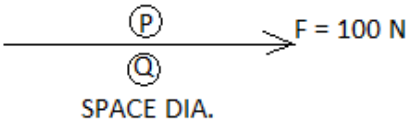
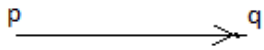
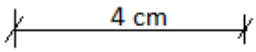
Model Answer: Winter 2017

Subject: Engineering Mechanics | **Sub. Code: 17204**

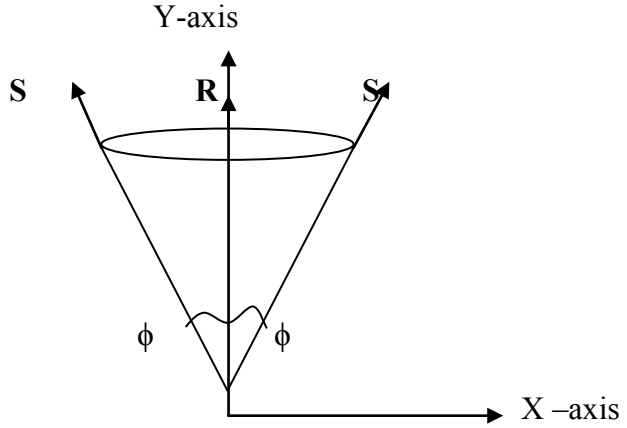
Important Instructions to Examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by the candidate and those in the model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and the model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1		**Attempt any TEN of the following :**		**(20)**
	(a)	**Define Simple Machine.**		
	Ans.	**Simple Machine:** It is a device used in lifting a heavy load applied at one point by applying comparatively smaller force called effort applied at another convenient point.	**02**	**02**
	(b)	**Define Mechanical Advantage.**		
	Ans.	**Mechanical Advantage:** It is the ratio of the load (W) lifted by the machine to the effort (P) applied to lift the load.	**02**	**02**
	(c)	**Define Ideal Effort.**		
	Ans.	**Ideal Effort:** It is the ratio of actual load to velocity ratio of machine.	**02**	**02**
	(d)	**Define Statics and Dynamics.**		
	Ans.	**Statics:** It is the branch of applied mechanics which deals with forces and their action on bodies at rest.	**01**	**02**
		Dynamics: It is the branch of applied mechanics which deals with forces and their action on bodies in motion.	**01**	

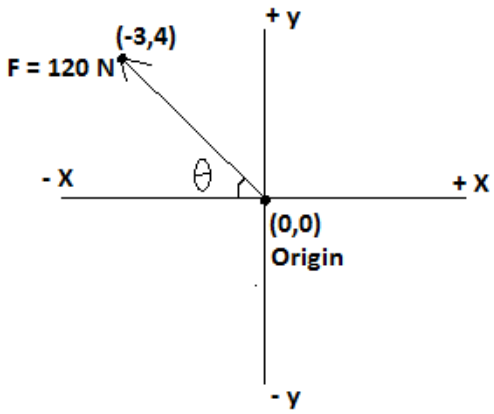
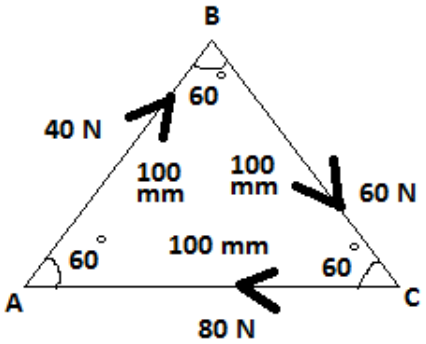
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.	(e) Ans.	**Define force and write its S.I. unit.** **Force:** It is an external agency either push or pulls which changes or tends to change the state of rest or of uniform motion of a body, upon which it acts. S. I. Unit of force – Newton (N)	**01** **01**	**02**
	(f) Ans.	**State principle of transmissibility of forces.** **Principle of transmissibility of forces**: It states that, "if a force acts at a point on a rigid body, it is assumed to act at any other point on the line of action of force within the same body".	**02**	**02**
	(g) Ans.	**State Bow's Notation. Where it is used?** Consider a force of 100 N is acting on a body. In this method, capital letters P & Q are marked on both side of line of action of force. A force of 100 N is now read as PQ as shown below in space diagram. To represent a force of 100 N graphically, pq is drawn parallel to PQ as shown in vector diagram.  SPACE DIA.   VECTOR DIA. SCALE = 1 cm = 25 N **Use:** Bow's notation is used in graphical method to indicate the force.	**01** **01**	**02**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.				
	(h)	**Define free body and free body diagram.**		
	Ans.	**Free Body:** In statics, for considering the equilibrium of the bodies under any system of forces, each body is separated from its surrounding; such body is known as a free body**.**	**01**	**02**
		Free Body Diagram: If all active and reactive forces acting on free body are shown in the diagram such diagram is known as free body diagram.	**01**	
	(i)	**List the conditions of equilibrium for co-planer non-concurrent forces.**		
	Ans.	1) $\Sigma Fx = 0$ i. e. Algebric sum of all the forces along X-axis must be equal to zero. 2) $\Sigma Fy = 0$ i. e. Algebric sum of all the forces along Y-axis must be equal to zero. 3) $\Sigma M = 0$ i. e. Algebric sum of moment of all the forces about any point must be equal to zero.	**02**	**02**
	(j)	**Define angle of repose.**		
	Ans.	**Angle of repose**: It is defined as the angle made by the inclined plane with the horizontal plane at which the body placed on an inclined plane is just on the point of moving down the plane, under the action of its own weight.	**02**	**02**

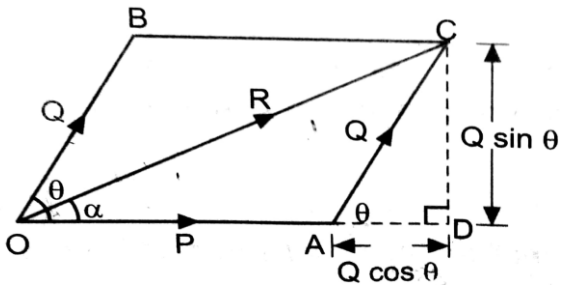
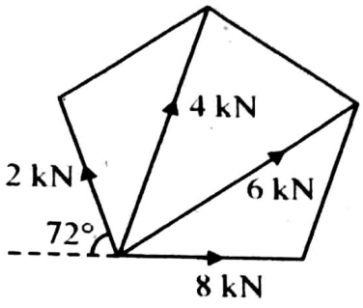
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.	(k)	**Define cone of friction.** **Cone of friction**: The resultant reaction S makes an angle ϕ with normal reaction R as shown for given set of axes XY.  If X axis is rotated about Y axis, the resultant reaction S will also rotate. The line of action of action of S will always lie on surface of right circular cone whose vertex angle is equal to 2ϕ. This cone is known as cone of friction.	**02**	**02**
	(l) **Ans.**	**The pitch of a double start square threaded screw is 10 mm. Determine the velocity ratio.** Velocity Ratio is given by - $VR = 2\pi L / np$ OR $VR = 2\pi R / np$ Where, L = Length of handle R = Radius of effort wheel P = pitch of screw ***(Note : The data given in this question is insufficient. If students try to attempt, give appropriate marks.)***	**02**	**02**

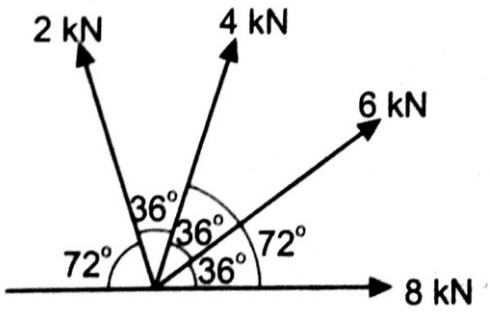
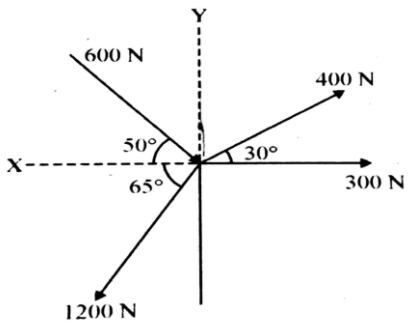
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		**Attempt any FOUR of the following :**		**(16)**
	(a)	**State Reversibility of a machine. Define self locking machine. State the conditions for reversibility and self locking.**		
	Ans.	**Reversibility of a machine**: Sometimes a machine is capable of doing some work in reverse direction, even after the effort is removed. Such a machine is called the reversible machine and the action of such a machine is known as Reversibility of a machine.	**01**	
		Self-locking machine: A machine which is not capable of doing work in reverse direction after the effort is removed is called self locking machine.	**01**	**04**
		Conditions for reversibility of machine : $\eta\ \% > 50\ \%$	**01**	
		Conditions for Self locking machine : $\eta\ \% < 50\ \%$	**01**	
	(b)	**A Weston differential pulley consists of a lower block and a upper block. The upper block has two pulleys, one of which has a radius of 125 mm and other has a radius of 115 mm. If the efficiency of the machine is 40%, calculate the effort required to raise a load of 1500 N.**		
	Ans.	$D = 2R = 2\times125 = 250mm$ $d = 2r = 2\times115 = 230mm$ $VR = \frac{2D}{D-d} = \frac{2\times250}{250-230} = 25$	**02**	
		$\%\eta = \frac{MA}{VR}\times100$ $40 = \frac{MA}{25}\times100$ $MA = 10$		**04**
		$\because \quad MA = \frac{W}{P}$ $10 = \frac{1500}{P}$ $\boxed{P = 150N}$	**02**	

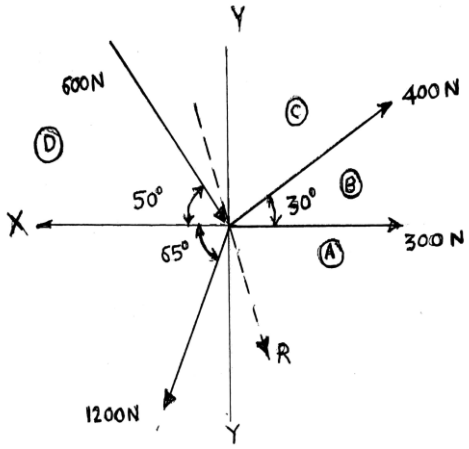
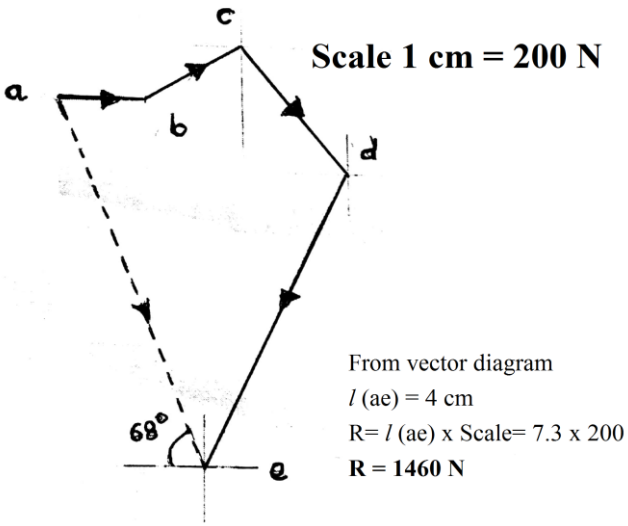
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.	(c)	**A double purchase crab used in a laboratory has following dimensions :** **Diameter of load drum = 160 mm** **Length of the handle = 360 mm** **No. of teeth on pinions = 20 and 30** **No. of teeth on spur wheel = 75 and 90** **When tested it was found that an effort of 90 N was required to lift a load of 1800 N and an effort of 135 N was required to lift a load of 3150 N. Determine :** **(i) Law of machine** **(ii) Probable effort to lift a load of 4500 N**		
	Ans.	$VR = \frac{2L \times N_1 \times N_3}{d \times N_2 \times N_4} = \frac{2 \times 360 \times 75 \times 90}{160 \times 20 \times 30} = 50.625$	**01**	
		Using law of machine $P = mW + C$ Putting values of load and effort $90 = m(1800) + C$ ---- (i) $135 = m(3150) + C$ ---- (ii) Solving simultaneous equations $m = 0.033$		
		Putting value of m in eqn (i) $90 = (0.033 \times 1800) + C$ $C = 30.6$ N	**01**	**04**
		Hence, Law of machine $\boxed{P = (0.033)\,W + 30.6\ N} \quad ---(iii)$	**01**	
		Using, eqn. (iii) $P = (0.033)\,W + 30.6$ N $P = (0.033 \times 4500) + 30.6$ $\boxed{P = 179.1\ N}$	**01**	
	(d)	**Resolve the force of 120 N acting from origin to point (-3, 4) along x and y axis.**		

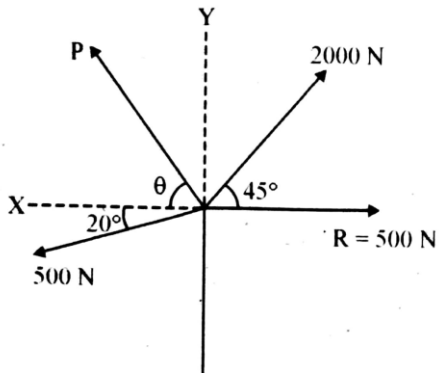
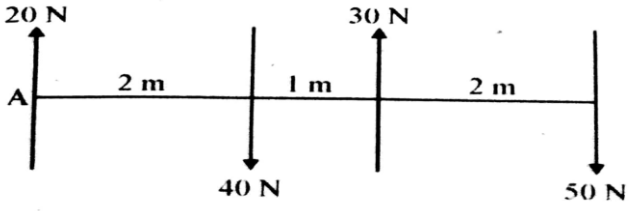
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.	(d) Ans.			
		$\theta = \tan^{-1}\left\lvert\frac{y_2 - y_1}{x_2 - x_1}\right\rvert = \tan^{-1}\left\lvert\frac{4-0}{3-0}\right\rvert = 53.13°$	01	
		$Fx = - F \cos \Theta = - 120 \cos 53.13^0 = -72$ N	1 ½	04
		$Fy = F \sin \Theta = 120 \sin 53.13^0 = 95.99$ N	1 ½	
	(e)	**Three forces 40 N, 60 N and 80 N act along three sides of an equilateral triangle of sides 100 mm each taken in order. Find the magnitude and position of resultant force.**		
	Ans.	***(Note: The point at which position of Resultant is to be find is not mentioned)***		
				
		1) Resolving all forces -		
		$\Sigma Fx = + 40 \cos 60 + 60 \cos 60 - 80 = - 30$ N	01	
		$\Sigma Fy = + 40 \sin 60 - 60 \sin 60 = -17.320$ N		
		2) Magnitude of Resultant		
		$R=\sqrt{(\Sigma Fx)^2+(\Sigma Fy)^2}$		
		$R=\sqrt{(-30)^2+(-17.320)^2}$		
		$\boxed{R=34.640N}$	01	

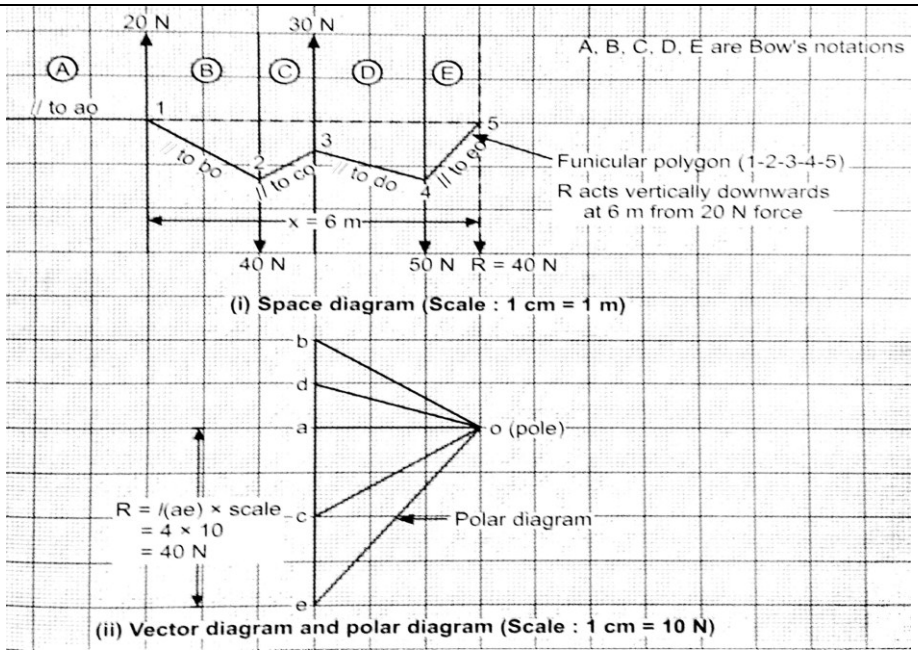
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.	**(e)**	3) Position of resultant Let x be the perpendicular distance of the resultant from point A. Using Varignon's theorem of moment $\Sigma M_{F_A} = M_{R_A}$ $60 \sin 60 \times 100 = R \times x$ $60 \sin 60 \times 100 = 34.64 \times x$ $x = 150$ mm from point A. The resultant must be located at a perpendicular distance of 150 mm from point A on upper side of A so as to produce the clockwise moment about point A ***(Note: The position of resultant with respect to Point B and C (i.e. x) will change according to forces taken in order.)***	**02**	**04**
	f)	**Define moment of force. State its SI unit. Define couple and write its types.**		
	Ans.	**Moment of force:** It is rotational effect produced by a force on a body on which it acts. It is equal to the magnitude of the force multiplied by the perpendicular distance of the point from the line of action of force.	**01**	
		S. I. Unit of moment: N-m, kN-m, kN-mm	**01**	**04**
		Couple: Two equal, unlike, parallel, non-collinear forces form a couple.	**01**	
		Types of couple : 1) Clockwise couple 2) Anticlockwise couple	**01**	

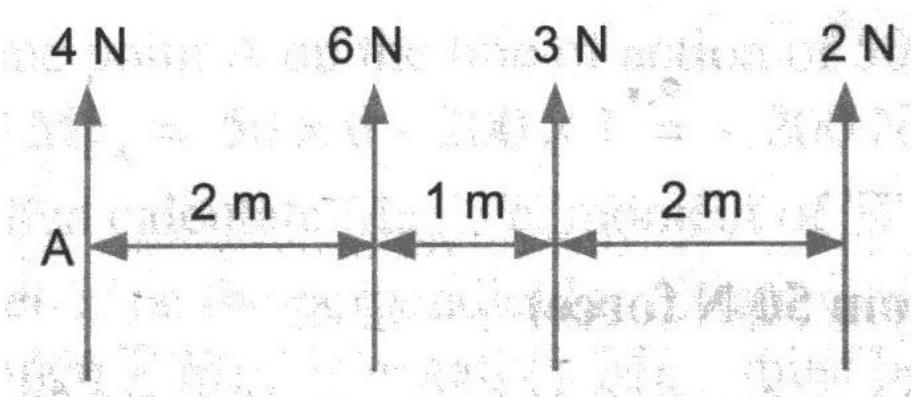
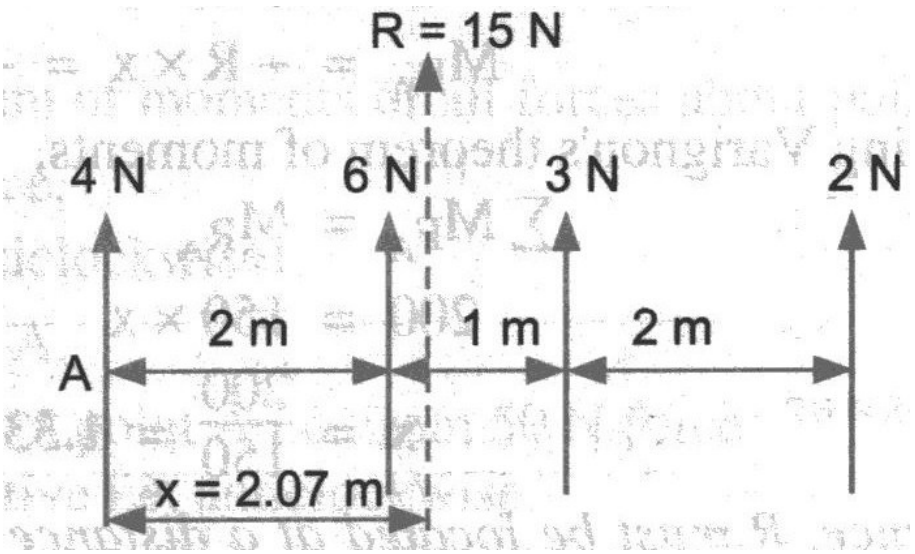
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.		**Attempt any FOUR of the following**		**(16)**
	(a)	**State parallelogram law of forces and write equations for magnitude and direction of resultant force.**		
	Ans.	**Parallelogram law of forces:**		
		It states, "If two forces acting at and away from the point be represented in magnitude and direction by adjacent sides of a parallelogram, then the diagonal of the parallelogram passing through the point of intersection of the two forces represents the resultant in magnitude and direction."	**01**	
			**01**	**04**
		Equation for magnitude of resultant force:		
		$R = \sqrt{P^2 + Q^2 + 2P.Q.\cos\theta}$	**01**	
		Equation for direction of resultant force:		
		$\alpha = \tan^{-1}\left(\frac{Q\sin\theta}{P + Q\cos\theta}\right)$	**01**	
	(b)	**Forces of 2, 4, 6 and 8 kN act on regular pentagon as shown in Fig. No.1 Find analytically the resultant in magnitude and direction.**		
				
		Fig No. 1		

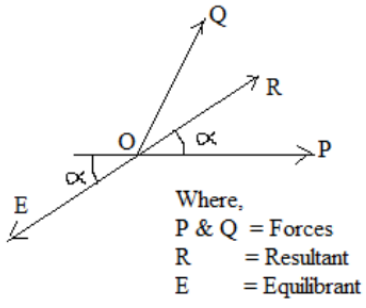
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.	(b) Ans.	$\sum F_x = 8 + 6\cos 36^0 + 4\cos 72^0 - 2\cos 72^0$ $\sum F_x = 13.47$ kN $\sum F_y = 6\sin 36^0 + 4\sin 72^0 + 2\sin 72^0$ $\sum F_y = 9.23$ kN $R = \sqrt{\sum F_x^2 + \sum F_y^2}$ $R = \sqrt{13.47^2 + 9.23^2}$ $\boxed{R = 16.33\ kN}$ $\tan\theta = \frac{\sum F_y}{\sum F_x} = \frac{9.23}{13.47}$ $\theta = \tan^{-}(0.6852)$ $\boxed{\theta = 34.42^0}$	01 01 01 01	04
				
	(c)	**A concurrent force system is shown in Fig. No.2 Find graphically the resultant of this force system.** 		

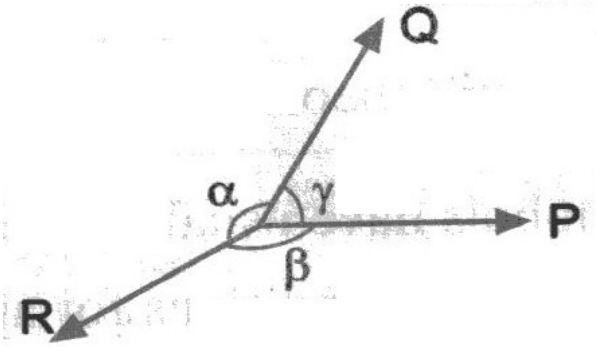
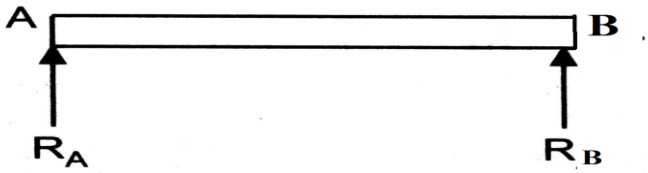
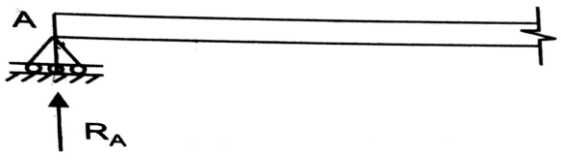
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.	(c) Ans.	 Space Diagram  Vector Daigram From vector diagram *l* (ae) = 4 cm R= *l* (ae) x Scale= 7.3 x 200 **R = 1460 N**	02 02	04

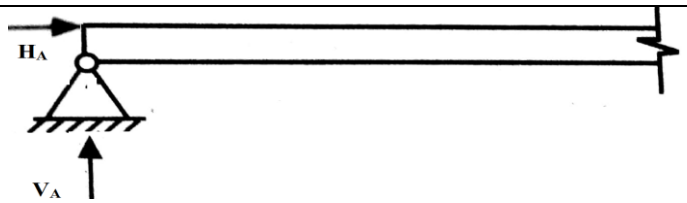
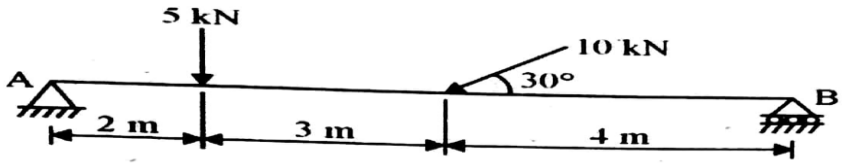
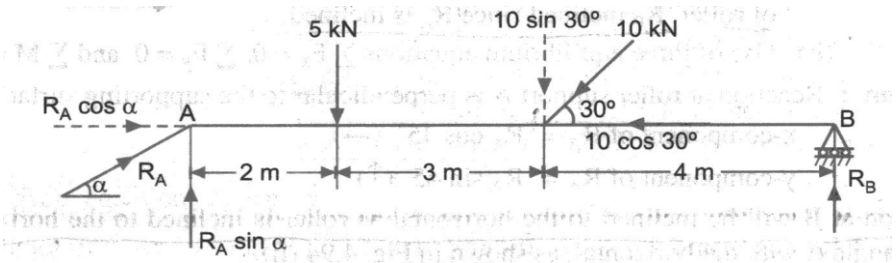
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.	(d)	**The resultant of a system of forces as shown in Fig. No. 3 is 500n and acts along X-axis towards the right. Find analytically the unknown force ' P ' and its inclination with X-axis.**		
				
		Fig. No. 3		
		$\sum F_x = 2000\cos 45^0 - 500\cos 20^0 - P\cos\theta - 500$		
		$1414.21 - 469.85 - P\cos\theta = 500$		
		$\boxed{P\cos\theta = 444.36}$	01	
		$\sum F_y = 2000\sin 45^0 - 500\sin 20^0 + P\sin\theta$		
		$1414.21 - 171.01 + P\sin\theta = 0$		
		$\boxed{P\sin\theta = -1243.2}$	01	
		$\theta = \tan^{-1}\left\lvert\frac{\sum F_y}{\sum F_x}\right\rvert = \tan^{-1}\left\lvert\frac{1243.2}{444.36}\right\rvert$		04
		$\boxed{\theta = 70.28^0}$	01	
		$P = \frac{444.36}{\cos(70.28)} = 1316.91N$		
		$\boxed{P = 1316.91N}$	01	
	(e)	**Locate graphically the position of resultant for the parallel force system as shown in Fig. No.4 with respect to point 'A'.**		
				
		Fig. No. 4		

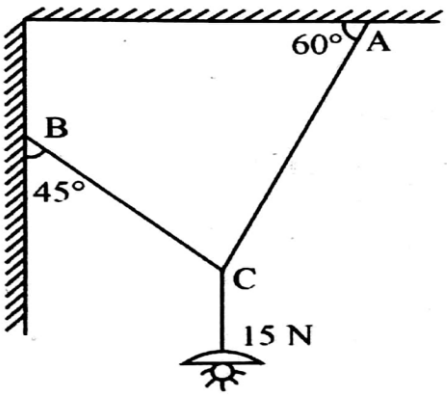
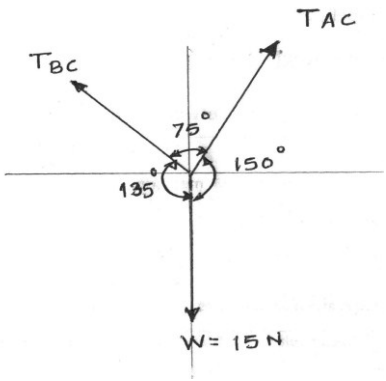
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.	**(e) Ans.**	 From vector diagram, l (ae) = 4 cm R= l (ae) x Scale= 4 x 10 **R = 40 N** Point 'e' lies below 'a' and line joining 'a' and 'e' is the resultant. Hence resultant is Downwards. Measure distance of R from A X = 6 cm= 6 x 1 **X= 6 m**	**02** **01** **01**	**04**
	(f)	**A set of four parallel forces of magnitude 4N, 6N, 3N and 2N are acting in upward direction. The distance between first two forces is 2m and that between last two is 2m. The distance between forces 6N and 3N is 1m. Find analytically the resultant and show its position on sketch with respect to 4 N force.**		
	Ans.	*Step* 1) *Magnitude of resultant* $R = \Sigma F$ $= 4 + 6 + 3 + 2$ $\boxed{R = 15\ N}$	**01**	

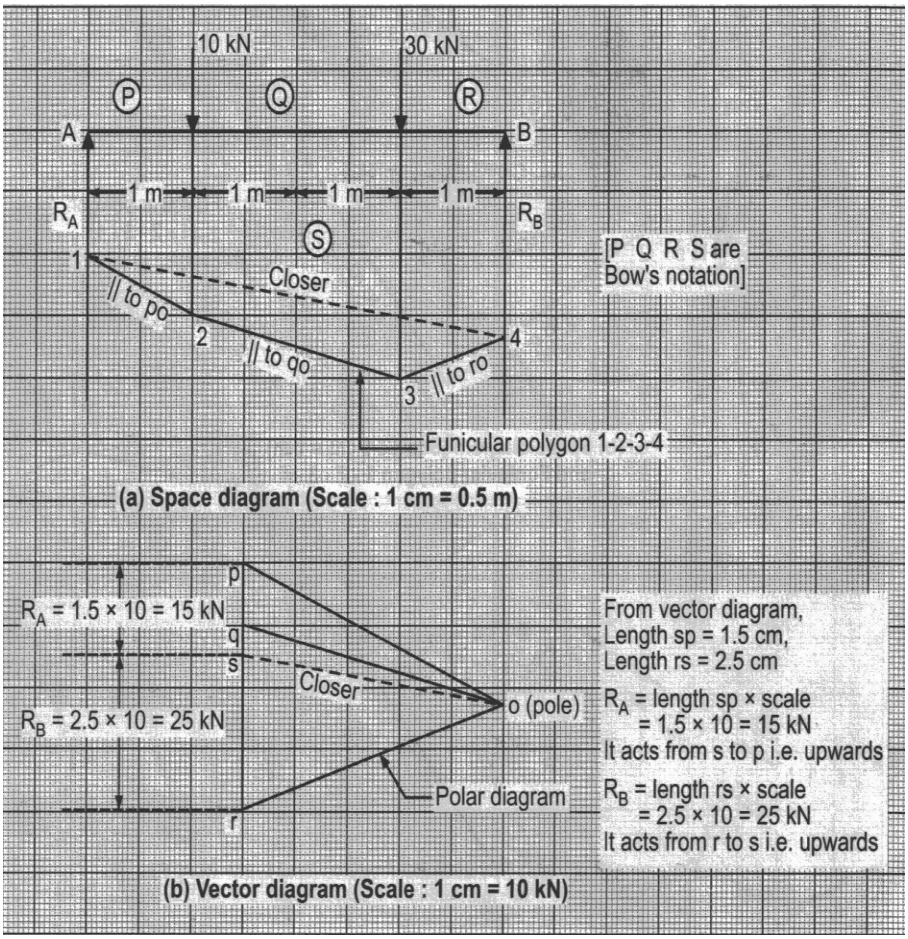
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3.	**(f)**	*Step* 2) *Direction of resultant* *Positive* sign indicates of R that it acts vertially upwards *Step* 3 *Position of resultant* *Taking moments of all forces about* 4*N force* $\sum M_{F_A} = (4\times0)-(6\times2)-(3\times3)-(2\times5)$ $= -31$ N.m $M_{R_A} = -Rx = -15x$ Use varigon's theorem of moments $\sum M_{F_A} = M_{R_A}$ $-31 = -15x$ $\boxed{x = 2.07 \text{ m}}$ R= 15N upword, X= 2.06 m from 4 N force on right side  	**01** **01** **01**	**04**

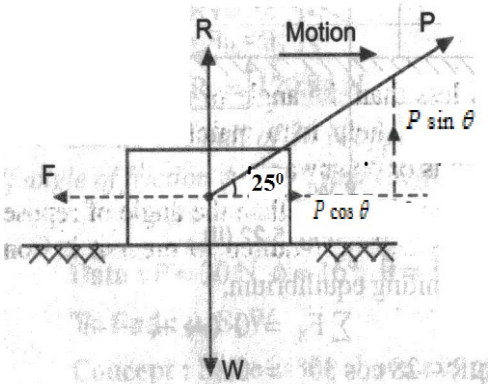
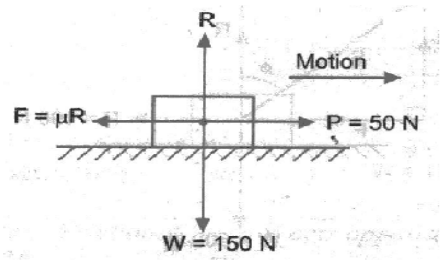
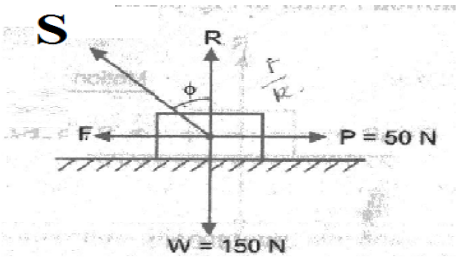
<table>
<tr><th>Que. No.</th><th>Sub. Que.</th><th>Model Answers</th><th>Marks</th><th>Total Marks</th></tr>
<tr><td>Q. 4</td><td></td><td>Attempt any FOUR of the following:</td><td></td><td>(16)</td></tr>
<tr><td></td><td>(a)</td><td>Differentiate equilibrant from resultant.</td><td></td><td></td></tr>
<tr><td></td><td>Ans.</td><td>
<table>
<tr><th>Sr. No</th><th>Resultant</th><th>Equilibrant</th></tr>
<tr><td>1</td><td>Resultant is a single force which can produce the same effect on the body as it is produced by all forces acting together</td><td>Equilibrant is a single force which when acts with other forces brings the set of forces & body in equilibrium</td></tr>
<tr><td>2</td><td>It is donated by R</td><td>It is donated by E</td></tr>
<tr><td>3</td><td>It causes displacement of body.</td><td>It keeps the body at rest</td></tr>
<tr><td>4</td><td>The set of forces which causes the displacement of a body are called as components of a resultant or component forces.</td><td>The set of forces which keeps the body at rest are called as components of a equilibrant or equilibrant forces.</td></tr>
<tr><td>5</td><td colspan="2"> 
</td></tr>
</table>
</td><td>01 mark each (any four)</td><td>04</td></tr>
<tr><td></td><td>(b)</td><td>State and explain Lami’s theorem. List limitation of Lami’s theorem.</td><td></td><td></td></tr>
<tr><td></td><td>Ans.</td><td>Lami’s Theorem: It states that, ‘if three forces acting at a point on a body keep it at rest, then each force is proportional to the sine of the angle between the other two forces’.</td><td>01</td><td></td></tr>
</table>

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.	**(b)**			**04**
		$\frac{P}{sin\alpha} = \frac{Q}{sin\beta} = \frac{R}{\sin\gamma}$	**01**	
		Limitations of Lami's theorem 1) This theorem is applicable only for three forces. 2) This theorem is applicable when forces are concurrent. 3) This theorem is applicable only when body is in equilibrium. 4) This theorem is not applicable for non-concurrent force system.	**02**	
	(c)	**Enlist three types of end supports of beam with types of reaction they offer with help of neat a sketch.**		
	Ans.	**Three types of Support reaction of beam**		
		(1) Simply Supported beam		
		(2) Roller supported beam	**1 ½**	
		(3) Hinged beam		
			**½**	
		1) Simply Supported beam		
			**½**	
		2) Roller supported beam		

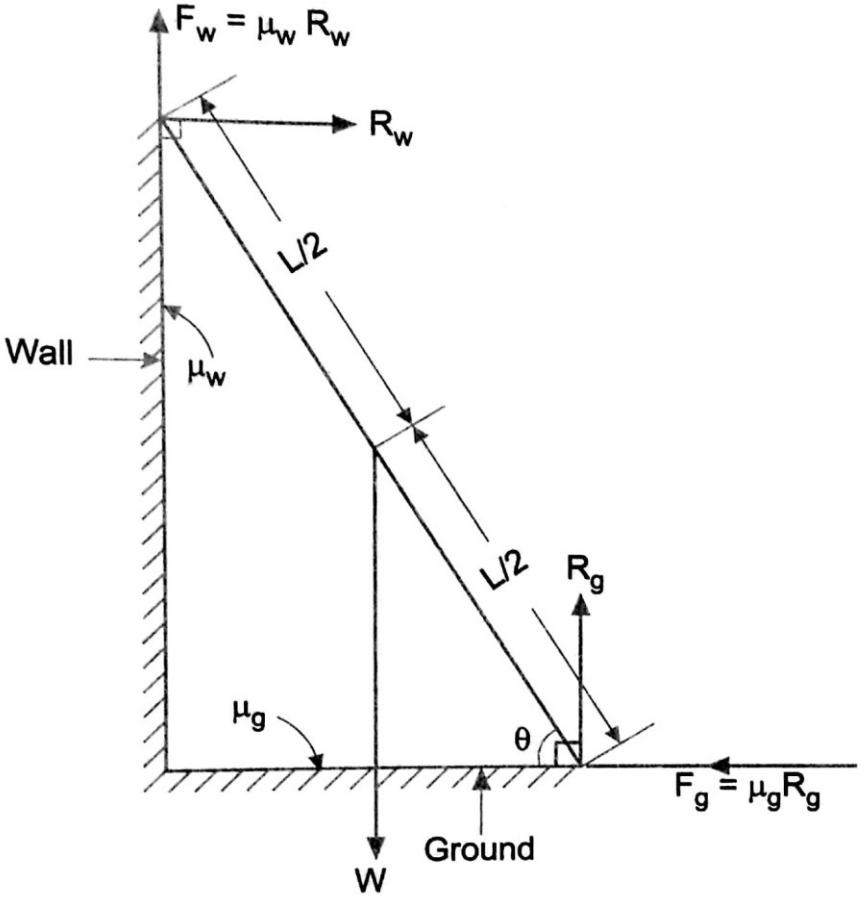
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.	(c)		½	
		3) Hinged beam		
	(d)	**Find analytically the reaction at supports as shown in Fig.No.5.**		
				
		Fig. No. 5		
	Ans.	$\Sigma M_A = 0$		
		Taking moment of all forces @ point A	**01**	
		$-R_B \times 9 + 5 \times 2 + 5 \times 5 = 0$		
		$35 = 9 R_B$		
		$\boxed{R_B = 3.88\ kN}$		
		$\Sigma Fy = 0$		
		$R_A \sin\alpha - 5 - 5 + R_B = 0$		
		$R_A \sin\alpha = 6.12 kN$		
		$\Sigma Fx = 0$		
		$R_A \cos\alpha - 8.66 = 0$	**01**	**04**
		$R_A \cos\alpha = 8.66 kN$		
		$\alpha = \tan^{-1}\left\lvert\frac{R_A \sin\alpha}{R_A \cos\alpha}\right\rvert = \tan^{-1}\left\lvert\frac{6.12}{8.66}\right\rvert = 34.99°$	**01**	
		Substituting the value of α in		
		$R_A \sin\alpha = 6.12 kN$		
		$R_A = 10.68 kN$	**01**	
		$\boxed{R_B = 3.88 kN}$		
				

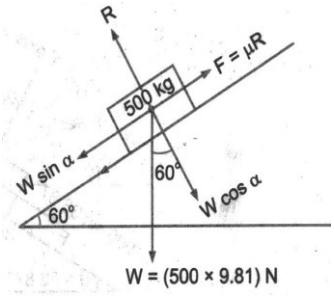
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.	(e)	**An electric light fixture weighing 15N hangs from 'C' by two strings AC and BC. The string AC is inclined at 60^0 to the horizontal and BC at 45^0 to the vertical as shown in fig.No.6 Using Lami's theorem determine forces in string AC and BC.**		
				
		Fig. No. 6		
	Ans.		**01**	
		Free body diagram		
		Applying Lami's theorem,	**01**	
		$\frac{15}{\sin 75^0} = \frac{T_{AC}}{\sin 135^0} = \frac{T_{BC}}{\sin 150^0}$		**04**
		$\frac{15}{\sin 75^0} = \frac{T_{AC}}{\sin 135^0}$		
		$T_{AC} = \frac{15}{\sin 75^0} \times \sin 135^0$		
		$\boxed{T_{AC} = 10.98N}$	**01**	
		$\frac{15}{\sin 75^0} = \frac{T_{BC}}{\sin 150^0}$		
		$T_{BC} = \frac{15}{\sin 75^0} \times \sin 150^0$		
		$\boxed{T_{BC} = 7.76N}$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.	(f)	**A simply supported beam of 4 m span is loaded with an u.d.l. of 5 kN/m for 2 m from left end and a point load of 30kN at 1m from right end .Find the support reactions using graphical method.**		
	Ans.		02 02	04

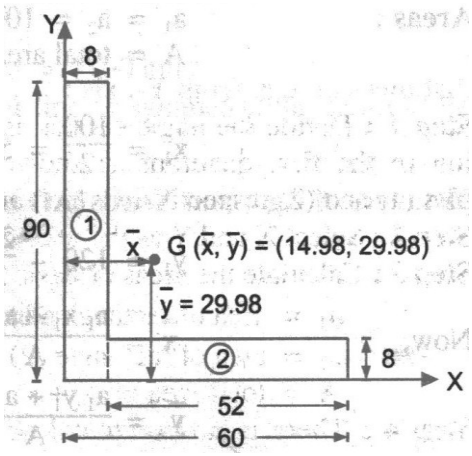
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		**Attempt of FOUR of the following:**		**(16)**
	(a)	**A body of weight 300N is lying on a rough horizontal plane having a coefficient of friction 0.3. Find the magnitude of force which can move the body, while acting at an angle of 25^0 with the horizontal.**		
	Ans.	Given: W= 300N, $\mu = 0.3, \quad \theta = 25^0$ $Find: P$ 	**01**	
		$\sum F_X = 0$ $P\cos\theta - F = 0$ $P\cos\theta - \mu R = 0$ $(\therefore F = \mu R = Friction\ factor)$ $P\cos 25 - 0.3R = 0$ $0.906P - 0.3R = 0$		**04**
		$0.3R = 0.906P$ $\boxed{R = 3.021\ \text{P}}$	**1 ½**	
		$\sum F_Y = 0$ $R + P\sin\theta - W = 0$ $3.021\ \text{P} + \text{P}\sin 25 - 300 = 0$ $\boxed{P = 87.12N}$	**1 ½**	
	b)	**A body of weight 150N is resting on a rough horizontal plane and can be just moved by a force of 50 N applied horizontally. Find the coefficient of friction. Also find magnitude and direction of resultant reaction.**		
	Ans.	Step 1 For limiting equilibrium $\sum \text{F}_\text{X} = 0$, and $\sum \text{F}_\text{Y} = 0$ $\sum \text{F}_\text{Y} = 0$ 50 - F = 0  		

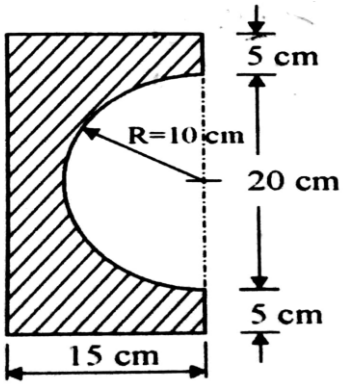
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.	**(b)**	$50 - \mu R = 0$		
		$\boxed{\mu R = 50\ N}$		
		$\sum F_Y = 0$		
		$\sum F_Y = 0$		
		$R - W = 0$		
		$R - 150 = 0$		
		$\boxed{R = 150\ N}$	**01**	
		$\mu R = 50$		
		$\mu \times 150 = 50$		
		$\boxed{\mu = 0.33}$		
		Step 2		
		To find the resultant reaction and direction,		
		For limiting equilibrium,		
		$\sum F_X = 0$		
		$P - F = 0$		
		$F = P$		
		$\boxed{F = 50N}$	**01**	
		Resultant reaction ,		**04**
		$S = \sqrt{F^2 - R^2}$		
		$S = \sqrt{50^2 - 150^2}$		
		$\boxed{S = 158.11N}$	**01**	
		$\mu = \tan\phi$		
		$\phi = \tan^{-}(\mu)$		
		$\phi = \tan^{-}(0.33)$		
		$\boxed{\phi = 18.43^0}$	**01**	
		Or		
		$\tan\phi = \frac{F}{R}$	**Or**	
		$\tan\phi = \left(\frac{50}{150}\right)$		
		$\boxed{\phi = 18.43^0}$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.	(c)	**Draw a neat sketch of ladder resting against smooth wall. Show all active and reactive forces. Elaborated notations used.**		
	Ans.		02	
		Where, μ_g = Coefficient of friction between the ladder and the ground. μ_w = Coefficient of friction between the ladder and the wall. R_g = Normal reaction at the ground. R_w = Normal reaction at the wall. F_g =Force of friction between the lader and the ground. F_w = Force of friction between the lader and the wall.	01	04
		The force of friction between the ladder and wall is given by $$F_W = \mu_w R_W$$		
		If the wall is smooth, $$\mu_w = 0 \qquad \therefore F_W = 0$$	01	

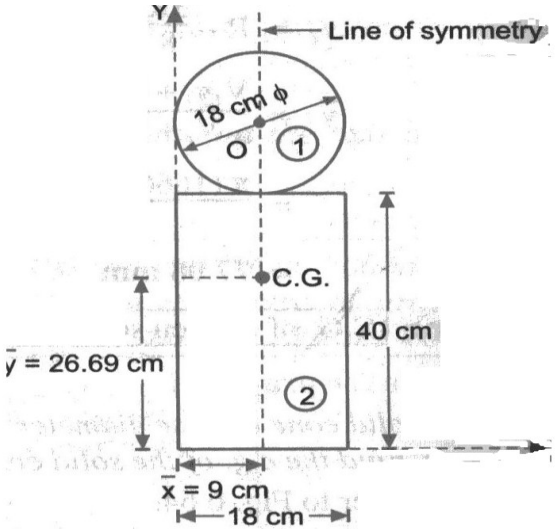
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.	(d)	**A heavy stone of mass 500kg is on a hill slope of 60^0 incline. If the coefficient of friction between ground and stone is 0.4 is the stone stable? Justify.**		
	Ans.	Step 1) For limiting equilibrium, $\sum F_X = 0$, $R - W\cos\alpha = 0$ $R = 500\times 9.811\cos 60^0$ $\boxed{R = 2452.5\ N}$  	01	
		Step 2) Friction force, $F = \mu R$ $F = 0.4\times 2452.5$ $\boxed{F = 981N}$ .....(i)	01	
		Step 3) *Component* of weight down the plane $W\sin\alpha = 500\times 9.81\times\sin 60^0$ $\boxed{W = 4247.85N}$ .....(ii)	01	04
		Comparing equation (i) and (ii) $W\sin\alpha > F$ *Step* 4) The stone will slide down the plane because of its own i.e. It will not be stable.	01	
	(e)	**For a certain machine the law is P = (0.08 W + 5) N. Calculate the effort required to lift a load of 5 kN. Also calculate maximum M.A. and identify the type of machine. V.R. of the machine is 20.**		
	Ans.	Step 1) Effort requried to lift 5 kN load P = (0.08W+5)N $P = \big((0.08\times 5000)+5\big)$ $\boxed{P = 405N}$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5.	**(e)**	Step 2) Maximum M. A. $M.A.=\frac{1}{m}=\frac{1}{0.08}$ $\boxed{\text{Maximum M.A.} = 12.5}$	**01**	**04**
		Step 3) Type of machine $\eta_{max}=\frac{1}{m\times VR}X100=\frac{1}{0.08\times 20}X100$ $\boxed{\eta_{max}=62.5\%}$	**01**	
		Step 4) $\eta_{max}=62.5\%>50\%$ Since the maximum efficiency is more then 50%, the machine Reversible.	**01**	
	(f)	**The screw jack has a pitch of 3 mm and efficiency 28%. Find the effort required at the end of arm 360 mm to lift the load of 5 kN.**		
	Ans.	Pitch = 3mm, $\eta = 28\%$, W = 5kN, L= 360 mm		
		$V.R.=\frac{2\pi L}{p}=\frac{2\times\pi\times 360}{3}$	**01**	
		V.R.=753.98		
		$MA=\frac{W}{P}=\frac{5000}{P}$	**01**	
		$\eta\% = \frac{MA}{VR}\times 100\%$		**04**
		$28=\left(\frac{\frac{5000}{P}}{753.98}\right)$	**01**	
		$P = 23.68N$ $\boxed{P = 23.68N}$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6		**Attempt any FOUR of the following:**		**(16)**
	(a)	**Find centroid of ISA 90 x 60 x 8 mm.**		
	Ans.	*Step* 1) $a_1 = 90 \times 8 = 720 mm^2$, $a_1 = 52 \times 8 = 416 mm^2$, $A = a_1 + a_1 = 720 + 416$ $\boxed{A = 1136 mm^2}$ *Step* 2) $x_1 = \frac{8}{2} = 4mm$, $x_2 = 8 + \frac{52}{2} = 34mm$, $y_1 = \frac{90}{2} = 45mm$, $y_2 = \frac{8}{2} = 4mm$, *Step* 3) $\bar{x} = \frac{a_1 x_1 + a_2 x_2}{A}$ $= \frac{(720 \times 4) + (416 \times 34)}{1136}$ $\boxed{\bar{x} = 14.98mm}$ $\bar{y} = \frac{a_1 y_1 + a_2 y_2}{A}$ $= \frac{(720 \times 45) + (416 \times 4)}{1136}$ $\boxed{\bar{y} = 29.98mm}$ $G(\bar{x}, \bar{y}) = (14.98mm,\ 29.98mm)$ 	**01** **01** **04** **01** **01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.	(b)	**Find the centroid of plate shown in Fig. No. 7.**		
	Ans.	 **Fig. No. 7**		
		Step 1) $a_1 = Area\ of$ rectangle $a_1 = 15 \times 30 = 450\ \text{cm}^2$ $a_2 = Area\ of$ semi-circle, $a_2 = \frac{\pi R^2}{2} = \frac{\pi \times 10^2}{2} = 157.08 cm^2$ $A = a_1 - a_2 = 450 - 157.08 = 292.92\ cm^2$	**01**	
		Step 2) *To* find $\bar{x}$ $x_1 = \frac{15}{2} = 7.5\ cm,$	**01**	**04**
		$x_2 = 15 - \frac{4R}{3\pi} = 15 - \frac{4 \times 10}{3\pi} = 10.76\ cm,$ $\bar{x} = \frac{a_1 x_1 - a_2 x_2}{A}$ $= \frac{(450 \times 7.5) - (157.08 \times 10.76)}{292.92}$ $= 5.75\ cm$	**01**	
		$\boxed{\bar{x} = 5.75\ cm}$ $\bar{y} = \frac{30}{2}$ $\boxed{\bar{y} = 15 cm}$ $G(\bar{x}, \bar{y}) = (5.75\ cm,\ 15 cm)$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.	**(c)**	**State and explain Varignon's theorem of moments.**		
	Ans.	**Varignon's theorem**:- It states that, the algebraic sum of moments of all forces about any point is equal to moment of resultant about the same point.	**02**	
		Let, $\sum M_{F_A}$ = Algebraic sum of moments of all forces about point A M_{R_A} = Moment of Resultant about point A Then, $\sum M_{F_A} = M_{R_A}$		**04**
		i.e $F_1x_1 + F_2x_2 + F_3x_3 + ... + F_nx_n = R \times x$	**01**	
		Where, $F_1, F_2, F.....F_n$ is the forces from the point A $x_1, x_2, x_3, ...x_n$ is the perpendicular distances of forces from the point A x is the perpendicular distance of the resultant from the point A	**01**	
	d)	**Compare the terms centroid and center of gravity.**		
	Ans.	**Sr. No.** / **Centroid** / **Center of gravity** 1 / It is defined as the point through which the entire area of a plane geometrical figure is assumed to act, for all positions of the lamina. / It is defined as the point through which the whole weight of the body is assumed to act, irrespective of the position of a body. 2 / e. g. Triangle, Square / e. g. Cone, Cylinder. 3 / $\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3 + ... + a_nx_n}{a_1 + a_2 + a_3 + ... + a_n}$ / $\bar{x} = \frac{V_1x_1 + V_2x_2 + V_3x_3 + ... + V_nx_n}{V_1 + V_2 + V_3 + ... + V_n}$ 4 / $\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3 + ... + a_ny_n}{a_1 + a_2 + a_3 + ... + a_n}$ / $\bar{y} = \frac{V_1y_1 + V_2y_2 + V_3y_3 + ... + V_ny_n}{V_1 + V_2 + V_3 + ... + V_n}$	**01 mark each**	**04**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.	**(e)**	**A solid sphere of 18 cm in diameter is placed on the top of cylinder which is also 18 cm in diameter and 40 cm high such that their axes coincide. Find C.G. of the combination.**		
				
		$\bar{X} = \frac{18}{2} = 9cm$	**01**	
		$V_1 = \frac{4}{3}\pi r^3$ $V_1 = \frac{1}{3} \times \pi \times 9^2$ $\boxed{V_1 = 3053.63\ cm^3}$		
		$V_2 = \pi r^2 h =$ $V_2 = \pi \times 9^2 \times 40$ $\boxed{V_2 = 10178.76 cm^3}$	**01**	**04**
		$y_1 = 40 + \frac{18}{4} = 40 + 9 = 49\ cm$ $y_2 = \frac{40}{2} = 20\ cm$		
		Step 3) $\bar{y} = \frac{V_1 y_1 + V_2 y_2}{V_1 + V_2}$ $\bar{y} = \frac{(3053.63 \times 49) + (10178.76 \times 20)}{3053.63 + 10178.76}$ $\bar{y} = \frac{353203.07}{13232.4}$	**01**	
		$\boxed{\bar{y} = 26.69cm}$	**01**	
		$(\bar{X}, \bar{Y}) = (9cm,\ 26.69cm)$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.	**(f)** **Ans.**	**The frustum of a cone has top diameter 30 cm and bottom diameter 60 cm with height 18 cm. Find the center of gravity of frustum.**		
		Step 1)		
		$\bar{x} = \frac{60}{2} = 30cm$	**01**	
		By similar triangles,		
		$\frac{h}{60} = \frac{h_2}{30}$		
		$h = \left(\frac{60}{30}\right) \times h_2$		
		$h = 2\ h_2$		
		$h_1 + h_2 = h$		
		$18 + h_2 = 2\ h_2$		
		$\boxed{h_2 = 18cm}$		
		Step 2)		
		$V_1 =$ Full volume of cone		
		$V_1 = \frac{1}{3}\pi r_1^2 h = \frac{1}{3} \times \pi \times 30^2 \times 36$	**01**	
		$\boxed{V_1 = 33929.2\ cm^3}$		
		$V_2 = V$olume of cut cone		
		$V_2 = \frac{1}{3}\pi r^2 h_2 = \frac{2}{3} \times \pi \times 15^3 \times 18$		**04**
		$\boxed{V_2 = 4241.15\ cm^3}$	**01**	
		$y_1 = \frac{h}{4} = \frac{36}{4} = 9\ cm$		
		$y_2 = h_1 + \frac{h_2}{4} = 18 + \frac{18}{4} = 22.5\ cm$		
		Step 3)		
		$\bar{y} = \frac{V_1 y_1 - V_2 y_2}{V_1 - V_2}$		
		$= \frac{(33929.2 \times 9) - (4241.15 \times 22.5)}{33929.2 - 4241.15}$	**01**	
		$\boxed{\bar{y} = 7.0714cm}$