F.Y. Diploma : Sem. II
[AE/CE/CH/FG/ME/PT/PG]

Applied Mechanics

Time : 3 Hrs.] Prelim Question Paper Solution **[Marks : 70**

Q.1 Attempt any FIVE of the following : [10]

Q.1(a) How will you find whether machine is reversible or not? [2]

Ans.: By calculating the efficiency of machine, we can decide whether the machine is reversible or not.
If $\%\eta < 50\%$ machine is non-reversible i.e. self-locking machine. [2 marks]
If $\%\eta > 50\%$ machine is reversible.

Q.1(b) Differentiate between statics and dynamics. [2]

Ans.: Statics is the branch of applied mechanics which deals with forces and their action on bodies at rest. [1 mark]
Dynamics is the branch of applied mechanics which deals with forces and their action on bodies in motion. [1 mark]

Q.1(c) State Varignon's theorem. [2]

Ans.: Varignon's theorem states, "The algebraic sum of moments of all forces about any point is equal to moment of resultant about the same point". [1 mark]
Let, ΣMFA = Algebraic sum of moments of all forces about point A
MRA = Moment of Resultant about point A [1 mark]
Then, $\Sigma MFA = MRA$

Q.1(d) Define Simple Machine. [2]

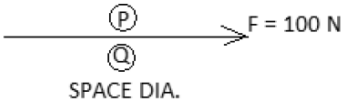
Ans.: Simple Machine [2 marks]
It is a device used in lifting a heavy load applied at one point by applying comparatively smaller force called effort applied at another convenient point.

Q.1(e) Define force and write its S.I. unit. [2]

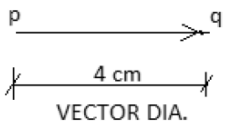
Ans.: Force [1 mark]
It is an external agency either push or pulls which changes or tends to change the state of rest or of uniform motion of a body, upon which it acts.
S. I. Unit of force – Newton (N) [1 mark]

Q.1(f) State Bow's Notation. Where it is used? [2]

Ans.: 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. [1 mark]



To represent a force of 100 N graphically, pq is drawn parallel to PQ as shown in vector diagram.



SCALE = 1 cm = 25 N

Use: Bow's notation is used in graphical method to indicate the force. [1 mark]

Q.1(g) List the conditions of equilibrium for co-planer non-concurrent forces. [2]

Ans.: Conditions of equilibrium for co-planer non-concurrent forces [2 marks]

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.

Q.2 Attempt any THREE of the following : [12]

Q.2(a) The velocity ratio of a certain machine is 50. Determine the effort required to lift a load of 1500 N if the efficiency of the machine is 40%. [4]

Ans.:

$$\%\eta = \frac{MA}{VR} \times 100$$

$$40 = \frac{MA}{50} \times 100 \quad \text{[2 marks]}$$

$$MA = 20$$

But, $MA = \frac{W}{P}$

$$20 = \frac{1500}{P}$$

$$P = 75 \text{ N} \quad \text{[2 marks]}$$

Q.2(b) In a differential axle and wheel, the diameter of wheel is 400 mm and that of axle are 100 mm and 80 mm, if an effort of 50 N can lift a load of 1500 N, find V.R. and efficiency of the machine. [4]

Ans.:

$$VR = \frac{2D}{d_1 - d_2} = \frac{2 \times 400}{100 - 80}$$

$$VR = 40 \quad \text{[2 marks]}$$

$$M.A. = \frac{1500}{50} = 30$$

$$\%\eta = \frac{M.A.}{V.R.} \times 100 = \frac{30}{40} \times 100$$

$$\%\eta = 75\% \quad \text{[2 marks]}$$

Q.2(c) 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. [4]

Ans.:

$D = 2R = 2 \times 125 = 250$ mm

$d = 2r = 2 \times 115 = 230$ mm

$$VR = \frac{2D}{D - d} = \frac{2 \times 250}{250 - 230} = 25 \quad \text{[2 marks]}$$

$$\%\eta = \frac{MA}{VR} \times 100$$

$$MA = 10$$

$\because \frac{W}{P}$

$$10 = \frac{1500}{P}$$

$$P = 150 \text{ N} \quad \text{[2 marks]}$$

Q.2(d) A double purchase crab used in a laboratory has following dimensions : [4]

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.: $VR = \frac{2L \times N_1 \times N_3}{d \times N_2 \times N_4} = \frac{2 \times 360 \times 75 \times 90}{160 \times 20 \times 30} = 50.625$ [1 mark]

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 equation (i) [1 mark]

$90 = (0.033 \times 1800) + C$

$C = 30.6$ N

Hence, Law of machine

$P = (0.033)\,W + 30.6$ N … (iii) [1 mark]

Using, eqn. (iii)

$P = (0.033)\,W + 30.6$ N

$P = (0.033 \times 4500) + 30.6$

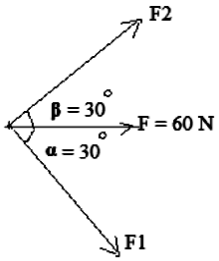
$P = 179.1$ N [1 mark]

Q.3 Attempt any THREE of following : [12]

Q.3(a) What are the components of 60 N force acting horizontal in two directions on other side, at an angle of 30° each? [4]

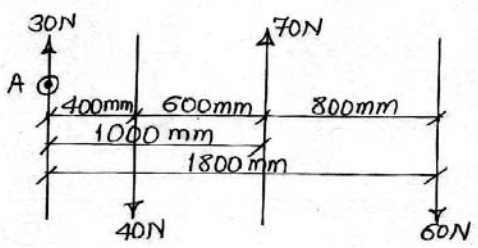
Ans.: $F_1 = \frac{F \sin\alpha}{\sin(\alpha+\beta)} = \frac{60 \sin 30}{\sin(30+30)} = 34.64$ N [2 marks]

$F_2 = \frac{F \sin\beta}{\sin(\alpha+\beta)} = \frac{60 \sin 30}{\sin(30+30)} = 34.64$ N [2 marks]



Q.3(b) Four forces of 30 N ↑, 40 N ↓, 70 N ↑ and 60 ↓ are acting in a series. Distances between the forces are 400 mm, 600 mm and 800 mm respectively. Find the moment of a couple. [4]

Ans.: [Diagram - 2 marks]

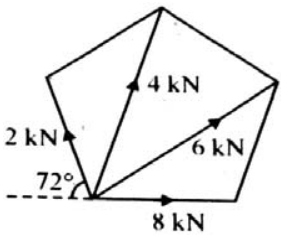


Taking moment of all forces about 30 N force i.e. about point A

$M = (30 \times 0) + (40 \times 400) - (70 \times 1000) + (60 \times 1800)$

$M = 54000$ Nm (Clockwise) [2 marks]

Q.3(c) Forces of 2, 4, 6 and 8 kN act on regular pentagon as shown in Figure. Find analytically the resultant in magnitude and direction. [4]



Ans.: $\sum F_x = 8 + 6\cos 36° + 4\cos 72° - 2\cos 72°$

ΣF_x = 13.47 kN

ΣF_y = 6 sin 36° + 4 sin 72° + 2 sin 72°

ΣF_y = 9.23 kN [1 mark]

$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$

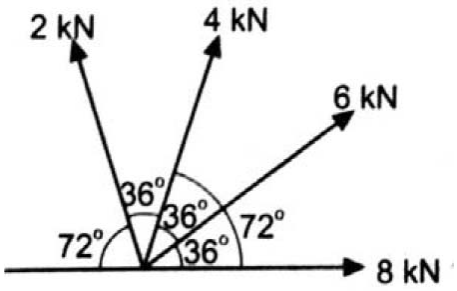
$R = \sqrt{13.47^2 + 9.23^2}$

R = 16.33 kN [1 mark]

$\tan\theta = \frac{\Sigma F_y}{\Sigma F_x} = \frac{9.23}{13.47}$

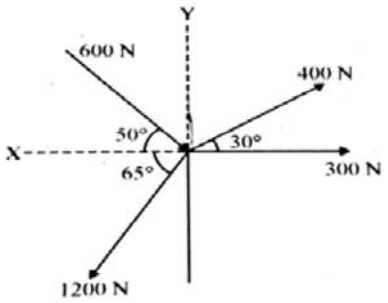
$\theta = \tan^{-}(0.6852)$

θ = 34.42° [1 mark]

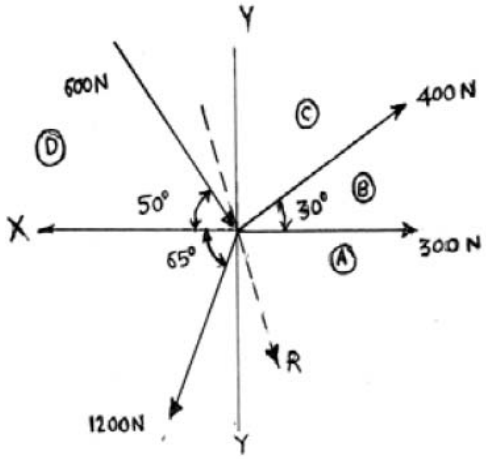


[1 mark]

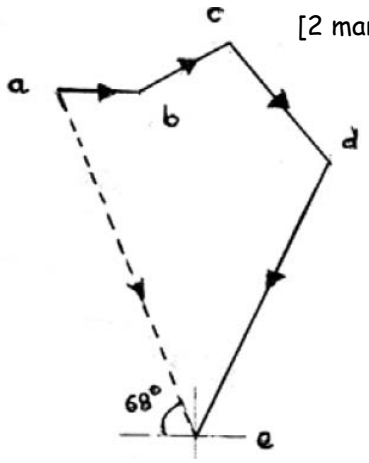
Q.3(d) *A* **concurrent force system is shown in figure. Find graphically the resultant of this force system.** **[4]**



Ans.: [2 marks each diagram]



Space Diagram



Vector Diagram

From vector diagram

$\ell(ae)$ = 4 cm

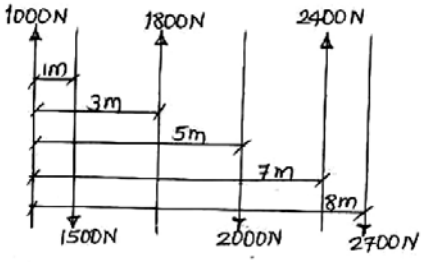
$R = \ell(ae) \times \text{scale} = 7.3 \times 200$

R = 1460 N

Q.4 Attempt any THREE of following : **[12]**

Q.4(a) Six parallel forces of magnitude 1000 N, 1500 N, 1800 N, 2000 N, 2400 N and 2700 N are acting at 1, 3, 5, 7, 8 m from the 1st force. Forces 1st, 3rd and 5th are acting upwards while other acting downwards. Find the resultant force analytically. **[4]**

Ans.:



1) Magnitude of Resultant

R = +1000 – 1500 + 1800 – 2000 + 2400 – 2700 = -1000 N

= 1000 N (↓) [2 marks]

- ve sign indicates Resultant acts vertically downwards.

2) Position of Resultant

Considering Varignon's theorem of moment & taking moment of all forces @ about 1000 N force.

Let, R acts at x distance from 1000 N force.

$\Sigma MF = MR$

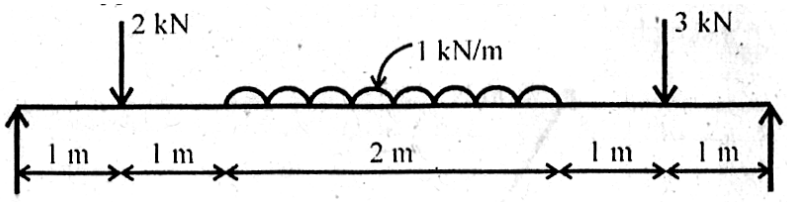
$(1000 \times 0) + (1500 \times 1) - (1800 \times 3) + (2000 \times 5) - (2400 \times 7) + (2700 \times 8) = R \times x$

$10900 = 1000 \times x$

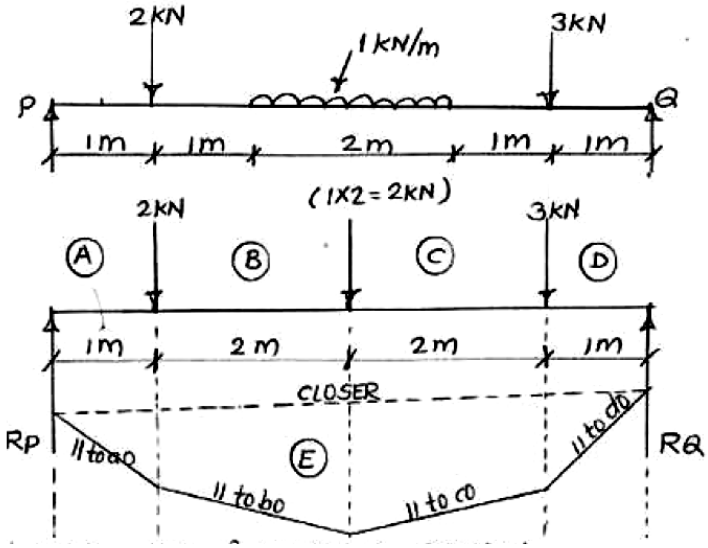
$x = 10.9$ m [2 marks]

Hence, R must be located at 10.9 m distance from 1000 N force, so as to produce clockwise moment.

Q.4(b)Find the support reaction of the beam graphically. See figure. **[4]**



Ans.: [2 marks]



Space DIA and Funicular Polygon : Scale = 1m = 0.5m

$R_P = \ell(ae) \times$ scale

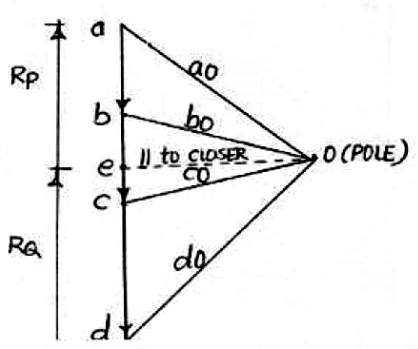
$= 3.2 \times 1$

$R_P = 3.2$ kN

$R_Q = \ell(de) \times$ scale

$= 3.8 \times 1$

$R_Q = 3.8$ kN



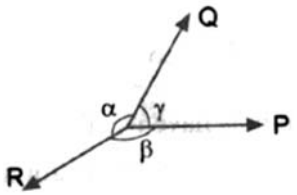
[2 marks]

Q.4(c) State and explain Lami's theorem. List limitation of Lami's theorem. **[4]**

Ans.: Lami's Theorem [1 mark]

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'.

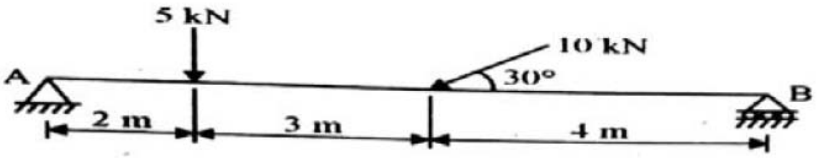
$$\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$$ [1 mark]



Limitations of Lami's theorem [2 marks]

(i) This theorem is applicable only for three forces.
(ii) This theorem is applicable when forces are concurrent.
(iii) This theorem is applicable only when body is in equilibrium.
(iv) This theorem is not applicable for non-concurrent force system.

Q.4(d) Find analytically the reaction at supports as shown in Figure. **[4]**



Ans.: $\sum M_A = 0$

Taking moment of all forces @ point A [1 mark]

$R_B \times 9 + 5 \times 2 + 5 \times 5 = 0$

$35 = 9\ R_B$

$R_B = 3.88$ kN

$\sum F_y = 0$

$R_A \sin\alpha - 5 - 5 + R_B = 0$

$R_A \sin\alpha = 6.12$ kN

$\sum Fx = 0$

$R_A \cos\alpha - 8.66 = 0$ [1 mark]

$R_A \cos\alpha = 8.66$ kN

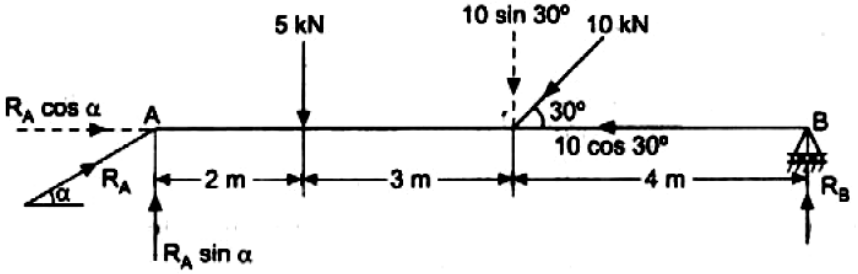
$$\alpha = \tan^{-1}\left|\frac{R_A \sin\alpha}{R_A \cos\alpha}\right| = \tan^{-1}\left|\frac{6.12}{8.66}\right| = 34.99°$$ [1 mark]

Substituting the value of α in

$R_A \sin\alpha = 6.12$ kN

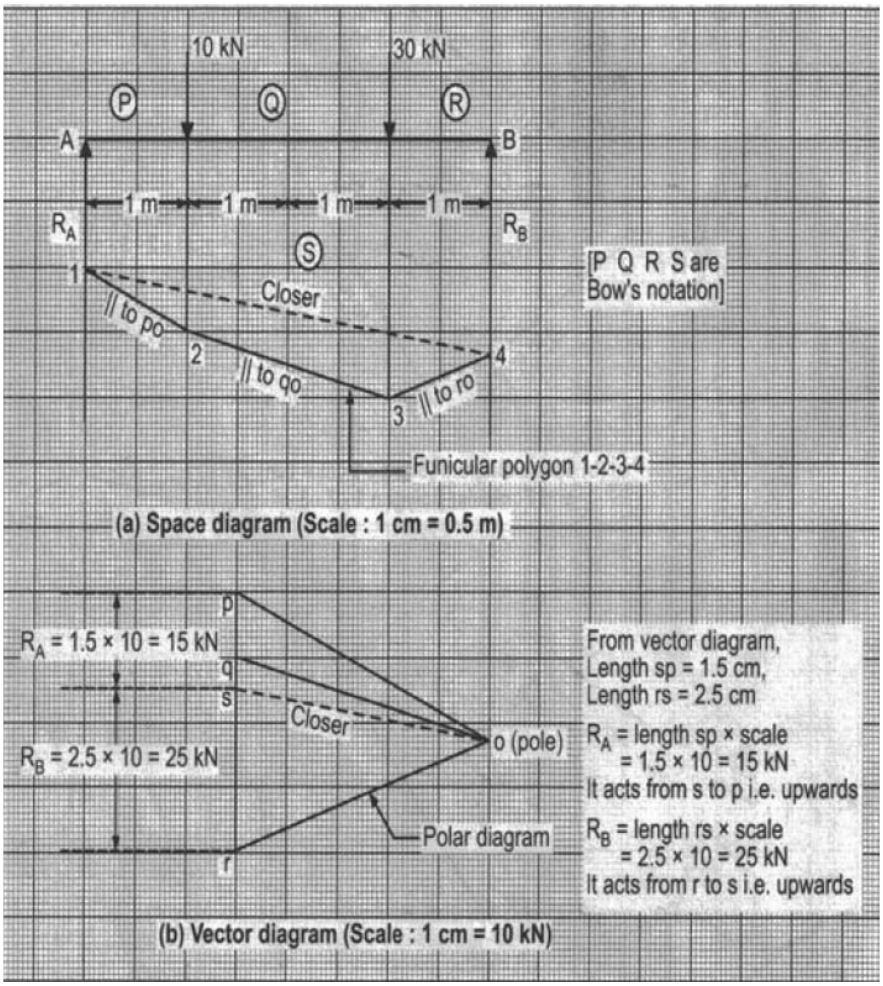
$R_A = 10.68$ kN

$R_B = 3.88$ kN [1 mark]



Q.4(e) 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. **[4]**

Ans.:



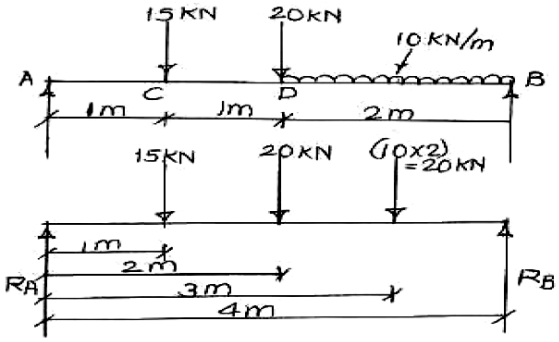
[2 marks]

[2 marks]

Q.5 Attempt any TWO of following : **[12]**

Q.5(a) A beam of span 4 m is simply supported at its ends. It carries concentrated load of 15 kN and 20 kN at 1 m and 2 m from left hand support respectively. It carries U.D.L. of 10 kN/m for 2 m from the right end. Determine reactions at the support. **[6]**

Ans.: [Diagram - 1 mark]



1) Equivalent point load and it's position

Equivalent point load = Intensity of udl × span of udl

= 10 X 2

= 20 KN

Position from equivalent point load from RA

= 1 m + 1 m+ Span of udl / 2

= 2 + (2/2) = 3 m

2) Applying equilibrium conditions

$\Sigma Fy = 0$ ($\uparrow$ +ve, $\downarrow$–ve) and $\Sigma M = 0$ ($\circlearrowright$+ve, $\circlearrowleft$–ve)

$\Sigma Fy = 0$

$RA - 15 - 20 - 20 + RB = 0$ [1 mark]

$RA + RB = 55$ KN ... (1)

$\Sigma M_A = 0$

Taking moment of all forces @ point A

$(RA \times 0) + (15 \times 1) + (20 \times 2) + (20 \times 3) - (RB \times 4) = 0$ [1 mark]

$RB = 28.75$ KN

Putting value of RB in eqn. (1)

$RA + 28.75 = 55$ [1 mark]

$RA = 26.25$ KN

Q.5(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. **[6]**

Ans.: Step 1

For limiting equilibrium

$\Sigma F_x = 0$, and $\Sigma F_y = 0$

$\Sigma F_y = 0$

$50 - F = 0$

$50 - \mu R = 0$

$\mu R = 50$ N

$\Sigma F_y = 0$

$R - W = 0$

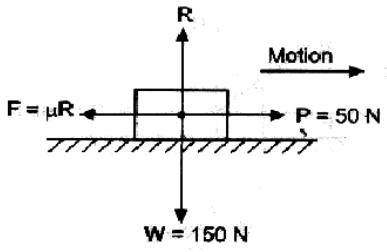
$R - 150 = 0$

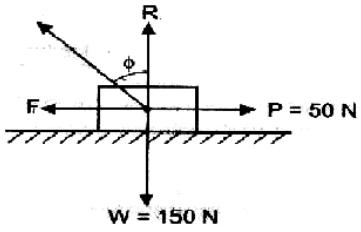
$R = 150$ N [1 mark]

$\mu R = 50$

$\mu \times 150 = 50$

$\mu = 0.33$





Step 2

To find the resultant reaction and direction,

For limiting equilibrium,

$\Sigma F_x = 0$

$P - F = 0$

$F = P$

$F = 50$ N [1 mark]

Resultant reaction,

$S = \sqrt{F^2 - R^2}$

$S = \sqrt{50^2 - 150^2}$

$S = 158.11$ N [1 mark]

$\mu = \tan \phi$

$\phi = \tan^{-}(\mu)$

$\phi = \tan^{-}(0.33)$

$\delta = 18.43°$ [1 mark]

OR

$$\tan \phi = \frac{F}{R}$$

$$\tan \phi = \left(\frac{50}{150}\right)$$

$\phi = 18.43°$

Q.5(c) A heavy stone of mass 500kg is on a hill slope of 600 incline. If the coefficient of friction between ground and stone is 0.4 is the stone stable ? Justify. **[6]**

Ans.: **Step 1**

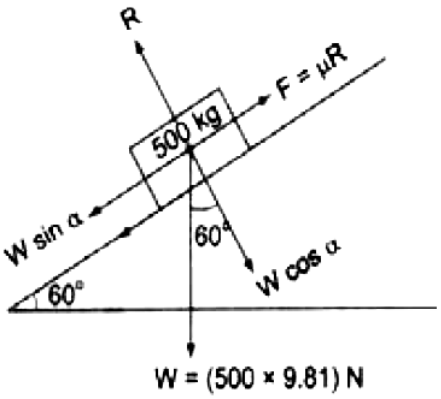
For limiting equilibrium,

$$\sum F_x = 0,$$

$$R - W\cos\alpha = 0$$

$$R = 500 \times 9.811 \cos 60°$$

$$R = 2452.5 \text{ N}$$ [1 mark]



Step 2

Friction force,

$$F = \mu R$$

$$F = 0.4 \times 2452.5$$

$$F = 981 \text{ N} \quad \ldots (i)$$ [1 mark]

Step 3

Component of weight down the plane

$$W \sin\alpha = 500 \times 9.81 \times \sin 60°$$

$$W = 4247.85 \text{ N} \quad \ldots (ii)$$ [1 mark]

Comparing equation (i) and (ii)

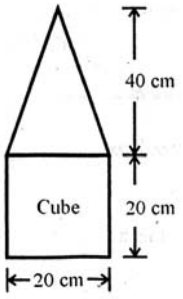
$$W \sin\alpha > F$$

Step 4

The stone will slide down the plane because of its own i.e. it will not be stable. [1 mark]

Q.6 Attempt any TWO of following : **[12]**

Q.6(a) A solid cone of height 40 cm is placed on a cube of side 20 cm as shown in figure. Locate the position of C.G. with respect to tip of the cone. **[6]**

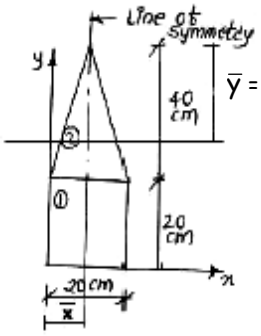


Ans.: **1) Volume Calculation**

$$V_1 = 20 \times 20 \times 20 = 8000 \text{ cm}^3$$

$$V_2 = (1/3)\pi r^2 h = (1/3)\pi(10)^2 \times 30 = 4188.79 \text{ cm}^3$$

$$V = V_1 + V_2 = 12188.79 \text{ cm}^3$$



[1 mark]

2) $\bar{y}$ calculation

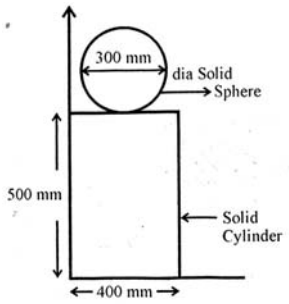
$$y_1 = h_1 - \frac{h_1}{4} = 40 - \frac{40}{4} = 30 \text{ cm}$$

$$Y_2 = 40 + \frac{20}{2} = 50 \text{ cm}$$ [1 mark]

3) $$\bar{y} = \frac{V_1 y_1 + V_2 y_2}{V}$$

$$\bar{y} = 36.87 \text{ cm}$$ [2 marks]

Q.6(b) Find the centre of gravity of composite solid w.r.t x and y-axis. See figure. **[6]**

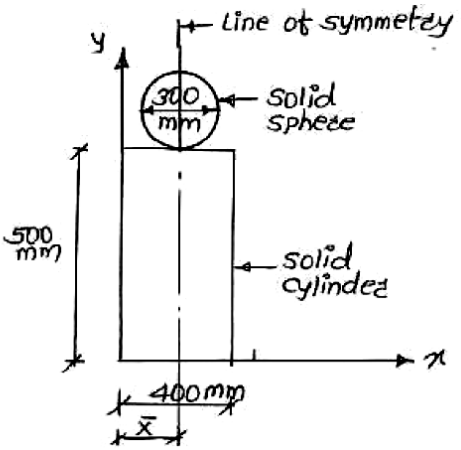


Ans.: 1) Figure is symmetric @ y–y axis and hence,

$\bar{x}$ = Maximum horizontal dimension /2 [1 mark]

= 400 / 2

= 200 mm



2) Volume Calculation

$V_1 = \pi r_1^2 h_1 = \pi(200)^2 \times 500 = 62831853\ mm^3$ [1 mark]

$V_2 = (4/3)\pi r_2^3 = (4/3)\pi(150)^3 = 14137167\ mm^3$

$V = V_1 + V_2 = 76.96902 \times 10^6\ mm^3$

3) $\bar{y}$ calculation

$Y_1 = \frac{500}{2} = 250$ mm [1 mark]

$Y_2 = 500 + 150 = 650$ mm

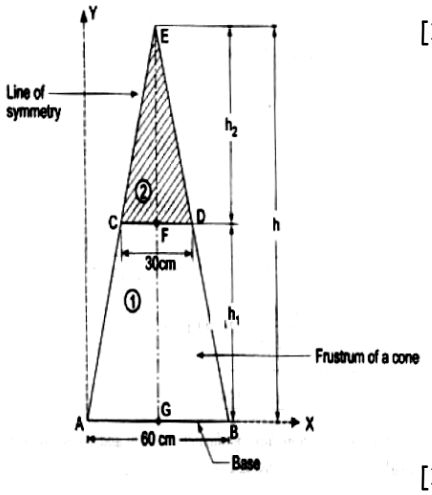
$\bar{y} = \frac{V_1 y_1 + V_2 y_2}{V}$

$\bar{y} = 323.47$ mm [1 mark]

Q.6(c) 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. **[6]**

Ans.: **Step 1**

$\bar{x} = \frac{60}{2} = 30$ cm [1 mark]



By similar triangles,

$\frac{h}{60} = \frac{h_2}{30} \Rightarrow h = \left(\frac{60}{30}\right) \times h_2$

$h = 2\ h_2$

$h_1 + h_2 = h$

$18 + h_2 = 2\ h_2$

$h_2 = 18$ cm

Step 2

V_1 = Full volume of cone

$V_1 = \frac{1}{3}\pi r_1^2 h = \frac{1}{3} \times \pi \times 30^2 \times 36 = 33929.2\ cm^3$ [1 mark]

V_2 = Volume of cut cone

$V_2 = \frac{1}{3}\pi r^2 h_2 = \frac{2}{3} \times \pi \times 15^3 \times 18 = 4241.15\ cm^3$ [1 mark]

$Y_1 = \frac{h}{4} = \frac{36}{4} = 9$ cm, $Y_2 = h_1 + \frac{h_2}{4} = 18 + \frac{18}{4} = 22.5$ cm

Step 3

$\bar{y} = \frac{V_1 y_1 - V_2 y_2}{V_1 - V_2} = \frac{(33929.2 \times 9) - (4241.15 \times 22.5)}{33929.2 - 4241.15} = 7.0714$ cm [1 mark]

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