup process is very fast, Make the existing wired network protocol apply to adhoc network with fewer modifications. **Disadvantages:**Excessive control overhead during high mobility, Node must wait for a table update message initiated by the destination node cause stale routing information at nodes.
7	**What is the function of sequence number in AODV protocol? (May 2015) BTL 1** AODV differs from other on-demand routing protocols in that is usesnumbers to determine an up-to-date path to a destination. Every entry in the routing table is associated with a sequence number. The sequence number act as a route timestamp, ensuring freshness of the route. Upon receiving a RREQ packet, an intermediate node compares its sequence number with the sequence number in the RREQ packet. If the sequence number already registered is greater than that in the packet, the existing route is more up-to-date.
8	**List the types of on-demand routing protocols**. **BTL 1**

Destination-Sequenced Distance-Vector Routing (DSDV), Ad hoc On-Demand Distance Vector (AODV) Routing, ABR Associativity-Based Routing, Signal Stability based Adaptive Routing (SSA).

9 **List the types of hybrid routing protocols. BTL 1**

Core Extraction Distributed Ad Hoc Routing (CEDAR), Zone routing protocol (ZRP), Zone-Based Hierarchical Link State **Routing Protocol** (ZHLS).

10 **What are the advantages of dynamic source routing protocol (DSRP)? BTL 1**

Routes are discovered only when they are needed, Reduces overhead of route maintenance, Route caching reduce the cost of route discovery, A single route discovery may yield many routes to the destination, due to intermediate nodes may reply route request from local caches & Does not require symmetric links.

11 **Why DSDV is not suitable for high mobility networks? (May 2015) BTL 1**

Excessive control overhead during high mobility, Node must wait for a table update message initiated by the destination node cause stale routing information at nodes.

12 **Mention any four qualities of service metrics that are used to evaluate the performance of the network? BTL 1**

The following basic metrics of QoS were used to evaluate the performance of the network:

*****Throughput: determines the amount of data moved from node to a node in a certain period of time.

*****Delay: Time that a package takes to go from one point to another of the network.

*****Jitter: difference between the delay of the current package and the next one.

*****Packet loss: It measures the success rate in the transmission of packages between two nodes of the network.

13 **Give the difference between Ad hoc on demand Distance vector routing protocol (AODV) and dynamic sequence routing protocol (DSR). BTL 1**

Ad hoc on demand Distance vector routing protocol (AODV)	**Dynamic sequence routing protocol (DSR)**
DSR has access to greater amount of routing information than AODV by the virtual of SR	AODV can gather limited information.
DSR: in a single query-reply cycle, source learns route to each intermediate node in the route in addition to the dest. Each intermediate node also learns route to other nodes on the route. Promiscuous listening also helps to learn the route to every node on the route	AODV: no source routing or promiscuous listening. It causes AODV to rely on a route discovery flood more often, generating more network overhead

14 **Differentiate proactive and reactive protocol. Write examples for each. (May 2012,April 2014) BTL 1**

Proactive protocol	**Reactive protocol**
1. It has lower latency due to maintenance of routes at all times	It can result in much higher overhead due to frequent route updates

	2. It has lower latency due to maintenance of routes at all times | It has lower overhead since routes are maintained only on-demand basis An example for Reactive protocols are Ad hoc On-Demand Distance Vector or AODV and Temporary Ordering Routing Algorithm or TORA.An Example for proactive protocol is Destination Sequence Distance Vector (DSDV).
15	**What are the advantages of hierarchical routing protocol? (April 2014) BTL 1** Using hierarchy information, it helps to reduce the routing table size.
16	**List the objectives of a transport layer protocol ? BTL 1** End-to-end connection, End-to-end delivery of data packets, Flow control & Congestion control..
17	**List the advantages of TCP over Ad Hoc Wireless Networks. BTL 1** TCP taking 90% of the traffic is predominant in the Internet, Focuses on TCP extension in ad hoc wireless networks, Transport protocol should be independent of the network layer technology..
18	**. List the Disadvantages of TCP-F. BTL 1** *If a route to the sender is not available at the failure point (FP), then additional control packets may need to be generated for routing the route failure notification (RFN) packet. *Requires modification to the existing TCP & The congestion window after a new route is obtained may not reflect the achievable transmission rate acceptable to the network and the TCP-F receiver.
19	**What is called TCP with explicit link failure notification (TCP-ELFN)? BTL 1** It handles explicit link failure notification & uses TCP probe packets for detecting the route reestablishment.The ELFN is originated by the node detecting a path break upon detection of a link failure to the TCP sender.
20	**List out the 4 types of end to end approach in TCP over adhoc wireless network. BTL 1** TCP with explicit link failure notification (TCP-ELFN), Feedback-based TCP (TCP-F), TCP with buffering capability and sequence information (TCP-Bus) & Ad Hoc TCP (ATCP).
21	**List the advantages of TCP-F. BTL 1** TCP-F stands for TCP Feedback**.** Advantages: Simple, permits the TCP congestion control mechanism to respond to congestion.
22	**List the pros and cons of split-TCP. BTL 1** **Pros:** Enhance parallelism. Reduce bandwidth consumption on retransmission. **Cons:** Optimal frequency of proxy placement is not clear.
23	**Why proactive routing protocols are not suitable for high mobility networks? (April 2016) BTL 1** Proactive routing protocols incur too much overhead in maintaining topology information and perform very badly in large networks(not scalable).Because of mobility their performance degrades very heavily, which is the main reason why this type of protocols are not suitable for scalability in high mobility conditions.
24	**Why does TCP not work well in adhoc network? (April 2016) BTL 2** Misinterpretation of packet loss, Frequent path breaks, Effect of path length, Misinterpretation of congestion window, Asymmetric link behavior, Uni-directional

	path: TCP ACK requires RTS-CTS-Data-ACK exchange, Multipath routing, Network partitioning and remerging & The use of sliding-window-based transmission..
25	**List the issues in designing a transport layer protocol for Adhoc wireless networkBTL 1** Induced traffic, Induced throughput unfairness, Separation of congestion control, reliability and flow control, Power and bandwidth constraints, Misinterpretation of congestion & Dynamic topology.
PART-B	
1	**Explain in detail proactive routing (Table Driven) protocol with neat sketch. (April2014) BTL 2** **Proactive routing protocol:** (1m) DSDVR-Destination Sequenced distance vector routing(3m) WRP Wireless routing protocol(3m) CGSR cluster-head gateway switch routing protocol(3m) FSR Fisheye state rotuing(3m) All protocols with explanation and diagrams
2	**Explain in details reactive routing (on-demand) protocol with neat sketch. (May2012) BTL 2** **Reactive Routing protocols:** (1m) DSR Dynamic source routing (4m) AODV Adhoc ondemand routing(4m) TORA Temporarily ordered routing(4m)
3	**Explain about contention based MAC protocol. (Nov/Dec 2018) BTL 2** MACAW (3m) FAMA (3m) MACA by invitation(3m) BTMA (3m)
4	**Classify and explain adhoc wireless network based on routing topology.(May2013) BTL 5**

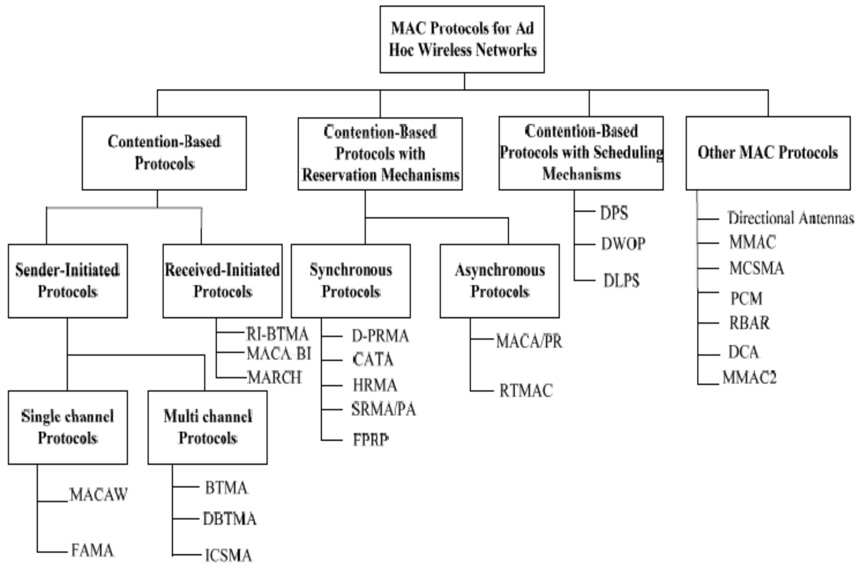


Figure 6.2: MAC protocols for ad hoc network

5 **Explain the types of Hybrid adhoc network routing protocols based on routing information update mechanism. (May2013) BTL 3**

Hybrid routing Protocols: (1m)
CEDAR-Core extraction distributed ad hoc routing protocol (4m)
ZRP -Zone routing protocol(4m)
ZHLS - Zone based hierarchical link state routing protocol (4m)

PART-C

1 **Explain the issues in designing a transport layer protocol & design goals of transport layer protocol for adhoc wireless networks.(May 2013) BTL 2**

Induced Traffic (7m)
Induced Throught unfairness
Separation of congestion control, reliability and flow control
Power and bandwidth constraints
Misinterpretation of congestion
Dynamic topology
Completely decoupled transport layer
esign Goals Of Transport Layer (6m)

2 **Explain TCP over ad hoc wireless networks in detail with neat sketch. BTL 2**

Feedback based TCP(3m)
TCP with explicit link failure notification(3m)
TCP-BUS(3m)
Adhoc TCP(2m)
Split TCP(2m)

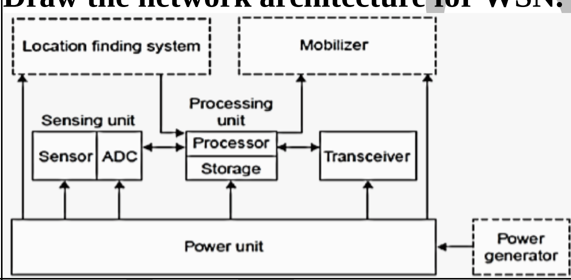
3 **Give the Advantage and disadvantage of Adhoc wireless routing protocols. (May 2013) BTL 2**

Table driven routing (5)
On demand routing(4)
Hybrid routing (4)

UNIT IV WIRELESS SENSOR NETWORKS (WSNS) AND MAC PROTOCOLS

Single node architecture: hardware and software components of a sensor node - WSN Network architecture: typical network architectures-data relaying and aggregation strategies -MAC layer protocols: self-organizing, Hybrid TDMA/FDMA and CSMA based MAC- IEEE 802.15.4.

PART- A

1	**What are the four conceptual building blocks of time synchronization protocols? BTL 1** Resynchronization event detection block, remote clock estimation block, clock correction block, and synchronization mesh setup block.
2	**What are the main components of a WSN node? BTL 1** Controller, Communication devices, Sensors/actuators Memory, Power supply are the main components of a WSN node..
3	**What are the hardware and software components of a sensor node? BTL 1** WSN Operating Systems: TinyOS, Contiki, MANTIS,BTnut etc., WSN Simulators: NS-2, Glomosim, OPNET etc., WSN Emulators: TOSSIM, ATEMU, Avrora etc.,
4	**What is inbound neighbor? BTL 1** An inbound neighbor of node (say A) is a neighbor whose transmissions A can hear but not vice versa.
5	**Draw the network architecture for WSN. BTL 2** 
6	**What is outbound neighbor? BTL 1** An outbound neighbor of node (say A) is a neighbor that receives A.s transmissions but not vice versa.
7	**What are beacons? BTL 1** Beacons are issued by the transmitter on the wakeup channel periodically and without prior carrier sensing. Such a beacon indicates the MAC addresses of transmitter and receiver. As soon as the receiver picks up the beacon, it sends an acknowledgment frame back on the wakeup channel (causing the transmitter to stop beacon transmission), switches on the transceiver for the data channel, and both nodes can proceed to execute the regular MAC protocol on the data channel, like for example an RTS/CTS handshake. Any other node receiving the beacon on the wakeup channel recognizes that the packet is not destined for it and goes back to sleep mode. The transmitter sends these beacons at least for one full wakeup period to be sure to hit the receivers listen period. .
8	**What is gossiping? BTL 1** In gossiping, the packets are forwarded to an arbitrary one. The packets randomly traversing the network in the hope of eventually finding the destination node. Clearly, the packet delay can be substantially larger.

9	**What is meant by routing protocolBTL 1** Routing protocols distribute routing information throughout all routers on a network. By knowing about all other routers connected to the network, each router can determine the best path to use to deliver your traffic. Examples of routing protocol would be OSPF, RIP, EIGRP or BGP.
10	**What is meant by clustering? BTL 1** The sensor networks form a group which is termed as clusters. More number of clusters are formed which forms a hierarchy. Each cluster has a Cluster Head (CH) which collects data from its member nodes and report it to base station. Example of clustering is Leach protocol.
11	**Define node centric network. BTL 2** In node-centric network, certain nodes are addressed by source nodes and packets should be delivered to these nodes.
12	**What is meant by Layered Architecture? BTL 1** A layered architecture has a single powerful base station, and the layers of sensor nodes around it correspond to the nodes that have the same hop-count to the BS. In the in-building scenario, the BS acts an access point to a wired network, and small nodes form a wireless backbone to provide wireless connectivity.
13	**What are the two basic kinds of sensor network architecture? BTL 1** Layered Architecture and Clustered Architecture are the two basic kinds of sensor network architecture
14	**How wakeup radio concept is adopted in WSN? BTL 2** The node will be always in the receiving state when a packet is transmitted to it, in the transmitting state when it transmits a packet, and in the sleep state at all other times; the idle state is avoided.
15	**What are the communication patterns in sensor networks? BTL 1** Broadcast : Base station transmits message to all its immediate neighbors. Converge cast : a group of sensors communicates to a specific sensor Local gossip: a sensor node sends a message to its neighboring nodes within a range**.**
16	**What are the design factors of a WSN? BTL 1** (i)Fault Tolerance (ii)Scalability (iii)Production Costs (iv)Hardware Constraints (v)Sensor Network Topology (vi)Environment (vii)Transmission Media (viii)Power Consumption
17	**How do clusters communicate? BTL 2** Whether clusters overlap or not, a node that is adjacent to two cluster heads can assist in the communication between two clusters – it forms a gateway (other names are bridge, boundary node). The idea is that intra cluster communication can be routed via the cluster heads, then use the gateways for any inter cluster communication.
18	**Explain how clustering solves the issue of scalability of WSN network. BTL 2** Clustering allows hierarchical structures to be built on the nodes and enables more efficient use of scarce resources, such as frequency spectrum, bandwidth, and power. Clustering can be used to thin out parts of the network where an excessive number of nodes may be present. A simplified long range communication network can be set up using only cluster-heads and gateways—all other nodes communicate via their cluster-head

19 **What is the role of cluster head? BTL 1**

The role of cluster head is to organize medium access within the cluster and participate in routing decisions.

20 **Define hierarchical network. BTL 2**

In a hierarchical network topology, some nodes assume special roles. Cluster based network is an example for hierarchical network. In cluster based network, cluster heads have control over other nodes in the cluster.

21 **Define data centric network. BTL 1**

In data centric network, the set of target nodes is only implicitly described by providing certain attributes that these nodes have to fulfill.

22 **What is UNPF? BTL 1**

UNPF is a set of protocols for complete implementation of a layered architecture for sensor networks

23 **Distinguish between Bluetooth vs IEEE 802.15.4. BTL 4**

Bluetooth	**IEEE 802.15.4**
Bluetooth based WPAN	IEEE 802.15.4 LR-WPAN
Data range is 10m to 100m	Data range is nearly 10m
Data rate is nearly 1Mb/s	Data rate is 20 kb/s,40kb/s,250kb/s.
Power consumption is a low.	Power consumption is ultra low
Few devices	Many devices
Battery life is low	Battery lasts years. peer to peer,Star

24 **What are the three operations in UNPF protocol structure? BTL 1**

Network initialization and maintenance, MAC protocol, Routing protocol

25 **What are the characteristics of IEEE 802.15.4? BTL 1**

(i).IEEE 802.15.4 LR-WPAN (ii).Data range is nearly 10m (iii).Data rate is 20 kb/s,40kb/s,250kb/s. (iv)Power consumption is ultra low. (v)Battery lasts years. (vi) peer to peer,Star.

PART-B

1 **State and explain the various hardware components and their composition into functioning node of a WSN. (April/May 2016)BTL 5**

Introduction (4m)

Hardware subsystem of a sensor node(9m)

- Computing subsystem
- Power supply subsystem
- Communication subsystem
- Sensing subsystem

2 **Write notes on single node architecture with block diagrams BTL 2**

Single node architecture(8m)

- Sensing unit
- Processing unit
- Communication unit
- Power supply unit

	Block diagram(5m)
3	**i) Explain the wireless MAC protocols in WSN. (Nov/Dec 2018) BTL 2** Self organizing MAC for sensor networks**(2m)** Network initialization Link layer Organization Neighbor Discovery ChannelAssignment Eavesdrop and register MAC protocol**(2m)** Static nodes Mobile sensor nodes Operation of EAR protocol**(2m)** Broadcast invitation Mobile invite Mobile response Mobile Disconnect Three Phases: **(4m)** Registration phase Connection phase Disconnection phase Hybrid TDMA/FDMA CSMA- based MAC protocols**(3m)** S-MAC T-MAC D-MAC B-MAC X-MAC WISE-MAC
4	**Write short notes on data relaying and data aggregation strategies. BTL 2** **Data Relaying:** (3m) Event and sink node Data diffusion Algorithms used(4m) Flooding Gossiping Rumor routing Sequential assignment routing Directed diffusion **Data Aggregation Strategies:** (6m) Continuous packet sensing and dissemination(CPSD) Continuous packet collection and Dissemination(CPCD) Continuous packet Aggregation and Dissemination(PPAD) Programmed demand based aggregation and dissemination(PDAD) Weighted event and demand based data aggregation (WEDDA)
5	**Explain the physical and MAC layer protocols defined by IEEE 802.15.4. BTL 2** Introduction(2m) Services and features of IEEE 802.15.4(2m)

	IEEE 802.15.4. topologies(3m) Star Topology Peer to Peer topology IEEE 802.15.4 protocol stack(6m) Physical layer MAC layers Other Layers
PART-C	
1	**Explain in detail the mechanisms that form typical parts of WSNs BTL 2** Basic concepts **(3m)** Subsystems of sensor nodes**(5m)** Advantages and limitations of sensor networks**(5m)**
2	**Describe the hardware and software subsystems of a typical sensor node in detail. BTL 3** Introduction(1m) Hardware subsystem of a sensor node(6m) Computing subsystem Power supply subsystem Communication subsystem Sensing subsystem **Software subsystem of a sensor node**(6m) Operating System Microcode Sensor drivers Communication processor Communication drivers Data Processingmimi-apps
3	**Explain some of the schedule based MAC protocols in WSN.** BTL 2 Self organizing MAC for sensor networks**(2m)** Network initialization Link layer Organization Neighbor Discovery ChannelAssignment Eavesdrop and register MAC protocol**(2m)** Static nodes Mobile sensor nodes Operation of EAR protocol**(2m)** Broadcast invitation Mobile invite Mobile response Mobile Disconnect Three Phases: **(4m)** Registration phase Connection phase Disconnection phase Hybrid TDMA/FDMA CSMA- based MAC protocols**(3m)**

	S-MAC T-MAC D-MAC B-MAC X-MAC WISE-MAC
UNIT V WSN ROUTING, LOCALIZATION & QOS ssues in WSN routing – OLSR- Localization – Indoor and Sensor Network Localization-absolute nd relative localization, triangulation-QOS in WSN-Energy Efficient Design-Synchronization-Transport Layer issues.	
PART-A	
1	**What are the high –level Qos attributes in WSN? BTL 1** Event detection/ reporting probability, Event classification error, Event detection delay, Missing reports, approximation accuracy and tracking accuracy.
2	**Define positioning accuracy and precision with respect to localization. BTL 2** Positioning accuracy is the largest distance between the estimated and the true position of an entity (high accuracy indicates a small maximal mismatch). Precision is the ratio with which a given accuracy is reached, averaged over many repeated attempts to determine a position.
3	**Define QOS. BTL 1** QOS is closely related to the type of a network's service is the quality of that service which is the amount and quality of information that can be extracted at given sinks about the observed objects or area. Therefore, adapted quality concepts like reliable detection of events or the approximation quality of a, say, temperature map is important. .
4	**What are the assumptions made for geographical routing? BTL 1** A typical assumption is that the location of the target is known.
5	**Highlight the salient feature of location-based routing. BTL 3** For many applications, it is necessary to address physical locations, for example, as "any node in a given region" or "the node at/closest to a given point". When such requirements exist, they have to be supported by a proper routing scheme.When the position of source and destination is known as are the positions of intermediate nodes, this information can be used to assist in the routing process.
6	**Define localization. BTL 2** In many circumstances, it is useful or even necessary for a node in a wireless sensor network to be aware of its location in the physical world. For example, tracking or event-detection functions are not particularly useful if the WSN cannot provide any information where an event has happened. Manually configuring location information into each node during deployment is not an option. Similarly, equipping every node with a Global Positioning System (GPS) receiver fails because of cost and deployment limitations. Localization is the process of finding the physical position of a sensor node. Three main approaches exist to determine a node's position: Using information about a node's neighborhood (proximity-based approaches), exploiting geometric properties of a given scenario (triangulation and trilateration), and trying to analyze characteristic properties of the position of a node in comparison with premeasured properties (scene

	analysis).
7	**Highlight the salient feature of location-based routing. BTL 2** For many applications, it is necessary to address physical locations, for example, as "any node in a given region" or "the node at/closest to a given point". When such requirements exist, they have to be supported by a proper routing scheme. When the position of source and destination is known as are the positions of intermediate nodes, this information can be used to assist in the routing process.
8	**What are the assumptions made for geographical routing? BTL 1** A typical assumption is that the location of the target is known
9	**Define data centric storage. BTL 1** Accompanying the data-centric networking development are some considerations on *storing* data within the network. The name of the data is used to represent a key under which the data can be looked up.
10	**Give some examples of unicast protocols. BTL 1** Distance vector routing on top of topology control, Maximizing time to first node outage as a flow problem
11	**Define network life time. BTL 1** Network life time is defined as the time until the first node fails or runs out of energy. Or it is the time until the network is disconnected in two or more partitions, the time until 50% or some other fixed ratio of nodes have failed, or the time when for the first time a point in the observed region is no longer covered by at least a single sensor node..
12	**Define energy scavenging. BTL 1** Energy scavenging is defined as recharging the battery with energy gathered from the environment – solar cells or vibration-based power generation are conceivable options.
13	**Mention various performance metrices of WSN. BTL 1** Quality of service, Energy efficiency, Scalability, Robustness
14	**What are the various schemes for improving quality of wireless channels? BTL 1** Optimization of transmission parameters, Diversity mechanisms, Equalization, Forward error correction, ARQ
15	**Give two examples for time synchronization protocols based on sender/receiver synchronization. BTL 1** Lightweight time synchronization (LTS) protocol, Timing-Sync Protocol for Sensor Networks (TPSN)
16	**List the time synchronization protocols based on receiver/receiver synchronization. BTL 1** Reference broadcast synchronization (RBS) protocol, Hierarchy Referencing Time Synchronization (HRTS) protocol.
17	**What are the important performance metrics of time synchronization algorithms? BTL 1** Precision: maximum synchronization error between a node and real time or between two nodes, the mean error, the error variance are relevant quantities. Energy costs the energy costs of a time synchronization protocol depend on several factors: the number of packets exchanged in one round of the algorithm, the amount of computation needed to process the packets, and the required resynchronization frequency. Memory requirements to estimate drift rates, a history of previous time synchronization

	packets is needed. In general, a longer history allows for more accurate estimates at the cost of increased memory consumption. Fault tolerance: How well can the algorithm cope with failing nodes, with error-prone and time variable communication links.
18	**What are the four conceptual building blocks of time synchronization protocols? BTL 1** Resynchronization event detection block, remote clock estimation block, clock correction block, and synchronization mesh setup block
19	**Distinguish between lateration and angulation. BTL 1** In addition to mere connectivity/proximity information, the communication between two nodes often allows to extract information about their geometric relationship. For example, the distance between two nodes or the angle in a triangle can be estimated. Using elementary geometry, this information can be used to derive information about node positions. When distances between entities are used, the approach is called lateration; when angles between nodes are used, the approach is called angulation.
20	**What are the three main approaches to determine a node's position? BTL 1** Three main approaches exist to determine a node's position: • Using information about a node's neighborhood (proximity-based approaches), • Exploiting geometric properties of a given scenario (triangulation and trilateration), • Trying to analyze characteristic properties of the position of a node in comparison with premeasured properties (scene analysis).
21	**.Name the measurable figures of merit. BTL 1** Energy per correctly received bit, energy per reported (unique) event, Delay/energy trade-offs, Network lifetime.
22	**Define WSN tunneling. BTL 1** WSN tunneling is defined as connecting two WSNs with a tunnel over the Internet. All protocol messages are tunneled between these two networks and simply using the Internet as a transport network
23	**What are the high –level Qos attributes in WSN? BTL 1** Event detection/ reporting probability, Event classification error, Event detection delay, Missing reports, approximation accuracy and tracking accuracy.
24	**Define positioning accuracy and precision with respect to localization. BTL 1** Positioning accuracy is the largest distance between the estimated and the true position of an entity (high accuracy indicates a small maximal mismatch). Precision is the ratio with which a given accuracy is reached, averaged over many repeated attempts to determine a position.
25	**Define QOS. BTL 1** QOS is closely related to the type of a network's service is the quality of that service which is the amount and quality of information that can be extracted at given sinks about the observed objects or area. Therefore, adapted quality concepts like reliable detection of events or the approximation quality of a, say, temperature map is important. .
	PART-B
1	**Write short notes on Quality of Service. (April/May 2015) BTL 1** **QOS Parameters**(1m) Throughtput Delay

	Jitter Packet loss rate **Qos Challenges**(1m) Resource constraints Redundant data Dynamic network topology Less reliable medium Mixed traffic **Quality Of sensor Network**(1m) Coverage Exposure
2	**i) Explain about Energy efficient routing protocol for WSNs. BTL 2** Dynamic Voltage scaling(5m) Software **i) Describe in detail the types of data aggregation operations. (Nov/Dec 2016)BTL 2** **Data Aggregation Strategies:** (8m) Continuous packet sensing and dissemination(CPSD) Continuous packet collection and Dissemination(CPCD) Continuous packet Aggregation and Dissemination(PPAD) Programmed demand based aggregation and dissemination(PDAD) Weighted event and demand based data aggregation (WEDDA)
3	**Explain Localization in WSNs. BTL 2** Introduction(1m) Types Of Localization: (12m) GPS based Localization Indoor Localization Absolute Localization Relative Localization Triangulation Localization
4	**Explain about Transport layer issues in wireless sensor networks. (Nov/Dec 2018) BTL 2** Challenges(1) Pump slowly ,Fetch quickly protocol(6m) Error recovery Protocol Functions Message relaying Relay initiated error recovery Selective status reporting Event to Sink reliable Transport (ESRT) protocol(6m) Self Configuration Energy awareness Congestion control Collective identification Biased Implementation

5	**i) Discuss any two energy optimal localization algorithm adopted in WSN. BTL 2** GPS based Localization(3m) Indoor Localization(3m) **ii) Explain any two time synchronization algorithm of Wireless Sensor Network. BTL 2** Synchronization and its types (7m) Time Synchronization Low power Synchronization Global Synchronization Clock Synchronization
PART-C	
1.	**Discuss on the energy efficient design of sensor nodes. BTL 2** Introduction (3m) Dynamic Voltage scaling(6m) Software (4m)
2.	**Write short notes on OLSR BTL 1** Introduction(2m) Basic concepts(2m) Neighbor Discovery(4m) Hello message Topology control message Mutiple interface Declaration Topology Dissemination(3m) Route Computation(2m)
3.	**Discuss about transport layer issues in WSN. BTL 2** Introduced Traffic(2m) Induced throughput unfairness(2m) Power and bandwidth constraints(2m) Misinterpretation of congestion(2m) Completely decoupled transport layer(2m) Dynamic topology(3m)

Prepared by
Name and Signature of the Faculty

Approved by
Name and Signature of HoD

CS6007 INFORMATION RETRIEVAL L T P C 3 0 0 3

OBJECTIVES:

- The Student should be made to:
- Learn the information retrieval models.
- Be familiar with Web Search Engine be exposed to Link Analysis.
- Understand Hadoop and Map Reduce.
- Learn document text mining techniques.

UNIT I INTRODUCTION 9

Introduction -History of IR- Components of IR - Issues –Open source Search engine Frameworks the impact of the web on IR - The role of artificial intelligence (AI) in IR – IR Versus Web Search Components of a Search engine- Characterizing the web.

UNIT II INFORMATION RETRIEVAL 9

Boolean and vector-space retrieval models- Term weighting - TF-IDF weighting- cosine similarity – Preprocessing - Inverted indices - efficient processing with sparse vectors – Language Model based IR - Probabilistic IR –Latent Semantic Indexing - Relevance feedback and query expansion.

UNIT III WEB SEARCH ENGINE –INTRODUCTION AND CRAWLING 9

Web search overview, web structure, the user, paid placement, search engine optimization/ spam. Web size measurement - search engine optimization/spam – Web Search Architectures - crawling Meta-crawlers- Focused Crawling - web indexes –- Near-duplicate detection - Index Compression XML retrieval.

UNIT IV WEB SEARCH – LINK ANALYSIS AND SPECIALIZED SEARCH 9

Link Analysis –hubs and authorities – Page Rank and HITS algorithms -Searching and Ranking – Relevance Scoring and ranking for Web – Similarity - Hadoop & Map Reduce - Evaluation Personalized search - Collaborative filtering and content-based recommendation of documents and products – handling "invisible" Web - Snippet generation, Summarization, Question Answering, Cross Lingual Retrieval.

UNIT V DOCUMENT TEXT MINING 9

Information filtering; organization and relevance feedback – Text Mining -Text classification and clustering - Categorization algorithms: naive Bayes; decision trees; and nearest neighbour - Clustering algorithms: agglomerative clustering; k-means; expectation maximization (EM).

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of the course, students will be able to

- Apply information retrieval models.
- Design Web Search Engine.
- Use Link Analysis.
- Use Hadoop and Map Reduce.
- Apply document text mining techniques.

TEXT BOOKS:

1. C. Manning, P. Raghavan, and H. Schütze, Introduction to Information Retrieval , Cambridge University Press, 2008.
2. Ricardo Baeza -Yates and Berthier Ribeiro - Neto, Modern Information Retrieval: The Concepts and Technology behind Search 2nd Edition, ACM Press Books 2011
3. Bruce Croft, Donald Metzler and Trevor Strohman, Search Engines: Information Retrieval in Practice, 1st Edition Addison Wesley, 2009.
4. Mark Levene, An Introduction to Search Engines and Web Navigation, 2nd EditionWiley, 2010.

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1. Stefan Buettcher, Charles L. A. Clarke, Gordon V. Cormack, Information Retrieval: Implementing and Evaluating Search Engines, The MIT Press, 2010.
2. Ophir Frieder "Information Retrieval: Algorithms and Heuristics: The Information Retrieval Series ", 2nd Edition, Springer, 2004.
3. Manu Konchady, "Building Search Applications: Lucene, Ling Pipe", and First Edition, Gate Mustru 2007.

Subject Code: CS6007 **Year/Semester: IV/07**
Subject Name: INFORMATION RETRIEVAL **Subject Handler: N.GLADISS MERLIN**

UNIT I – INTRODUCTION

Introduction - History of IR - Components of IR - Issues – Open source Search engine Frameworks - The impact of the web on IR - The role of artificial intelligence (AI) in IR – IR Versus Web Search - Components of a Search engine - Characterizing the web

PART * A

Q.No.	Questions
1.	**What is information retrieval? (Nov/Dec'16)**BTL1 Information Retrieval is finding material of an unstructured nature that satisfies an information need from within large collections.
2	**List out the components of IR block diagram.** BTL1 • **Input** – Store Only a representation of the document • **A document representative** – Could be list of extracted words considered to be significant. • **Processor** – Involve in performance of actual retrieval function • **Feedback** – Improve • **Output** – A set document numbers.
3	**What is objective term and non-objective term?** BTL1 **Objective Terms** – Are extrinsic to semantic content, and there is generally no disagreement about how to assign them. **Nonobjective Terms** – Are intended to reflect the information manifested in the document, and there is no agreement about the choice or degree of applicability of these terms.
4	**Write the type of natural language technology used in information retrieval.** BTL1 Two types • Natural language interface make the task of communicating with the information source easier, allowing a system to respond to a range of inputs. • Natural Language text processing allows a system to scan the source texts, either to retrieve particular information or to derive knowledge structures that may be used in accessing information from the texts.
5	**What is search engine?** BTL1 A search engine is a document retrieval system design to help find information stored in a computer system, such as on the WWW. The search engine allows one to ask for content meeting specific criteria and retrieves a list of items that match those criteria.
6	**What is conflation?** BTL1 Stemming is the process for reducing inflected words to their stem, base or root form, generally a written word form. The process of stemming is often called as conflation.
7	**What is an invisible web?** BTL1 Many dynamically generated sites are not index able by search engines; This phenomenon is known as the invisible web.
8	**Define Zipf's law**BTL1 An empirical rule that describes the frequency of the text words. It state that the i^{th} most frequent word appears as many times as the most frequent one divided by i^{θ}, for some $\theta > 1$.

9	**What is open source software?** BTL1 Open source software is software whose source code is available for modification or enhancement by anyone. "Source code" is the part of software that most computer users don't ever see; it's the code computer programmers can manipulate to change how a piece of software—a "program" or "application"—works. Programmers who have access to a computer program's source code can improve that program by adding features to it or fixing parts that don't always work correctly.
10	**What is proprietary software?** BTL1 Proprietary software is computer software which is the legal property of one party. The term of use for other parties is defined by contracts or licensing agreements. These terms may include various privileges to share, alter, dissemble, and use the software and its code.
11	**What is closed software?** BTL1 Closed software is a term for software whose license does not allow for the release or distribution of the software's source code. Generally it means only the binaries of a computer program are distributed and the license provides no access to the programs source code. The source code of such programs is usually regarded as a trade secret of the company. Access to source code by third parties commonly requires the party to sign a non-disclosure agreement.
12	**List the advantage of open source**BTL1 • The right to use the software in any way. • There is usually no license cost and free of cost. • The source code is open and can be modified freely. • Open standards. • It provides higher flexibility.
13	**List the disadvantage of open source.** BTL1 • There is no guarantee that development will happen. • It is sometimes difficult to know that a project exist, and its current status. • No secured follow-up development strategy.
14	**What are the reasons for selecting open software?** BTL1 • Development and maintenance of open source software is a community based activity. • Open source software licenses are copyright protected they strictly ensure the user freedom to use, modify and distribute the programs. • Is interoperable customizable according to the needs and fulfills the software industry standards. • Open source software allows everyone to use, study, modify and distribute the software. • Allows a broader perspective when comes to its support.
15	**What do you mean by Apache License?** BTL1 The Apache License is a free software license written by the Apache Software Foundation (ASF). The name Apache is a registered trademark and may only be used with the trademark holders express permission. Apache license is a high performance, Full-featured text search engine library written entirely in Java.
16	**Write the features of GPL version2.** BTL1 • It gives permission to copy and distribute the programs unmodified source code. It allows modifying the programs source code and distributing the modified source code. • User distributes compiled versions of the program, both modified and unmodified. • All modified copies are distributed under the GPL v2. • All compiled versions of the program are accompanied by the relevant source code.
17	**Outline the impact of the Web on information retrieval. (Apr/May'17)** BTL1 Finding the documents relevant to user queries. Technically IR studies the acquisition, organization, storage, retrieval and distribution of information.

18	**Specify the role of an IR system. (Nov/Dec'1)**BTL1 • The role of an IR system • Support the user in • Exploring a problem domain, understanding its terminology, concepts and structure • Clarifying, refining and formulating an information need • Finding documents that match the information need description • As many relevant documents as possible • As few non-relevant documents as possible.
19	**What is Peer-to-peer Search? (Nov/Dec'17)** BTL1 Peer-to-Peer Search which currently means storing files in a directory that is accessible by people outside a local network. Essentially, this is file sharing with the entire Internet. Other uses include reducing corporate server bandwidth bottlenecks, storing enterprise data, distributed processing, knowledge management aggregation, collaboration, automatically distributing updates for software and real-time updating such as auctions and news syndication.
20	**What are the performance measures for search engine? (Nov/Dec'17)**BTL1 • Effectiveness (quality of results) • Efficiency (response time and throughput).
21	**Give any two advantages of using artificial intelligence in information retrieval tasks. (Apr/May'18)** BTL1 • Focused on the representation of knowledge, reasoning and intelligent action • Formalisms for representing knowledge and queries
22	**How does the large amount of information available in web affect information retrieval system implementation? (Apr/May'18)** BTL1 • Distributed data • Volatile data • Large Volume • Unstructured and redundant data • Quality of data • Heterogeneous data
23	**State the difficulties faced in Information retrieval.** BTL1 • Vocabularies mismatching (synonyms, polysemy) • Queries are ambiguous, they are partial specification of user's need • Content representation may be inadequate and incomplete • The notion of relevance is imprecise, context and user-dependent
PART * B	
1	**Appraise the history of IR. (8M) (Apr/May '17)** BTL5 **Answer: Page 6-9 - Ricardo Baez** • Finding material - unstructured nature (4 M) • Historical mile stones (4 M)
2	**Explain in detail about the components of IR. (13 M) (Nov/Dec '16)** BTL1

	Answer: Page No. 9-10 - Ricardo Baeza Architecture (2 M) ***Components:*** • Text operations (3 M) • Indexing (2 M) • Searching (2 M) • Ranking (2 M) • Query operations (2 M)
3	**Explain the issues in the process of Information Retrieval. (8M) (Nov/Dec'17)** (BTL1) **Answer: Page 4-6 - Bruce Croft** • Relevance (4 M) • Evaluation (2 M) • Emphasis information (2M)

3	**Discuss in detail about the framework of Open Source Search engine with necessary diagrams.(13M)** BTL2
	Answer: Page 27-28 - Stefan Buettcher
	
	Nutch:
	• Architecture (2 M)
	• Four major components (3 M)
	    • Searcher
	    • Indexer
	    • Database
	    • Fetcher
	• Crawling (2 M)
	• Indexing text (2 M)
	• Indexing hypertext (1 M)
	• Removing duplicates (1 M)
	• Link analysis (1 M)
	• Summarizing (1 M)

5	**Explain the Role of AI in IR. (8M) (Nov/Dec'16)** BTL3 **Answer: Page 1.19 – 1.20 - I.A.Dhotre** • AI (1 M) • NLP (2 M) • NLP techniques (2 M) • Two types - Natural language technology (2M) • Applying NLP **(2M)**
6	**Differentiate Information Retrieval from Web Search. (8M) (Nov/Dec'17)** BTL4 **Answer: Page 1-2 - Ricardo Baez** Language, File types, Document length, Document structure, Spam, amount of data, size, queries, ranking etc., (8M)
8	**Write a short note on Characterizing the web for search. (8M)(Nov/Dec'16)** BTL4 **Answer: Page 367-371 - Ricardo Baez**

	• Measuring web (4 M) • Modeling web (4 M)
	PART * C
1	**What is search engine? Explain with diagrammatic illustration the components of a search engine. (15M)(Apr/May'18)** BTL2 **Answer: Page 13-16 - Bruce Croft** • Search engine-collecting information. (4 M) • Architecture - search engine. (4 M) • Indexing process. (4 M) • Querying process. (3M)
2	**Examine the various impact of WEB on IR. (15M**)BTL1 **Answer: Page 27-28 -Stefan Buettcher** • Heterogeneity (4M) • Web information (3 M) • Inexperienced users (4 M) • Software tools (2 M) • Multimedia information (2 M)

UNIT II - INFORMATION RETRIEVAL	
Boolean and vector-space retrieval models - Term weighting - TF-IDF weighting - cosine similarity – Preprocessing - Inverted indices - efficient processing with sparse vectors – Language Model based IR - Probabilistic IR – Latent Semantic Indexing - Relevance feedback and query expansion.	
PART * A	
Q.No.	**Questions**
1.	**What do you mean information retrieval models?** BTL1 A retrieval model can be a description of either the computational process or the human process of retrieval: The process of choosing documents for retrieval; the process by which information needs are first articulated and then refined.
2	**What is cosine similarity?** BTL1 This metric is frequently used when trying to determine similarity between two documents. Since there are more words that are in common between two documents, it is useless to use the other methods of calculating similarities.
3	**What is language model based IR?** BTL1 A language model is a probabilistic mechanism for generating text. Language models estimate the probability distribution of various natural language phenomena.
4	**Define unigram language.** BTL1 A unigram (1-gram) language model makes the strong independence assumption that words are generated independently from a multinomial distribution.
5	**What are the characteristics of relevance feedback?** BTL1 • It shields the user from the details of the query reformulation process. • It breaks down the whole searching task into a sequence of small steps which are easier to grasp. • Provide a controlled process designed to emphasize some terms and de-emphasize others.
6	**What are the assumptions of vector space model?** BTL1 • Assumption of vector space model: • The degree of matching can be used to rank-order documents • This rank-ordering corresponds to how well a document satisfying a user's information needs.
7	**What are the disadvantages of Boolean model?** BTL1 • It is not simple to translate an information need into a Boolean expression • Exact matching may lead to retrieval of too many documents. • The retrieved documents are not ranked. • The model does not use term weights.
8	**Define term frequency.** BTL1 Term frequency: Frequency of occurrence of query keyword in document.
9	**Explain Luhn's ideas.** BTL1 Luhn's basic idea to use various properties of texts, including statistical ones, was critical in opening handling of input by computers for IR. Automatic input joined the already automated output.
10	**What is stemming? Give example. (Apr/May'17)** BTL1 Stemming is the process to replace all the variants of a word with the single stem of the word. Variants include plurals, gerund forms (ing-form), third person suffixes, past tense suffixes, etc., Example: connect: connects, connected, connecting, connection etc., Stemming is either based on linguistic dictionaries or on algorithms.

11	**What is Recall?** BTL1 Recall is the ratio of the number of relevant documents retrieved to the total number of relevant documents retrieved
12	**What is precision?** BTL1 Precision is the ratio of the number of relevant documents retrieved to the total number of documents retrieved.
13	**Explain Latent semantic Indexing.** BTL1 Latent Semantic Indexing is a technique that projects queries and documents into a space with “latent” Semantic dimensions. It is statistical method for automatic indexing and retrieval that attempts to solve the major problems of the current technology. It is intended to uncover latent semantic structure in the data that is hidden. It creates a semantic space where in terms and documents that are associated are placed near one another.
14	**List the retrieval models. (Nov/Dec’16)** BTL1 • Boolean model • Vector space model • Language model • Probabilistic model
15	**Define document preprocessing. (Nov/Dec’16)** BTL1 The document processing is a procedure which takes documents as input and converts it into a structure by number of transformations. Document pre-processing includes 5 stages of transformations: • Lexical analysis • Stop word elimination • Stemming • Index-term selection • Construction of term categorization structures
16	**Define an inverted index. (Apr/May’17)**BTL1 An inverted index is a list of all documents containing that word • The index may be a bit vector • It may also contain the location(s) of the word in the document
17	**What is Zone index? (Nov/Dec’17)** BTL1 Zones are similar to fields, except the contents of a zone can be arbitrary free text. Whereas a field may take on a relatively small set of values, a zone can be thought of as an arbitrary, unbounded amount of text. For instance, document titles and abstracts are generally treated as zones.
18	**State Bayes rule. (Nov/Dec’17)** BTL1 The theorem provides a way to revise existing predictions or theories given new or additional evidence. In finance, Bayes' theorem can be used to rate the risk of lending money to potential borrowers. The formula is as follows: $P(A\|B) = \frac{P(A \cap B)}{P(B)} = \frac{P(A) * P(B\|A)}{P(B)}$ Bayes' theorem is also called Bayes' Rule or Bayes' Law.
19	**Can the tf-idf weight of a term in a document exceed 1? Why? (Apr/May’18)** BTL1 Yes, the tf-idf weight of a term in a document exceed 1. TF-IDF is a family of measures for scoring a term with respect to a document (relevance). The simplest form of TF (word, document) is the number of times

	word appears in document. TFIDF can be 1 in the naive case, or to add the IDF effect, just do it log(number of documents/number of documents in which word is present).
20	**Consider the two texts, “Tom and Jerry are friends” and “Jack and Tom are friends”. What is the cosine similarity for these two texts? (Apr/May’18)** BTL1 Here are two very short texts to compare: • “Tom and Jerry are friends” • “Jack and Tom are friends” We want to know how similar these texts are, purely in terms of word counts (and ignoring word order). We begin by making a list of the words from both texts: Tom and Jerry are friends Jack Now we count the number of times each of these words appears in each text: Tom 1 1 and 1 1 Jerry 1 0 are 1 1 friends 1 1 Jack 0 1 B: [1,1,0,1,1,1] The cosine similarity for these two texts is 0.83.
21	**What is Boolean Model?** BTL1 Index terms are considered to be either present or absent in a document and to provide equal evidence with respect to information needs. A document is represented as set of keywords. Queries are Boolean expression of keywords connected by AND, OR and NOT including the use of brackets to indicate scope. [[Rio & Brazil] | [Hilo & Hawaii]] & hotel &! Hilton]
22	**What are the advantages of Boolean retrieval model?** BTL1 • Easy to understand for simple queries • Clean formalism • Boolean models can be extended to include ranking • Reasonably efficient implementation possible for normal queries
23	**Define Vector space model.** BTL1 In this model, documents and queries are assumed to be part of t-dimensional vector space, where t is the number of index terms (words, stems, phrases etc.). A document D_i is represented by a vector of index terms: $D_i = (d_{i1}, d_{i2}, \ldots\ldots d_{ij})$ where d_{ij} represents the weight of the jth term.
24	**What is Inverse document frequency?** BTL1 Terms that occur in many documents in the collection are less useful for discriminating among documents. If a term appears in all documents in a set, then it loses its distinguishing power. The inverse document frequency (idf) of a term i is given by: $idf_i = \log(N/n_i)$ Where n_i is the number of documents in which the term i occurs N is the total number of documents
25	**Define tf-idf weighting** BTL1 A term occurring frequently in the document but rarely in the rest of the collection is given high weight. A typical combined term importance is tf-idf weighting: $W_{if} = tf_{ij}\ idf_i = if_{ij} \log_2(N/df_i)$

PART * B

1	**Explain Boolean model with an example. (8M)** BTL1 **Answer: Page 1-15 - C. Manning Text** • Boolean model • Boolean Relevance • Implementation • Advantages	 (2 M) (2 M) (2 M) (2 M)
2	**Explain vector space retrieval model with an example. (10M) (Apr/May'17)** BTL1 **Answer: Page No. 237-243 - Bruce Croft** • Vector space retrieval model concepts • Vector representation – documents, Queries • Vector space retrieval model • Advantage • Disadvantage	 (2 M) (2 M) (2 M) (2 M) (2 M)
3	**Briefly explain weighting. (8M) (Nov/Dec'16)** BTL1 **Answer: Page No. 107-110 - C. Manning** • Weighting scheme • Idf • Tf-idf weighting	 (4 M) (2 M) (2 M)
4	**Briefly explain cosine similarity. (8M) (Nov/Dec'16)** BTL1 **Answer: Page 2.11-I.A.Dhotre** • Metric frequently - find similarity • Cosine similarity representation	 (4 M) (4 M)
5	**Explain the inverted indices in detail. (8M)** BTL1 **Answer: Page No. 33-45 - Stefan Buettcher** • Phrase search • Implementing inverted indices • Documents and other elements	 (2 M) (4 M) (2 M)
6	**Explain the Probabilistic IR model in detail. (8M) (Nov/Dec'17)** BTL1 **Answer: Page 201-216 - C. Manning** • Basic probability theory • Probability Ranking Principle • Binary independence model	 (2 M) (4 M) (2 M)
7	**Give an example for latent semantic indexing and explain the same. (13 M) (Apr/May'17)** BTL1 **Answer: Page 2.18-2.19 - I.A.Dhotre** • Semantic indexing • General idea • Goal- indexing • Example	 (4 M) (4 M) (4 M) (1 M)
8	**Write about query expansion. (8 M) (Nov/Dec'16)** BTL1	

	Answer: Page No.173 to 176 - C. Manning • Query Expansion (2 M) • Automatic thesaurus generation (4M) • Example (2 M)
	PART*C

1	**What is relevance feedback? Explain the different types of relevance feedback and also explain with an example an algorithm for relevance feedback. (15 M) (Nov/Dec'16)** BTL1
	Answer: Page 163 to 172 - C. Manning
	
	• Relevance feedback and pseudo relevance
	    • The Rocchio algorithm (3M)
	    • Probabilistic relevance feedback (2M)
	    • Relevance feedback work (2M)
	    • Relevance feedback –web (2M)
	    • Relevance feedback strategies (2M)
	    • Pseudo relevance feedback (2M)
	    • Indirect relevance feedback (2M)

2	**Explain the Language model IR in detail. (15 M)(Apr/May'18)** BTL1 **Answer: Page 2.14 -2.15 -I.A.Dhotre,** • Finite automata and language models (6 M) • Types of language models (2 M) • Unigram Language Model (4 M) • N-gram Language Model (3 M)
3	**Explain the preprocessing in detail. (15M)** BTL1 **Answer: Page 86-97 - Bruce Croft** • Stop word removal (4 M) • Stemming (4 M) • Text preprocessing (4 M) • Web page preprocessing (3M)

UNIT III - WEB SEARCH ENGINE – INTRODUCTION AND CRAWLING

Web search overview, web structure, the user, paid placement, search engine optimization/ spam. Web size measurement - search engine optimization/spam – Web Search Architectures - crawling - meta-crawlers- Focused Crawling - web indexes –- Near-duplicate detection - Index Compression – XML retrieval.

PART * A

Q.No.	Questions
1.	**Define web server.** BTL1 Web server is a computer connected to the internet that runs a program that takes responsibility for storing, retrieving and distributing some of the web files.
2	**What is web Browsers?** BTL1 A web browser is a program. Web browser is used to communicate with web servers on the Internet, Which enables it to download and display the web pages. Netscape Navigator and Microsoft Internet Explorer are the most popular browser software’s available in market.
3	**Define paid submission of search service.** BTL1 In paid submission user submit website for review by a search service for a preset fee with the expectation that the site will be accepted and included in that company’s search engine, provided it meets the stated guidelines for submission. Yahoo! is the major search engine that accepts this type of submission. While paid submissions guarantee a timely review of the submitted site and notice of acceptance or rejection, you’re not guaranteed inclusion or a particular placement order in the listings.
4	**State paid inclusion programs of search services.** BTL1 Paid inclusion programs allow you to submit your website for guaranteed inclusion in a search engines database of listings for a set period of time. While paid inclusion guarantees indexing of submitted pages or sites in a search database, you’re not guaranteed that the pages will rank well for particular queries.
5	**Define pay-for-placement.** BTL1 In pay-for-placement, you can guarantee a ranking in a search listing for the terms of your choice. Also known as paid placement, paid listing, or sponsored listings, this program guarantees placement in search results. The leaders in pay-for-placement are Google, Yahoo! and Bing.
6	**Define Search Engine Optimization.** BTL1 Search Engine Optimization is the act of modifying a website to increase its ranking in organic, crawler-based listing of search engines. There are several ways to increase the visibility of your website through the major search engines on the internet today.
7	**Describe benefit of SEO.** BTL1 • Increase your search engine visibility • Generate more traffic from the major search engines • Make sure your website and business get NOTICED and VISITED • Grow your client base and increase business revenue
8	**What is web crawler? (Nov/Dec’16)** BTL1 A web crawler is a program which browses the world web in a methodical, automated manner. Web crawlers are mainly used to create a copy of all the visited pages for later processing by a search engine that will index the downloaded pages to provide fast searches.
9	**Define focused crawler.** BTL1

A focused crawler or topical crawler is a web crawler that attempts to download only pages that are relevant to a pre-defined topic or set of topic.

10 **What is hard and soft focused crawling?** BTL1

In **hard focused crawling** the classifier is invoked on a newly crawled document in a standard manner. When it returns the best matching category path, the out-neighbors of the page are checked into the database if and only if some node on the best matching category path is marked as good.
In **soft focused crawling** all out-neighbors of a visited page are checked into DB2, but their crawl priority is based on the relevance of the current page.

11 **Distinguish between SEO and Pay-per-click.** BTL1

S.No	SEO	Pay-Per-click
1	SEO results take 2 weeks to 4 months.	It results in 1-2 days.
2	It is very difficult to control flow of traffic.	It has ability to turn on and at any moment.
3	Requires ongoing learning and experience to reap results.	Easier for a novice.
4	It is more difficult to target local markets.	Ability to target “local” market.
5	Better for long-term and lower margin campaigns.	Better for short-term and high-margin campaigns.
6	Generally more cost-effective , does not penalize for more traffic.	Generally more costly per visitor and per conversion.

12 **What is the Near-duplicate detection?** BTL1

Near-duplicate is the task of identifying documents with almost identical content. Near- duplicate web documents are abundant. Two such documents differ from each other in a very small portion that displays advertisements, for example. Such differences are irrelevant and for web search.

13 **What are the requirements of XML information retrieval systems? (Nov/Dec’16)** BTL1

- Query language that allows users to specify the nature of relevant components, in particular with respect to their structure.
- Representation strategies providing a description not only of the content of XML documents, but also their structure.
- Ranking strategies that determine the most relevant elements and rank these appropriately for a given query.

14 **What is schema heterogeneity? (Apr/May’17)** BTL1

	In many cases, several different XML schemas occur in a collection since the XML documents in an IR application often come from more than one source. This phenomenon is called schema heterogeneity or schema diversity.
15	**What are the politeness policies used in web crawling? (Nov/Dec'17)** BTL1 Web servers have both implicit and explicit policies regulating the rate at which a crawler can visit them. These politeness policies must be respected.
16	**Define an inverted index. (Apr/May'17** BTL1 An inverted index is a list of all documents containing that word • The index may be a bit vector. • It may also contain the location(s) of the word in the document.
17	**What is inversion in indexing process? (Nov/Dec'18)** BTL1 An inverted index (also referred to as postings file or inverted file) is an index data structure storing a mapping from content, such as words or numbers, to its locations in a database file, or in a document or a set of documents (named in contrast to a forward index, which maps from documents to content). The purpose of an inverted index is to allow fast full text searches, at a cost of increased processing when a document is added to the database. The inverted file may be the database file itself, rather than its index. It is the most popular data structure used in document retrieval systems used on a large scale for example in search engines.
18	**How do spammers use cloaking to server spam to the web users? (Apr/May'17)** BTL1 Search engines soon became sophisticated enough in their spam detection to screen out a large number of repetitions of particular keywords. Spammers responded with a richer set of spam techniques, the best known of which we now describe. The first of these techniques is cloaking. Here, the spammer's web server returns different pages depending on whether the http request comes from a web search engine's crawler (the part of the search engine that gathers web pages) or from a human user's browser.
19	**Can a digest of the characters in a web page be used detect near duplicate web pages? Why?** BTL1 Yes. The simplest approach to detecting duplicates is to compute, for each web page, a fingerprint that is a succinct (say 64-bit) digest of the characters on that page. Then, whenever the fingerprints of two web pages are equal, we test whether the pages themselves are equal and if so declare one of them to be a duplicate copy of the other. This simplistic approach fails to capture a crucial and widespread phenomenon on the Web: near duplication. A solution to the problem of detecting near-duplicate web pages is shingling technique.

20	**Mention the processing steps in indexing process.** BTL1
	Indexing process:
	• Input: list of normalized tokens for each document
	• Sort the terms alphabetically
	• Merge multiple occurrences of the same term
	• Record the frequency of occurrence of the term in the document
	    o not needed by Boolean models
	    o used by vector space models
	• Group instances of the same term and split dictionary and postings

21	**List out the bitwise methods used in compression schemes for inverted lists.** BTL1 • Unary coding • Elias gamma coding • Delta coding • Golomb coding • Variable-byte scheme

22	**Differentiate Text centric and Data centric XML.** BTL1 **Text Centric** XML document retrieval is characterized by • Long text fields (e.g., section of a document) • In exact matching • Relevance ranked results • Relational databases do not deal well with this use case **Data Centric** Data centric XML mainly encodes numerical and non-text XML attribute-value data. When querying data-centric XML, we want to impose exact match conditions in most cases. This puts the emphasis on the structural aspects of XML documents and queries.
23	**List out the search engine optimization techniques.** BTL1 • Domain name strategies • Linking strategies • Keywords • Title tags • Meta description tags
24	**List out the parameters used to measure the size of the web.** BTL1 • Number of hosts • Number of HTML pages
25	**List out web search engine components.** BTL1 • Spider • Indexer • User • Online query processor
26	**Define XML retrieval.** BTL1 XML retrieval or XML information retrieval is the content-based retrieval of documents structured with XML (eXtensible Markup Language). As such it is used for computing relevance of XML documents.
	PART * B
1	**Write short note on web search overview and web structure.(8M)** BTL1 **Answer: Page No.507 -512 -Stefan Buettcher** • Web structure (4M) • Bow-Tie Structure (4M)
2	**Write a short note on the user and paid placement. (8M)** BTL1 **Answer: Page 3.3 – 3.4 - I.A. Dhotre** • Web search user (4M) • Paid search service (4M) ▪ Paid submission ▪ Pay-for-inclusion ▪ Pay-for-placement
3	**Explain about search engine optimization/Spam. (13M) (Nov/Dec'17)** BTL1 **Answer: Page 427 - 429 - C. Manning**

	• Early history (2M) • First generation of spam (2M) • diagram –Cloaking (2M) • Paid inclusion model (2M) • Doorway page (2M) • Search engine optimizers (SEO) (3M)
4	**Discuss in detail of web size measurement.(13M) (Nov/Dec'16)** BTL1 **Answer: Page 225-230 - Mark Levene** • Random searches (3M) • Random IP addresses (4M) • Random walks (3M) • Random queries (3M)
5	**Elaborate on web search architectures. (13M) (Nov/Dec'18)** BTL1 **Answer: Page 1.20 – 1.25 - I.A.Dhotre** Centralized architecture-components (7M) • Crawler - diagram • Index • Query engine • User Interface Distributed Architecture (6M) • Harvest architecture • Goals of Harvest • Components of Harvest • Features of Harvest
6	**Describe meta crawlers. (13M) (Nov/Dec'16)** BTL1 **Answer: Page 3.10 – 3.12 - I.A.Dhotre** • Meta searcher (4M) • Advantages (1M) • Metasearch engine (4M) • Components -Met crawler (4M)
7	**Describe focused crawling. (13M) (Nov/Dec'17)** BTL1 **Answer: Page- 41-Bruce Croft** • Vertical Search (4M) • Web Pages (4M) • Focused, Topical, Crawling (4M) • Outgoing Links (1M)
8	**Explain in detail about finger print algorithm for near-duplicate detection.(8M) (Nov/Dec'17)** BTL1 **Answer: Page 437- 441 - C. Manning** • Finger print algorithm (2M)

	• finding duplicates (2M) • Finding near-duplicates (2M) • shingle sketches (2M)
9	**Explain the index compression with an example. (10M) (Apr/May'17)**BTL1 **Answer: Page 85 - 105 - C. Manning** • Lossy And Lossless Compression (2M) • Heaps' Law (2M) • Zipf's Law (2M) • Dictionary Compression (2M) • Dictionary As A String (2M)
	PART*C
1	**Draw the basic crawler architecture and describe its components and also explain the working of a web crawler with an example. (15M)(Apr/May'18)** BTL1 **Answer: Page No. 541-549 in Stefan Buettcher** • Web crawler definition (4M) • Features- Crawler (4M) • Basic operation (4M) • Web Crawler Architecture (3M)
2	**Write short notes on i) Deep Web ii) Site maps iii) Distributed crawling (15M) (Nov/Dec'17))** BTL2 **Answer: Page 41 to 45 - Bruce Croft** Deep Web (8M) • Deep Web fall • Private sites • Form results • Scripted pages Site maps (4M) • Crawling • Sitemap File Distributed crawling (3M) • Crawling • sites • crawler • computing resource
3	**Explain with an example the framework of a XML retrieval system and its challenges with appropriate examples. (15M)(Apr/May'18)** BTL2 **Answer: Page 195- 215 - C. Manning** • Challenges - XML retrieval (4M) • vector space model (4M) • Evaluation (4M) • Text-centric and data-centric (3M)

UNIT IV - WEB SEARCH – LINK ANALYSIS AND SPECIALIZED SEARCH

Link Analysis – hubs and authorities – Page Rank and HITS algorithms - Searching and Ranking – Relevance Scoring and ranking for Web – Similarity - Hadoop & Map Reduce - Evaluation - Personalized search - Collaborative filtering and content-based recommendation of documents and products – handling “invisible” Web - Snippet generation, Summarization, Question Answering, Cross-Lingual Retrieval

PART * A

Q.No.	Questions
1.	**What is link analysis?** BTL1 Link analysis is a collections of documents connected by hyperlinks. Hyperlinks provide a valuable source of information for web information retrieval.
2	**What is query independent ranking?** BTL1 Query-independent ranking is a score assigned to each page without a specific user query with the goal of measuring the intrinsic quality of a page.
3	**What is query dependent ranking?** BTL1 Query-dependent ranking is a score of measuring the quality and the relevance of a page tot a given user query which is assigned to some of the pages.
4	**Define authorities. (Nov/Dec’18)** BTL1 Authorities are pages that are recognized as providing significant, trustworthy and useful information on a topic. In-degree is one simple measure of authority. However in-degree treats all links as equal.
5	**Define hubs.** BTL1 Hubs is defined as a index pages that provide lots of useful links to relevant content pages. Hub pages for IR are included in the home page.
6	**What are the properties of Hadoop?** BTL1 • Hadoop is a distributed file system. At Goggle Map Reduce, operation are run on a special file system called Google File System that is highly optimized for this purpose. • GFS is not open source. Doug Cutting and Yahoo! reverse engineered the GFS and called it Hadoop Distributed File System. • The Yahoo! reverse engineered the GFS and called it Hadoop Distributed File System. • The software framework that supports HDFS, Map Reduce and other related entities is called the project Hadoop or simply Hadoop.
7	**What are the Hadoop Distributed File System?** BTL1 Hadoop Distributed File System are the very large data sets, where data’s are stored reliably, and to stream those data sets at high bandwidth to user application. HDFS stores file system metadata and application data separately. The HDFS namespace is a hierarchy of files and directories. Files and directories are represented on the NameNode by nodes, Which record attributes like permissions, modification and access times, namespace and disk space quotas.
8	**Define Map Reduce.** BTL1 Map Reduce is defined as a programming model and software framework first developed by Google. Intended to facilitate and simplify the processing of vast amounts of data in parallel on large clusters of commodity hardware in a reliable, fault-tolerant manner.
9	**List out the characteristics of Map Reduce? (Apr/May’17) & (Nov/Dec’17)** BTL1 • Very large scale data: peta, exa bytes

	• Write once and read many data. It allows for parallelism without murexes • Map and Reduce are the main operations: Simple code • All the map should be completed before reduce operation starts. • Map and reduce operations are typically performed by the same physical processor. • Number of map tasks and reduce tasks are configurable. • Operations are provisioned near the data. • Commodity hardware and storage.
10	**What are the limitations of Hadoop/MapReduce?** BTL1 • Cannot control the order in which the maps or reductions are run. • For maximum parallelism, you need Maps and Reduces to not depend on data generated in the same MapReduce job. • A database with an index will always be faster than a MapReduce job on unindexed data. • Reduce operations do not take place until all Maps are complete. • General assumption that the output of Reduce is smaller than the input to Map, large data source used to generate smaller final values
11	**What is Cross-Lingual Retrieval? (Apr/May'18)** BTL1 Cross – Lingual Retrieval are the retrieval of documents that are in a different language from the one in which the query is expressed. This allows users to search document collections in multiple language and retrieve relevant information in a form that is useful to them, even when they have little or no linguistic competence in the target languages.
12	**Define Snippets. (Nov/Dec'17)** BTL1 Snippets is defined as a short fragments of text extracted from the document content or its metadata. They may be static or query based. In static snippet, it always shows the first 50 words of the document, or the content of its description metadata, or a description taken from a directory site such as dmoz.org.
13	**List the advantages of invisible web content.** BTL1 • Specialized content focus – large amounts of information focused on an exact subject. • Contains information than might not be available on the visible web. • Allows a user to find a precise answer to a specific question • Allow a user to find Webpages from a specific date or time.
14	**What is collaborative filtering?** BTL1 Collaborative filtering is a method of making automatic predictions about the interests of a single user by collecting preferences or taste information from many users. It uses given rating data by many users for many items as the basic for predicting missing ratings and/or for creating a top-N recommendation list for a given user, called the active user.
15	**What do you mean by item-based collaborative filtering? (Apr/May'17)** BTL1 Item-based CF is a model-based approach which produces recommendations based on the relationship between items inferred from the rating matrix. The assumption behind this approach is that users will prefer items that are similar to other items they like.
16	**What are the two problems of user based CF?** BTL1 The two main problems of user-based CF are that the whole user database has to be kept in memory and that expensive similarity computation between the active user and all other users in the database has to be performed.
17	**Define user based collaborative Filtering. (Nov/Dec'16)** BTL1 User-based collaborative filtering is defined as the algorithms work off the premise that if a user(A) has a similar profile to another user (B), then A is more likely to prefer things that B prefers when compared with a user chosen at random..

18	**What is the goal of snippet generation?** BTL1 The goal of snippet generation is • Present the most informative bit of a document in light of the query. • Present something which is self-contained i.e., a clause or a sentence. • Present something short enough to fit in output. • Be fast, accurate (where are the snippets stored?).
19	**Compute the Jaccard's similarity for the two list of words (time, flies,like,an,arrow) and (how,time,flies). (Apr/May'18)** BTL1 Consider two sets A= {**time, flies, like, an, arrow**} and B = {**how, time,flies**}. How similar are A and B? A can be represented as A={1,2,3,4,5} and B can be represented as B={6,1,2} The Jaccard similarity is defined JS(A, B) = $\lvert A \cap B\rvert / \lvert A \cup B\rvert$ JS(A,B) = $\lvert\{1,2\}\rvert / \lvert\{1,2,3,4,5,6\}\rvert = 2/6=0.33$
20	**What is summarization?** BTL1 **S**ummarization is the process of reducing a text document with a computer program in order to create a summary that retains the most important points of the original document. Technologies that can make a coherent summary take into account variables such as length, writing style and syntax.
21	**What are types of PWS (personalized web search)?** BTL1 • User profiling • Hyperlink analysis • Community based PWS • User location based PWS
22	**Differentiate Text centric and Data centric XML.** BTL1 **Text Centric** • Long text fields (e.g., section of a document) • In exact matching • Relevance ranked results • Relational databases do not deal well with this use case **Data Centric** • Data centric XML mainly encodes numerical and non-text XML attribute-value data. • When querying data-centric XML, we want to impose exact match conditions in most cases. • This puts the emphasis on the structural aspects of XML documents and queries.
23	**Define Individualization.** BTL1 Individualization is defined as the totality of characteristics that distinguishes an individual. Uses the user's goals, prior and tacit knowledge, past information-seeking behaviors.
24	**Define contextualization.** BTL1 Contextualization is defined as the interrelated condition that occur within an activity which includes factors like the nature of information available, the information currently being examined and the applications in use.
25	**Define Corpus.** BTL1 Corpus is defined as the collection of written texts, especially the entire works of a particular author or a body of writing on particular subject.

PART * B	
1	**Write a short notes on i) Link analysis ii) Hubs and Authorities (13M)** BTL1 **Answer: Page: 461-477 - C. Manning** Link analysis • Web as a graph. (2M) • Anchor text and the web graph. (3M) Hubs and Authorities • Broad-topic searches. (3M) • Key consequences. (2M) • Example. (3M)
2	**Explain Page Rank in detail. (13M) (Nov/Dec'16) & (Apr/May'17)** BTL2 **Answer: Page:421-439 - C. Manning** • Page rank. (3M) • Markov chains. (3M) • The Page Rank computation. (3M) • Topic-specific Page Rank. (4M)
3	**Explain searching and ranking with an example. (13M)** BTL2 **Answer: Page: 4.23 to 4.33 - N.Jayanthi** • Indexes and ranking. (3M) • Inverted indexes. (3M) • Ranking. (2M) • Page rank. (2M) • Queries and Challenges. (3M)
4	**Explain how relevance scoring is used to rank the pages. (13M)** BTL2 **Answer: Page:4.34 to 4.35 - N.Jayanthi** • Relevance ranking. (4M) • Page Ranking (3M) • Relevance using hyperlinks. (2M) • User query (4M)
6	**Explain the various methods to find the similarity of two documents using similarity measures. (13M)** **Answer: Page:4.36 to 4.43 - N.Jayanthi** BTL2 • Similarity measures. (2M) • Methods to find similarity of documents. (2M) • Computing similarity. (2M) • Set similarity. (2M) • Using Jaccard coefficient. (2M) • Comparing signatures. (3M)
7	**How does Map Reduce Work? Illustrate the usage of Map Reduce programming model in Hadoop. (13M) (Apr/May'18)** BTL2 **Answer: Page:4.6 – 4.8 - I.A.Dhotre**

	• Hadoop framework. (3M) • Map reduce. (3M) • Characteristics. (2M) • Logical data flow diagram. (3M) • Hadoop/Map reduce limitations. (2M)
9	**Explain Personalized search. (13M) (Nov/Dec'18)** BTL2 **Answer: Page No. 4.65 to 4.69 - N.Jayanthi** • Personalized web search. (3M) • User profiling. (3M) • Hyperlink analysis. (2M) • Community based PWS. (2M) • User location based PWS. (3M)
10	**Explain collaborative filtering with an example. (13M) (Apr/May'17)** BTL2 **Answer: Page:333-346 - Mark Levene** • User-Based Collaborative Filtering. (2M) • Item-Based Collaborative Filtering. (2M) • Model-Based Collaborative Filtering. (2M) • Content-Based Recommendation Systems. (2M) • Evaluation of Collaborative Filtering Systems. (2M) • Scalability of Collaborative Filtering Systems. (2M) • Case Study of Amazon.co.uk. (1M)
11	**Explain content based recommendation system with an example. (13M) (Apr/May'17) & (Nov/Dec'17)** BTL2 **Answer: Page:4.23 – 4.24 - I.A.Dhotre** • Process performed - content based recommender. (3M) • Recommendation process. (3M) • Advantages of Content-based approach. (4M) • Disadvantages of Content-based approach. (3M)
	PART*C
1	**Explain in detail about Community-based Question Answering system. (15M) (Nov/Dec'17) & (Apr/May'18)** BTL2 **Answer: Page:4.85 to 4.91 - N.Jayanthi** • Community-based Question. (3M) • Natural Language Annotations. (3M) • The AI lab, factual queries. (3M) • Open domain QA. (2M) • Redundancy based method. (2M) • Semantic Headers. (2M)
2	**Write a short notes on i) Handling invisible web ii) Snippet generation iii) Summarization (15M)** BTL2 **Answer: Page: 4.25 – 4.26 - I.A.Dhotre** (i)Handling invisible web • Using the search engine- find hidden content. (4M) ii)Snippet generation

	• Steps for document based snippet generation. (3M) • Steps for indexed based snippet generation. (2M) • Query based summarization. (2M) iii)Summarization • Static summarization. (2M) • Dynamic summarization. (2M)
3	**Explain in detail cross lingual information retrieval and its limitations in web search.(15M) (Nov/Dec'16)** BTL2 **Answer: Page;4.28 – 4.29 - I.A.Dhotre** • Information retrieval cycle. (4M) • Query translation. (4M) • Document translation. (4M) • Limitations (3M)

UNIT V - DOCUMENT TEXT MINING
Information filtering; organization and relevance feedback – Text Mining - Text classification and clustering - Categorization algorithms: naive Bayes; decision trees; and nearest neighbor - Clustering algorithms: agglomerative clustering; k-means; expectation maximization (EM).
PART * A

Q.No.	**Questions**
1.	**What is information filtering?** BTL2 An information filtering system is a system that removes redundant or unwanted information from an information stream using (semi)automated or computerized methods prior to presentation overload and increment of the semantic signal-to-noise ratio.
2	**What are the characteristics of information filtering? (Nov/Dec'18)**BTL4 • Filtering system involve large amounts of data. • Information filtering systems deal with textual information. • It is applicable for unstructured or semi-structured data.
3	**Differentiate information filtering and information Retrieval. (Apr/May'17)** BTL4

S.No.	**Information Filter**	**Information Retrieval**
1	IF is concerned with the removal of textual information from an incoming stream and its dissemination to groups or individuals.	IR systems are concerned with the collection and organization of texts so that users can then easily find a text in the collection.
2	Information filtering is concerned with repeated uses of the system by users with long-term, but changing interests and needs.	A query represents a one-time information need.

<table>
<tr><td></td><td><table><tr><td>3</td><td>Filtering is based on descriptions of individual or group interests or needs that are usually called profiles.</td><td>Retrieval of information is instead based on user specified information needs in the form of a query.</td></tr><tr><td>4</td><td>IF systems deal with dynamic data</td><td>IR systems deal with static databases</td></tr></table></td></tr>
<tr><td>4</td><td>What is text mining? BTL1
Text mining is understood as a process of automatically extracting meaningful, useful, previously unknown and ultimately comprehensible information from textual document repositories.
Text mining can be visualized as consisting of two phases: Text refining that transforms free-form text documents into a chosen intermediate form, and knowledge distillation that deduces patterns or knowledge from the intermediate form.</td></tr>
<tr><td>5</td><td>State classification BTL1
Classification is a technique used to predict group membership for data instances. For example, you may wish to use classification to predict whether the weather on a particular day will be “sunny”, “rainy” or “cloudy”.</td></tr>
<tr><td>6</td><td>What is clustering? BTL2
Clustering is a process of partitioning a set of data in a set of meaningful subclasses. Every data in the subclass shares a common trait. It helps a user to understand the natural grouping or structure in a data set.</td></tr>
<tr><td>7</td><td>What are the desirable properties of a clustering algorithm? (Apr/May’17) BTL4
• Scalability (in terms of both time and space)
• Ability to deal with different data types
• Minimal requirements for domain knowledge to determine input parameters
• Interpretability and usability</td></tr>
<tr><td>8</td><td>What is decision tree? BTL1
A decision tree is a simple representation for classifying examples. Decision tree learning is one of the most successful techniques for supervised classification learning. A decision tree or a classification tree is a tree in which each internal node is labeled with an input features. The arcs coming from a node labeled with a feature are labeled with each of the possible values of the feature. Each leaf of the tree is labeled with a class or a probability distribution over the classes.</td></tr>
<tr><td>9</td><td>List the advantages of decision tree. BTL4
• Decision tree can handle both nominal and numeric input attributes.
• Decision tree representation is rich enough to represent any discrete value classifier.
• Decision trees are capable of handling database that may have errors.
• Decision trees are capable of handling datasets that may have missing values.
• It is self-explanatory and when compacted they are also easy to follow.</td></tr>
<tr><td>10</td><td>List the disadvantages of decision tree. BTL4
• Most of the algorithms require that the target attribute will have only discrete values.
• Most decision-tree algorithms only examine a single field at a time.
• Decision trees are prone to errors in classification problems with much class.
• As decision tree use the “divide and conquer” method, they tend to perform well if a few highly relevant attribute exists, but less so if many complex interactions are present.</td></tr>
<tr><td>11</td><td>What is supervised learning? (Nov/Dec’17) BTL1
In supervised learning, both the inputs and the outputs are provided. The network then processes the inputs and compares its resulting outputs against the desired outputs. Errors are then propagated back through the system, causing the system to adjust the weights which control the network.</td></tr>
</table>

12	**What is unsupervised learning? (Nov/Dec'17)** BTL1 In an unsupervised learning, the network adapts purely in response to its inputs. Such networks can learn to pick out structure in their input.
13	**What is dendrogram? (Nov/Dec'17)** BTL1 Decompose data objects into a several levels of nested partitioning called a dendrogram. A clustering of the data objects is obtained by cutting the dendrogram at the desired level, then each connected component forms a cluster.
14	**What is the use of Expectation-Maximization algorithm? (Apr/May'18)** BTL1 Expectation-Maximization algorithm is extremely widely used for "hidden-data" problems. Hidden Markov Models
15	**List the advantages and disadvantages of EM algorithm.** BTL4 **Advantages:** • Its simplicity • Ease of implementation **Disadvantages:** • Finding good seeds is more critical for EM then for K-means • This is prone to get stuck in local optima if the seeds are not chosen well
16	**What is k-means algorithm?** BTL1 K-means is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem. K-means clustering aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean serving as a prototype of the cluster.
17	**Give the applications of clustering in IR.** BTL4 • Search result clustering • Scatter –gather • Collection clustering • Language modeling • Cluster-based retrieval
18	**What is relevance feedback?** BTL1 Relevance feedback is a feature of information retrieval systems. The idea behind relevance feedback is to take the results that are initially returned from a given query and to use information about whether or not those results are relevant to perform a new query. User feedback on relevance of docs in initial set of results.
19	**List pros and cons of Hierarchical agglomerative clustering.** BTL4 **Advantages** ➢ It can produce an ordering of the objects which may be informative for data display ➢ Smaller clusters are generated, which may be helpful for discovery **Disadvantages** ➢ No provision can be made for a relocation of objects that may have been 'incorrectly' grouped at an early stage. The result should be examined closely to ensure it make sense. ➢ Use of different distance metrics for measuring distances between clusters may generate different results. Performing multiple experiments and comparing the results is recommended to support the veracity of the original results.
20	**Mention the different types of clustering methods.** BTL1 • Partitioning methods • Hierarchical methods • Density-based methods • Grid-based methods • Model-based clustering methods

21 **Name the types of data in clustering analysis.** BTL1

- Interval-scaled variable – e.g., salary, height
- Binary variables – e.g., gender(M/F), has cancer (T/F)
- Nominal variables – e.g., religion (Hindu, Christian, Muslim etc.,)
- Ordinal variables – e.g., military rank (soldier, sergeant, lutenant, captain etc.,)
- Ratio-scaled variables – e.g., population growth (1,10,1000, …)
- Variables of mixed types – e.g., multiple attributes with various types

22 **List out the category of algorithms in classification.** BTL1

- Naïve Bayesian classification
- Decision tree classification
- K-Nearest Neighbor algorithm (KNN)

23 **Differentiate Agglomerative and Divisive clustering.** BTL4

S.No.	Agglomerative clustering (bottom up)	Divisive clustering (top down)
1	Start with 1 point (singleton)	Start with a big cluster
2	Recursively add two or more appropriate clusters	Recursively divide into smaller clusters

24 **Differentiate Data mining and Text mining.** BTL4

S.No.	Data mining	Text Mining
1	Structured data	Unstructured data (Text)
2	Process directly	Linguistic processing or natural language processing (NLP)
3	Identify casual relationship	Discover unknown information

PART * B

1 **Explain in detail about organization and relevance feedback. (13M)** BTL2

Answer: Page 5.2 - 5.7 - N.Jayanthi-Charulatha Publications

- Rocchio algorithm for relevance feedback (4M)
- Probabilistic relevance feedback (4M)
- Pseudo relevance feedback (4M)
- Indirect relevance feedback (1M)

2 **Write a short notes on i) Text mining ii) Text classification and clustering (13M)** BTL1

Answer:

i) Page 5.8 - I.A.Dhotre, Technical Publications

ii)Page No. 5.9 – 5.16 - I.A.Dhotre, Technical Publications

Binary classification (1M)
Assessing classification performance (2M)
Clustering (2M)
Desirable properties-clustering algorithm (2M)
Distance between clusters (2M)
Supervised learning after clustering (2M)
Clustering applications (2M)

3 **State Bayes theorem. Discuss in detail about the working of Naïve Bayesian classifier with an example. (13M) (Nov/Dec'18)** BTL4

	Answer: Page 5.16 - 5.22 - I.A.Dhotre, Technical Publications Bayes Theorem. (4M) Prior Probability (4M) Posterior Probability. (5M)
6	**Explain in detail the Multiple-Bernoulli and the multinomial models. (13M) (Nov/Dec'17)** BTL1 **Answer: Page 234- 264 - C. Manning** • Relation - Multinomial Unigram Language Model (4M) • The Bernoulli Model (4M) • Properties of Naïve Bayes (1M) • Variant of Multinomial Model And Feature Selection (4M)
7	**How hierarchical agglomerative clustering works? Explain with an example. (13M)** BTL2 Answer: Page 5.38 - 5.40 - I.A.Dhotre, Technical Publications • Hierarchical Clustering (3M) • Agglomerative Clustering (2M) • Method Based on Probabilities (2M) • K-nearest neighbours clustering. (2M) • Euclidian Distance (2M) • Mahalanobis Distance (2M)
9	**Explain in detail about the decision tree. (13M)** BTL1 **Answer: Page No. 5.13 - 5.17 - N.Jayanthi, Charulatha Publications** • 2 Phases Algorithm (3M) • Attribute Selection Measures (3M) • Information Gain (4M) • Information filtering. (3M)
	PART*C
1	**What is clustering? Explain k-means clustering algorithm with an example. (15M) (Apr/May'18)**BTL1 **Answer: Page 5.36 - 5.38 - I.A.Dhotre, Technical Publications** Select initial centroid at random (4M) Assign each object to the cluster with the nearest centroid. (4M) Measurement of attribute selection (4M) Probabilistic models (2M) Unsupervised selection (1M)
2	**Explain the Expectation Maximization problem in detail. (15M) (Nov/Dec'17)** BTL2 **Answer: Page 5.36 - 5.38 - I.A.Dhotre, Technical Publications** Basic Setting In EM And Process (5M) Regression model (4M) Eclureit circuit (3M) Relevance Expansion (3M)