SUMMER- 13 EXAMINATION

Subject code : 12015 **Model Answer :Engineering Mechanics**

Important instruction 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 model answer may vary. The examiner may give credit for any equivalent figure drawn.

5) Credits may be given stepwise for numerical problems. In some cases the assumed constant values may be vary and there may be some difference in the candidates answer and model answer.

6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidates understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept.

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

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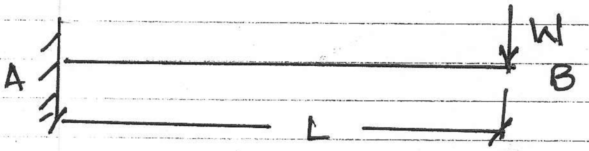
Subject Code- 12015 **Model Answer:** Engineering Mechanics

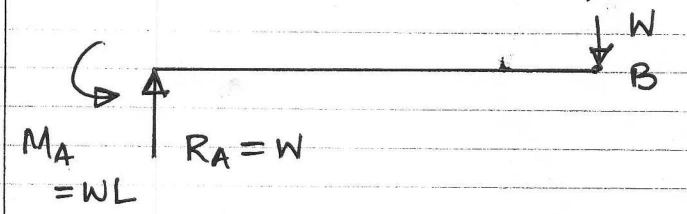
Q. 1	Attempt any TEN	20 Marks
(a)	Newton force :- "1 N force is that force which when acts on a body of mass 1 kg produces an acceleration of 1 m/sec² in it." OR A force which produces an acceleration of 1m/sec² in a body of mass 1kg is called as unit Newton force or one Newton force.	1 M
	$1N = 1kg \times 1m/sec^2$ $1N = 1\ kg.m/sec^2$	1 M.
(b)	condition of equilibrium wrt. moment for Non-concurrent system. → The Algebraic sum of Moment of all forces about any point is equal to zero. $\therefore \Sigma M = 0$ $\therefore \Sigma$ clockwise moment $- \Sigma$ Anticlockwise moment $= 0$ $\therefore \Sigma$ clockwise moment $= \Sigma$ Anticlockwise moment	2M
(c)	If three concurrent non-collinear forces are in equilibrium, then each force is equilibrant of remaining two forces.	2M

Q 1.

(d)

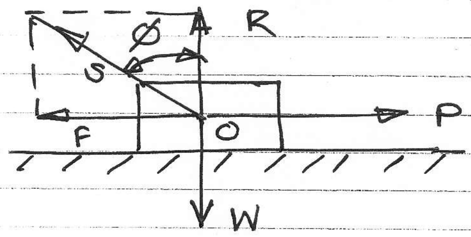


Loading diagram — 1M



FBD. — 1M.

(e)



where
Ø = angle of friction — 1M.

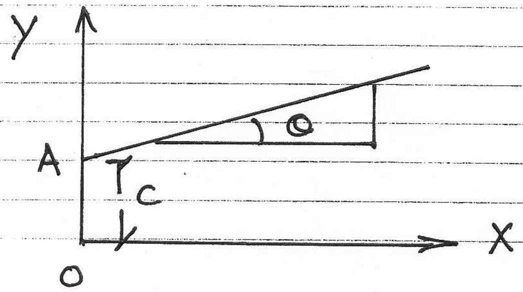
<u>Angle of friction</u> :- It is the angle made by Resultant reaction with the normal reaction, when body is in limiting equilibrium. — 1M.

(f)

(i) If geometrical shape is symmetrical about x and y axis, then centroid lies at the intersection of Axis of symmetry. — 1M

(ii) If geometrical shape is symmetrical about any one axis, then the centroid lies on that axis — 1M

(g)



1M

<u>Law of Machine</u> :- The relation between the load lifted (W) and the effort applied (P) is known as the law of Machine.

$\therefore P = mW + C$ — 1M

where

p = effort

w = load

m = slope

∴ c = effort required at zero load.

(h) Ideal Machine :- when efficiency of machine is 100% then it is called as ideal Machine — 2M.

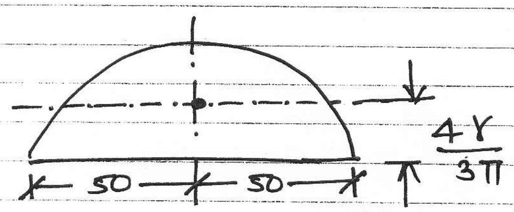
or

It is a machine in which friction is zero

or

It is a machine in which output is equal to input.

(i)



1M

$$\therefore \bar{y} = \frac{4r}{3\pi} = \frac{4 \times 50}{3\pi} = 21.22 \text{ mm}$$ 1M.

(j) Dynamic or Kinetic friction :-

It is the friction experienced by a body in motion — 1M

Two Types of Dynamic friction

(i) Rolling friction.

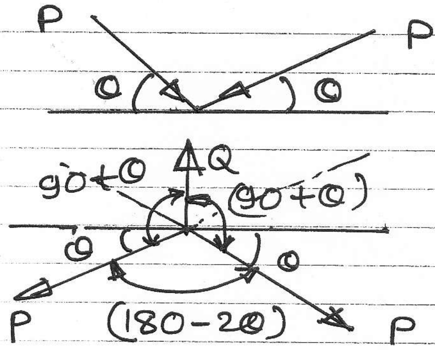
(ii) sliding friction. — 1M

(k) Graphical conditions of equilibrium for non-concurrent forces

(i) force diagram or Vector diagram must be a closed figure — 1M

(ii) funicular Polygon must be a closed figure. — 1M

Q1 (l)



1M

use lami's theorem

$$\frac{P}{\sin(90+\theta)} = \frac{P}{\sin(90+\theta)} = \frac{Q}{\sin(180-2\theta)}$$

$$\therefore \frac{P}{\cos\theta} = \frac{Q}{\sin 2\theta}$$

$$\therefore Q = \frac{\sin 2\theta}{\cos\theta} \cdot P$$ (Acting away from the point) 1M

$$Q = \frac{2\sin\theta\cancel{\cos\theta}}{\cancel{\cos\theta}} \times P$$

$$\boxed{Q = 2P\sin\theta}$$

(m) velocity Ratio for differential axle and wheel

$$\therefore V.R. = \frac{2D}{d_1 - d_2}$$ 1M

$\therefore$ where D = diameter of wheel

$\therefore$ d_1 = diameter of bigger axle 1M

$\therefore$ d_2 = diameter of smaller axle

(n) $\mu = 0.30$

we have to find angle of Repose

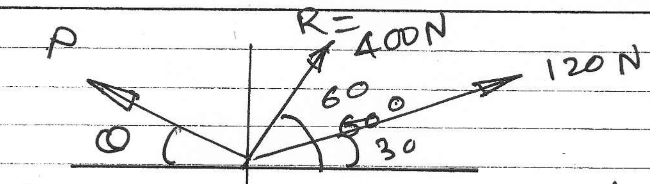
As $\mu = \tan\alpha$ 1M

$0.3 = \tan\alpha$

$\therefore \alpha = \tan^{-1}(0.3)$

$\therefore \boxed{\alpha = 16.699^\circ}$ 1M

Q 2 (a)



∴ Resolving forces and resultant.

$\therefore \Sigma f_x = -P\cos\theta + 120\cos 30$

$\therefore 400\cos 60 = -P\cos\theta + 120\cos 30$

$\therefore P\cos\theta = 103.92 - 200$

$\therefore P\cos\theta = -96.08 \quad \text{---} \quad (1)$ 1M

$\therefore \Sigma f_y = P\sin\theta + 120\sin 30$

Resolve R vertically

$\therefore 400\sin 60 = P\sin\theta + 120\sin 30$

$\therefore P\sin\theta = 286.41 \quad \text{---} \quad (2)$ 1M

Divide eq^n (2) by eq^n (1)

$$\frac{P\sin\theta}{P\cos\theta} = \frac{286.41}{-96.08}$$

$\tan\theta = -2.98$ 1M

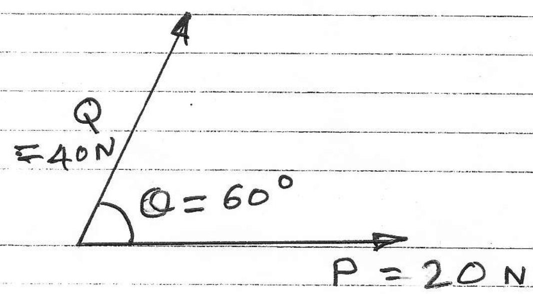
$\theta = -71.455°$ → where −ve sign indicates Anticlockwise angle with X axis

∴ put value of θ in eq^n

$P\sin 71.455 = 286.41$

$\boxed{P = 302.096\text{ N}}$ 1M.

(b)



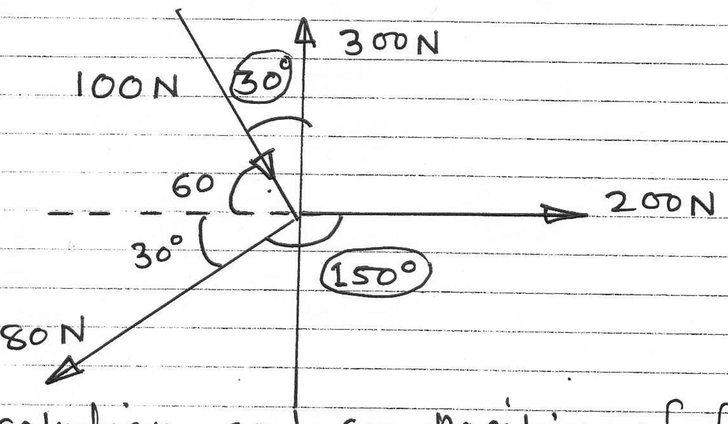
Data

P = 20N

Q = 40 N

* Magnitude of Resultant (R)

$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$ 1M

Q 2 (b) cont.	$R = \sqrt{(20)^2 + (40)^2 + 2 \times 20 \times 40 \times \cos 60}$	
	$R = \sqrt{2800}$	
	$R = 52.915\ N$	1M
	* Direction of Resultant w.r.t to P force $\therefore P = 20N$	
	$\tan\alpha = \dfrac{Q\sin\theta}{P + Q\cos\theta}$	1M
	$= \dfrac{40\sin 60}{20 + 40\cos 60}$	
	$= \dfrac{34.641}{40}$	
	$= 0.866$	
	$\alpha = 40.893^\circ$ w.r.t to 20N force	1M
	OR	
	$\alpha = 19.107^\circ$ w.r.t to 40N force	
(c)		
	Resolution and composition of forces	
	$\Sigma fx = 200 + 100\cos 60 - 80\cos 30$	
	$= 180.718\ N$	1M
	$\Sigma fy = 300 - 100\sin 60 - 80\sin 30$	
	$= 173.397\ N$	1M

Q 2 (c) cont.

* Magnitude of Resultant

$\therefore R = \sqrt{(\Sigma fx)^2 + (\Sigma fy)^2}$

$\therefore R = \sqrt{(180.718)^2 + (173.397)^2}$

$\therefore R = 250.450$ N — 1M

* Direction of Resultant

$\therefore \tan\theta = \dfrac{\Sigma fy}{\Sigma fx}$

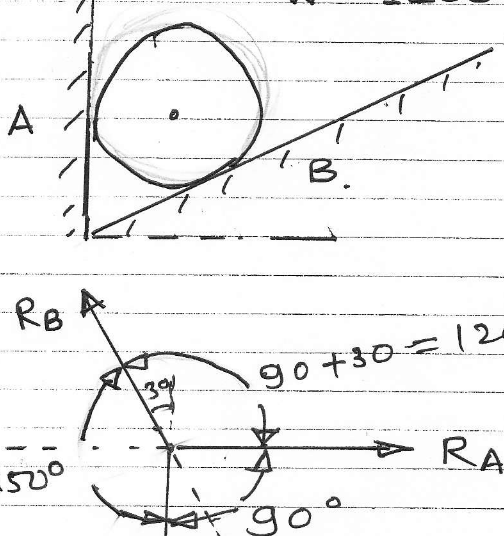
$= \dfrac{173.397}{180.718}$

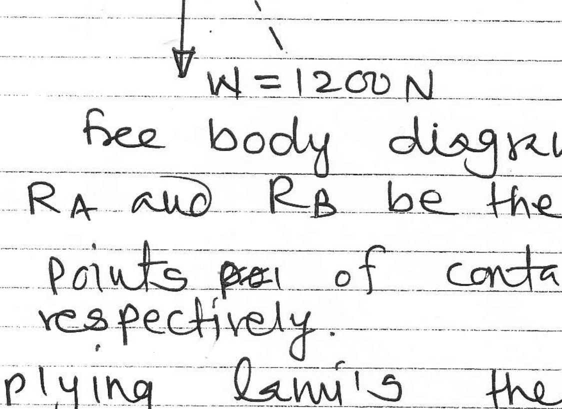
$= 0.959$

$\therefore \theta = 43.815^\circ$ — 1M

Q2 (d)

$\therefore W = 1200$ N





free body diagram — 1 M

let R_A and R_B be the reactions at points of contact A and B respectively.

Applying lami's theorem to forces R_A, R_B & 1200 N.

Q 2 (d) cont.

$$\frac{R_A}{\sin 150} = \frac{R_B}{\sin 90} = \frac{1200}{\sin 120}$$ 1M

considering first and third term.

$$\therefore \frac{R_A}{\sin 150} = \frac{1200}{\sin 120}$$

$$\therefore R_A = \frac{1200 \times \sin 150}{\sin 120}$$

$$\therefore R_A = 692.820\ N$$ 1M

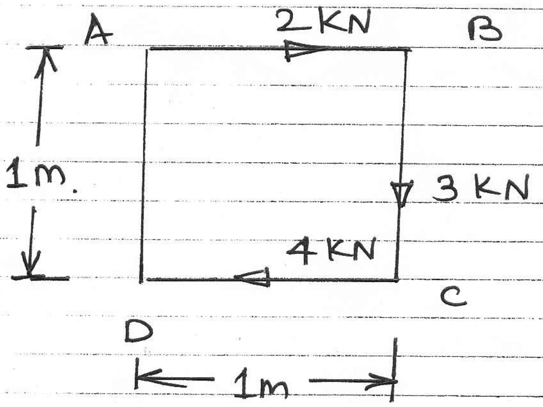
considering second and third term

$$\therefore \frac{R_B}{\sin 90} = \frac{1200}{\sin 120}$$

$$\therefore R_B = \frac{1200 \times \sin 90}{\sin 120}$$

$$\therefore R_B = 1385.64\ N$$ 1M

(e)



* composition of forces

$\Sigma fx = 2 - 4$

$= -2\ KN = 2\ KN\ (\leftarrow)$ $\frac{1}{2}$M

$\Sigma fy = -3\ KN$

$= 3\ KN\ (\downarrow)$ $\frac{1}{2}$M

* Magnitude of Resultant

$$R = \sqrt{(\Sigma fx)^2 + (\Sigma fy)^2}$$

Q 2 (e) cont.

$\therefore R = \sqrt{(-2)^2 + (-3)^2}$

$\therefore R = 3.605 N$ 1M

* Direction of resultant (θ)

$\therefore \tan\theta = \dfrac{\Sigma fy}{\Sigma fx}$

$= \dfrac{-3}{-2}$

$\therefore \theta = \tan^{-1}(1.5)$

$\therefore \theta = 56.309$ 1M

* location of Resultant w.r.t.

Taking moment of all forces about 'A'

$\Sigma M_{fA} = 3\times1 + 4\times1$

$= 7 KN\text{-}m$ ---- (1)

let 'x' be the distance of 'R' from Point 'A'

$\therefore$ Moment of R about 'A'

$M_{RA} = R \times x$ ---- (2)

equating eqn (1) and (2)

$R\times x = 7$

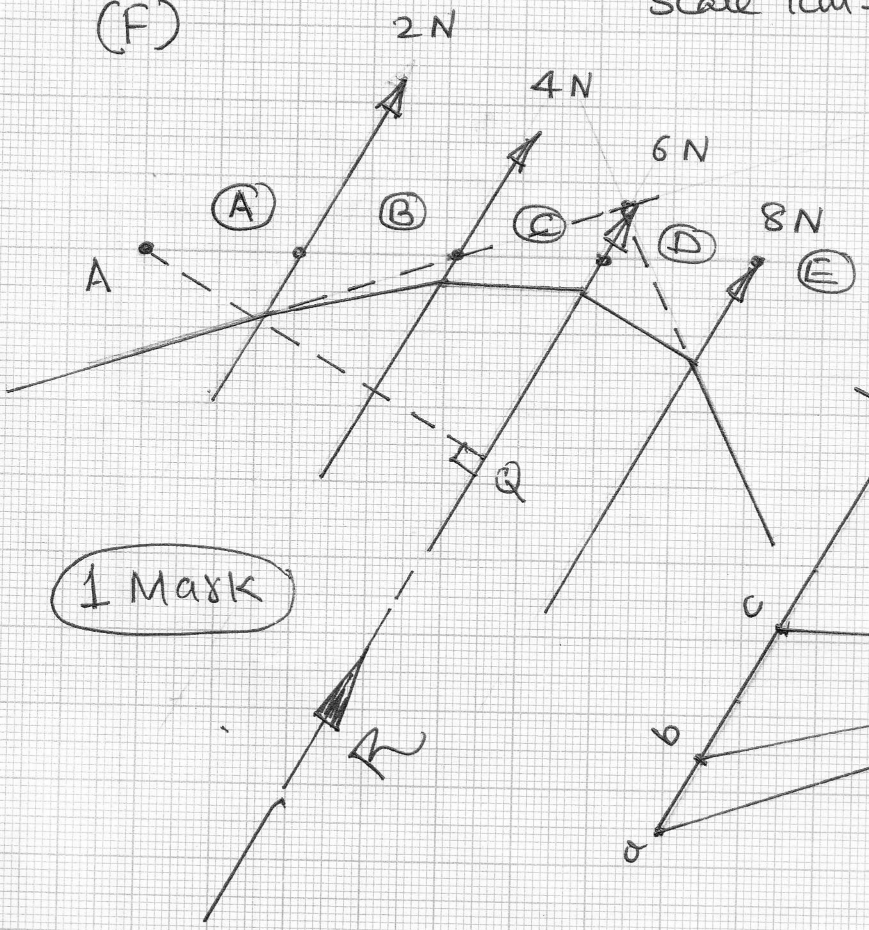
$3.605x = 7$

$\therefore \boxed{x = 1.942 m}$ 1M

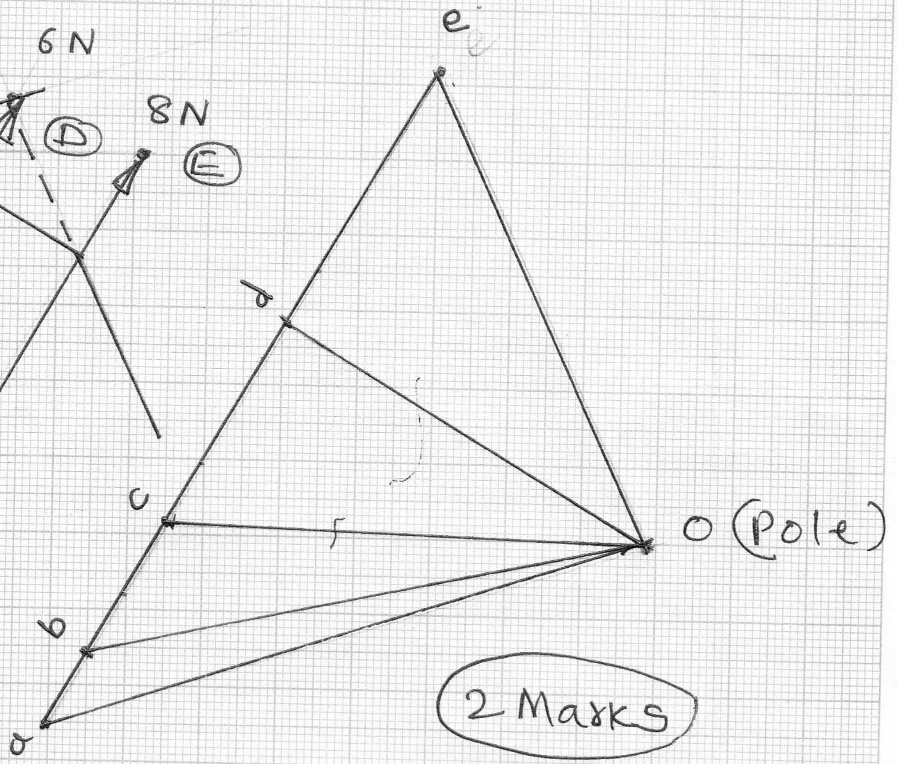
Q 2
(F)

Space diagram

scale 1cm = 0.5m



1 Mark



2 Marks

Vector diagram scale 1cm = 2N

calculations

① Magnitude of Resultant (R)

R = l(ae) X 2 N

R = 10 X 2

R = 20 N (↗ at 60° to horizontal) $\frac{1}{2}$ M

② Distance of Resultant (x)

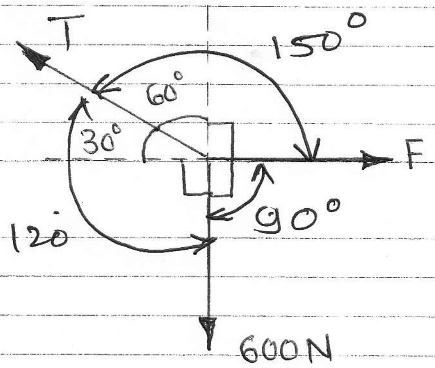
Horizontal distance from 'A' = 6cm x 0.5m
= 3m.

Perpendicular distance from A

∴ x = l(AQ) = 5.3 x 0.5 = 2.65m $\frac{1}{2}$ M

Q-3

a)



applying Lamis Theorem 01

$$\frac{F_1}{\sin\theta_1} = \frac{F_2}{\sin\theta_2} = \frac{F_3}{\sin\theta_3}$$ 01

$$\therefore \frac{600}{\sin 150^\circ} = \frac{T}{\sin 90^\circ} = \frac{F}{\sin 120^\circ}$$

i) $$\frac{600}{\sin 150^\circ} = \frac{T}{\sin 90^\circ}$$

$$\therefore T = \frac{600 \times \sin 90^\circ}{\sin 150^\circ}$$

$$\therefore T = \frac{600}{0.5} = 1200N$$

$$\therefore \boxed{T = 1200\,N}$$ 01

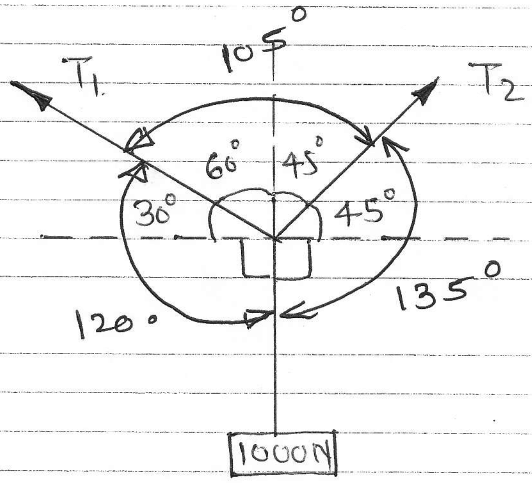
ii) $$\frac{600}{\sin 150} = \frac{F}{\sin 120^\circ}$$

$$F = \frac{600 \times \sin 120^\circ}{\sin 150^\circ}$$

$$F = \frac{519.615}{0.5}$$

$$\boxed{F = 1039.23\,N}$$ 01

b)



01

Apply Lamis Theorem

i) $$\frac{1000}{\sin 105^\circ} = \frac{T_1}{\sin 135^\circ} = \frac{T_2}{\sin 120^\circ}$$ 01

$$T_1 = \frac{1000 \times \sin 135^\circ}{\sin 105^\circ}$$

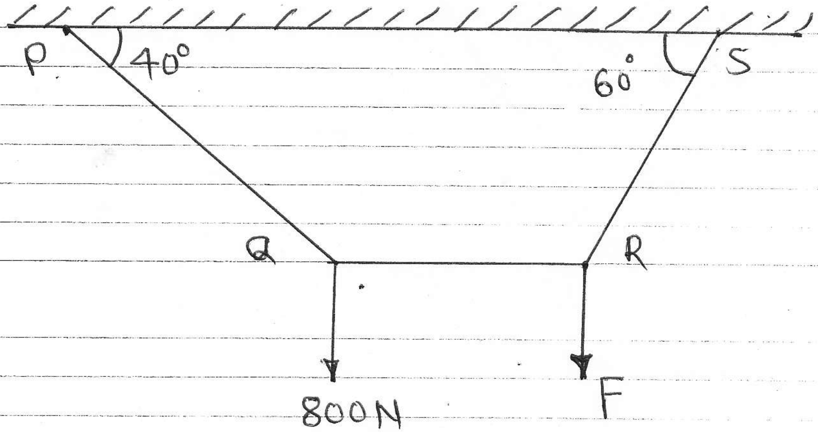
$$\boxed{T_1 = 732.05\ N}$$ 01

ii) $$\frac{1000}{\sin 105^\circ} = \frac{T_2}{\sin 120^\circ}$$

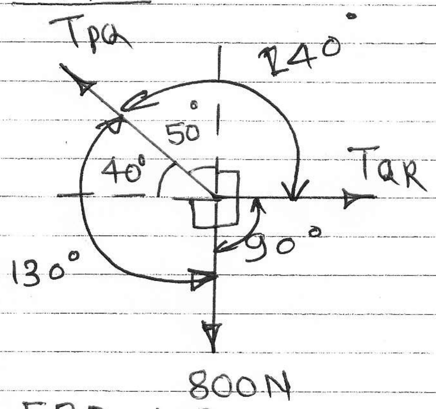
$$T_2 = \frac{1000 \times \sin 120^\circ}{\sin 105^\circ}$$

$$\boxed{T_2 = 896.58\ N}$$ 01

c)



Step-I



FBD at Q

Joint Q

i) applying Lamis Theorum

$$\frac{800}{\sin 140^\circ} = \frac{T_{PQ}}{\sin 90^\circ} = \frac{T_{QR}}{\sin 130^\circ}$$

$$\therefore \frac{800}{\sin 140^\circ} = \frac{T_{PQ}}{\sin 90^\circ}$$

$$T_{PQ} = \frac{800 \times \sin 90^\circ}{\sin 140^\circ}$$

$\boxed{T_{PQ} = 1244.58\,N}$ Tension 01

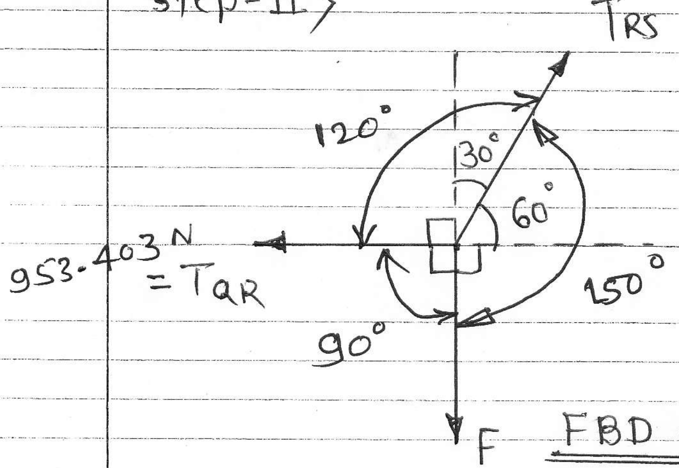
ii) $$\frac{800}{\sin 140^\circ} = \frac{T_{QR}}{\sin 130^\circ}$$

$$\therefore T_{QR} = \frac{800 \times \sin 130^\circ}{\sin 140^\circ}$$

$\therefore \boxed{T_{QR} = 953.403\,N}$ Tension 01

Joint R

Step-II>



FBD at R

$$\frac{F}{\sin 120^\circ} = \frac{T_{RS}}{\sin 90^\circ} = \frac{953.403}{\sin 150^\circ}$$

$$\frac{F}{\sin 120^\circ} = \frac{953.403}{\sin 150^\circ}$$

$$F = \frac{953.403 \times \sin 120^\circ}{\sin 150^\circ}$$

$$\boxed{F = 1651.34\ N}$$ 01

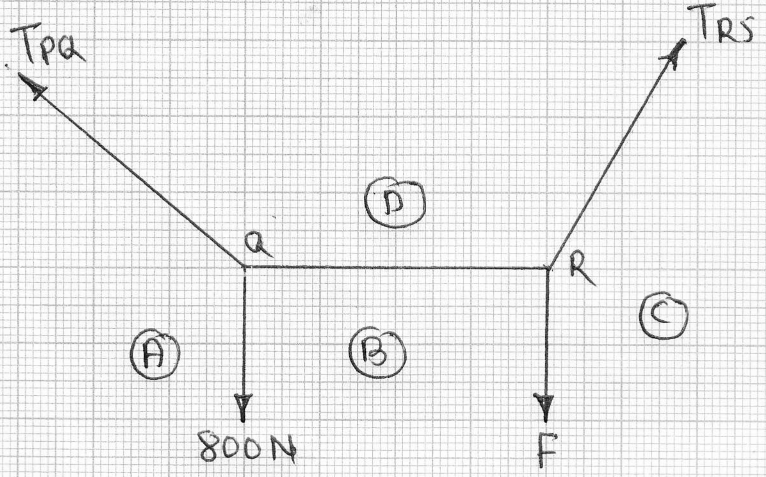
$$\frac{T_{RS}}{\sin 90} = \frac{953.403}{\sin 150^\circ}$$

$$T_{RS} = \frac{953.403 \times \sin 90^\circ}{\sin 150^\circ}$$

$$\boxed{T_{RS} = 1906.806\ N}$$ Tensile 01

Q-3 (d)

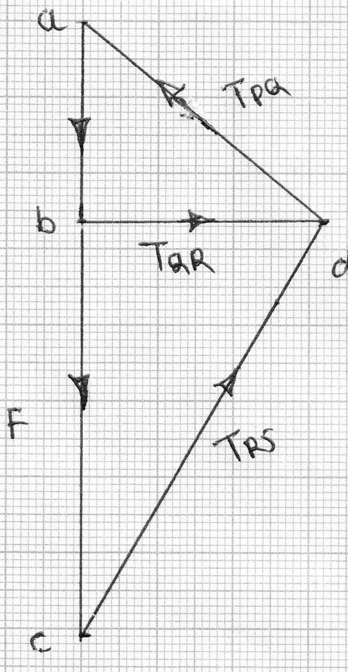
Scale
1cm = 300N



01 Mark

From The graph

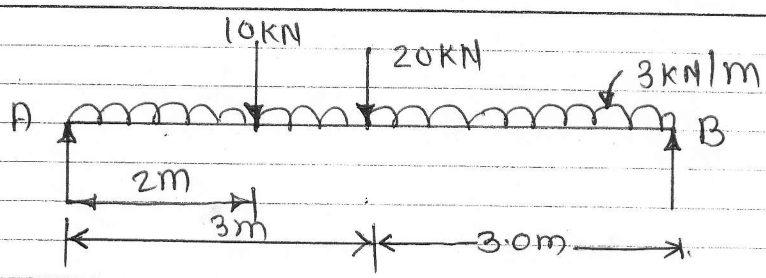
T_{PQ} = ab × scale factor = 4.15 × 300 = 1244.53N	01/2 M
T_{QR} = bd × scale factor = 3.176 × 300 = 953N	01/2 M
T_{RS} = cd × scale factor = 6.35 × 300 = 1906 N	01/2 M
F = bc × scale factor = 5.5 × 300 = 1650.64 N	01/2 M



VECTOR DIAGRAM

(01-Marks)

e)



01

$\Sigma F_y = 0$

$R_A + R_B = 10 + 20 + (3 \times 6)$

$R_A + R_B = 48$ —— (1)

$\Sigma M_A = 0$

$-R_B \times 6 + (20 \times 3) + (10 \times 2) + (3 \times 6) \times \frac{6}{2} = 0$

$-R_B \times 6 + 60 + 20 + 54 = 0$

$-R_B \times 6 + 134 = 0$

$\boxed{R_B = 22.33\ KN}$ $1\frac{1}{2}$

put R_B value in eqn (1)

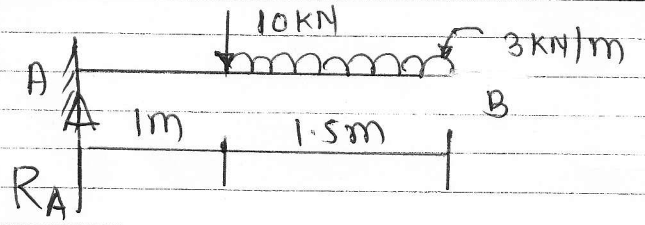
$R_A + R_B = 48$

$R_A + 22.33 = 48$

$R_A = 48 - 22.33$

$\boxed{R_A = 25.67\ KN}$ $1\frac{1}{2}$

f)



0

$\Sigma F_y = 0$

$0 = R_A - 10 - 3 \times 1.5$

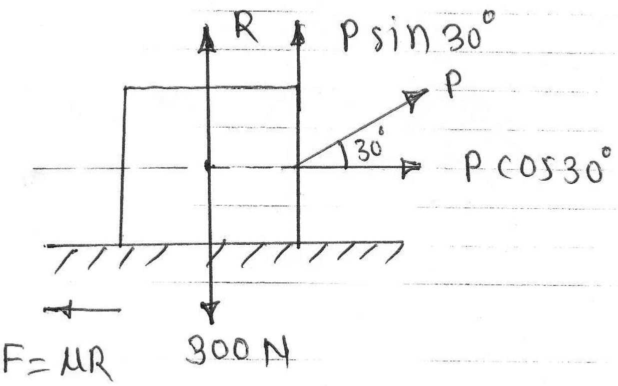
$R_A = 3 \times 1.5 + 10$

$R_A = 14.5\ KN$ 02

$\boxed{R_A = 14.5\ KN}$

Q-4

a)



$\Sigma fx = 0$

$P\cos 30° - \mu R = 0$

$\mu R = P\cos 30°$

$R = \dfrac{P\cos 30°}{\mu}$

$R = P \times 3.464$

$\boxed{R = 3.464P}$ 02

$\Sigma fy = 0$

$R - 300 + P\sin 30° = 0$

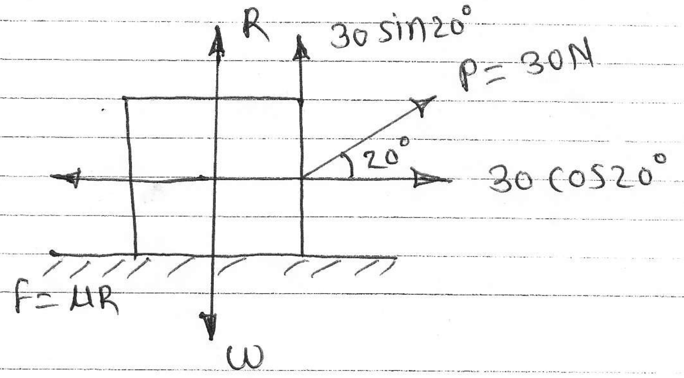
$R - 300 + 0.5P = 0$

$3.464P - 300 + 0.5P = 0$

$3.964P = 300$

$\boxed{P = 75.68 \text{ N}}$ 02

b



$\Sigma f_y = 0$

$R - w + 30 \sin 20° = 0$

$R - w + 10.26 = 0$

$\boxed{R = w - 10.26}$ ——— (1) 01

$\Sigma f_x = 0$

$30 \cos 20° - \mu R = 0$

$30 \cos 20° = \mu R$

$R = \frac{30 \cos 20°}{\mu}$

$R = \frac{30 \cdot \cos 20°}{0.20} = \frac{28.19}{0.20}$

$\therefore \boxed{R = 140.95 \text{ N}}$ 01

Put value of R in eq^n (1)

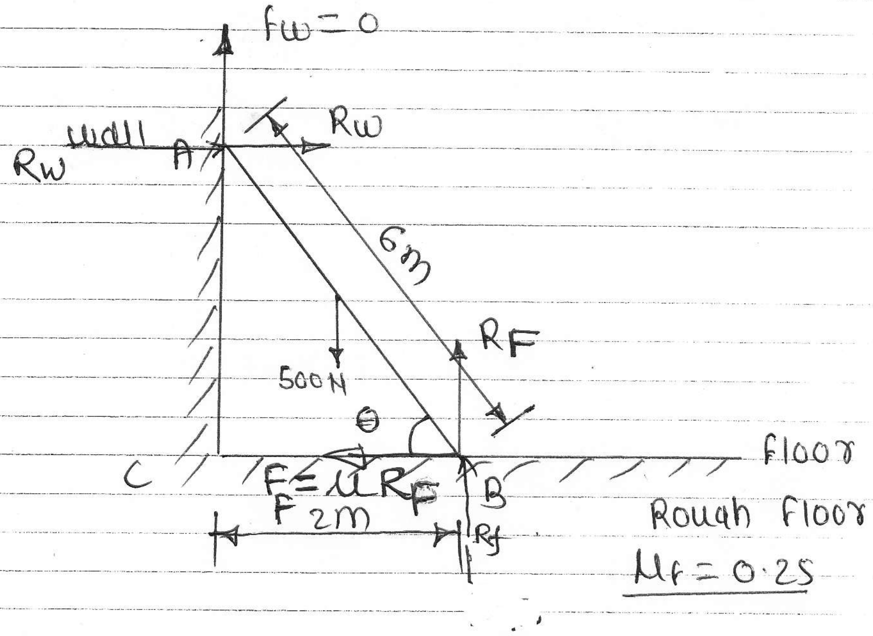
$\therefore R = w - 10.26$

$140.95 = w - 10.26$

$w = 140.95 + 10.26$

$\boxed{w = 151.21 \text{ N}}$ 01

c)



01

$\Sigma f_x = 0$

$R_w - F_f = 0$

$R_w - 0.25 R_f = 0$

$\boxed{R_w = 0.25 R_F}$ 01

$\Sigma f_y = 0$

$f_w + R_f - 500 = 0$ ∴ As $f_w = 0$

$\boxed{R_f = 500\,N}$ 01

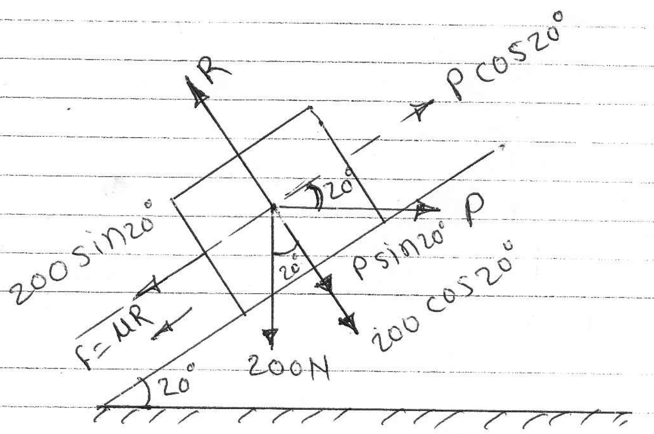
frictional force

$F_f = 0.25 \times R_F$

$= 0.25 \times 500$

$\boxed{F_f = 125\,N}$ 01

d



01

$\Sigma f_x = 0$

$P\cos 20^\circ - 200\sin 20^\circ - \mu R = 0$

$P\cos 20^\circ - 68.40 - 0.2R = 0$

$P\cos 20 - 0.2R = 68.40 \quad \text{—— (1)}$ 01

$\Sigma f_y = 0$

$R - P\sin 20^\circ - 200\cos 20^\circ = 0$

$R - P\sin 20^\circ - 187.94 = 0$

$R - P\sin 20^\circ = 187.94 \quad \text{—— (2)}$

$R = 187.94 + 0.34P$ 01

Put value of R in eqn (1)

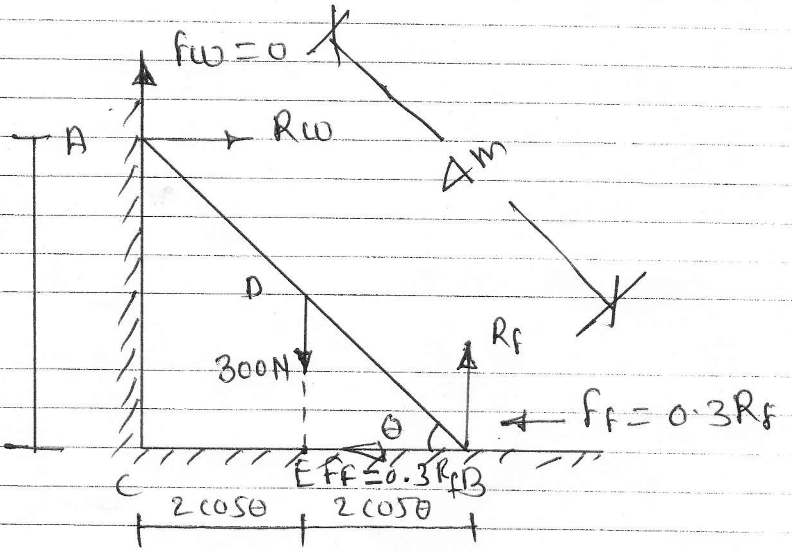
$P\cos 20^\circ - 0.2(187.94 + 0.34P) = 68.40$

$0.94P - 37.588 - 0.068P = 68.40$

$0.88P = 68.40 + 37.588$

$\boxed{P = 120.44\,N}$ 01

e)



i) in ΔABC

$$\sin\theta = \frac{AC}{AB} = \frac{AC}{4}$$

$$\therefore \boxed{AC = 4\sin\theta}$$

in ΔDBE

$$\cos\theta = \frac{BE}{BD} = \frac{BE}{2}$$

$BE = 2\cos\theta$. 01

ii) $\Sigma M = 0$

$R_w - 0.3R_f = 0$

$R_w = 0.3R_f$ —— 1

$\Sigma F_y = 0$

$R_f - 300 = 0$

$\boxed{R_f = 300\,N}$ 01

$R_w = 0.3R_f$

$R_w = 0.3 \times 300$

$\boxed{R_w = 90\,N}$ 01

Taking moment at point (B)

$M_B = 0$

$R_W \times 4 \sin\theta - 300 \times 2\cos\theta = 0$

$R_W \times 4\sin\theta = 600\cos\theta$

but $\boxed{R_W = 90N}$ put in above eqⁿ

$\therefore \quad 90 \times 4 \sin\theta = 600 \cos\theta$

$360 \sin\theta = 600 \cos\theta$

$$\frac{\sin\theta}{\cos\theta} = \frac{600}{360}$$

$\tan\theta = 1.6667$

$\therefore \boxed{\theta = 59.036^\circ}$ 01

F) Laws of static friction

i) The direction of frictional force is opposite to that of motion. 1 for

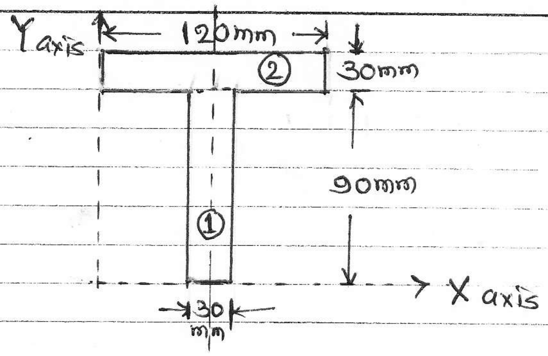
ii) Frictional force acts at the common surface of contact. any four

iii) The limiting value of frictional force is proportional to normal reaction.

iv) Limiting friction is independent of area of contact.

v) friction is dependent on material and roughness at surface of contact.

Q 5
a)



Area $A_1 = 90 \times 30 = 2700 \text{ mm}^2$

$A_2 = 120 \times 30 = 3600 \text{ mm}^2$ 1

Total Area (A) $= 6300 \text{ mm}^2$
$(A_1 + A_2)$.

Due to axis of symmetry (Y axis) vertical axis.

$\bar{x} = \frac{120}{2} = 60 \text{ mm}$. 1

To find $\bar{y}$

y_1 = Dist. of centroid of Area A_1 from X axis

$= \frac{90}{2} = 45 \text{ mm}$.

y_2 = Dist of centroid of Area A_2 from X axis. 1

$= 90 + \frac{30}{2} = 105 \text{ mm}$.

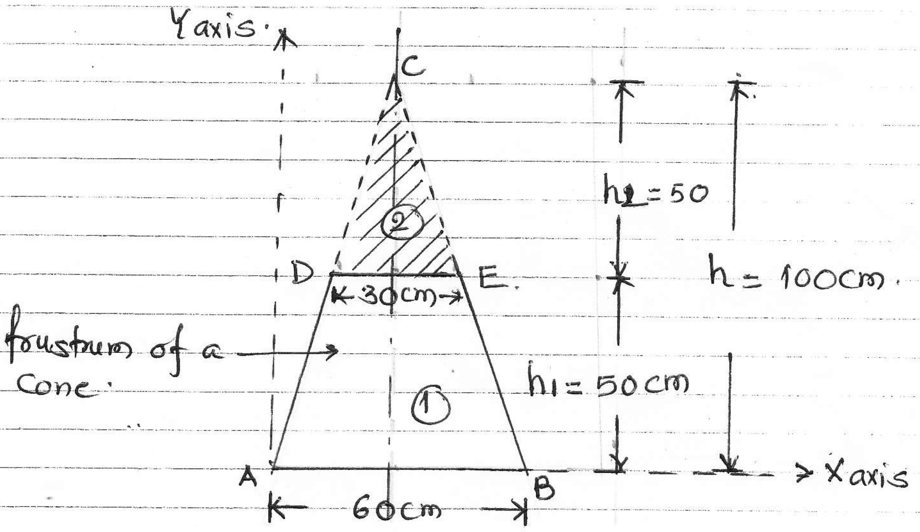
$\therefore \bar{Y} = \frac{A_1 y_1 + A_2 y_2}{A}$

$= \frac{(2700 \times 45) + (3600 \times 105)}{6300}$

$= 79.29 \text{ mm}$. 1

$\therefore$ Centroid $= (60, 79.29)$.

5 b).



1

Continued.....

5 b) Considering two cones (ABC) and (CDE) as shown in fig.

$$\frac{AB}{DE} = \frac{h}{h_1}$$

$$\therefore \frac{60}{30} = \frac{h_1+50}{h_1}$$

$$\therefore 60h_1 = 30(h_1+50)$$

$$2h_1 = h_1 + 50$$

$$\therefore h_1 = 50\text{ cm}$$ 1

Due to axis of symmetry (vertical axis),

$$\bar{x} = \frac{60}{2} = 30\text{ cm}$$

Volume of cone: V_1 = for Cone (ABC).

$$V_1 = \frac{1}{3}\pi r_1^2 h$$

$$= \frac{1}{3}\times\pi\times(30)^2\times 100$$

$$= 94247.78\text{ cm}^3$$

V_2 = for cone (CDE) 1

$$V_2 = \frac{1}{3}\pi r_2^2 \times h_2'$$

$$= \frac{1}{3}\pi(15)^2\times 50$$

$$= 11780.97\text{ cm}^3$$

Net volume = Volume of frustum of a cone.

$$V = V_1 - V_2 = 94247.78 - 11780.97$$

$$= 82466.81\text{ cm}^3$$

To find $\bar{Y}$

$$y_1 = \frac{100}{4} = 25\text{ cm}$$

$$y_2 = 50 + \frac{50}{4} = 62.5\text{ cm}$$

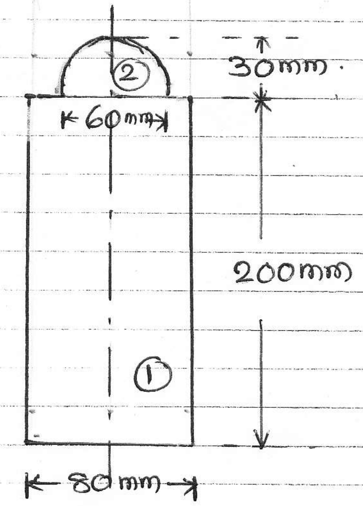
$$\therefore \bar{Y} = \frac{V_1y_1 - V_2y_2}{V_1 - V_2} = ~~94247.78~~$$

$$= \frac{(94247.78\times 25) - (11780.97\times 62.5)}{82466.81}$$

$$\bar{Y} = 19.64\text{ cm}$$ 1

$\therefore$ Centroid = (30 cm, 19.64 cm).

5 c).



1.

$V_1 =$ Vol. of cylinder $= \pi r^2 h$.

$= \pi (40)^2 \times 200 = 1005309.65 \text{ mm}^3$

$V_2 =$ Vol. of hemisphere.

$= \frac{2}{3} \pi r^3 = \frac{2}{3} \pi (30)^3$

$= 56548.67 \text{ mm}^3$

$\therefore$ Total volume $V = V_1 + V_2$.

$V = 1005309.65 + 56548.67$

$= 1061858.32 \text{ mm}^3$ 1

Due to axis of symmetry $\bar{x} = \frac{80}{2} = 40\text{mm}$. 1.

To find $\bar{Y}$

$y_1 = \frac{200}{2} = 100 \text{mm}$

$y_2 = 200 + \frac{3}{8}(30) = 211.25 \text{mm}$

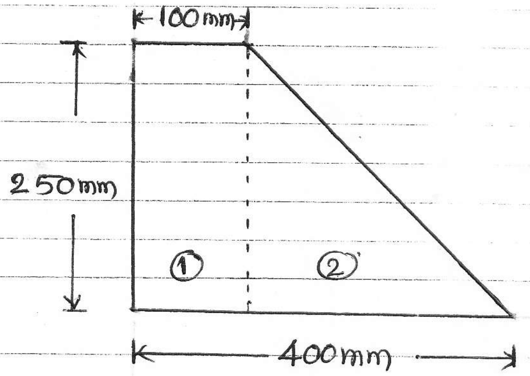
$\therefore \bar{Y} = \frac{V_1 y_1 + V_2 y_2}{V}$

$= \frac{(1005309.65 \times 100) + (56548.67 \times 211.25)}{1061858.32}$

$= 105.924 \text{ mm}$.

$\therefore$ Centroid $= (40, 105.924)$. 1

5d)



Area $A_1 = 100 \times 250 = 25000\ mm^2$

$A_2 = \frac{1}{2} \times 300 \times 250 = 37500\ mm^2$ 1

Total Area $(A) = 62500\ mm^2$

To find $\bar{x}$:

$x_1 = \frac{100}{2} = 50\ mm$

$x_2 = 100 + \left(\frac{1}{3} \times 300\right) = 200\ mm.$

$\therefore \bar{x} = \frac{A_1 x_1 + A_2 x_2}{A}$

$= \frac{(25000 \times 50) + (37500 \times 200)}{62500}$

$= 140\ mm.$ 1

To find $\bar{Y}$ = $y_1 = \frac{250}{2} = 125\ mm$

$y_2 = \frac{1}{3} \times 250 = 83.33\ mm.$

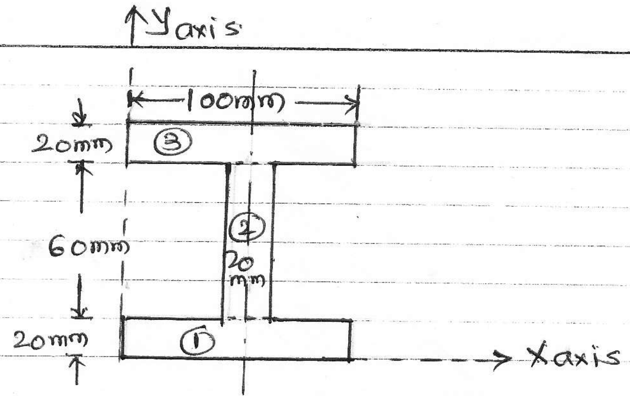
$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A}$

$= \frac{(25000 \times 125) + (37500 \times 83.33)}{62500}$ 1

$= 100\ mm.$

Centroid = $(140, 100\ mm)$.

5 e).



1

Area $A_1 = 100 \times 20 = 2000 \, mm^2$

$A_2 = 60 \times 20 = 1200 \, mm^2$

$A_3 = 100 \times 20 = 2000 \, mm^2$

Total Area $= 5200 \, mm^2$ 1

Due to axis of symmetry $\bar{x} = \frac{100}{2} = 50 \, mm.$

OR

To find $\bar{x}$ $\quad x_1 = 50, \; x_2 = 50, \; x_3 = 50 \, mm.$

$$\therefore \bar{x} = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A}$$

$$= \frac{(2000 \times 50) + (1200 \times 50) + (2000 \times 50)}{5200}$$

$= 50 \, mm.$ 1

To find $\bar{y}$

$y_1 = \frac{20}{2} = 10 \, mm.$

$y_2 = 20 + \frac{60}{2} = 50 \, mm$

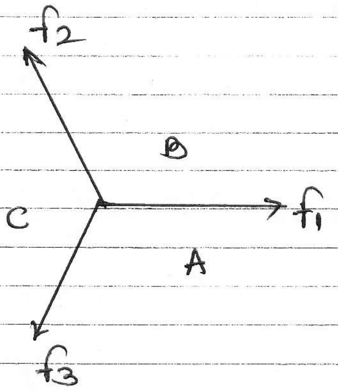
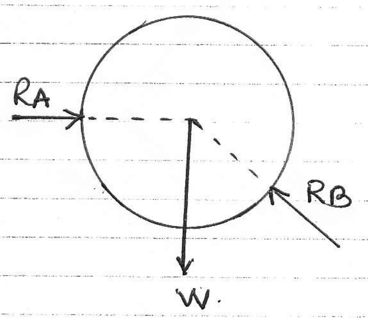
$y_3 = 20 + 60 + \frac{20}{2} = 90 \, mm.$

$$\therefore \bar{y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A}$$

$$= \frac{(2000 \times 10) + (1200 \times 50) + (2000 \times 90)}{5200}$$

$= 50 \, mm.$ 1

Centroid $(50 \, mm, 50 \, mm)$

5 f).	i). Scalar quantity	Vector quantity	
	a). It is a physical quantity having only magnitude but no direction.	a) It is a physical quantity having both magnitude and direction.	1/2
	b) Examples: Mass, area, volume density, time, speed, work etc	b) Examples: Momentum, moment, velocity, force, etc	1/2
	ii) Force	Couple	
	a) It is an external agency which changes or tends to change the state of rest or uniform motion of a body.	a) Two equal, unlike, parallel, non-collinear forces form a couple and it produces only rotary motion without linear motion.	1/2
	b) S.I unit of force is Newton.	S.I unit of Couple is N-m.	1/2
	iii). Space Diagram.	Free Body Diagram.	
	a) It shows exact location and direction of the forces with the help of Bow's notation.	a) If a body is separated from its surrounding it is called as free body and if all active & reactive forces acting on the body are shown then it is called as free body diagram.	1/2
	b). 	b). 	1/2

5 f). iv).

Resultant.	Equilibriant.	
a) It is a single force which can produce the same effect on the body as it is produced by all the forces acting together	a) It is a single force which brings the system of forces or body in equilibrium when acts on the body with other forces.	½
b) It creats the motion in the body.	b) It Keeps the body at rest.	½

Q 6.
a).

Data: Effort wheel radius (R) = 15 cm.
Load drum radius (r) = 30 cm.
No. of teeth on worm wheel (T) = 50.
Worm screw is single threaded $n = 1$.

$$\text{Velocity Ratio} = \frac{RT}{nr}$$

$$= \frac{15 \times 50}{1 \times 30}$$

$$= 25 \quad 2$$

To find. Load (W) when (P) = 30N and efficiency (η) = 40%.

$$\%\eta = \frac{M.A}{V.R} \times 100$$

$$40 = \frac{M.A}{25} \times 100$$

$$\therefore M.A = 10. \quad 1$$

$$M.A = \frac{W}{P}$$

$$10 = \frac{W}{30}$$

$$W = 300\,N. \quad 1$$

6 b	Data: Load (W) = 20KN = 20000N.	
	Effort (P) = 200 N.	
	Length of handle (l) = 250 mm	
	Pitch of screw (p) = 5 mm.	
	$V.R = \frac{2\pi l}{p}$	
	$= \frac{2 \times \pi \times (250)}{5} = 314.16$	1
	$M.A = \frac{W}{P} =$	
	$= \frac{20,000}{200} = 100.$	1.
	% efficiency (%η) = $\frac{M.A}{V.R} \times 100.$	
	$= \frac{100}{314.16} \times 100 = 31.83$	2
6 c	Data: Load (W_1) = 3.0KN = 3000 N.	
	effort (P_1) = 60 N.	
	Load (W_2) = 5.0KN = 5000N.	
	Effort (P_2) = 90 N.	
	Law of machine – $P = mW + C.$	
	$60 = m(3000) + C \ldots (i)$	
	$90 = m(5000) + C \ldots (ii)$	
	Subtracting (i) from (ii)	
	$30 = 2000\,m$	
	$\therefore m = \frac{30}{2000} = 0.015$	1
	∴ from (i) or (ii)	
	$60 = 0.015(3000) + C$	
	$C = 15$	1

6 c	Continued	
	$\therefore$ Law of machine _ $P = 0.015W + 15$	1.
	Maximum Mechanical Advantage $= \frac{1}{m}$.	
	$= \frac{1}{0.015} = 66.67$.	1.
6 d).	i) Maximum efficiency $= \frac{\text{Max. M.A.}}{\text{V.R.}} = \frac{1/m}{\text{V.R.}}$	
	$\therefore$ Maximum $\eta = \frac{1}{m \times \text{V.R.}}$	2.
	where m = slope of the line.	
	V.R = Velocity ratio.	
	ii) Irreversible machine:	
	A machine which is not capable of doing work in the reverse direction after the effort is removed, is called the irreversible or non-reversible machine.	
	The condition for the machine to be non-reversible is that its efficiency must be less than 50%.	2
6 e)	Data: Dia of effort wheel. (D) = 15 cm.	
	Dia. of Load drum (d) = 10 cm.	
	No. of teeth on spur (Ts) = 60	
	No. of teeth on pinion (T_P) = 20.	
	Effort (P) = 60N.	
	Load (W) = 1000 N.	

6 e) Continued......

$$\text{Velocity Ratio (V.R)} = \frac{D}{d} \times \frac{T_{s_1}}{T_{p_1}} \times \frac{T_{s_2}}{T_{p_2}}$$

$$= \frac{15}{10} \times \frac{60}{20} \times \frac{60}{20} = 13.5 \qquad 1$$

$$\text{Mechanical Advantage (M.A)} = \frac{\text{Load}}{\text{Effort}} = \frac{W}{P}$$

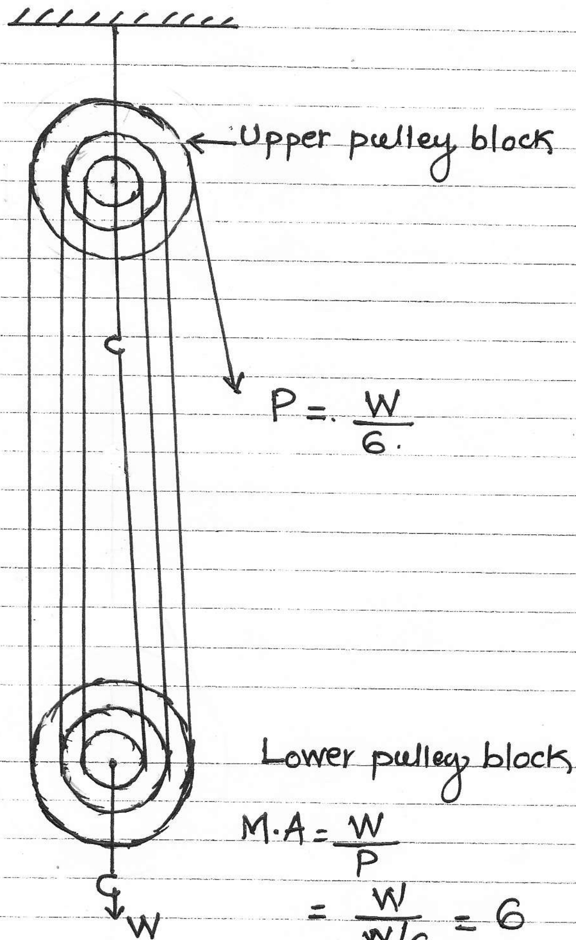
$$= \frac{1000}{60} = 16.67 \qquad 1$$

$$\%\ \text{efficiency} = \frac{M.A}{V.R} \times 100$$

$$= \frac{16.67}{13.50} \times 100$$

$$\%\ \eta = 123.48 \qquad 2$$

6 f. Three Sheave pulley block



$$M.A = \frac{W}{P}$$

$$= \frac{W}{W/6} = 6 \qquad 3$$

~~Assuming~~ NO friction $M.A = V.R$

$\therefore V.R = 6 \qquad 1$

Note for Examiner: In the above answers if students are writing some additional points or information which may be correct but not included in the model answer sheet. Examiners are requested to go through each answer carefully.