SRM VALLIAMMAI ENGNIEERING COLLEGE

(An Autonomous Institution)

SRM Nagar, Kattankulathur – 603203.

DEPARTMENT OF MATHEMATICS

S.No	QUESTIONS	BT Level	Competence
	UNIT I PROBABILITY AND RANDOM VARIABLES Probability – Axioms of probability – Conditional probability – Baye's theorem – Discrete and continuous random variables – Moments – Moment generating functions – Binomial, Poisson, Geometric, Uniform, Exponential and Normal distributions.		
	Part - A (2 MARK QUESTIONS)		
1.	What is the probability that a non-leap year selected at random will contain 53 Tuesdays?	BTL1	Remembering
2.	A is known to hit the target in 2 out of 5 shots. B is known to hit the target in 3 out of 4 shots. Find the probability of the target being hit when both try?	BTL1	Remembering
3.	If A and B are events in S such that $P(A) = 1/3$, $P(B) = 1/4$ and $P(A \cup A) = 1/2$. Find $P(A \cap \bar{B})$ and $P(A\vert\bar{B})$.	BTL1	Remembering
4.	The mean of Binomial distribution is 20 and standard deviation is 4. Find the parameters of the distribution.	BTL1	Remembering
5.	If 3% of the electric bulbs manufactured by a company are defective, Find the probability that in a sample of 100 bulbs exactly 5 bulbs are defective.	BTL1	Remembering
6.	Suppose that, on an average , in every three pages of a book there is one typographical error. If the number of typographical errors on a single page of the book is a Poisson random variable. What is the probability if at least one error on a specific page of the book?	BTL1	Remembering
7.	The probability that a candidate can pass in an examination is 0.6. What is the probability that he will pass in third trial?	BTL2	Understanding
8.	If the MGF of a uniform distribution for a RV X is $\frac{1}{t}(e^{5t} - e^{4t})$. Find E(X).	BTL2	Understanding
9.	Suppose that the life of industrial lamp(in thousands of hours) is exponentially distributed with mean life of 3000 hours, find the probability that the lamp will last between 2000 and 3000 hours.	BTL2	Understanding
10.	State the memory less property of the exponential distribution.	BTL2	Understanding
11.	If a random variable X has the MGF $M_X(t) = \frac{2}{2-t}$. Find the mean of X.	BTL3	Applying
12.	Show that the function $f(x) = \begin{cases} e^{-x}, & x \geq 0 \\ 0, & x < 0 \end{cases}$ is a probability density function of a continuous random variable X.	BTL3	Applying
13.	Find the Moment generating function of a continuous random variable X whose pdf is $f(x) = \begin{cases} xe^{x/2}, & x > 0 \\ 0, & x \leq 0 \end{cases}$	BTL3	Applying
14.	The number of hardware failures of a computer system in a week of operations has the following p.d.f, Find the mean of the number of failures in a week. No.of failures: 0, 1, 2, 3, 4, 5, 6 Probability: .18, .28, .25, .18, .06, .04, .01	BTL4	Analyzing
15.	The number of hardware failures of a computer system in a week of operations has the following p.d.f, Calculate the value of K. No.of failures: 0, 1, 2, 3, 4, 5, 6 Probability: K, 2 K, 2 K, K, 3 K, K, 4 K	BTL4	Analyzing
16.	A random variable X has following probability distribution. X: 1, 2, 3, 4 P(x): 0.4, 0.3, 0.2, 0.1 Find K.	BTL4	Analyzing
17.	The pdf of a continuous random variable X is $f(x) = k(1 + x), 2 < x < 5$, Find k.	BTL5	Evaluating

<table>
<tr><td>18.</td><td>For a continuous distribution $f(x) = k(x - x^2), 0 \le x \le 1$, where k is a constant. Find k.</td><td>BTL5</td><td>Evaluating</td></tr>
<tr><td>19.</td><td>If $f(x) = kx^2, 0 < x < 3$, is to be a density function, find the value of k.</td><td>BTL6</td><td>Creating</td></tr>
<tr><td>20.</td><td>If the pdf of a RV is $f(x) = \frac{x}{2}, 0 \le x \le 2$, find $P(X > 1.5)$.</td><td>BTL6</td><td>Creating</td></tr>
<tr><td colspan="4">Part – B (16-MARK QUESTIONS)</td></tr>
<tr><td rowspan="2">1.</td><td>(a)A bolt is manufactured by 3 machines A, B, and C. A turns out twice as many items as B and machines B and C produce equal number of items. 2% of bolts produced by A and B are defective and 4% of bolts produced by C are defective. All bolts are put into 1 stock pile and 1 is chosen from this pile. What is the probability that it is defective?</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>(b) Find the MGF of Binomial distribution and hence find its mean and variance</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td rowspan="2">2.</td><td>(a) A bag contains 5 balls and it is not known how many of them are white. Two balls are drawn at random from the bag and they are noted to be white. What is the change that all balls in the bag are white?</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>(b) Find the MGF of Geometric distribution and hence find its mean and variance</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td rowspan="2">3.</td><td>(a) An urn contains 10 white and 3 black balls. Another urn contains 3 white and 5 black balls. Two balls are drawn at random from the first urn and placed in the second urn and then 1 ball is taken at random from the latter. What is the probability that it is a white ball?</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>(b)Derive the MGF of Poisson distribution and hence find its mean and variance</td><td>BTL3</td><td>Applying</td></tr>
<tr><td rowspan="2">4.</td><td>(a) A random variable X has the following probability distribution:
<table>
<tr><td>X</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>P(X)</td><td>0</td><td>k</td><td>$2k$</td><td>$2k$</td><td>$3k$</td><td>k^2</td><td>$2k^2$</td><td>$7k^2$+k</td></tr>
</table>
Find (i) the value of k
(ii) $P(1.5 < X < 4.5 / X > 2)$</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>(b) Find the MGF of Uniform distribution and hence find its mean and variance</td><td>BTL4</td><td>Analyzing</td></tr>
<tr><td rowspan="2">5.</td><td>(a)The probability mass function of a discrete R. V X is given in the following table:
<table>
<tr><td>X</td><td>-2</td><td>-1</td><td>0</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>P(X=x)</td><td>0.1</td><td>k</td><td>0.2</td><td>2k</td><td>0.3</td><td>k</td></tr>
</table>
the value of k, (2) P(X<1), (3) P(-1< X ≤ 2), (4) E(X)</td><td>BTL3</td><td>Understanding</td></tr>
<tr><td>(b) Find the MGF of Exponential distribution and hence find its mean and variance.</td><td>BTL5</td><td>Evaluating</td></tr>
<tr><td rowspan="2">6.</td><td>(a)The probability mass function of a discrete R. V X is given in the following table
<table>
<tr><td>X</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td>P(X)</td><td>a</td><td>3a</td><td>5a</td><td>7a</td><td>9a</td><td>11a</td><td>13a</td><td>15a</td><td>17a</td></tr>
</table>
Find (i) the value of a , (ii) $P(X < 3)$, (iii) Mean of X, (iv) Variance of X.</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>(b) Find the MGF of Normal distribution and hence find its mean and variance</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td rowspan="2">7.</td><td>(a) The probability mass function of a RV X is given by $P(X = r) = kr^3$, $r = 1,2,3,4$. Find (1) the value of k, (2) $P(\frac{1}{2} < X < \frac{5}{2} / X > 1)$, (3) Mean and (4) Variance</td><td>BTL5</td><td>Evaluating</td></tr>
<tr><td>(b) State and Prove the memory less property of Exponential distribution</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>8.</td><td>(a) Out of 2000 families with 4 children each , Find how many family would you expect to have i) at least 1 boy ii) 2 boys iii) 1 or 2 girls iv) no girls</td><td>BTL1</td><td>Remembering</td></tr>
</table>

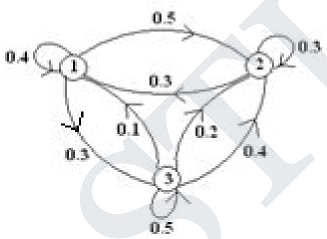
	(b) If f(x) = $\begin{cases} ax, & 0 \le x \le 1 \\ a, & 1 \le x \le 2 \\ 3a - ax, & 2 \le x \le 3 \\ 0, & elsewhere \end{cases}$ is the pdf of X. Calculate (i) the value of a , (ii) the cumulative distribution function of X	BTL6	Evaluating
9.	(a) Messages arrive at a switch board in a Poisson manner at an average rate of 6 per hour. Find the probability that exactly 2 messages arrive within one hour, no messages arrives within one hour and at least 3 messages arrive within one hour.	BTL1	Remembering
	(b) Let X be a continuous R.V with probability density function $f(x) = \begin{cases} xe^{-x}, & x > 0 \\ 0\ , & otherwise \end{cases}$, Find (1) The cumulative distribution of X, (2)Moment Generating Function $M_x(t)$ of X, (3) P(X<2) and (4) E(X)	BTL6	Creating
10.	(a) The probability distribution of an infinite discrete distribution is given by P[X = j] = $\frac{1}{2^j}$ (j = 1,2,3…) Find (1)Mean of X, (2)P [X is even],(3) P(X is odd)	BTL1	Remembering
	(b) A random variable X has cdf $F(x) = \begin{cases} 0, if\ x < -1 \\ a(1+x), if -1 < x < 1 \\ 1, if\ x \ge 1 \end{cases}$. Find the value of a. also P(X>1/4) and $P(-0.5 \le X \le 0)$.	BTL4	Analyzing
11.	(a) In a normal population with mean 15 and standard deviation 3.5, it is found that 647 observations exceed 16.25. What is the total number of observations in the population	BTL1	Remembering
	(b) Find the MGF of the random variable X having the probability density function f(x) = $\begin{cases} \frac{x}{4}e^{-x/2} & x > 0 \\ 0 & \text{otherwise.} \end{cases}$ Also find the mean and variance.	BTL2	Understanding
12.	(a) Suppose that the life of a industrial lamp in 1,000 of hours is exponentially distributed with mean life of 3,000 hours. Find the probability that (i)The lamp last more than the mean life (ii) The lamp last between 2,000 and 3,000 hours (iii) The lamp last another 1,000 hours given that it has already lasted for 250 hours.	BTL2	Understanding
	(b)Assume that 50% of all engineering students are good in mathematics. Determine the probabilities that among 18 engineering students (i) exactly 10, (ii) atleast 10 are good in mathematics.	BTL1	Remembering
13.	(a) The life (in years) of a certain electrical switch has an exponential distribution with an average life of $\frac{1}{\lambda} = 2$. If 100 of these switches are installed in different systems; find the probability that at most 30 fail during the first year.	BTL1	Remembering
	(b) Assume that 50% of all engineering students are good in mathematics. Determine the probabilities that among 18 engineering students (i) exactly 10, (ii) atleast 16 are good in mathematics.	BTL3	Applying
14	(a) In an Engineering examination, a student is considered to have failed, secured second class, first class and distinction, according as he scores less than 45%,between 45% and 60% between 60% and 75% and above 75%respectively. In a particular year 10% of the students failed in the examination and 5% of the students get distinction. Find the percentage of students who have got first class and second class. Assume normal distribution of marks.	BTL2	Understanding

<table>
<tr><td></td><td>(b) Let X be a Uniformly distributed R. V. over [-5, 5].
Determine (i) $P(X \le 2)$, (ii) $P(|X|>2)$
(iii) Cumulative distribution function of X and (iv) Var(X)</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td colspan="4">UNIT II TWO – DIMENSIONAL RANDOM VARIABLES
Joint distributions – Marginal and conditional distributions – Covariance – Correlation and linear regression – Transformation of random variables – Central limit theorem (for independent and identically distributed random variables).</td></tr>
<tr><td colspan="4">Part – A (2-MARK QUESTIONS)</td></tr>
<tr><td>1</td><td>Define the conditional distribution function of two dimensional discrete and continuous random variables .</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>2</td><td>The joint probability distribution of X and Y is given by $p(x,y) = \frac{x+y}{21}$, $x = 1,2,3;$ $y = 1, 2$. Find the marginal probability distributions of X and Y .</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>3</td><td>Find the probability distribution of X + Y from the bivariate distribution of (X,Y) given below:
<table><tr><td>X \ Y</td><td>1</td><td>2</td></tr><tr><td>1</td><td>0.4</td><td>0.2</td></tr><tr><td>2</td><td>0.3</td><td>0.1</td></tr></table></td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>4</td><td>The joint probability function (X,Y) is given by $P(x,y) = k\,(2x+3y)$, $x = 0,1,2$ $y = 1,2,3$, Find the value of K.</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>5</td><td>Let X and Y have the joint p.m.f
<table><tr><td>Y \ X</td><td>0</td><td>1</td><td>2</td></tr><tr><td>0</td><td>0.1</td><td>0.4</td><td>0.1</td></tr><tr><td>1</td><td>0.2</td><td>0.2</td><td>0</td></tr></table>Find P(X+Y > 1)</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>6</td><td>If the joint pdf of (X, Y) is $f(x,y) = \begin{cases} \frac{1}{4}, 0 < x,y < 2 \\ 0, \ otherwise \end{cases}$. Find $P(X+Y \le 1)$</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>7</td><td>Let X and Y be random variables with joint density function
f(x,y) = $\begin{cases} 4xy , \ 0 < x < 1 , \ 0 < y < 1 \\ 0, \ otherwise \end{cases}$ formulate the value of E(XY)</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>8</td><td>The joint probability density function of the random variable (X,Y) is given by f(x, y) = $Kxye^{-(x^2 + y^2)}$, $x > 0, \ y > 0$
Calculate the value of K.</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>9</td><td>If the joint probability density function of a random variable X and Y is given by $f(x,y) = \begin{cases} \frac{x^3y^3}{16}, 0 < x < 2, 0 < y < 2 \\ 0, \quad otherwise \end{cases}$. Find the marginal functions of X and Y.</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>10.</td><td>If X and Y have joint pdf f(x,y) = $\begin{cases} x + y , 0 < x < 1, \ 0 < y < 1 \\ 0, \ otherwise \end{cases}$
Discuss whether X and Y are independent.</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>11</td><td>The joint probability density of a two dimensional random variable (X,Y) is given by $f(x,y) = \begin{cases} kxe^{-y}; 0 \le x2 , y > 0 \\ 0, \quad otherwise \end{cases}$. Evaluate k.</td><td>BTL3</td><td>Applying</td></tr>
<tr><td>12</td><td>The joint probability density function of a random varaiable (X,Y) is $f(x,y) = k\,e^{-(2x+3y)}, x \ge 0, \ y \ge 0$. Find the value of k.</td><td>BTL3</td><td>Applying</td></tr>
<tr><td>13</td><td>If X,Y denote the deviation of variance from the arithmetic mean and if $\rho = 0.5, \ \sum XY = 120, \sigma_y = 8, \sum X^2 = 90$, Find n, the number of times.</td><td>BTL3</td><td>Applying</td></tr>
<tr><td>14</td><td>The regression equations are x + 6y = 14 and 2x + 3y = 1.Point out the correlation coefficient between X & Y .</td><td>BTL4</td><td>Analyzing</td></tr>
</table>

15	If $\bar{X} = 970$, $\bar{Y} = 18, \sigma_x = 38$, $\sigma_y = 2$ and r =0.6 , Find the line of regression and obtain the value of X and Y = 20.	BTL4	Analyzing
16	In a partially destroyed laboratory, record of an analysis of correlation data, the following results only are legible; Varaince of X = 9; Regression equations are 8X - 10Y + 66 = 0 and 40X-18Y = 214. Find the mean values of X and Y?	BTL4	Analyzing
17	The regression equations are 3x + 2y = 26 and 6x + y = 31. Find the correlation coefficient**.**	BTL5	Evaluating
18	If X = Rcos∅ and Y = Rsin∅, how are the joint probability density function of (X,Y) and (R,∅) are related ?	BTL5	Evaluating
19	Give the acute angle between the two lines of regression.	BTL6	Creating
20	State Central Limit Theorem.	BTL6	Creating
Part – B (16 Mark Questions)			
1.	(a) Three balls are drawn at random without replacement from a box containing 2 white, 3 red and 4 blue balls. If X denotes the number of white balls drawn and Y denotes the number of red balls drawn, Identify the probability distribution of X and Y.	BTL1	Remembering
	(b)If X, Y are RV's having the joint density function $f(x,y) = k(6 - x - y), 0 < x < 2, 2 < y < 4,$ Find (i) $P(x < 1, y < 3)$ ii) $P(x < 1 / y < 3)$ iii) $P(y < 3/x < 1)$ iv) $P(X + Y < 3)$	BTL2	Understanding
2	(a)The joint distribution of X and Y is given by $f(x,y) = \frac{x+y}{21}$, $x = 1,2,3; y = 1,2$. Find the marginal distributions of X and Y.	BTL1	Remembering
	(b) The joint pdf a bivariate R.V(X, Y) is given by $f(x,y) = \begin{cases} Kxy \; ; & 0 < x < 1, 0 < y < 1 \\ 0 & , otherwise \end{cases}$ Find K. (2) Find P(X+Y<1). (3)Are X and Y independent R.V's.	BTL2	Understanding
3.	(a)If the joint pdf of (X, Y) is given by P(x, y) = K(2x+3y), x=0, 1, 2, 3, y = 1, 2, 3 Find all the marginal probability distribution. Also find the probability distribution of X+Y.	BTL1	Remembering
	(b)The joint pdf of X and Y is given by f(x,y)=$\begin{cases} kx(x-y), 0 < x < 2, -x < y < x \\ 0, \quad otherwise \end{cases}$ (i)Find K (ii) Find $f_x(x)$ and $f_y(y)$ (iii) $f_{\frac{y}{x}}\left(\frac{y}{x}\right)$	BTL3	Applying
4.	The joint pdf of a two dimensional random variable (X, Y) is given by $f(x,y) = xy^2 + \frac{x^2}{8}, 0 \le x \le 2, 0 \le y \le 1$. Compute (i) $P\left(X > 1 / Y < \frac{1}{2}\right)$ (ii)$P\left(Y < \frac{1}{2} / X > 1\right)$ (iii) $P(X + Y) \le 1$.	BTL2	Understanding
5.	From the following table for bivariate distribution of (X, Y). Find (i) $P(X \le 1)$ (ii) $P(Y \le 3)$ (iii) $P(X \le 1, Y \le 3)$ (iv) $P(X \le 1 / Y \le 3)$ (v) $P(Y \le 3 / X \le 1)$ (vi) $P(X + Y \le 4)$	BTL2	Understanding

X \ Y	1	2	3	4	5	6
0	0	0	$\frac{1}{32}$	$\frac{2}{32}$	$\frac{2}{32}$	$\frac{3}{32}$
1	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
2	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{64}$	0	$\frac{2}{64}$

<table>
<tr><td rowspan="2">6.</td><td>(a)The two dimensional random variable (X, Y) has the joint probability mass function $f(x,y) = \frac{x+2y}{27}, x = 0,1,2; y = 0,1,2$. Find the conditional distribution of Y given X = 1 also find the conditional distribution of X given Y = 1.</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>(b)Find $P(X < Y/X < 2Y)$ if the joint pdf of (X,Y) is $f(x,y) = e^{-(x+y)}, 0 \le x < \infty, \quad 0 \le y < \infty$.</td><td>BTL6</td><td>Creating</td></tr>
<tr><td rowspan="2">7.</td><td>(a)The following table represents the joint probability distribution of RV (X, Y). Find the marginal distributions of X and Y.
<table>
<tr><td rowspan="2">Y</td><td colspan="3">X</td></tr>
<tr><td>0</td><td>1</td><td>2</td></tr>
<tr><td>0</td><td>$\frac{3}{28}$</td><td>$\frac{9}{28}$</td><td>$\frac{3}{28}$</td></tr>
<tr><td>1</td><td>$\frac{3}{14}$</td><td>$\frac{3}{14}$</td><td>0</td></tr>
<tr><td>2</td><td>$\frac{1}{28}$</td><td>0</td><td>0</td></tr>
</table></td><td>BTL3</td><td>Applying</td></tr>
<tr><td>(b)If the joint pdf of a two-dimensional RV(X,Y) is given by $f(x,y) = \begin{cases} x^2 + \frac{xy}{3}; 0 < x < 1, 0 < y < 2 \\ 0, \ elsewhere \end{cases}$. Find (i) $P\left(X > \frac{1}{2}\right)$ (ii) $P(Y < X)$and (iii) $P\left(Y < \frac{1}{2} / X < \frac{1}{2}\right)$</td><td>BTL5</td><td>Evaluating</td></tr>
<tr><td rowspan="2">8.</td><td>(a)If f(x,y) = $\frac{6-x-y}{8}$, $0 \le x \le 2$, , $2 \le y \le 4$ for a bivariate random variable (X,Y), Find the correlation coefficient ρ.</td><td>BTL3</td><td>Applying</td></tr>
<tr><td>(b)If $X_1, X_2, X_3, \cdots X_n$ are Poisson variates with mean 2, use central limit theorem to estimate $P(120 < S_n < 160)$ where $S_n = X_1 + X_2 + X_3 + \cdots + X_n$ and n=75.</td><td>BTL5</td><td>Evaluating</td></tr>
<tr><td>9.</td><td>(a)From the following data , Find (i)The two regression equations (ii) The coefficient of correlation between the marks in Mathematics and Statistics (iii) The most likely marks in Statistics when marks in Mathematics are 30
Marks in Maths : 25 28 35 32 31 36 29 38 34 32
Marks in Statistics: 43 46 49 41 36 32 31 30 33 39</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>10.</td><td>Find the correlation coefficient for the following heights of fathers X, their sons Y and also find the equations of regression lines. Hence find the height of son when the height of father is 71
<table>
<tr><td>X</td><td>65</td><td>66</td><td>67</td><td>67</td><td>68</td><td>69</td><td>70</td><td>72</td></tr>
<tr><td>Y</td><td>67</td><td>68</td><td>65</td><td>68</td><td>72</td><td>72</td><td>69</td><td>71</td></tr>
</table></td><td>BTL4</td><td>Analyzing</td></tr>
<tr><td rowspan="2">11</td><td>(a)The equation of two regression lines obtained by in a correlation analysis is as follows: 3x + 12y = 19 , 3y + 9x =46. (i) Calculate the correlation coefficient (ii) Mean value of X &Y.</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>(b) Two random variables X and Y have the following joint probability density function $f(x,y) = \begin{cases} x + y; 0 \le x \le 1, 0 \le y \le 1 \\ 0, \ otherwise \end{cases}$. Find the probability density function of the random variable U = XY.</td><td>BTL6</td><td>Creating</td></tr>
<tr><td>12</td><td>(a)If X and Y independent Random Variables with pdf $e^{-x}, x \ge 0$ and $e^{-y}, y \ge 0$.
Find the density function of $U = \frac{X}{X+Y}$ and $V = X + Y$. Are they independent.</td><td>BTL1</td><td>Remembering</td></tr>
</table>

	(b) The lifetime of a certain brand of an electric bulb may be considered a RV with mean 1200h and standard deviation 250h. Find the probability, using central limit theorem, that the average life time of 60 bulbs exceeds 1250 h.	BTL6	Creating
13	(a) If X and Y each follow an exponential distribution with parameter 1and are independent, find the pdf of U = X-Y.	BTL2	Understanding
	(b) 20 dice are thrown. Find the approximate probability that the sum obtained is between 65 and 75 using central limit theorem.	BTL3	Applying
14	Two random variables X and Y have the joint density $f(x,y) = \begin{cases} 2-x-y, & 0<x<1,\ 0<y<1 \\ 0, & otherwise \end{cases}$ Calculate the Correlation coefficient between X and Y is -1 /11.	BTL1	Remembering
UNIT III RANDOM PROCESSES Classification – Stationary process – Markov process – Poisson process – Discrete parameter Markov chain – Chapman Kolmogorov equations – Limiting distributions.			
Part – A (2 Mark Questions)			
1.	Define Markov process .	BTL1	Remembering
2.	Define wide sense stationary process.	BTL1	Remembering
3.	Define Poisson process.	BTL1	Remembering
4.	Give the properties of Poisson process.	BTL1	Remembering
5.	Give the four types of a stochastic process.	BTL1	Remembering
6.	Consider the Markov chain with 2 states and transition probability matrix $P = \begin{bmatrix} \frac{3}{4} & \frac{1}{4} \\ \frac{1}{2} & \frac{1}{2} \end{bmatrix}$. Find the stationary probabilities of the chain.	BTL5	Evaluating
7.	The one-step transition probability matrix of a Markov chain with states (0,1) is given by $P = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$. Check whether it is irreducible Markov chain?	BTL6	Creating
8.	Find the transition matrix of the following transition diagram. 	BTL6	Creating
9.	Show that the random process $X(t) = A\cos(\omega_c t + \theta)$ is not stationary if it is assumed that A and ω_c are constants and θ is a uniformly distributed variable on the interval $(0,\pi)$.	BTL3	Applying
10.	Define Discrete Random Process with example.	BTL4	Analyzing
11.	Define continuous random process, Give an example.	BTL2	Understanding
12.	Explain whether the Markov chain with transition probability matrix $P = \begin{bmatrix} 0 & 1 & 0 \\ 1/2 & 0 & 1/2 \\ 0 & 1 & 0 \end{bmatrix}$ is irreducible or not?	BTL4	Analyzing
13.	Consider the random process $X(t) = cos(t + \phi)$, where ϕ is uniform random variable in $\left(-\pi/2, \pi/2\right)$. Check whether the process is stationary.	BTL5	Evaluating
14.	If X(t) and Y(t) are two wide – sense stationary random processes and $E\{\lvert X(0) - Y(0)\rvert^2\} = 0$, Show that $R_{XX}(\tau) = R_{XY}(\tau) = R_{YY}(\tau)$.	BTL3	Applying

15	Find the mean and variance of a stationary random process whose auto correlation function is given by $R_{XX}(\tau) = 18 + \frac{2}{6+\tau^2}$	BTL2	Understanding
16.	Derive the auto correlation for a Poisson process with rate λ.		
17.	A random process X (t) = A sin *t* + B cos *t* where A and B are independent random variables with zero means and equal standard deviations. Find the mean of the process.	BTL3	Applying
18.	Define a Markov chain.	BTL1	Remembering
19.	State Chapman Kolmogorov theorem.	BTL2	Understanding
20.	Find the mean and variance of a stationary random process whose auto correlation function is given by $R_{(Z)} = \frac{25Z^2 + 36}{6.25Z^2 + 4}$	BTL2	Understanding
	16-MARK QUESTIONS		
1.	The process {X(t)} whose probability distribution under certain conditions is given by $P\{X(t)=n\} = \begin{cases} \frac{(at)^{n-1}}{(1+at)^{n+1}}, & n=1,2 \\ \frac{at}{(1+at)}, & n=0 \end{cases}$ Show that it is not stationary.	BTL3	Applying
2.	**(a)** Given that the random process *X(t)* = *cos (t + φ)* where *φ* is a random variable with density function $f(x) = \frac{1}{\pi}, \frac{-\pi}{2} < \varphi < \frac{\pi}{2}$ .Check whether the process is stationary or not.	BTL2	Understanding
	(b) The transition probability matrix of a Markov chain {X_n}, n = 1,2,3, …. having 3 states 1,2 and 3 is $P = \begin{bmatrix} 0.1 & 0.5 & 0.4 \\ 0.6 & 0.2 & 0.2 \\ 0.3 & 0.4 & 0.3 \end{bmatrix}$ and the initial distribution is P(0) = (0.7, 0.2, 0.1). Evaluate i) $P(X_2 = 3)$, ii) $P(X_3 = 2, X_2 = 3, X_1 = 3, X_0 = 2)$	BTL5	Evaluating
3.	**(a)** Show that the random process *X*(*t*) = *A* sin(ω*t* + θ) is wide-sense stationary process where A and ω are constants and θ is uniformly distributed in (0, 2π).	BTL3	Applying
	(b) On a given day, a retired English professor, Dr. Charles Fish amuses himself with only one of the following activities reading (i), gardening (ii) or working on his book about a river valley (iii) for $1 \le i \le 3$, let $X_n = i$, if Dr. Fish devotes day *n* to activity *i*. Suppose that {X_n : n=1,2… } is a Markov chain, and depending on which of these activities on the next day is given by the t. p. m $P = \begin{bmatrix} 0.30 & 0.25 & 0.45 \\ 0.40 & 0.10 & 0.50 \\ 0.25 & 0.40 & 0.35 \end{bmatrix}$ Find the proportion of days Dr. Fish devotes to each activity.	BTL1	Remembering
4.	Two random processes X(t) and Y(t) are defined by *X(t) = A cos ω t + B sin ω t* and *Y(t) = B cos ω t – A sin ω t*. Show that X (t) and Y(t) are jointly wide – sense stationary if A and B are uncorrelated random variables with zero means and the same variances and ω is constant.	BTL2	Understanding
5.	**(a)** Consider a random process *X(t) = B cos (50 t + Φ)* where B and Φ are independent random variables. B is a random variable with mean 0 and variance 1. Φ is uniformly distributed in the interval [-π,π]. Find the mean and auto correlation of the process.	BTL1	Remembering

	(b) Let $\{X_n : n = 1,2,3 \ldots\ldots \}$ be a Markov chain on the space $S = \{1,2,3\}$ with one step t.p.m $P = \begin{bmatrix} 0 & 1 & 0 \\ 1/2 & 0 & 1/2 \\ 1 & 0 & 0 \end{bmatrix}$ 1.Sketch the transition diagram, 2. Is the chain irreducible? Explain. 3. Is the chain ergodic? Explain.	BTL5	Evaluating
6.	**(a)** Show that the random process $X(t) = A\cos(\omega + \theta)$ is wide sense stationary, if A and ω are constant and θ is a uniformly distributed random variable in $(0, 2\pi)$.	BTL1	Remembering
	(b) (i) Prove that a Poisson Process is a Markov chain. (ii) Find the mean and autocorrelation of the Poisson processes	BTL3	Applying
7.	**(a)** Three boys A, B and C are throwing a ball to each other. *A* always throws the ball to *B* and *B* always throws the ball to *C* but *C* is just as likely to throw the ball to *B* as to *A*. Show that the process is Markovian. Find the transition probability matrix and classify the states.	BTL2	Understanding
	(b) If the customers arrive in accordance with the Poisson process, with rate of 2 per minute, Find the probability that the interval between 2 consecutive arrivals is (i) more than 1 minute, (ii) between 1 and 2 minutes, (iii) less than 4 minutes.	BTL1	Remembering
8.	**(a)** Derive the balance equation of the birth and death process.	BTL4	Analyzing
	(b) A man either drives a car or catches a train to go to office each day. He never goes 2 days in a row by train but if he drives one day, then the next day he is just as likely to drive again as he is to travel by train. Now suppose that on the first day of the week, the man tossed a fair die and drove to work if and only if 6 appeared. Find (i) the probability that he takes a train on the third day (ii) the probability that he drives to work in the long run.	BTL2	Understanding
9.	**(a)** A fair die is tossed repeatedly. If X_n denotes the maximum of the numbers occurring in the first n tosses, find the transition probability matrix P of the Markov chain $\{X_n\}$. Find also $P\{X_2 = 6\}$ and P^2.	BTL6	Creating
	(b) An engineer analyzing a series of digital signals generated by at testing system observes that only 1 out of 15 highly distorted signal with no recognizable signal whereas 20 out of 23 recognized signals follow recognizable signals with no highly distorted signals between. Given that only highly distorted signals are not recognizable, find the fraction of signals that are highly distorted.	BTL4	Analyzing
10.	**(a)** Check whether the Poisson process $X(t)$ given by the probability law $P\{X(t) = n\} = \frac{e^{-\lambda t}(\lambda t)^n}{n!}, n = 0,1,2,\cdots$ is not stationary.	BTL6	Creating
	(b) A salesman's territory consists of three regions A, B, C. He never sells in the same region on successive days. If he sells in region A, then the next day he sells in B. However, if he sells either B or C, then the next day he is twice as likely to sell in A as in the other region. Explain How often does he sell in each of the regions in the steady state?	BTL4	Analyzing
11.	**(a)** (i) Prove that the sum of two independent Poisson process is a Poisson process. (ii) Prove that the difference of two independent Poisson process is not a Poisson process.	BTL3	Applying
	(b)Consider a Markov chain chain $\{X_n, n = 0, 1, 2, \ldots\}$ having states space $S = \{1,2\}$ and one step TPM $P = \begin{bmatrix} \frac{4}{10} & \frac{6}{10} \\ \frac{8}{10} & \frac{2}{10} \end{bmatrix}$.	BTL5	Evaluating

	(1) Draw a transition diagram, (2) Is the chain irreducible? (3) Is the state -1 ergodic? Explain. (4) Is the chain ergodic? Explain		
12.	**(a)** Suppose that the earthquakes occurs in a certain region of California, in accordance with a Poisson Process at a rate of 7 per year. What is the probability of no earthquakes in 1 year? What is the probability that exactly 3 of the next 8 years no earthquakes will occur?	BTL3	Applying
	(b) At an intersection, a working traffic light will be out of order the next day with probability 0.07, and an out of order traffic light will be working on the next day with probability 0.88. Find the state space and tpm. Also find $P(X_2=1)$.	BTL1	Remembering
13.	Consider the Markov chain $\{X_n, n= 0, 1, 2,3\ldots..\}$ having 3 states space S={1,2,3} and one step TPM $P=\begin{bmatrix} 0 & 1 & 0 \\ 1/2 & 0 & 1/2 \\ 0 & 1 & 0 \end{bmatrix}$ and initial probability distribution $P(X_0=i)=1/3$,i= 1,2,3. Compute (1) $P(X_3=2.\ X_2=1,X_1=2/X_0=1)$ (2) $P(X_3=2, X_2=1/X_1=2,X_0=1)$ (3) $P(X_2=2/X_0=2)$ (4) Invariant Probabilities of the Markov Chain.	BTL6	Creating
14.	**(a)** Consider the random process $Y(t) = X(t)\cos(\omega_0 t+\theta)$, where $X(t)$ is wide sense stationary process, θ is a Uniformly distributed R.V. over $(-\pi, \pi)$ and ω_0 is a constant. It is assumed that $X(t)$ and θ are independent. Show that $Y(t)$ is a wide sense stationary.	BTL3	Applying
	(b) A machine goes out of order whenever a component fails. The failure of this part follows a Poisson process with mean rate of 1 per week. Find the probability that 2 weeks have a elapsed since last failure. If there are 5 spare parts of this component in an inventory and that the next supply is not due in 10 weeks, find the probability that the machine will not be out of order in the next 10 weeks.	BTL5	Evaluating

UNIT IV QUEUEING MODELS

Markovian queues – Birth and death processes – Single and multiple server queueing models – Little's formula – Queues with finite waiting rooms – Queues with impatient customers : Balking and reneging.

Part – A (2 MARK QUESTIONS)

1.	State the characteristics of a queueing model.	BTL1	Remembering
2.	Write Kendall's notation for Queueing Model.	BTL2	Understanding
3.	What are the service disciplines available in the queueing model?	BTL1	Remembering
4.	For (M/M/1) : (∞ /FIFO) model, Write the Little's formula.	BTL3	Applying
6.	Write the formulae for P_0 and P_n in a Poisson queue system in the steady – state.	BTL2	Understanding
7.	Write the effective arrival rate for M/M/1: K/FIFO queueing model		
8.	What do you mean by transient and steady state queueing systems?	BTL2	Understanding
9.	Give the formula for average waiting time of a customer in the queue for (M/M/1): (K/FIFO).	BTL4	Analyzing
10.	Find the probability that a customer has to wait more than 15 *min* to get his service completed in a (M/M/1) : (∞/FIFO) queue system, if λ=6 *per hour* and μ= 10 *per hour?*.	BTL3	Applying
11.	If λ= 3 per hour, μ= 4 per hour and maximum capacity K = 7 in a (M/M/1) : (K/FIFO) system, Find the average number of customers in the system.	BTL6	Creating
12.	A drive in banking service is modeled as an M/M/1 queueing system with customer arrival rate of 2 per minute. It is desired to have fewer than 5 customers line up 99 percent of the time. How fast should the service rate be?	BTL4	Analyzing
13.	If people arrive to purchase cinema tickets at the average rate of 6 per minute, it takes an average of 7.5 seconds to purchase a ticket. If a person arrives 2 minutes	BTL1	Remembering

	before the picture starts and it takes exactly 1.5 minutes to reach the correct seat after purchasing the ticket. What he expect to be seated for the start of the picture?		
14.	Describe the formula for W_s and W_q for the M/M/1/N queueing system.	BTL4	Analyzing
15.	For (M/M/C): (N/FIFO) model, Write the formula for (*a*) average number of customers in the queue. (*b*) average waiting time in the system.	BTL5	Evaluating
16.	Consider an M/M/C queueing system. Find the probability that an arriving customer is forced to join the queue.	BTL1	Remembering
17.	Draw the transition diagram for M/M/1 queueing model.	BTL1	Remembering
18.	If there are 2 servers in an infinite capacity Poisson queue system with $\lambda = 10$ *per hour* and $\mu = 15$ *per hour,* Examine the percentage of idle time for each server?	BTL1	Remembering
19.	A self-service store employs one cashier at its counter. Nine customers arrive on an average every 5 *minutes* while the cashier can serve 10 customers in 5 *minutes.* Assuming Poisson distribution for arrival rate and exponential distribution for service rate, Find the average time a customer spends in the system.	BTL2	Understanding
20.	In a 3 server infinite capacity Poisson queue model if $\frac{\lambda}{\mu C} = \frac{2}{3}$, Calculate P_0.	BTL6	Creating
	PART – B		
1.	Arrivals at a telephone booth are considered to be Poisson with an average time of 12 min. between one arrival and the next .The length of a phone call is assumed to be distributed exponentially with mean 4 min. a) Find the average number of persons waiting in the system b) What is the probability that a person arriving at the booth will have to wait in the queue ? c) What is the probability that it will take him more than 10 min altogether to wait for the phone and complete his call? d) Estimate the fraction of the day when the phone will be in use e) The telephone department will install a second booth ,when convinced that an arrival has to wait on the average for atleast 3 min. for phone .By how much the flow of arrivals should increase in order to justify a second booth? f)What is the average length of the queue that forms from time to time?	BTL -2	Understanding
2	Customers arrive at a one man barber shop according to a Poisson with a mean inter arrival time of 20 min Customers spend an average of 15 min in the barber's chair 1) What is the expected number of customers in the barber shop ?In the Queue? 2) What is the probability that a customer will not have to wait for a hair cut? 3) How much can a customer expect to spend in the barbershop? 4) What are the average time customers spend in the queue? 5) What is the probability that the waiting time in the system is greater than 30 min? 6) What is the probability that there are more than 3 customers in the system?	BTL -3	Applying
3	There are three typists in an office .Each typist can type an average of 6 Letters per hour .If letters arrive for being typed at the rate of 15 letters per hour, a)What fraction of the time all the typists will be busy ? b)What is the average number of letters waiting to be typed? c)What is the average time a letter has to spend for waiting and for being typed ? d)What is the probability that a letter will take longer than 20 min waiting to be typed ?	BTL -6	Creating
4	A bank has two tellers working on savings accounts. The first teller handles withdrawals only. The second teller handles deposits only .It has been found that the service time distributions for both deposits and withdrawals are exponential with mean time of 3 min per customer. Depositors are found to arrive in Poisson fashion throughout the day with mean arrival rate of 16 per hour Withdrawers also arrive in a Poisson fashion with mean arrival rate 14 per hour. What would be the effect on the average waiting time for the customers if each teller handles both withdrawals and deposits? What would be the effect, if this could only be accomplished by increasing the service time to 3.5 min?	BTL -4	Analyzing

5	A 2 – person barber shop has 5 chair to accommodate waiting customers.Potential customers ,who arrive when all 5 chairs are full,leave without entering barber shop. Customers arrive at the average rate of 4 per hour and spend an average of 12 min in the barber's chair .Compute P_0, P_1, P_7, $E(N_q)$ and E (w)	BTL -3	Applying
6	**(a)** In a given M / M / 1 queueing system, the average arrivals is 4 customers per minute, ρ= 0.7. What are 1) mean number of customers L_s in the system 2) mean number of customers L_q in the queue 3) probability that the server is idle 4) mean waiting time W_s in the system.	BTL -2	Understanding
	(b) A petrol pump station has 4 pumps. The service times follow the exponential distribution with a mean of 6 min and cars arrive for service in a Poisson process at the rate of 30 cars per hour. (a)What is the probability that an arrival would have to wait in line? (b) Find the average waiting time, average time spent in the system and the average number of cars in the system (c) For what percentage of time would a pump be idle on an average?	BTL -1	Remembering
7	Customers arrive at a watch repair shop according to a Poisson process at a rate of one per every10 minutes , and the service time is exponential random variable with 8 minutes a)Find the average number of customers L_s in the shop . b)Find the average number of customers L_q in the queue. c)Find the average time a customer spends in the system in the shop W_s. d)What is the probability that the server is idle ?	BTL -4	Analyzing
8.	A car servicing station has 2 bays where service can be offered simultaneously .Because of space limtation,only 4 cars are accepted for servicing . The arrival pattern is Poisson with 12 cars per day.The service time in both bays is exponentially distributed with μ = 8 cars per day per bay. Write the average number of cars in the service station , the average number of cars waiting for service time a car spends in the system	BTL -1	Remembering
9.	(a) A repairman is to be hired to repair machines which breakdown at the average rate of 3 per hour The breakdown follow Poisson distribution .Non –productive time of machine is considered to cost Rs 16/hour. Two repair men have been interviewed. One is slow but cheap while the other is fast and expensive. The slow repairman charges Rs.8 per hour and he services at the rate of 4 per hour The fast repairman demands Rs .10 per hour and services at the average rate 6 per hour. Which repairman should be hired?	BTL -4	Analyzing
	(b) On average 96 patients per (24 hour) day require the service of an emergency clinic . Also an average a patient requires 10 minutes of active attention. Assume that the facility can handle only one emergency at a time .Suppose that it costs the clinic Rs.100 per patient treated to obtain an average service time of 10 minutes, and that each minute of decrease in this average time would cost Rs .10 per patient treated .How much would have to be budgeted by the clinic to decrease the average size of the queue from 1 1/3 patients to ½ patient?	BTL -4	Analyzing
10	**(a)** A telephone company is planning to install telephone booths in a new airport It has established the policy that a person should not have to wait more than 10 % of the times he tries to use a phone. The demand for use is estimated to be Poisson with an average of 30 per hour. The average phone call has an exponential distribution with a mean time of 5 min. how many phone should be installed?	BTL -4	Analyzing
	(b) A super market has two girls attending to sales at the counters. If the service time for each customer is exponential with mean 4 min and if people arrive in Poisson fashion at the rate of 10 per hour a) What is the probability that a customer has to wait for service? b) What is the expected percentage of idle time for each girl? c) If the customer has to wait in the queue, what is the expected length of the waiting time?	BTL -2	Understanding

11.	(a) A tele phone exchange has two long distance operators. The telephone company finds that during peak load, long distance calls arrive in a Poisson fashion at an average rate of 15 per hour. The length of service of these calls approximately exponentially distributed with mean length of 5 minutes. (1) What is the probability that a subscriber will have to wait for his long distance calls during the peack hours of the day? (2) If the subcribers will wait and are serviced in turn, what is the expected waiting time?	BTL -2	Understanding
	(b) A petrol pump station has 2 pumps. The service times follow the exponential distribution with a mean of 4minutes and cars arrive for service in a Poisson process at the rate of 10 cars per hour. Find the probability that a customer has to wait for service. What proportion of time the pumps remain idle?	BTL -3	Applying
12.	**(a)** A TV repairman finds that the time spend on his jobs has an exponential distribution with mean 30 minutes. If he repairs sets in the order in which they came in, and if the arrival of sets is approximately Poisson with an average rate of 10 per8 – hour day. What is the repairman's expected idle time in each day? How many jobs are ahead of the average set just brought in?	BTL -1	Remembering
	(b) Suppose people arrive to purchase tickets for a basketball game at the average rate of 4 *min.* It takes an average of 10 *seconds* to purchase a ticket. If a sports fan arrives 2 *min* before the game starts and if it takes exactly 1 ½ *min* to reach the correct seat after the fan purchased a ticket, then i) Can the sports fan expect to be seated for the start of the game? ii)What is the probability that the sports fan will be seated for the start of the game? iii) How early must the fan arrive in order to be 99% sure of being seated for the start of the game?	BTL -3	Applying
13.	**(a)** The railway marshalling yard is sufficient only for trains (there being 11 lines, one of which is earmarked for the shunting engine to reverse itself from the crest of the hump to the rear of the train). Trains arrive at the rate of 25 trains per day, inter – arrival time and service time follow exponential with an average of 30 minutes. Estimate the probability that the yard is empty. average queue length.	BTL -5	Evaluating
	(b) Assuming that customers arrive in a Poisson fashion to the counter at a supermarket at an average rate of 15 per hour and the service by the clerk has an exponential distribution, Describe and determine at what average rate must a clerk work in order to ensure a probability of 0.90 that the customer will not wait longer than 12 *minutes?*	BTL -5	Evaluating
14.	**(a)** At a port there are 6 unloading berths and 4 unloading crews. When all the berths are full, arriving ships are diverted to an overflow facility 20 kms .down the river. Tankers arrive according to a Poisson process with a mean of 1 for every 2 hours. It takes for an unloading crew, on the average, 10 *hours* to unload a tanker, the unloading time follows an exponential distribution Develop and Determine (i)how many tankers are at the port on the average? 9ii)how long does a tanker spend at the port on the average? (iii)what is the average arrival rate at the overflow facility?	BTL -6	Creating
	(b) Derive p_0, L_s, L_q, W_s, W_q for $(M/M/1):(\infty/FIFO)$ queueing model	BTL -1	Remembering

UNIT V ADVANCED QUEUEING MODELS Finite source models – M/G/1 queue – Pollaczek Khinchin formula – M/D/1 and M/EK/1 as special cases – Series queues – Open Jackson networks.			
Part A(2 mark questions)			
1.	Express Pollaczek- Khintchine formula.	BTL2	Understanding
2.	Define effective arrival rate with respect to an (M | M | 1): (GD / N/ ∞) queuing model.	BTL1	Remembering
3.	For an M/G/1 model if λ=5 and μ=6 min and σ=1/20, find the length of the queue.	BTL2	Understanding
4.	An one man barber shop taken 25 mins to complete a hair cut. If customers arrive in a Poisson fashion at an average rate of 1 per 40 mins, find the average length of the	BTL1	Remembering

<table>
<tr><td></td><td>queue.</td><td></td><td></td></tr>
<tr><td>5.</td><td>Define a tandem queue.</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>6.</td><td>Describe series queue .</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>7.</td><td>Define a two-stage series queue.</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>8.</td><td>Define Series Queue with blocking .</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>9.</td><td>A transfer line has two machines M1 and M2 with unlimited buffer space in between. Parts arrives the transfer line at the rate of 1 part every 2 mins. The processing rates of M1 and M2 are 1 per min. and 2 per min. respectively. Find the average number of parts in M1.</td><td>BTL3</td><td>Applying</td></tr>
<tr><td>10.</td><td>Define an open Jackson network.</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>11.</td><td>Write down the characteristics of an open Jackson network.</td><td>BTL3</td><td>Applying</td></tr>
<tr><td>12.</td><td>Write a expression for the traffic equations of an open Jackson network.</td><td>BTL4</td><td>Analyzing</td></tr>
<tr><td>13.</td><td>State the arrival theorem in the study of Jackson network</td><td>BTL4</td><td>Analyzing</td></tr>
<tr><td>14.</td><td>Define series queues.</td><td>BTL4</td><td>Analyzing</td></tr>
<tr><td>15.</td><td>Select and give any two examples for series queues.</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>16.</td><td>State Jackson's theorem for an open network</td><td>BTL5</td><td>Evaluating</td></tr>
<tr><td>17.</td><td>Compose classification of queuing networks.</td><td>BTL3</td><td>Applying</td></tr>
<tr><td>18.</td><td>Distinguish between open and closed networks.</td><td>BTL6</td><td>Creating</td></tr>
<tr><td>19.</td><td>What do you mean by bottleneck of a network?</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>20.</td><td>Consider a series facility with two sequential stations with respective service rates 3/min and 4/min. The arrival rate is 2/min. What is the average service time of the system, if the system could be approximated by a two sdtage tandom queue?</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td></td><td>PART – B (16-MARK QUESTIONS)</td><td></td><td></td></tr>
<tr><td>1.</td><td>State and Derive Pollaczek - Khinchin formula.</td><td>BTL6</td><td>Creating</td></tr>
<tr><td>2.</td><td>(b)`In a book shop there are two sections, one for text books and the other for note books . Customers fro ot side arrived at the text book section at a Poissson rate of 4 per hour and at the notebook section at a Poison rate of 3per hour. The service rates of T.B and N.B sections respectively 8 and 10 per hour. customer upon completion of service at T.B section is equally likely to go to the N.B section or to leave the book shop, where as a customer upon completion of service at N.B section will go to the T.B section with probability 1/3 and will leave the book shop otherwise. Find the joint steady state ptrobability tht there are 4 customers in the T.B section and 2 customers I nthe N.B section.Find also the average number of customers in the book shop and the average waiting time of the customers in the shop. Assume that there is only one sales man in each section.</td><td>BTL2</td><td>Understanding</td></tr>
<tr><td>3.</td><td>The open Jackson network the following informations are given:
<table>
<tr><td></td><td></td><td></td><td></td><td>r_{ij}</td><td></td><td></td></tr>
<tr><td>Station</td><td>C_j</td><td>μ_j</td><td>r_j</td><td>i = 1</td><td>i =2</td><td>i =3</td></tr>
<tr><td>1</td><td>1</td><td>10</td><td>1</td><td>0</td><td>0.1</td><td>0.4</td></tr>
<tr><td>2</td><td>2</td><td>10</td><td>4</td><td>0.6</td><td>0</td><td>0.4</td></tr>
<tr><td>3</td><td>1</td><td>10</td><td>3</td><td>0.3</td><td>0.3</td><td>0</td></tr>
</table>
Find (i) the joint probability for the number of customers in 1^{st} , 2^{nd} and 3^{rd} stations are 2,3,4 respectively.
(ii) the expected number of customer in each station.
(iii) the expected total number of customers in the system
(iv) the expected total waiting time in the system.</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td>4.</td><td>(a) In a computer programs for execution arrive according to Poisson law with a mean of 5 per minute. Assuming the system is busy, Find L_q, L_s, W_q , W_s if the service time is (i) uniform between 8 and 12 sec. (ii) discrete with values 2,7 and 12 sec. and probabilities: 0.2, 0.5, 0.3 .</td><td>BTL1</td><td>Remembering</td></tr>
<tr><td></td><td>(b)A one-man barber shop takes exactly 25 minutes to complete one hair-cut. If customers arrive at the barber shop in a Poisson fashion at an average rate of one every 40 minutes, Find the average time a customer spends in the shop. Also, Find the average time a customer must wait for service?</td><td>BTL2</td><td>Understanding</td></tr>
</table>

5.	**(a)** In a college canteen, it was observed that there is only one waiter who takes exactly 4 minutes to serve a cup of coffee once the order has been placed with him. If students arrive in the canteen at an average rate of 10 per hour , how much time one is expected to spend waiting for his turn to place the order	BTL1	Remembering
	(b) Find the average calling rate for the services of the crane and what is the average delay in getting service? In a heavy machine shop, the overhead crane is 75% utilized. Time study observations gave the average slinging time as 10.5 minutes with a standard deviation of 8.8 minutes. If the average service time is cut to 8.0 minutes with a standard deviation of 6.0 minutes, how much reduction will occur on average in the delay of getting served?	BTL3	Applying
6.	There are two service stations S1 and S2 in a line with unlimited buffer space in between. Customers arrives S1 at a rate of 1 per every 2 min. The service time rates of S1 and S2 are 1 and 2 per min. respectively. Find (i) the average number of customers at S1 and S2 (ii) The average waiting times at S1and S2 (iii) the total waiting time in the system.	BTL3	Applying
7.	**(a)**A repair facility is shared by a large number of machines for repair. The facility has two sequential stations with respective rates of service 2 per hour and 3 per hour. The cumulative failure rate of all the machines is 1 per hour. Assuming that the system behavior may be approximated by a two-station tandem queue Find (i) the average number of customers in both stations, (ii) the average repair time. (iii) the probability that both service stations are idle.	BTL2	Understanding
	(b) For $(M/E_2/1)$: (FIFO/∞/∞) queueing model with $\lambda = \frac{6}{5}$ *per hour and* $\mu = \frac{3}{2}$ per hour, find the average waiting time of a customer . Also find the average time he spends in the system	BTL4	Analyzing
8.	**(a)** In a charity clinic there are two doctors, one assistant doctor D1 and his senior doctor D2. The Junior doctor tests and writes the case sheet and then sends to the senior for diagnosis and Prescription of medicine. Only one patient is allowed to enter the clinic at a time due to capacity of space. A patient who has finished with D1 has to wait till the patient with D2 has finished. If Patients arrive according to Poisson with rate 1 per hour and service times are independent and Follow exponential with parameters 3 and 2, Find (i) the probability of a customer entering the Clinic, (ii) the average number of customers in the clinic, (iii) the average time spent by a patient Who entered the clinic.	BTL2	Understanding
	(b) Consider a queuing system where arrivals according to a Poisson distribution with mean 5/hr. Find expected waiting time in the system if the service time distribution is Uniform from t = 5 min to t = 15 minutes	BTL5	Evaluating
9.	Find Ls, Lq, Ws and Wq. Automatic car wash facility operates with only one Bay. Cars arrive according to a Poisson process , with mean of 4 cars per hour and may wait in the facility's parking lot if the bay is busy. (i)If the service time for all cars is constant and equal to 10 min (ii) Uniform distribution between 8 and 12 minutes (iii) Normal distribution with mean 12 minutes and SD 3minutes (iv) Follows discrete distribution 4,8 & 15 minutes with corresponding probability 0.2,0.6&0.2	BTL5	Evaluating
10.	**(a)** In a departmental store, there are two sections namely grocery section and perishable section. Customers from outside arrive the G-section according to a Poisson process at a mean rate of 10 per hour and they reach the p-section at a mean rate of 2 per hour. The service times at both the sections are exponentially distributed with parameters 15 and 12 respectively. On finishing the job in G-section, a customer is equally likely to go to the P-section or leave the store, where as a customer on finishing his job in the P-section will go to the G- section with probability 0.25 and leave the store otherwise. Assuming that there is only one salesman in each section, find (i) the probability that there are 3 customers in the G-section and 2 customers in the P-section, (ii) the average waiting time of a customer in the store.	BTL4	Analyzing

	(b) If a patient who goes to a single doctor clinic for a general check up has to go through 4 phases. The doctor takes on the average 4 minutes for each phase of the check up and the time taken for each phase is exponentially distributed. If the arrivals of the patients at the clinic are approximately Poisson at the average rate of 3 per hour, what is the average time spent by a patient (i) in the examination (ii) waiting in the clinic?	BTL6	Creating
11.	**(a)** In super market during peak hours customers arrive according to a Poisson process at a mean rate of 40 per hour. A customer on the average takes 45 min to choose the food products and other articles that the customers needs. These times are exponentially distributed. The billing times are also exponentially distributed with a mean 4 min. For each counter (i) Find the minimum number of counters required for billing during the peak hours. (ii) If the number of counters is one more than the minimum, how many will be in the queue? And how many will be in the supermarket?	BTL2	Understanding
	(b) In a network of 3 service station 1,2, 3 customer arrive at 1,2,3 from outside in accordance with Poisson process having rate 5, 10, 15 res. The service time at the stations are exponential with respect rate 10, 50, 100, A customer completing service at station -1 is equally likely to (i) go to station 2 (ii) go to station 3 or (iii) leave the system. A customer departing from service at station 2 always goes to station 3. A departure from service at station 3 is equally likely to go station 2 or leave the system. (a) Find the average number customer in the system consisting of all the three stations? (b) Examine the average time a customer spend in the system?		
12.	Consider the system of two servers where customers from out side the system arrive at server 1 at a Poisson rate 4 and at server 2 at a Poisson rate 5 . The service rate in 1 and 2 are respectively 8 and 10. A customer upon completion of service at server 1 is equally likely to go to server 2 or to leave the system : where as departure from sever 2 will go 25% of the time to server1 and will depart the system otherwise. Determine the limiting probabilities, average number of customers and average waiting time of a customer in the system.	BTL4	Analyzing
13.	Customers arrive at a service centre consisting of 2 service points S1 and S2 at a Poisson rate of 35/hour and form a queue at the entrance. On studying the situation at the centre, they decide to go to either S1 or S2 .The decision making takes on the average 30 seconds in an exponential fashion. Nearly 55% of the customers go to S1, that consists of 3 parallel servers and the rest go to S2, that consist of 7 parallel servers. The service times at S1, are exponential with a mean of 6 minutes and those at S2 with a mean of 20 minutes. About 2% of customers, on finishing service at S1 go to S2 and about 1% of customers, on finishing service at S2 go to S1. Explain & Find the average queue sizes in front of each node and the total average time a customer spends in the service centre.	BTL6	Creating
14.	In a two station service facility, queues are not allowed. Customers arrive at the facility at an average rate of 4 per hour; the server at each station serves at the rate of 5 customers per hour. If arrivals are Poisson and service times are exponential, find the probability that an arriving customers enter the system (a) effective arrival rate (b) Average (expected) number of customers in the system. (c) Expected time of a customer spends in the system.	BTL2	Understanding