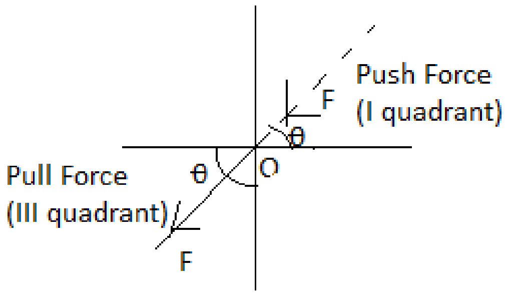
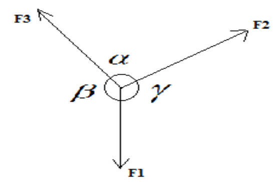
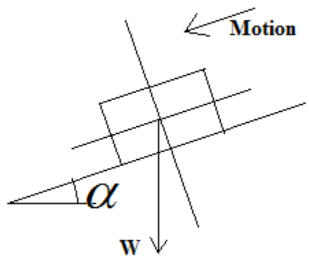
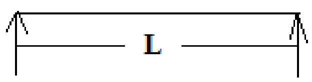
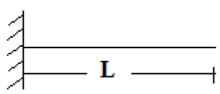
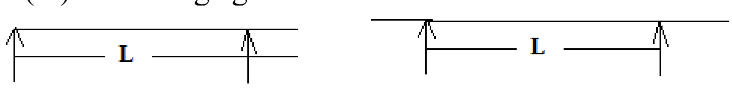
Model Answer: Summer 2018

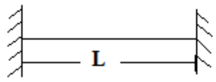
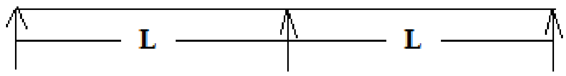
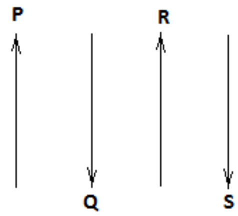
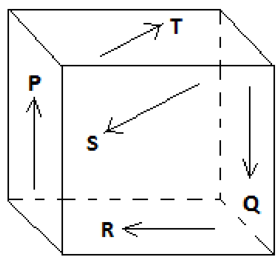
Subject: Applied Mechanics | **Sub. Code: 22203**

Important Instructions to examiners:

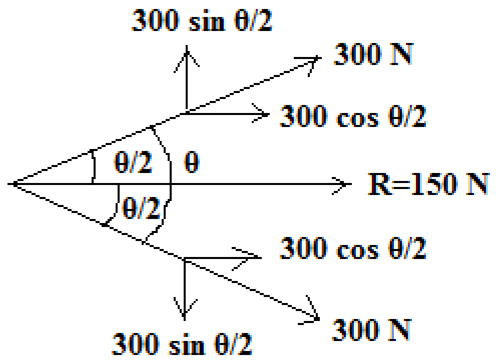
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.

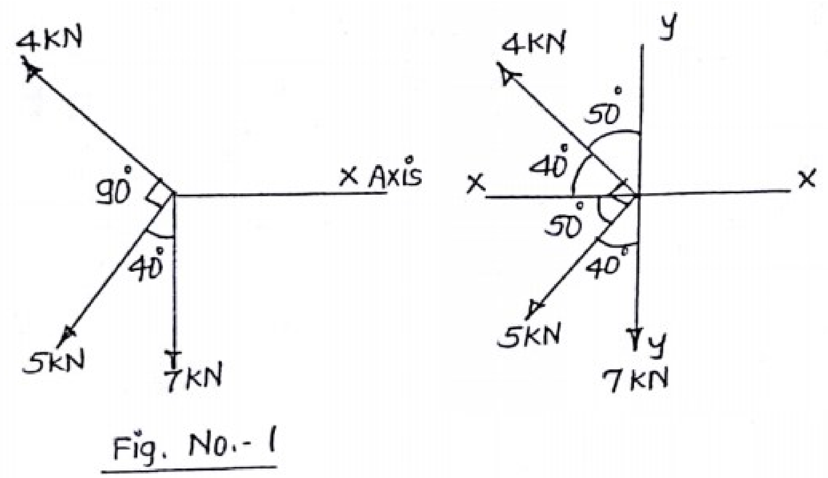
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1		**Attempt any FIVE of the following :**		10
	(a) Ans.	**State principle of transmissibility of force.** Principle of transmissibility of force states that, "if a force acts at a point on a rigid body, it is assumed to act at any other point on the line of action of force within the same body". As per this principle force of push nature can be made pull by extending the line of a force in opposite quadrant. 	2	2
	(b) Ans.	**Define load lost in friction.** Load lost in friction is defined as difference between ideal load and actual load. Mathematically , $W_f = W_i - W = (P \times VR) - W$	2	2
	(c) Ans.	**Define resultant force.** Resultant force is defined as a single force which can produce the same effect as it is produced by the number of forces acting together.	2	2

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1	(d) Ans.	**State Lami's theorem.** Lami's theorem states that, if three forces acting at a point on a body keep it at rest, then each force is proportional to the sin of the angle between the other two forces.	1	
		As per Lami's theorem, $\frac{F_1}{sin\alpha} = \frac{F_2}{sin\beta} = \frac{F_3}{\sin\gamma}$ 	1	2
	(e) Ans.	**Define angle of repose.** Angle of repose 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. 	2	2
	(f) Ans.	**Define centre of gravity.** **Centre of Gravity :-** 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. e.g. Cone, Cylinder.	2	2
	(g) Ans.	**State any two types of beam along with sketch.** Following are the different types of beams – (i) Simply supported beam  (ii) Cantilever beam  (iii) Over hanging beam 	1 each (any two)	2

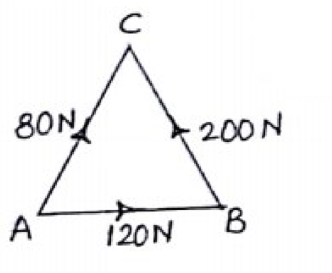
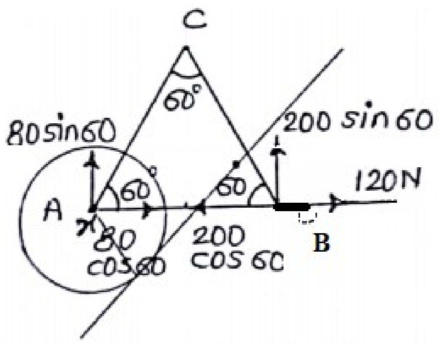
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1		(iv) Fixed Beam 		
		(v) Continuous beam 		
Q. 2		**Attempt any THREE of the following :**		12
	(a)	**Define unlike parallel force system and general force system with sketch.**		
	Ans.	Unlike parallel force system :- A force system in which parallel forces are acting in the opposite directions is called as unlike parallel force system.	1	
		 Unlike Parallel Force System	1	
		General force system :- A force system in which all forces act in different planes and do not possess on single point of concurrency is kNown as general force system.	1	
		 General Force System	1	4
	(b)	**In a machine, an effort required to lift a certain load is 200 N. When efficiency is 60%, find the ideal effort.**		
	Ans.	$\%\eta = \frac{MA}{VR} \times 100$ $60 = \frac{W/P}{VR} X100$	1	

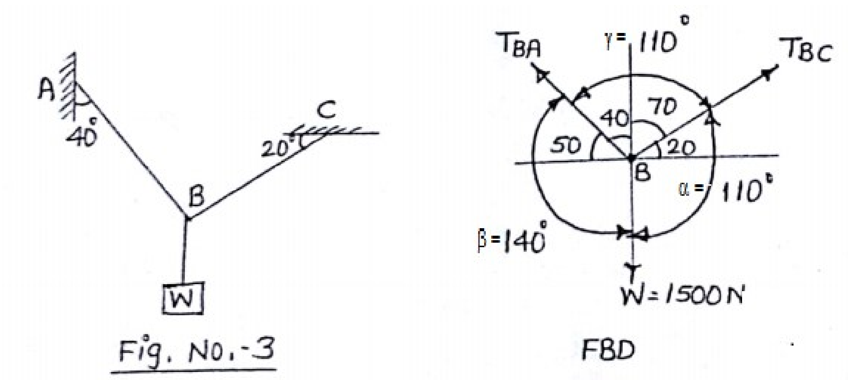
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		$60 = \frac{W/P}{VR} X100$		
		$60 = \left(\frac{W}{VR}\right) \times \frac{1}{P} \times 100$	1	
		$60 = \left(\frac{W}{VR}\right) \times \frac{1}{200} \times 100$	1	
		$\left(\frac{W}{VR}\right) = \frac{60 \times 200}{100}$		
		Since, $W/VR = P_i$	1	4
		$\boxed{P_i = 120N}$		
	(c) Ans.	**What are the characteristics of ideal machine?** Following are the characteristics of an ideal machine – (1) Efficiency of the machine is 100 %. (2) Output = Input (3) Machine is free from frictional losses. (4) Mechanical Advantage = Velocity Ratio	1 each	4
	(d) Ans.	**State four laws of static friction.** (1) The frictional force always acts tangential to the plane of contact and in the direction opposite to the impending motion. (2) When the body is in limiting equilibrium, the limiting friction bears a constant ratio to the normal reaction. This ratio is called as "Coefficient of friction". (3) The coefficient of friction depends only upon the nature of surfaces in contact and is independent of the surface area in contact. (4) The static friction is more than dynamic friction. (5) Force of friction is a self-adjusting force and it increases as the applied force increases up to limiting friction.	1 each (any four)	4
Q. 3		**Attempt any THREE of the following :**		12
	(a) Ans.	**Find the angle between two equal forces of magnitude 300 N each, if their resultant is 150 N** Using Law of Parallelogram of forces		
		$R^2 = P^2 + Q^2 + 2PQ\cos\theta$	1	
		$(150)^2 = (300)^2 + (300)^2 + (2 \times 300 \times 300)\cos\theta$	1	
		$22500 = 90000 + 90000 + 180000\cos\theta$		
		$\cos\theta = -\frac{157500}{180000} = -0.875$	1	

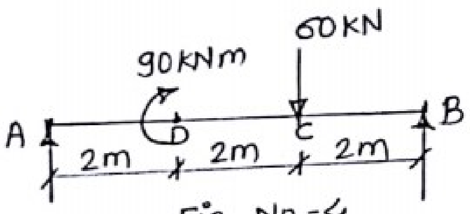
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3		$\theta = \cos^{-1}(-0.875)$ $\boxed{\theta = 151.04°}$	1	4
		OR 		
		1) $\sum F_x = 0 (\rightarrow +ve, \leftarrow -ve)$ $= +300\cos\left(\frac{\theta}{2}\right) + 300\cos\left(\frac{\theta}{2}\right)$ $= +600\cos\left(\frac{\theta}{2}\right)$	1	
		2) $\sum F_y = 0 (\uparrow +ve, \downarrow -ve)$ $= +300\sin\left(\frac{\theta}{2}\right) - 300\sin\left(\frac{\theta}{2}\right)$ $= 0$	1	
		3) $R = \sqrt{\sum F_x^2 + \sum F_y^2}$ $= \sqrt{\left(600\cos\left(\frac{\theta}{2}\right)\right)^2 + 0}$ $R^2 = \left(600\cos\left(\frac{\theta}{2}\right)\right)^2$ $R = \left(600\cos\left(\frac{\theta}{2}\right)\right)$ $150 = \left(600\cos\left(\frac{\theta}{2}\right)\right)$ $\left(\frac{\theta}{2}\right) = \cos^{-1}\left(\frac{150}{600}\right) = 75.52$	1	
		$\theta = 2 \times 75.52$ $\boxed{\theta = 151.04°}$	1	4

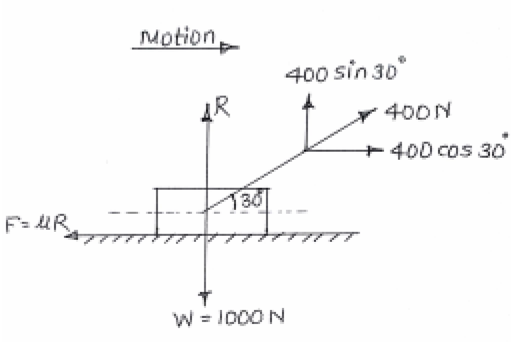
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	(b)	**Find analytically the resultant of the following concurrent force system. Refer to Figure No. 1**		
	Ans.	Fig. No.- 1		
		1) Resolving all forces $\sum Fx = -4\cos 40 - 5\cos 50$ = - 6.27 kN	1	
		$\sum Fy = 4\sin 40 - 5\sin 50 - 7$ = - 8.26 kN	1	
		2) Magnitude of Resultant $R = \sqrt{(\sum Fx)^2 + (\sum Fy)^2}$ $R = \sqrt{(-6.27)^2 + (-8.26)^2}$ R = 10.374 kN	1	
		3) Direction of Resultant $\theta = \tan^{-1}\left\|\frac{\sum Fy}{\sum Fx}\right\|$ $\theta = \tan^{-1}\frac{8.26}{6.27}$ θ = 52.80° (Resultant lies in III[rd] Quadrant)	1	4
	(c)	**The diameter of bigger and smaller Pulley's of Weston's differential pulley block is 250 mm and 100 mm respectively. Determine effort required to lift a load of 3 kN with 80% efficiency.**		
	Ans.	$VR = \frac{2D}{D-d}$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3		$VR = \frac{2 \times 250}{250 - 100}$ $VR = 3.33$	1	
		$\eta = \frac{MA}{VR} \times 100$ $80 = \frac{MA}{3.33} \times 100$ $MA = \frac{80 \times 3.33}{100}$ MA = 2.66	1	
		But, $MA = \frac{W}{P}$ $2.66 = \frac{3}{P}$ $P = \frac{3}{2.66}$ $P = 1.13\ KN$ =1130N	1	4
	(d)	**A machine has a V.R. of 250 and has its law P = (0.01W + 5) N, Find M.A., efficiency, effort lost in friction at a load of 1000 N and also state whether machine is reversible or not.**		
	Ans.	1) Mechanical Advantage P = (0.01x1000 + 5)N P = 15 N MA = $\frac{W}{P}$ MA = $\frac{1000}{15}$ MA = 66.67	1	
		2) Efficiency $\eta = \frac{MA}{VR} \times 100$ $\eta = \frac{66.67}{250} \times 100$ η = 26.67%	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3		3) Effort lost in friction at load of 1000 N		
		$Pi = \frac{W}{VR}$		
		$Pi = \frac{1000}{250}$		
		Pi = 4 N		
		$P_f = P - Pi$		
		$P_f = 15 - 4$		
		$P_f = 11$ N	1	
		4) Machine is non-reversible machine, as the value of $\eta < 50\%$.	1	4
Q. 4		**Attempt any THREE of the following :**		12
	(a)	**Calculate the resultant and its position wrt. point A for the force system shown in Figure No. 2. AB = BC = CA = 2m**		
	Ans.	 Fig. No.-2  		
		AB = BC = CA = 2m		
		1) Resolving all forces		
		$\sum Fx = 80Cos60 + 120 - 200Cos60$	1	
		$\sum Fx = 60N$		
		$\sum Fy = 80Sin60 + 200Sin60$		
		$\sum Fy = 242.49N$		
		2) Magnitude of Resultant		
		$R = \sqrt{(\sum Fx)^2 + (\sum Fy)^2}$		
		$R = \sqrt{(60)^2 + (242.49)^2}$	1	
		R = 249.80 N		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		3) Direction of Resultant $\theta = \tan^{-1}\left(\frac{\sum Fy}{\sum Fx}\right)$ $\theta = \tan^{-1}\left(\frac{242.49}{60}\right)$ $\theta = 76.10°$	1	
		4) Position of Resultant According to Varignon's Theorem $(\Sigma M_F)_A = (M_R)_A$ Let x be the perpendicular distance between the Resultant force and the moment point As the line of action of forces 80N and 120N passing through the moment point therefore their moment is zero. $-(200\sin 60 \times 2) = 249.80\,x$ x = - 1.39m (- Ve sign indicates that the distance 'x' should be taken to produce anticlockwise moment by Resultant)	1	4
	(b)	**Calculate the tension induced in the cable used for the assembly shown in Figure No. 3. W = 1500 N.**		
	Ans.		1	
		$\alpha = 110°$, $\beta = 140°$ and $\gamma = 110°$ According to Lami's Theorem $\frac{T_{BA}}{Sin\ \alpha} = \frac{T_{BC}}{Sin\ \beta} = \frac{W}{Sin\ \gamma}$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		$\frac{T_{BA}}{Sin\,110°} = \frac{T_{BC}}{Sin\,140°} = \frac{1500}{Sin\,110°}$	1	
		$\frac{T_{BA}}{Sin\,110°} = \frac{1500}{Sin\,110°}$		
		T_{BA} = 1500 N	1	
		$\frac{T_{BC}}{Sin\,140°} = \frac{1500}{Sin\,110°}$	1	4
		T_{BC} = 1026.06 N		
		OR		
		Using conditions of equilibrium,		
		$\sum F_y = 0$		
		$-W + (T_{BA} \times \sin 50) + (T_{BC} \times \sin 20) = 0 - - - (1)$	1	
		$\sum F_x = 0$		
		$-(T_{BA} \times \cos 50) + (T_{BC} \times \cos 20) = 0 - - - (2)$		
		$(T_{BA} \times \cos 50) = (T_{BC} \times \cos 20)$		
		$T_{BA} = T_{BC} \times \frac{\cos 20}{\cos 50}$	1	
		$T_{BA} = (1.462) T_{BC}$		
		Putting value of T_{BA} in equation (1)		
		$-1500 + (1.462 \times T_{BC} \times \sin 50) + (T_{BC} \times \sin 20) = 0$		
		$-1500 + (1.1198) T_{BC} + (0.342) T_{BC} = 0$		
		$T_{BC} = 1026.06\,N$	1	
		$T_{BA} = (1.462) T_{BC} = (1.462 \times 1026.118)$		
		$T_{BA} = 1500\,N$	1	4
	(c)	**Calculate the reaction of beam loaded as shown in Figure No.4.**		
		 Fig. No.-4		
	Ans.	$\Sigma M_A = 0$		
		$(R_A \times 0) + 90 + (60 \times 4) - (R_B \times 6) = 0$		
		$0 + 90 + 240 - 6R_B = 0$	2	
		R_B = 55 kN		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		$\Sigma Fy = 0$ $R_A - 60 + R_B = 0$ $R_A - 60 + 55 = 0$ $R_A = 5$ kN	2	4
	(d)	**A block weighing 1000N, resting on a horizontal plane requires a pull of 400N to start its motion. When applied at an angle of 30° with the horizontal. Find the coefficient of friction, along with normal reaction, force of friction and resultant reaction.**		
	Ans.	 		
		In limiting equilibrium $\Sigma Fy = 0$ $R - W + 400 Sin 30 = 0$ $R - 1000 + 200 = 0$ $R = 800$ N	1	
		$\Sigma Fx = 0$ $400 Cos 30 - F = 0$ $400 Cos 30 - \mu R = 0$ $346.41 - 800\mu = 0$ $\mu = 0.433$	1	
		$F = \mu R$ $= 0.433 \times 800$ $= 346.41$ N	1	
		$S = \sqrt{F^2 + R^2}$ $S = \sqrt{346.41^2 + 800^2}$ $S = 871.78$ N	1	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	(e)	**Calculate the reaction of beam loaded as shown in Figure No.5 use graphical method.**		

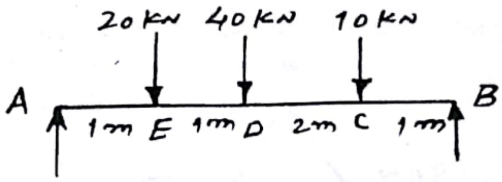
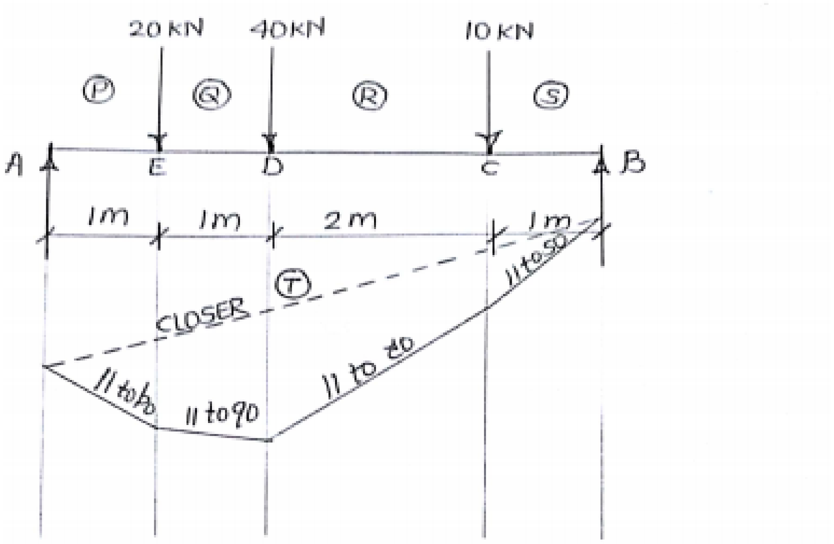


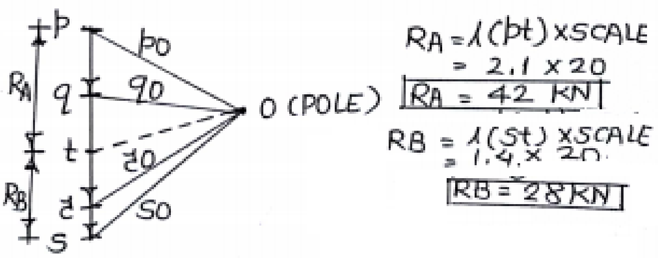
Fig. No. 5

Ans



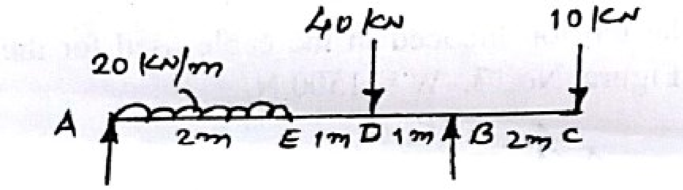
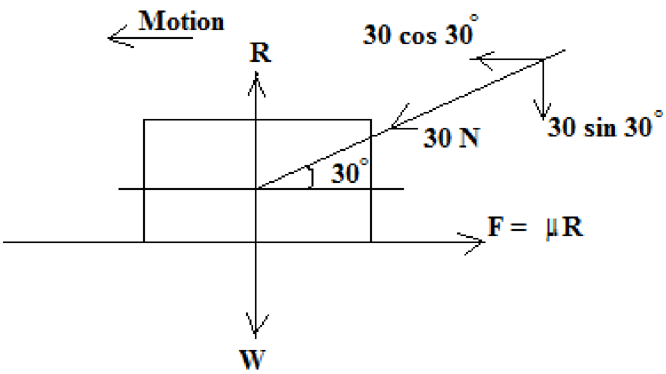
SPACE DIA. AND FUNICULAR POLYGON
SCALE = 1cm = 0.5m

(2 marks)



VECTOR DIA. AND POLAR DIA.
SCALE = 1cm = 20kN

(2 marks) — Total Marks: 4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		**Attempt any TWO of the following :**		12
	(a)	**Calculate reactions of beam loaded as shown in Figure No. 6.**  **Fig. No. 6**		
	Ans.	1) $\sum F_y = 0$ (Sign conventions - ↑= +ve, ↓= -ve)		
		$R_A + R_B = (20\times 2) + 40 + 10$	1	
		$R_A + R_B = 90 - - - - - - (1)$	1	
		2) $\sum M_A = 0$ (Sign conventions - Clockwise moment = +ve, Anti-clockwise moment = -ve)		
		$(R_A\times 0) + (20\times 2\times \frac{2}{2}) + (40\times 3) - (R_B\times 4) + (10\times 6) = 0$	1	
		$R_B = 55kN$	1	
		Putting value of R_B in equation (1)		
		$R_A + R_B = 90$		
		$R_A + 55 = 90$	1	
		$R_A = 35kN$	1	6
	(b)	**A push of 30 N applied at 30° to horizontal just to move the block of weight 'W' N. If angle of friction is 16°. Find coefficient of friction, total reaction and weight of block.**		
	Ans.		1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		Since φ=16°	1	
		$\mu=\tan\varphi=\tan 16°=0.286$		
		For limiting equilibrium,		
		$\sum F_x=0$-----(®+ve,¬-ve)		
		-30cos30°+F=0		
		-25.980+μR=0		
		(0.286)R=25.980	1	
		R=90.839N		
		$\sum F_y=0$-----(-+ve,¯-ve)		
		+R-30sin30°-W=0		
		+90.839-30sin30°-W=0	1	
		W=75.839N		
		F=μR=(0.286×90.839)=25.980N	1	
		Total Reaction $=S=\sqrt{F^2+R^2}=\sqrt{(25.980)^2+(90.839)^2}$	1	6
		S=94.481N		
	(c)	**A concurrent force system is shown in Figure No. 7. Find graphically the resultant of this force system.**		

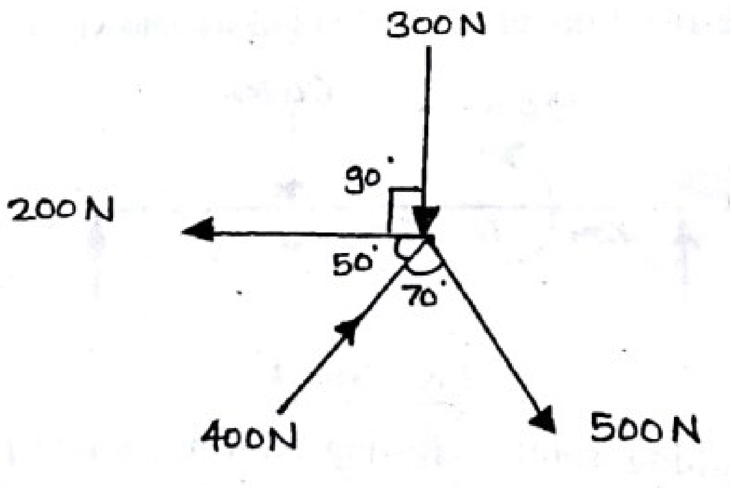
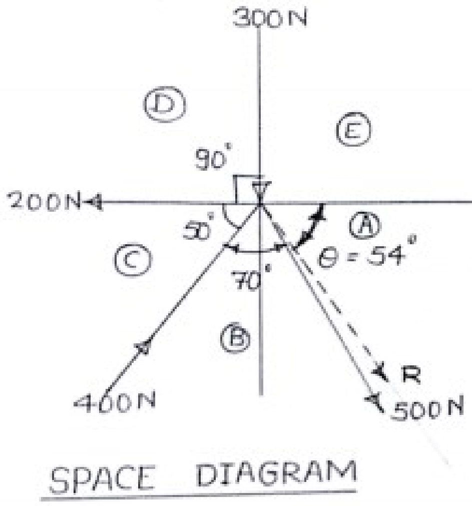
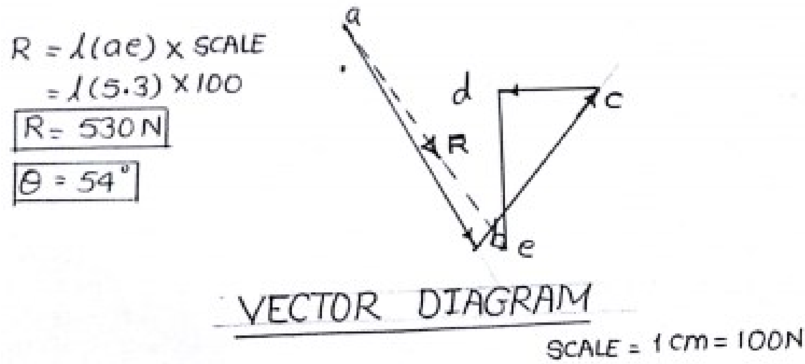


Fig. No. 7

<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. 5</td><td>Ans.</td><td>




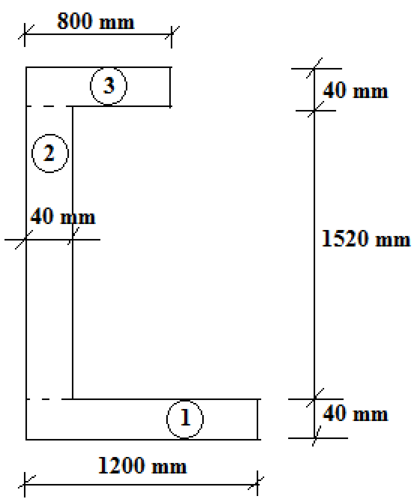
</td><td>3
3</td><td>6</td></tr>
<tr><td>Q. 6</td><td></td><td>Attempt any TWO of the following :</td><td></td><td>12</td></tr>
<tr><td></td><td>(a)</td><td>Locate the position of centroid for the section shown in Figure No. 8.


Fig. No. 8</td><td></td><td></td></tr>
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Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6	Ans.	1) Area calculation		
		$A_1 = 1200 \times 40 = 48000\ mm^2$		
		$A_2 = 1520 \text{ x } 40 = 60800\ mm^2$		
		$A_3 = 800 \times 40 = 32000\ mm^2$	1	
		$A = A_1 + A_2 + A_3 = 140800\ mm^2$		
		2) Location of $\bar{x}$ (from left side)		
		$x_1 = \frac{1200}{2} = 600$ mm		
		$x_2 = \frac{40}{2} = 20$ mm	1½	
		$x_3 = \frac{800}{2} = 400$mm		
		$\bar{x} = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A}$		
		$= \frac{(48000 \times 600) + (60800 \times 20) + (32000 \times 400)}{140800}$		
		$\bar{x} = 304.090$ mm from left side.	1	
		3) Location of $\bar{y}$ (from bottom)		
		$y_1 = \frac{40}{2} = 20$ mm		
		$y_2 = 40 + \frac{1520}{2} = 800$ mm	1½	
		$y_3 = 40 + 1520 + \frac{40}{2} = 1580$ mm		
		$\bar{y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A}$		
		$= \frac{(48000 \times 20) + (60800 \times 800) + (32000 \times 1580)}{140800}$		
		$\bar{y} = 711.363$ mm from bottom.	1	6
		G = (304.090 mm, 711.363 mm)		
	(b)	**Locate the centroid of lamina shown in Fig. No. 9.**		

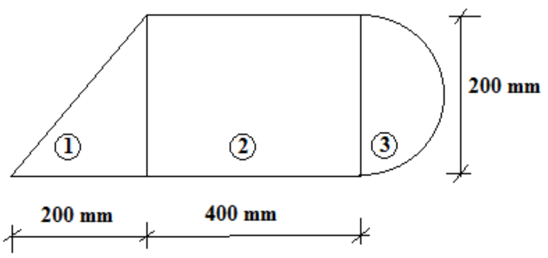
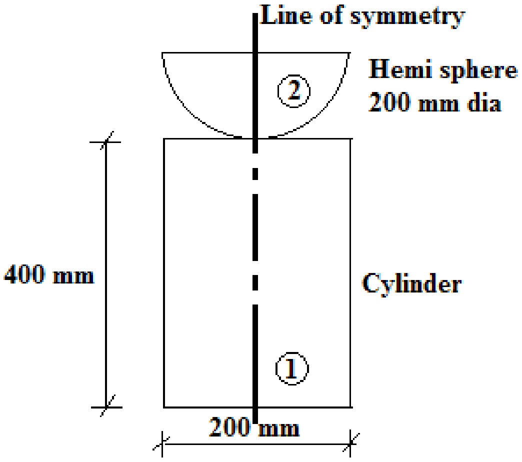


Fig. No. 9

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6	Ans.	1) Area calculation		
		$A_1 = \frac{1}{2} \times 200 \times 200 = 20000\ mm^2$	1	
		$A_2 = 400 \text{ x } 200 = 80000\ mm^2$		
		$A_3 = \frac{\pi \times (100)^2}{2} = 15707.96\ mm^2$		
		$A = A_1 + A_2 + A_3 = 115707.96\ mm^2$		
		2) Location of $\bar{x}$ (from left side)		
		$x_1 = \frac{2}{3} \times 200 = 133.33$ mm		
		$x_2 = 200 + \frac{400}{2} = 400$ mm	1½	
		$x_3 = 200 + 400 + \left(\frac{4 \times 100}{3 \times \pi}\right) = 642.44$ mm		
		$\bar{x} = \frac{A_1 x_1 + A_2 x_2 + A_3 x_3}{A}$		
		$= \frac{(20000 \times 133.33) + (80000 \times 400) + (15707.963 \times 642.441)}{115707.963}$		
		$\bar{x} = 386.819$ mm from left side.	1	
		3) Location of $\bar{y}$ (from bottom)		
		$y_1 = \frac{1}{3} \times 200 = 66.667$ mm		
		$y_2 = \frac{200}{2} = 100$ mm	1½	
		$y_3 = \frac{200}{2} = 100$ mm		
		$\bar{y} = \frac{A_1 y_1 + A_2 y_2 + A_3 y_3}{A}$		
		$= \frac{(20000 \times 66.667) + (80000 \times 100) + (15707.963 \times 100)}{115707.963}$		
		$\bar{y} = 94.238$ mm from bottom.	1	6
		G = (386.819 mm, 94.238 mm)		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6	(c)	**Find the centre of gravity for the solid shown in Fig. No. 10.**		
				
		Fig. No. 10		
	Ans.	1) Volume calculation		
		$V_1 = \pi \times R^2 \times h = \pi \times (100)^2 \times 400 = 12.566 \times 10^6 \text{ mm}^3$		
		$V_2 = \frac{2}{3} \times \pi \times (r)^3 = \frac{2}{3} \times \pi \times (100)^3 = 2.094 \times 10^6 \text{ mm}^3$	1	
		$V = V_1 + V_2 = 14.66 \times 10^6 \text{ mm}^3$		
		2) Location of $\bar{x}$ (from left side)		
		As figure is symmetric about yy axis,		
		$\bar{x} = \frac{200}{2}$	2	
		$\bar{x} = 100$ mm from left side.		
		3) Location of $\bar{y}$ (from bottom)		
		$y_1 = \frac{h}{2} = \frac{400}{2} = 200 \text{ mm}$	1	
		$y_2 = h + \left(r - \frac{3r}{8} \right) = 400 + \left(100 - \frac{3 \times 100}{8} \right) = 462.5 \text{ mm}$	1	
		$\bar{y} = \frac{V_1 y_1 + V_2 y_2}{V}$		
		$= \frac{(12.566 \times 10^6 \times 200) + (2.094 \times 10^6 \times 462.5)}{14.66 \times 10^6}$		
		$\bar{y} = 237.494$ mm from bottom.	1	6
		C. G. = (100 mm, 237.494 mm)		