FIRST SEMESTER B.TECH DEGREE EXAMINATION, JANUARY 2016

Course Code: BE 100

Course Name: ENGINEERING MECHANICS

100 Duration:3 Hours

PART A

Answer ALL questions. Each questions carries 5 Marks

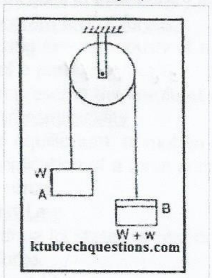
1. What are the laws of mechanics? State and explain them.

2. Find the support reactions of a cantilever beam of span 6m carrying a UDL of 6kN/m.

3. Explain moment of inertia and polar moment of inertia

4. Explain laws of friction.

5. Two equal weights 'W' are connected by light (weightless) string passing over a friction less pulley. A small weight 'w' is added to one side as shown in figure,



causing that the weight to fall.Determine the acceleration of the system assuming that the weight start from rest.

6. Explain instantaneous center of rotation.

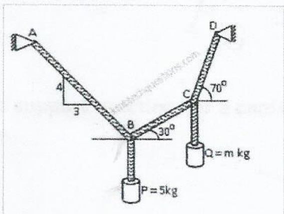
7. Explain the term free vibration and forced vibration.

8. A body is vibrating with simple harmonic motion of amplitude 120 mm and frequency 5 cps. Calculate the maximum velocity and acceleration of the body.

PART B

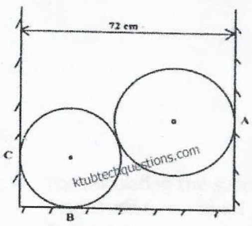
Answer any 2 complete questions each having 10 marks

9. Block P=5 kg and block Q of mass m kg are suspended through a chord, which is in equilibrium as shown in the figure.



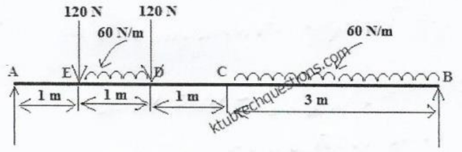
Determine the mass of the block Q.

10. Two homogeneous spherical balls rest between two vertical wall as shown in figure. The radius of smaller ball is 16 cm and weight is 1.15 kN. The radius of larger ball is 24 cm and its weight is 3.45 kN. Distance between the walls is 72 cm. Assuming the contact surfaces to be smooth,



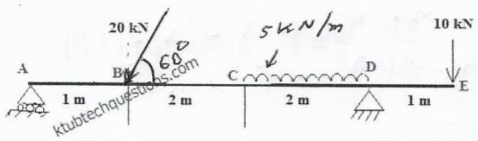
(a) Draw free body diagram of two balls (b) Determine the reactions at A,B, and C.

11. Determine the reactions at the supports A and B of the beam loaded as shown in figure below.

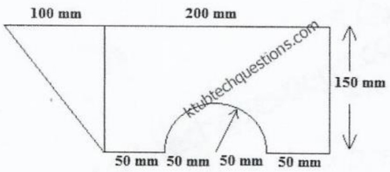


Answer any 2 complete Questions each having 10 marks

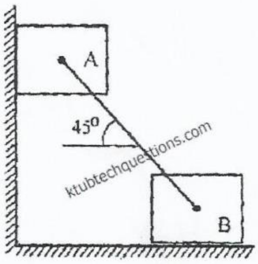
12. Determine the support reactions of the beam shown in figure



13. Calculate the centroid of the composite area shown in figure



14. Two identical block, A and B of weight W are supported by a rigid bar inclined 45° with the horizontal as shown in figure.



If both the blocks are in limiting equilibrium find the coefficient of friction, between the block and wall assuming it to be same.

Answer any 2 Questions each having 10 marks

15. A lift has an upward acceleration of 1.2 m/s2. (a) What force will a man weighting 750 N exerts on the floor of the lift? (b) What force he exert, if the lift had an acceleration 1.2 m/s2 downwards? (c) What upward acceleration would cause his weight to exert a force of 900N in the floor?

16. In a reciprocating engine mechanism the crank rotates at a **uniform** speed of 400 rpm. The length of the crank and connecting rod are 150 mm and 600 mm respectively. Find (a) the angular velocity of the connecting rod (b) velocity of the piston when the crank makes an angle of 250 with the horizontal.

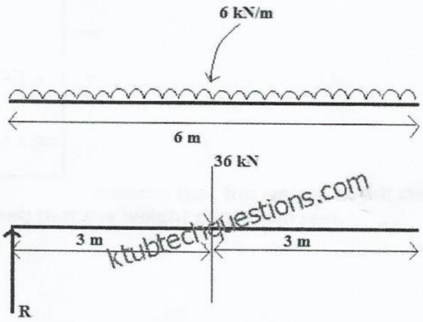
17. A body of mass 50 kg is suspended by two springs of stiffness 4 kN/m and 6 kN/m as shown in figure. The body is pulled 50 mm down from its equilibrium position and then released. Find (a) a

ANSWERS
PART A
Answer ALL questions. Each questions carries 5 Marks

1. What are the laws of mechanics? State and explain them.
ANS:
Fundamental principles in elementary mechanics are
(a) The parallelogram law of forces.
If two forces acting simultaneously at a point are represented in magnitude and direction by the adjacent sides of a parallelogram then the diagonal of the parallelogram passing through their point of intersection represents the resultant of the two forces in both magnitude and direction.
(b) Principle of transmissibility
The condition of equilibrium of motion of a rigid body will remain unchanged if the point of application of application of a force acting on the rigid body transmitted to any other point on the line of action of the force.
(c) Newton's First Law
Every body continue its states of rest or of uniform motion, in a straight line, unless it acted upon by some external force.
(d) Newton's Second Law
The acceleration of a particle is proportional to the resultant force acting on it and is in the direction of this force.
(e) Newton's Third Law
To every action there is an equal and opposite reaction.
(f) Newton's Law of gravitation
Two particle attracted towards each other along the line connecting them with a force whose magnitude is proportional to the product of their masses and inversly proportional to the sure of the distance between them.

$$F_G = \frac{G m_1 m_2}{r^2}$$

2. Find the support reactions of a cantilever beam of span 6m carrying a UDL of 6kN/m.
ANS:



For calculating the support reactions, the UDL can be replaced by a concentrated load of of magnitude 6×6=36 kN at the midpoint.
3. Explain moment of inertia and polar moment of inertia.
ANS:

4) The moments equation about the support yields

$\Sigma M = M - 36\,kN \times 3\,m = 0$

Hence reaction moment, $M = 108\,kN\,m$

The summation of forces gives

$\Sigma F = F - 36\,kN = 0$

Hence reaction force $F = 36\,kN$

Moment of Inertia (Mass Moment of Inertia) – I– is a measure of an object's resistance to changes in the rotation direction. Moment of Inertia has the same relationship to angular acceleration as mass has to linear acceleration.

- Moment of Inertia of a body depends on the distribution of mass in the body with respect to the axis of rotation

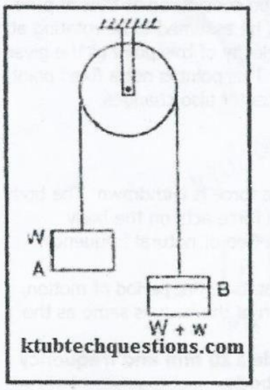
Polar moment of inertia is a quantity used to predict an object's ability to resist torsion, in objects (or segments of objects) with an invariant circular cross section and no significant warping or out-of-plane deformation. It is used to calculate the angular displacement of an object subjected to a torque. It is analogous to the area moment of inertia, which characterizes an object's ability to resist bending and is required to calculate displacement.

- The larger the polar moment of area, the less the beam will twist, when subjected to a given torque.

4. Explain laws of friction.
ANS:

- The force of friction always acts in a direction opposite to the direction in which the body moves or tends to move.
- Till the limiting value is reached. the magnitude of friction is equal to the force which the tends to move the body.
- The magnitude of limiting friction bears a constant ratio to the normal reaction between the two contact surfaces.
- The force of friction is independent of the area of contact between the two surfaces.
- The force of friction depends upon the roughness of the surfaces in contact.
- For low velocities, the frictional force is independent of magnitude of velocity. But generally the dynamic friction is less than the limiting friction.

5. Two equal weights 'W' are connected by light (weightless) string passing over a friction less pulley. A small weight 'w' is added to one side as shown in figure,



causing that the weight to fall.Determine the acceleration of the system assuming that the weight start from rest.
ANS:

Acceleration= $\frac{m2g-m1g}{m1+m2}$

Here m_2g=(W+w)

m_1g=W

m_2g=(W+w)

m_1=W/g

m_2=(W+w)/g

putting in (1), we ge

$$=\frac{(W+w)-w}{\frac{W}{g}+\frac{(W+w)}{g}}$$

Acceleration= $\frac{wg}{2W+w}$

6. Explain instantaneous center of rotation.

ANS:

The motion of rotation and translation of a body, at a give instant, can be considered as that of pure rotation of the body about a point. This point about which the body can be assumed to be rotating at the given instant is called instantaneous center of rotation. Since the velocity of this point at the given instant is zero, this point is called instantaneous center of zero velocity. This point is not a fixed point, and when the body changes its position, the position of instantaneous center also changes.

7. Explain the term free vibration and forced vibration.

ANS:

Free or natural vibration:

In free vibration the body at first is given an initial displacement and the force is withdrawn. The body starts vibrating and continues the motion of its own accord. No external force acts on the body further to keep it in motion. The frequency of free vibration is known as free or natural frequency.

Forced vibration:

When a periodic disturbing force keeps the body in vibration through out its entire period of motion, such vibration is said to be a forced vibration. The frequency of vibration of the body is same as the frequency of the applied force.

8. A body is vibrating with simple harmonic motion of amplitude 120 mm and frequency 5 cps. Calculate the maximum velocity and acceleration of the body.

ANS:

r= 120 mm= 0.12 m

f= 5 cps

ω= 2пf

= 2п x 5= 10п rad/sec

Maximum velocity, V_{max} = rω

= 0.12 x 10п = 3.77 m/s

Maximum acceleration, a_{max} = $\omega^2 r$

= $(10\pi)^2$ x0.12

=118.43 m/s^2

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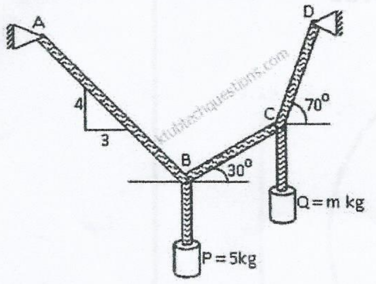
PART B

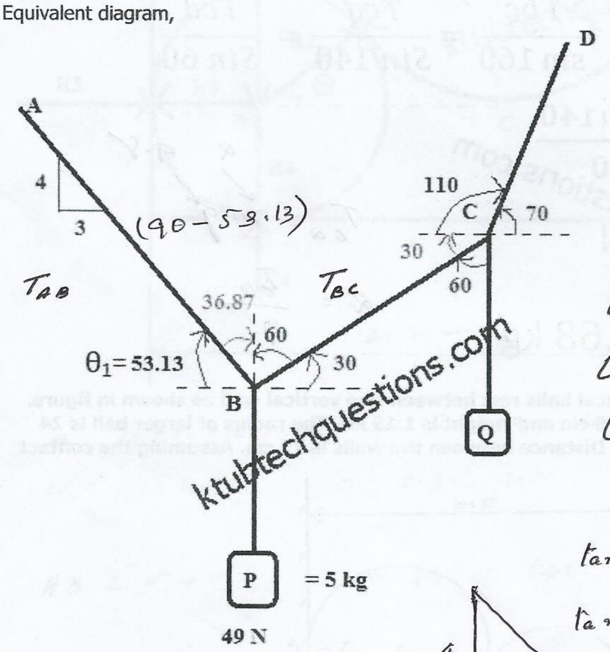
Answer any 2 complete questions each having 10 marks

9. Block P=5 kg and block Q of mass m kg are suspended through a chord, which is in equilibrium as shown in the figure.



ANS:

Equivalent diagram,



$\angle ABC = 96.87^\circ$

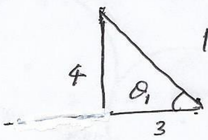
$\angle ABP = 143.13^\circ$

$\angle PBC = 120^\circ$

$\tan\theta_1 = \frac{4}{3}$

$\tan^{-1}\frac{4}{3} = \theta_1$

$\theta_1 = 53.13^\circ$



Applying Lami's theorem at **B**;

$\angle BCD = 140^\circ$

$\angle BCQ = 60^\circ$

$\angle DCQ = 160^\circ$

$$\frac{49}{\sin 96.87} = \frac{Tab}{\sin 120} = \frac{Tbc}{\sin 143.13}$$

$$T_{bc} = \frac{49 * \sin(143.13)}{\sin(96.87)}$$

$$= 29.61 \text{ N}$$

Applying Lami's theorem at C;

$$\frac{Tbc}{\sin 160} = \frac{Tcq}{Sin\ 140} = \frac{Tcd}{Sin\ 60}$$

$$T_{CQ} = \frac{29.61 * sin140}{sin160}$$

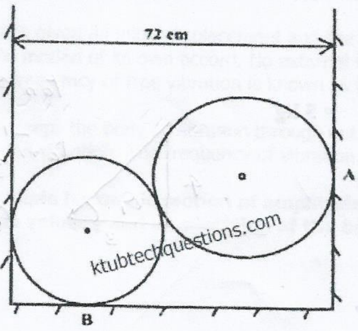
$$= 55.64 \text{ N}$$

$T_{CQ} = mg$

$Q = \frac{T_{CQ}}{g}$

$$Q = \frac{55.64}{9.8} = 5.68 \text{ kg}$$

10. Two homogeneous spherical balls rest between two vertical wall as shown in figure. The radius of smaller ball is 16 cm and weight is 1.15 kN. The radius of larger ball is 24 cm and its weight is 3.45 kN. Distance between the walls is 72 cm. Assuming the contact



surfaces to be smooth,
(a) Draw free body diagram of two balls (b) Determine the reactions at A,B, and C.
ANS:

Free Body Diagram

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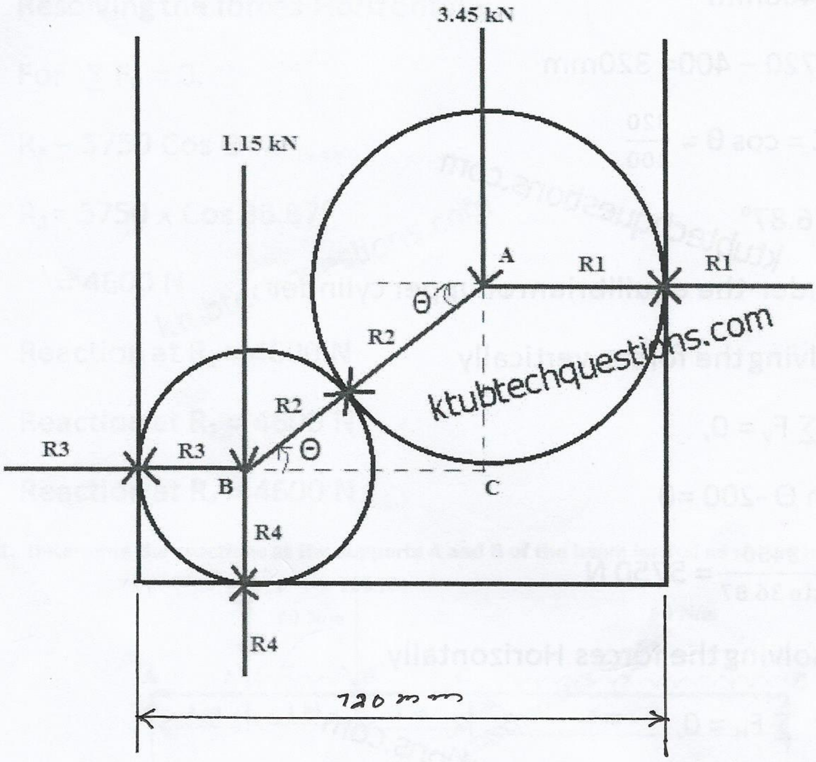


$r_1 = 16\,cm = 160\,mm, \quad r_2 = 24\,cm = 240\,mm$

$w_1 = 1.15\,kN \qquad w_2 = 3.45\,kN$

$AB = r_1 + r_2 = 160 + 240 = 400\,mm$

$BC = 720 - \overset{400}{(r_1 + r_2)} = 320\,mm$

AB = 400mm

BC = 720 – 400= 320mm

$<ABC = \cos\theta = \frac{320}{400}$

$\Theta = 36.87°$

Consider the equilibrium of upper cylinder

Resolving the forces vertically

For $\sum F_v = 0$,

$R_2 \sin\Theta - 200 = 0$

$R_2 = \frac{3450}{\sin 36.87} = 5750$ N

Resolving the forces Horizontally,

For $\sum F_H = 0$,

$R_2 \cos\Theta - R_1 = 0$

$R_1 = R_2 \cos\Theta = 5750 \times \cos 36.87° = 4600$ N

Consider the equilibrium of lower cylinder.

Resolving the forces vertically,

For $\sum F_v = 0$

$R_4 - 1150 - 5750 \times \sin\theta = 0$

$R_4 = 1150 + 5750 \times \sin 36.87° = 4600$ N

Resolving the forces Horizontally,

For $\sum F_H = 0$,

$R_3 - 5750 \cos \Theta = 0$

$R_3 = 5750 \times \cos 36.87^\circ$

$= 4600$ N

Reaction at $R_1 = 4600$ N

Reaction at $R_3 = 4600$ N

Reaction at $R_4 = 4600$ N

11. Determine the reactions at the supports A and B of the beam loaded as shown in

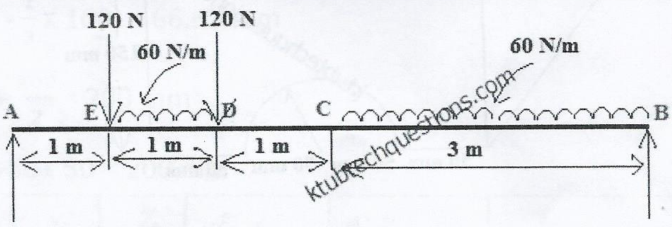
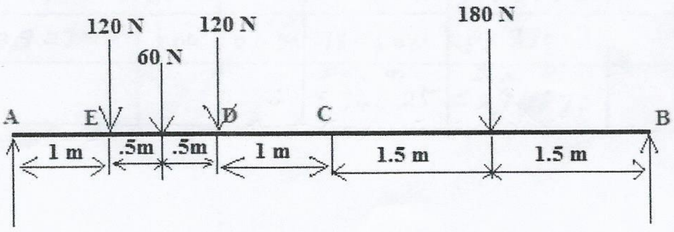


figure below.

ANS:

For calculating the support reactions, the UDL can be replaced by a concentrated load of magnitude 60×3 =180 kN at the midpoint of BC are shown in figure.



Consider the free body diagram

For $\sum F_v = 0$

$R_A - 120 - 60 - 120 - 180 + R_B = 0$

$R_A + R_B = 480$ ——>(1)

For $\sum M = 0$ Taking moment about A

$1\times120+1.5\times60+2\times120+4.5\times180-6R_B=0$

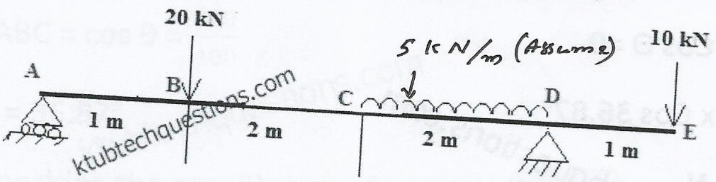
$R_B=(1260)/6$

R_B=210.

RA=270.

Answer any 2 complete Questions each having 10 marks

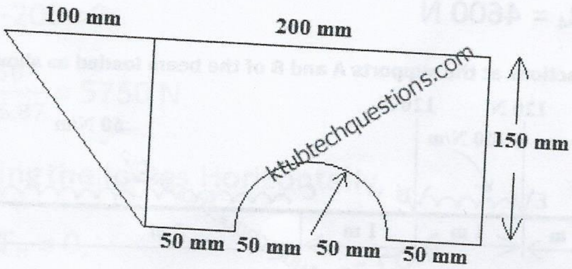
12. Determine the support reactions of the beam shown in figure



ANS: Ref. P 16-17

Data insufficient; UDL between C and D Not Given;

13. Calculate the centroid of the composite area shown in figure:



ANS:

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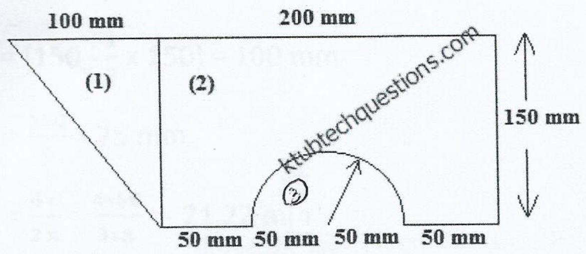


$A_1 = \frac{1}{2} \text{x} 100 \text{x} 150$

$= 7500 \text{ mm}^2$

$A_2 = 200 \text{ x} 150 = 30000 \text{ mm}^2$

$A_3 = \frac{\pi}{2} r^2 = \frac{\pi}{2} \text{x } 50^2 = 3927 \text{ mm}^2$

$X_1 = (100 - \frac{1}{3} \text{x } 100) = 66.67 \text{ mm}$

$X_2 = 100 + \frac{200}{2} = 200 \text{ mm}$

$X_3 = 100 + 50 + 50 = 200 \text{ mm}$

Area (A_i)	x_i mm	y_i mm	$A_i x_i$ mm^3	$A_i y_i$ mm^3	
7500 mm^2	66.67	100	500025	750000	
30000 mm^2	200	75.0	6000000	2250000	
3927 mm^2	200	21.22	-785400	83330.94	
		Σ	$\Sigma A_i x_i$ 574625	$\Sigma A_i y_i$ 2916670	

13

$Y_1 = (150 - \frac{1}{3} \times 150) = 100$ mm

$Y_2 = \frac{150}{2} = 75$ mm

$Y_3 = \frac{4r}{3\pi} = \frac{4*50}{3*\pi} = 21.22$ mm

$\bar{X} = \frac{A1X1 + A2X2 - A3X3}{A1 + A2 - A3}$

$= \frac{7500*66.67 + 30000*200 - 3927*200}{7500+30000-3927}$ $= \frac{500025 + 6000000 - 785400}{33573}$ = 574625

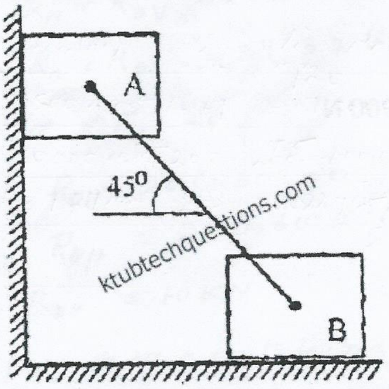
= 170.21 mm

$\bar{Y} = \frac{A1Y1 + A2Y2 - A3Y3}{A1 + A2 - A3}$

$= \frac{7500*100+30000*75-3927*21.22}{7500+30000-3927}$ $= \frac{750000 + 2250000 - 83330.94}{33573}$ = 2916670

= 86.88 mm

14. Two identical block, A and B of weight W are supported by a rigid bar inclined 45° with the horizontal as shown in figure.



If both the blocks are in limiting equilibrium find the coefficient of friction, between the block and wall assuming it to be same.

ANS:

[pdf-embedder url="http://ktubtechquestions.com/wp-content/uploads/2016/05/Since-the-bar-is-in-compression.pdf"]

Answer any 2 Questions each having 10 marks

15. A lift has an upward acceleration of 1.2 m/s². (a) What force will a man weighting 750 N exerts on the floor of the lift? (b) What force he exert, if the lift had an

acceleration 1.2 m/s²downwards? (c) What upward acceleration would cause his weight to exert a force of 900N in the floor?
ANS:

(a) When the lift moves upward.

$a = 1.2\ m/s^2$

$W = 750\ N$

$R = W\ [1 + \frac{a}{g}] = 750[1 + \frac{1.2}{9.81}]$

$= 841.74\ N$

(b) When the lift moves downward.

$a = 1.2\ m/s^2$

$W = 750\ N$

$R = W[1 - \frac{a}{g}]$

$= 750\ [1 - \frac{1.2}{9.81}]$

$= 658.26\ N$

(c) The required acceleration for R = 900 N

When lift moves up

$W = 750\ N$

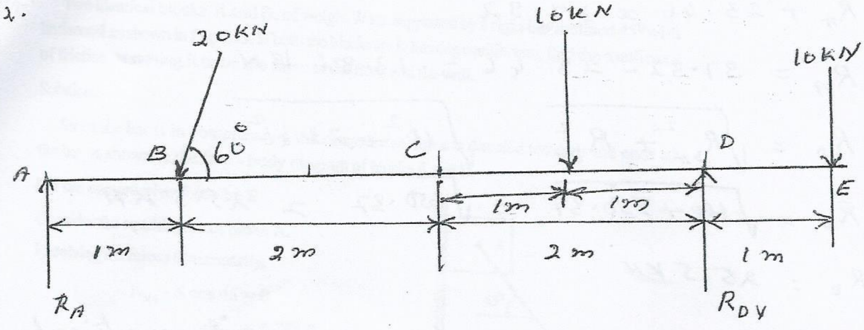
$R = 900\ N$

$R = W[1 + \frac{a}{g}]$

$900 = 750[1 + \frac{a}{9.81}]$

$a = 1.96\ m/s^2$

12.



Assume inclination of 20 KN force $\theta = 60^0$

uniform distributed load 5 KN/m

For calculating the support reactions, the UDL can be replaced by a concentrated load of magnitude $5 \times 2 = 10$ KN at the mid point of CD

For $\Sigma F_V = 0$

$R_A - 20 \sin 60 - 10 + R_{DV} - 10 = 0$

$R_A + R_{DV} = 20 \sin 60 + 10 + 10 = 17.32 + 10 + 10$

$R_A + R_{DV} = 37.32$ KN

For $\Sigma F_H = 0$

$R_{DH} - 20 \cos 60 = 0$

$R_{DH} = 20 \cos 60 = 10$ KN

$R_{DH} = 10$ KN

For $\Sigma m = 0$, taking moments about A

$20 \sin 60 \times 1 + 10 \times 4 - R_{DV} \times 5 + 10 \times 6 = 0$

$5 R_{DV} = 20 \times \frac{\sqrt{3}}{2} + 40 + 60 = 17.32 + 40 + 60$

$R_{DV} = \frac{117.32}{5} = 23.46$ KN

$R_A + 23.46 = 37.32$

$R_A = 37.32 - 23.46 = 13.86$ KN

$R_D = \sqrt{R_{DH}^2 + R_{DV}^2} = \sqrt{10^2 + 23.46^2}$

$R_D = \sqrt{100 + 550.37} = \sqrt{650.37} = 25.5$ KN

$R_D = 25.5$ KN

Inclination of reaction R_D with vertical

$$\theta_D = \tan^{-1}\frac{R_{DH}}{R_{DV}} = \tan^{-1}\frac{10}{23.46} = 23.09^{0}$$

Support reaction $R_A = 13.86$ KN

$R_D = 25.5$ KN

Inclination of reaction R_D with vertical $= 23.09^{0}$

14. Two identical blocks, A and B, of weight W are supported by a rigid bar inclined 45^0 with horizontal as shown in Fig.4.13. If both the blocks are in limiting equilibrium, find the coefficient of friction, assuming it to be the same at the floor and the wall.

Solution.

Since the bar is in compression, the compressive force is directed towards the ends of the bar as shown in the free - body diagram of blocks A and B.

Let the compressive force be S.

Consider the equilibrium of block A.

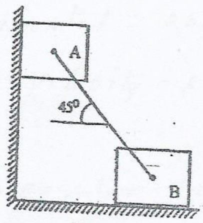


Fig.4.13

Resolving the forces horizontally,

$$R_{NA} - S\cos 45 = 0$$

$$R_{NA} = 0.707\,S$$

Resolving the forces vertically,

$$\mu R_{NA} + S\sin 45 - W = 0$$

$$\mu \times 0.707\,S + 0.707\,S = W$$

$$0.707\,S(1+\mu) = W \quad \text{—(i)}$$

Consider the equilibrium of block B.

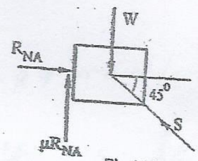


Fig.4.14

Resolving the forces vertically,

$$R_{NB} - W - S\sin 45 = 0$$

$$R_{NB} = W + 0.707\,S$$

Resolving the forces horizontally,

$$S\cos 45 - \mu R_{NB} = 0$$

$$S\cos 45 - \mu\,(W + 0.707\,S) = 0$$

$$0.707\,S - \mu \times 0.707\,S = \mu W$$

$$0.707\,S(1-\mu) = \mu W \quad \text{—(ii)}$$

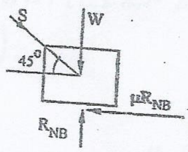


Fig.4.15

From eqns (i) and (ii)

$$\frac{0.707\,S(1-\mu)}{0.707\,S(1+\mu)} = \frac{\mu W}{W}$$

$$1-\mu = \mu(1+\mu)$$

$$1-\mu = \mu + \mu^2$$

$$\mu^2 + 2\mu - 1 = 0$$

$$\mu = \frac{-2+\sqrt{4+4}}{2} = \frac{-2+2\sqrt{2}}{2}$$

$$= 0.414$$

Q. 16

solution

Given data : Crank rotation speed $N = 400$ rpm

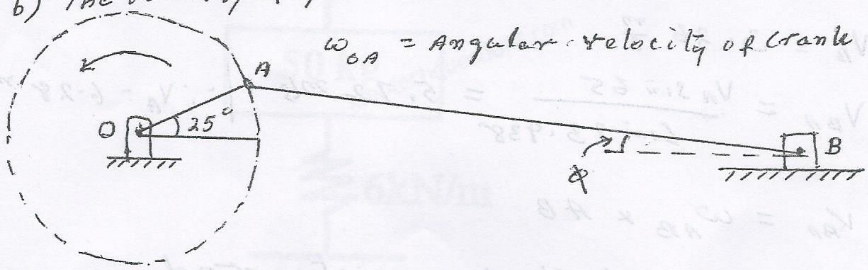
$l_c = 150\,mm = 0.15\,m$

$l_{con} = 600\,mm = 0.6\,m$

Crank angle with horizontal = 25°

To find a) The angular velocity of the Con. rod

b) The velocity of piston



a)

$$\omega_{OA} = \frac{2\pi N}{60} = \frac{2\pi \times 400}{60} = 41.89 \; rad/s$$

$$V_A = \omega_{OA} \times OA = 41.89 \times 0.15 = 6.28 \; m/s$$

$V_A = 6.28\; m/s$ (perpendicular to OA, 65° inclined with horizontal)

$$V_B = V_A + V_{BA}$$

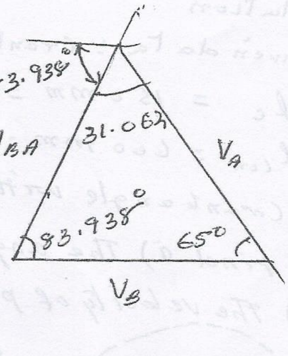
Let the inclination of AB with horizontal be ϕ, then $OA \sin 25 = AB \sin\phi$

$$\sin\phi = \frac{OA \sin 25}{AB} = \frac{15}{60}\sin 25 = 0.1056$$

$$\phi = 6.062^\circ$$

V_{BA} is perpendicular to AB or inclined $90 - 6.062 = 83.938^\circ$ with horizontal

$$\frac{V_A}{\sin 83.938} = \frac{V_B}{\sin 31.062} = \frac{V_{BA}}{\sin 65}$$



Velocity of piston

$$V_B = V_A \frac{\sin 31.062}{\sin 83.938}$$

$$= 6.28 \times \frac{0.516}{0.994} = 3.258 \frac{m}{s}$$

$$V_B = 3.26 \frac{m}{s}$$

$$V_{BA} = \frac{V_A \sin 65}{\sin 83.938} = 5.72 \text{ m/s}$$ | $\because V_A = 6.28$ m/s

$$V_{BA} = \omega_{AB} \times AB$$

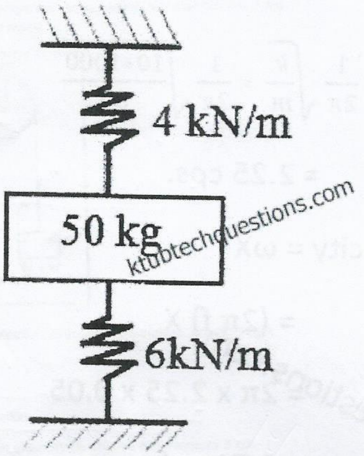
Angular velocity of connecting rod

$$\omega_{AB} = \frac{V_{BA}}{AB} = \frac{5.72}{0.6} = 9.53 \frac{rad}{s}$$

16. In a reciprocating engine mechanism the crank rotates at a uniform speed of 400 rpm. The length of the crank and connecting rod are 150 mm and 600 mm respectively. Find (a) the angular velocity of the connecting rod (b) velocity of the piston when the crank makes an angle of 250 with the horizontal.

ANS:

17. A body of mass 50 kg is suspended by two springs of stiffness 4 kN/m and 6 kN/m as



shown in figure. The body is pulled 50 mm down from its equilibrium position and then released. Find (a) a frequency of oscillation (b) maximum velocity (c) maximum acceleration.

ANS:

The springs are in parallel. Hence the equivalent stiffness;

$$k_e = k_1 + k_2$$

$$= 4 + 6 = 10 \text{ kN/m}$$

(i) Frequency $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{10*1000}{50}}$

$$= 2.25 \text{ cps.}$$

(ii) Maximum velocity = ωX

$$= (2\pi f)\,X$$

$$= 2\pi \times 2.25 \times 0.05$$

$$= 0.71 \text{ m/s}$$

(iii) acceleration = $\omega^2 X = (2\pi f)^2 \times 0.05$

$$= (2\pi \times 2.25)^2 \times 0.05$$

$$= 10 \text{ m/s}^2$$