CLASS TEST S.No.:01_JPCE_10062024

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CIVIL ENGINEERING

Engineering Mechanics

Duration : 1:00 hr. **Maximum Marks : 50**

Read the following instructions carefully

1. This question paper contains **25** objective questions. **Q.1-25 carry two** marks each.
2. Answer all the questions.
3. Questions must be answered on Objective Response Sheet (ORS) by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number. Each question has only one correct answer. In case you wish to change an answer, erase the old answer completely using a good soft eraser.
4. There will be NEGATIVE marking. For each wrong answer 1/3rd of the full marks of the question will be deducted. More than one answer marked against a question will be deemed as an incorrect response and will be negatively marked.
5. Write your name & Roll No. at the specified locations on the right half of the ORS.
6. Using HB pencil, darken the appropriate bubble under each digit of your registration number.
7. No charts or tables will be provided in the examination hall.
8. Use the blank pages given for rough work.
9. Choose the Closest numerical answer among the choices given.

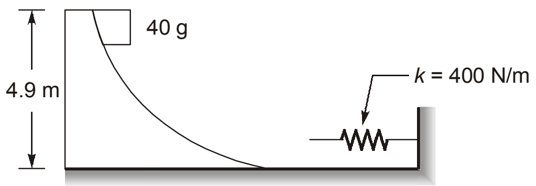
DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

Q.1 An elevator of mass 500 kg is ascending with an acceleration of 3 m/s^2. During the ascent, its operator whose mass is 100 kg is standing on the scale placed on the floor. What will be the total tension in the cables of the elevator during this motion?
(Take, $g = 10\ m/s^2$)
(a) 4.2 kN (b) 6.5 kN
(c) 780 N (d) 7.8 kN

Q.2 A particle is thrown with a velocity of 10 m/s at an elevation of 60° to the horizontal. What will be the velocity of another particle thrown at an elevation of 30° which will have equal time of flight?
(a) 17.32 m/s (b) 5.77 m/s
(c) 5 m/s (d) 20 m/s

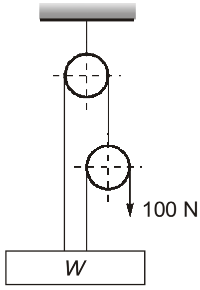
Q.3 A rod of length L is hinged from one end. It is brought to a horizontal position and released. The angular velocity of the rod when it is in vertical position is
(a) $\sqrt{\frac{2g}{L}}$ (b) $\sqrt{\frac{3g}{L}}$
(c) $\sqrt{\frac{g}{2L}}$ (d) $\sqrt{\frac{g}{L}}$

Q.4 A 40 g mass is released on a smooth curved surface from rest at a height of 4.9 m as shown in figure. The maximum compression of the spring is



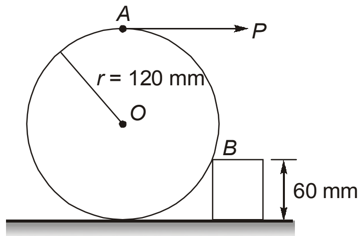
(a) 4.9 cm
(b) 9.8 cm
(c) 19.6 cm
(d) 4.2 cm

Q.5 In a frictionless pulley system as shown in figure, each pulley weighs 40 N. The weight W (in N), that can be lifted by the system under the conditions shown is



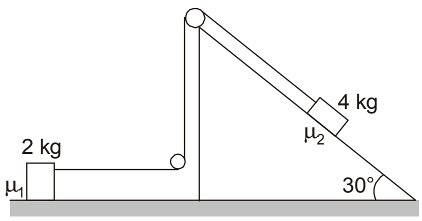
(a) 340 (b) 200
(c) 300 (d) 380

Q.6 A roller of weight 500 N has a radius of 120 mm and is pulled over a step of height 60 mm by a horizontal force P. The magnitude of P to just start the roller over the step is



(a) 288.68 N (b) 125 N
(c) 166.67 N (d) 250 N

Q.7 If the tension in the string in the figure is 16 N and the acceleration of each block is 0.5 m/s^2. The value of friction coefficient μ_2 is
(Take $g = 10\ m/s^2$)



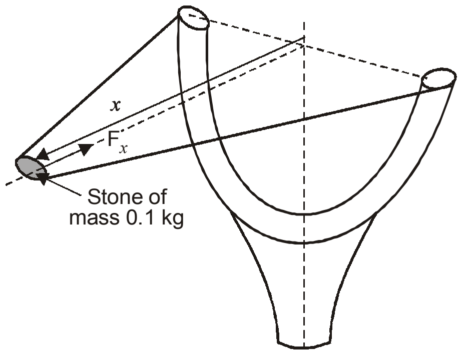
(a) 0.69 (b) 0.069
(c) 0.58 (d) 0.058

Q.8 A swimmer swims at the speed of 7 km/h in still water. His speed against the flow is 5 km/h. If he is swimming in the direction of flow. He will cover 90 km in ____ hour.
(a) 18 (b) 10
(c) 30 (d) 27

Q.9 A stone with a mass of 0.1 kg is catapulted as shown in the figure. The total force F_x (in N) exerted by the rubber band as a function of distance x (in m) is given by,

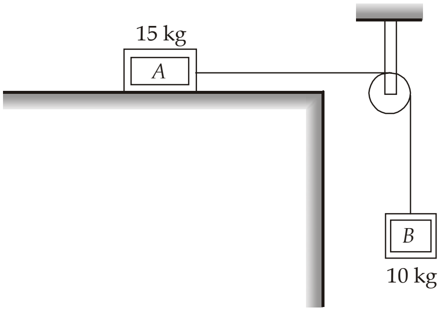
$$F_x = 300x^2$$

If the stone is displaced by 0.1 m from the un-stretched position (x = 0) of the rubber band then the energy stored in the rubber band is



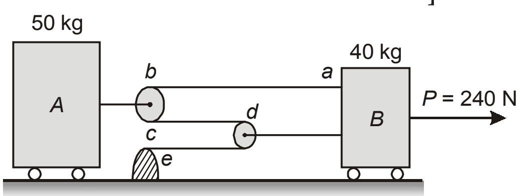
(a) 0.1 Joules (b) 1 Joules
(c) 10 Joules (d) 100 Joules

Q.10 What will be the acceleration of a solid body A of mass 15 kg, when it is being pulled by another body of mass 10 kg along a smooth horizontal plane as shown in figure? [Take $g = 10\ m/s^2$]



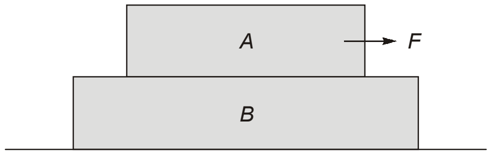
(a) $3\ m/s^2$ (b) $2\ m/s^2$
(c) $4\ m/s^2$ (d) $1\ m/s^2$

Q.11 Blocks A and B are connected through a cable $abcde$ as shown in the figure given below. If a force P is applied on block B then the acceleration of block B is
[Consider acceleration of block A as 1.5 times of acceleration of block B]



(a) $1.08\ m/s^2$ (b) $1.23\ m/s^2$
(c) $1.57\ m/s^2$ (d) $1.72\ m/s^2$

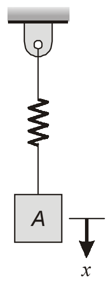
Q.12 Block A of mass 10 kg rests on a second block B of mass 8 kg. A force F equal to 100 N pulls block A. The coefficient of friction between A and B is 0.5 and between B and ground, is 0.1. The speed of block A relative to block B at 1 s if system starts from rest is [Take $g = 9.81\ m/s^2$]



(a) 0.06 m/s (b) 0.12 m/s
(c) 0.18 m/s (d) 0.24 m/s

Q.13 A particle is moving along a circular path. Equation of angular velocity is $\omega = 12 + 9t - 3t^2$ rad/s, where t is in seconds. What is maximum angular speed (in rad/s) of particle and at what time (in sec) it reaches the maximum speed?
(a) 18.75 and 3.0 (b) 9.25 and 3.0
(c) 18.75 and 1.5 (d) 9.25 and 1.5

Q.14 The vertical motion of mass A is defined by the relation $x = 10 \sin 2t + 15 \cos 2t + 100$, where x and t are expressed in mm and seconds, respectively. The magnitude of maximum acceleration of mass A will be



(a) $72.11\ mm/sec^2$ (b) $63.26\ mm/sec^2$
(c) $54.33\ mm/sec^2$ (d) $48.67\ mm/sec^2$

Q.15 At a certain instant, the linear momentum of a particle is given by

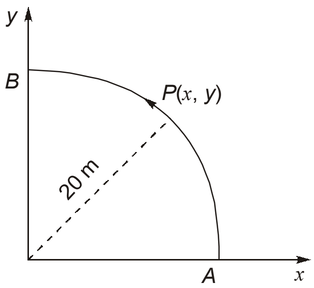
$I = -2\hat{i} - \hat{j} + \hat{k}$ kg m/s and its position vector is $r = 2\hat{i} - 3\hat{j} + 2\hat{k}\ m$.

The magnitude of angular momentum of the particle about the origin of coordinate axes is nearly (in kgm^2/s)
(a) 7 (b) 8
(c) 9 (d) 10

Q.16 Two particle system with the particles having masses 10 kg and 20 kg. If the first particle is pushed towards the centre of mass through a distance 15 mm, then by what distance (in mm) should the second particle be moved so as to keep the centre of mass at the same position

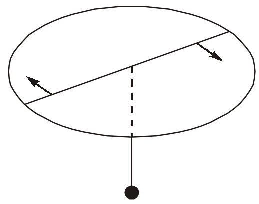
(a) 30 mm (b) 5 mm
(c) 7.5 mm (d) 15 mm

Q.17 A point P moves in a counter-clockwise direction on a circular path as shown in the figure. The movement of P is such that it sweeps out a length $s = t^3 + 5$, where s is in meters and t is in seconds. The radius of the path is 20 m. The acceleration of P when $t = 2$ is ________ m/s^2.



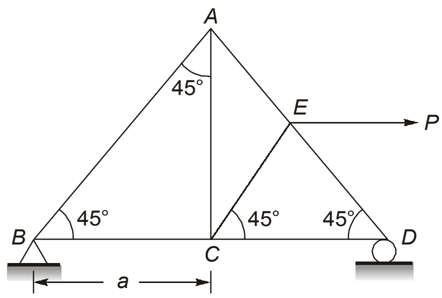
(a) 10 (b) 12
(c) 14 (d) 16

Q.18 A horizontal circular platform of radius 0.5 m and mass 0.45 kg is free to rotate about its axis. Two massless spring toy-guns, each carrying a steel ball of mass 0.05 kg are attached to the platform at a distance 0.25 m from the centre on its either sides along its diameter (see figure). Each gun simultaneously fires the balls horizontally and perpendicular to the diameter in opposite directions. After leaving the platform, the balls have horizontal speed of 9 m/s with respect to ground. The rotational speed of the platform (in rad/s) after the balls leave the platform is



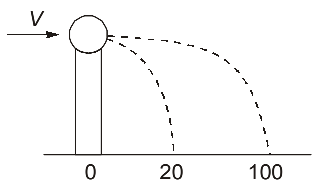
(a) 2 (b) 4
(c) 8 (d) 12

Q.19 A truss $BAECD$, hinged at B, roller supported at D, is subjected to horizontal force P at E as shown in figure. The force in the member BC is



(a) P (b) 0.75 P
(c) 0.5P (d) 0.25P

Q.20 A ball of mass 0.2 kg rests on a vertical post of height 5 m. A bullet of mass 0.01 kg, travelling with velocity V m/s in a horizontal direction, hits the centre of the ball. After the collision, the ball and the bullet travel independently. The ball hits the ground at a distance of 20 m and the bullet at a distance of 100 m from the post. The velocity V of the bullet is : (Take $g = 10\ m/s^2$)

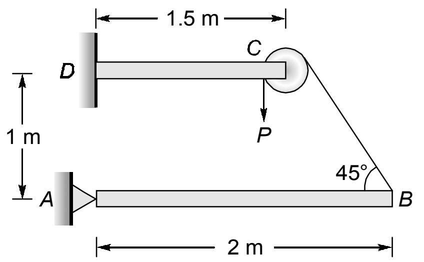


(a) 250 m/s
(b) $250\sqrt{2}$ m/s
(c) 400 m/s
(d) 500 m/s

Q.21 A ball is dropped on the ground from the height of 1 m. The coefficient of restitution is 0.6. The height to which the ball will rebound is

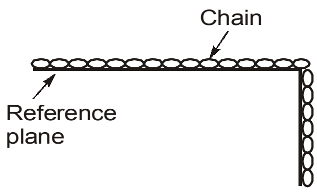
(a) 0.6 m (b) 0.4 m
(c) 0.36 m (d) 0.16 m

Q.22 A beam AB, 2 m long, uniform in cross-section is held in equilibrium by the application of a force 'P' as shown below. If the self weight of beam AB is 100 kN then the magnitude of force 'P' is



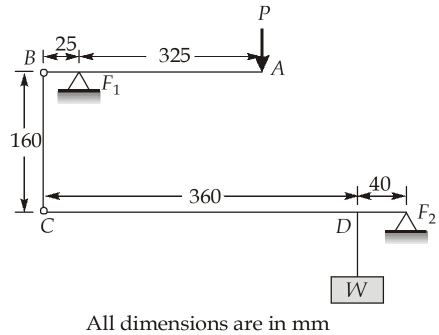
(a) 35.35 kN (b) 45.56 kN
(c) 70.71 kN (d) 91.12 kN

Q.23 A uniform chain of length 'l' and mass 'm' overhangs a smooth table with its two third part lying on the table. Then the kinetic energy of the chain as it completely slips off the table is:



(a) $\frac{mgl}{18}$ (b) $\frac{mgl}{2}$
(c) $\frac{2mgl}{3}$ (d) $\frac{4mgl}{9}$

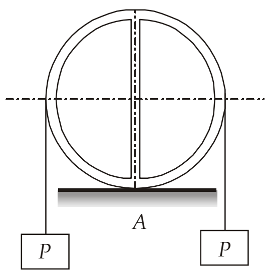
Q.24 A compound lever as shown in figure is required to lift a heavy load W. What will be the value of weight W, if an effort (P) of 250 N is applied at A?



All dimensions are in mm

(a) 32.5 kN (b) 31.5 kN
(c) 29.25 kN (d) 35.00 kN

Q.25 Two halves of a round homogenous cylinder are held together by a thread wrapped round the cylinder with two weights each equal to P attached to its ends as shown in figure. If the weight of complete cylinder is W and the plane of contact, of both of its halves, is vertical, what will be the minimum value of P, for which both halves of the cylinder will be in equilibrium on a horizontal plane?



(a) $\frac{W}{2}$ (b) $\frac{2W}{3\pi}$
(c) $\frac{W}{2\pi}$ (d) $\frac{3W}{2\pi}$

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ENGINEERING MECHANICS

CIVIL ENGINEERING

Date of Test : 10/06/2024

ANSWER KEY

1.	(d)	6.	(a)	11.	(c)	16.	(c)	21.	(c)
2.	(a)	7.	(d)	12.	(b)	17.	(c)	22.	(c)
3.	(b)	8.	(b)	13.	(c)	18.	(b)	23.	(d)
4.	(b)	9.	(a)	14.	(a)	19.	(b)	24.	(a)
5.	(a)	10.	(c)	15.	(d)	20.	(d)	25.	(b)

DETAILED EXPLANATIONS

1. (d)

Given: Mass of elevator = 500 kg

Mass of operator = 100 kg

Upward acceleration = $3\ m/s^2$

Total tension in the cable of the elevator = $(m_1 + m_2)(g + a)$

$= (500 + 100)(10 + 3) = 600 \times 13$

Total tension in the cable of the elevator = 7800 N = 7.8 kN

2. (a)

Given:Velocity of first particle, $u_1 = 10$ m/s

Angle of projection for first particle, $\alpha_1 = 60°$

Angle of projection for second particle, $\alpha_2 = 30°$

Velocity of second particle, $u_2 = ?$

Given, Time of flight is same.

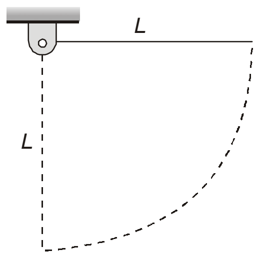
$$t_1 = t_2$$

$$\frac{2u_1 \sin\alpha_1}{g} = \left(\frac{2u_2 \sin\alpha_2}{g}\right)$$

$$u_2 = \frac{10\times\sin 60°}{(\sin 30°)} = \frac{10\times\frac{\sqrt{3}}{2}}{\frac{1}{2}} = 10\times\sqrt{3}$$

$$u_2 = 17.32\ m/s$$

3. (b)



Applying conservation of energy,

$$mgL = \frac{mgL}{2} + \frac{1}{2}I\omega^2$$

$$\Rightarrow \quad I\omega^2 = mgL$$

$$\Rightarrow \quad \frac{mL^2}{3}\omega^2 = mgL \quad \text{[The moment of inertia about the end of the rod is } \frac{mL^2}{3}\text{]}$$

$$\therefore \quad \omega = \sqrt{\frac{3g}{L}}$$

4. **(b)**

Using conservation of energy,

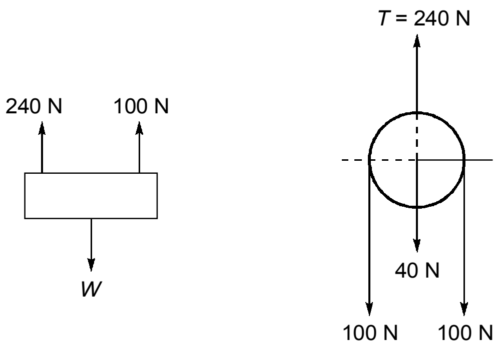
$$mgh = \frac{1}{2}kx^2$$

$$\Rightarrow \quad x = \sqrt{\frac{2mgh}{k}} = \sqrt{\frac{2\times0.04\times9.81\times4.9}{400}}$$

$$\therefore \quad x = 0.098 \text{ m} = 9.8 \text{ cm}$$

5. **(a)**

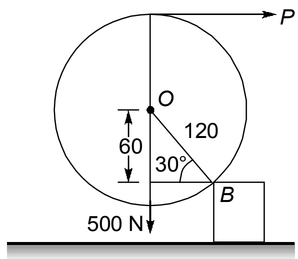
The FBD of the weight W is



So, $240 + 100 = W$ (240 N includes weight of pulley and tension carried by rope)

$\therefore$ $W = 340$ N

6. **(a)**

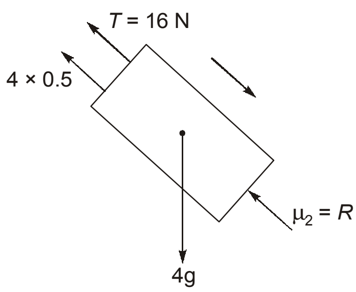


Taking moment about B,

$$P \times (60 + 120) = 500 \times 120\cos30°$$

$$\therefore \quad P = 288.68 \text{ N}$$

7. **(d)**



$$\Rightarrow \quad \mu_2 R + 4 \times 0.5 + 16 - 4g\sin30° = 0$$

$$\Rightarrow \quad \mu_2 20\sqrt{3} + 2 + 16 - 20 = 0$$

$$\Rightarrow \quad \mu_2 = \frac{2}{20\sqrt{3}} = 0.0577$$

8. (b)

$$\text{Speed of flow} = 7 - 5 = 2 \text{ km/h}$$

$$\text{Speed of swimmer with flow} = 7 + 2 = 9 \text{ km/hr}$$

$$\text{Time required} = \frac{90}{9} = 10 \text{ hour}$$

9. (a)

Change in the stored energy of rubber band = $F\,dx$

$$\Rightarrow \quad dE = 300x^2 dx$$

Integrating,

$$\int_0^E dE = \int_0^{0.1} 300x^2\,dx$$

$$\Rightarrow \quad E = 300 \times \frac{x^3}{3}\Big|_0^{0.1} = 0.1 \text{ Joule}$$

10. (c)

Given: $m_A = 15$ kg, $m_B = 10$ kg

For mass B, $m_B g - T = m_B a$

$$10g - T = 10\,a \quad \text{...(i)}$$

For mass A, $T = m_A a$

$$T = 15\,a \quad \text{...(ii)}$$

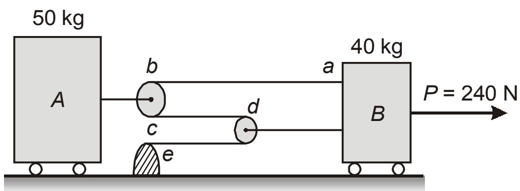
Addition equation (i) and (ii)

$$(10g - T) + (T) = (15 + 10)a$$

$$a = \frac{10g}{25} = \frac{10 \times 10}{25} = 4 \text{ m/s}^2$$

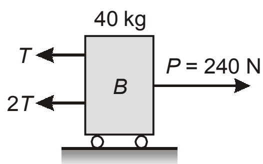
$$\text{Acceleration, } a = 4 \text{ m/s}^2$$

11. (c)



As given, acceleration $a_A = 1.5\,a_B$

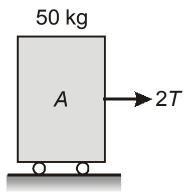
For block *B*:



$$\Sigma F = \text{Mass} \times \text{Acceleration}$$

$$240 - 3T = 40\,a_B \quad \text{...(i)}$$

For block *A*:



$\Rightarrow \quad \Sigma F = \text{Mass} \times \text{Acceleration}$

$\Rightarrow \quad 2T = 50\, a_A$ ...(ii)

$\Rightarrow \quad 2T = 50 \times 1.5\, a_B$

$\Rightarrow \quad 2T = 75\, a_B$ ...(iii)

Using equation (i) and (iii), we get

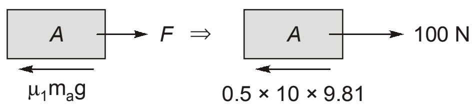
$\Rightarrow \quad 240 - 1.5 \times 75\, a_B = 40\, a_B$

$\Rightarrow \quad 152.5\, a_B = 240$

$\therefore \quad a_B = 1.57\ \text{m/s}^2$

12. (b)

Free body diagram of A:

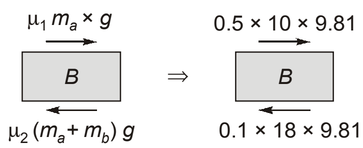


Writing equation of motion for A.

$100 - 0.5 \times 10 \times 9.81 = 10a$

$\Rightarrow \quad a = 5.095\ \text{m/s}^2$

Free body diagram of B:



Writing equation of motion for B.

$49.05 - 17.658 = 8\, a$

$\Rightarrow \quad a = 3.924\ \text{m/s}^2$

After 0.1s, $V_A = U_a + a_a t.$

$V_A = 0 + 5.095 \times 0.1$

$V_A = 0.5095\ \text{m/s}$

Similarly, $V_B = 0 + 3.924 \times 0.1$

$V_B = 0.3924\ \text{m/s}$

$\therefore$ Relative velocity of A w.r.t. B $= V_A - V_B$

$= 0.5095 - 0.3924 \simeq 0.12\ \text{m/s}$

13. (c)

$$\omega = 12 + 9t - 3t^2$$

$$\frac{d\omega}{dt} = 9 - 6t = 0$$

$\Rightarrow \quad t = 1.5\text{s}$

$$\frac{d^2\omega}{dt^2} = -6 < 0$$

Hence, at t = 1.5 sec maximum value of angular velocity will occur

$$\therefore \quad \omega_{max} = 12 + 9 \times 1.5 - 3 \times 1.5^2$$
$$= 12 + 13.5 - 6.75$$
$$= 18.75 \text{ rad/s}$$

14. (a)

$$x = 10 \sin 2t + 15 \cos 2t + 100$$
$$v = \frac{dx}{dt} = 20 \cos 2t - 30 \sin 2t$$
$$a = \frac{dv}{dt} = -40 \sin 2t - 60 \cos 2t \quad \ldots(i)$$

For a_{max}, $\frac{da}{dt} = 0$

$\Rightarrow \quad -80 \cos 2t + 120 \sin 2t = 0$

$$\tan 2t = \frac{2}{3}$$

$\Rightarrow \quad 2t = 33.69$

Now using equation (i), we get

$$a_{max} = -40 \sin(33.69) - 60 \times \cos(33.69) = -72.11 \text{ mm/s}^2$$

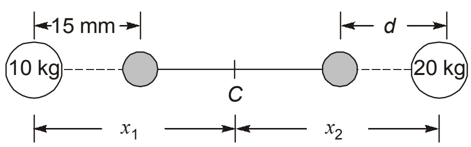
15. (d)

$$I = -2\hat{i} - \hat{j} + \hat{k}$$
$$r = 2\hat{i} - 3\hat{j} + 2\hat{k}$$

Angular momentum $= H = r \times I$

$$= (2\hat{i} - 3\hat{j} + 2\hat{k}) \times (-2\hat{i} - \hat{j} + \hat{k}) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & -3 & 2 \\ -2 & -1 & 1 \end{vmatrix}$$
$$= \hat{i}(-3+2) - \hat{j}(2+4) + \hat{k}(-2-6)$$
$$= \hat{i}(-1) - 6\hat{j} - 8\hat{k} = -\hat{i} - 6\hat{j} - 8\hat{k}$$
$$|H| = \sqrt{1^2 + 6^2 + 8^2} = 10.01 \text{ kg m}^2\text{/s} \simeq 10 \text{ kg m}^2\text{/s}$$

16. (c)



To keep centre of mass at C

$$m_1 x_1 = m_2 x_2 \quad \rightarrow \quad (\text{Let } 10 \text{ kg} = m_1, 20 \text{ kg} = m_2)$$

and $\quad m_1(x_1 - 15) = m_2(x_2 - d)$

$$15\,m_1 = m_2 d$$

$$d = \frac{15 \times 10}{20} = 7.5 \text{ mm}$$

17. (c)

$$|\vec{V}| = \frac{ds}{dt} = 3t^2$$

Now, $$a_r = \frac{v^2}{R} = \frac{\left(3\times(2)^2\right)^2}{20} = 7.2 \text{ m/s}^2$$

and $$a_t = \frac{dv}{dt} = 6t = 12 \text{ m/s}^2$$

∴ $$a = \sqrt{a_r^2 + a_t^2} = 14 \text{ m/s}^2$$

18. (b)

Using conservation of angular momentum,

$$2\,mvr = I\omega,$$

where, $$I = \frac{MR^2}{2}$$

⇒ $$2 \times 0.05 \times 9 \times 0.25 = \frac{1}{2}\times 0.45 \times 0.5^2 \times \omega$$

∴ $$\omega = 4 \text{ rad/s}$$

19. (b)

Now, $$\Sigma F_x = 0 - R_{B2} = -P$$

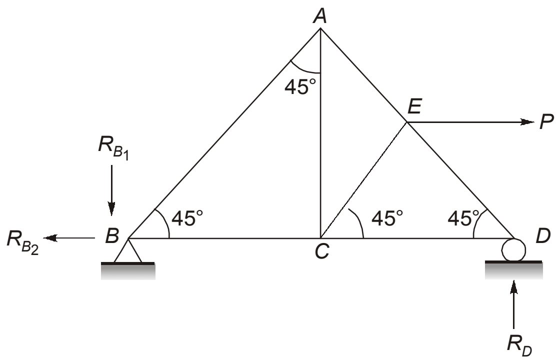
⇒ $$R_{B2} = P$$

and, $$\Sigma F_y = 0 - R_D = -R_{B1}$$

⇒ $$R_D = R_{B1}$$

Also, $$\Sigma M_B = R_D \times 2a = P \times \frac{a}{2}$$

⇒ $$R_D = R_{B1} = \frac{P}{4}$$



Analysis of joint B,

So, $$F_{AB}\sin 45 = \frac{P}{4}$$

⇒ $$F_{AB} = \frac{\sqrt{2}P}{4}$$

Also, $$P = F_{BC} + F_{AB}\cos 45°$$

⇒ $$F_{BC} = P - F_{AB}\cos 45° = P - \frac{\sqrt{2}P}{4}\times\frac{1}{\sqrt{2}} = \frac{3P}{4}$$

Hence, $$F_{BC} = 0.75\,P$$

20. **(d)**

$$5 = \frac{1}{2}\times(10)t^2$$

$\Rightarrow$ $t = 1$ sec

Now, $V_{ball} = 20$ m/s

$V_{bullet} = 100$ m/s

Also, by conservation of momentum, we have

$$0.01\,V = 0.2 \times 20 + 0.01 \times 100$$

$$\therefore \quad V = \frac{4+1}{0.01} = \frac{5}{0.01} = 500 \text{ m/s}$$

21. **(c)**

Coefficient of restitution,

$$e = -\frac{\Delta V}{\Delta u} = -\frac{v_2 - v_1}{u_2 - u_1}$$

here, $u_2 = 0$,

$v_2 = 0$

$$e = \frac{v_1}{u_1}$$

$$v^2 - u^2 = 2\,ah$$

when ball is dropped from height,

$$u = 0$$

Let final velocity is u_1

$$u_1^2 = 2ah_1$$

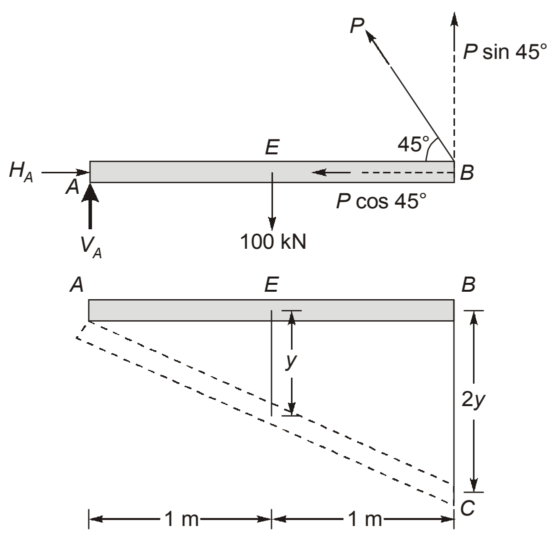
$$v_1^2 = 2ah_2$$

$$e^2 = \left(\frac{v_1}{u_1}\right)^2 = \frac{h_2}{h_1}$$

$$\therefore \quad h_2 = h_1 \times e^2 = 0.36 \text{ m}$$

22. **(c)**

Free body diagram of beam *AB*,

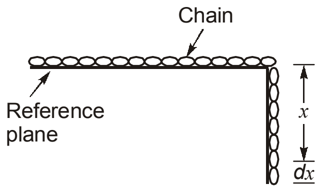


Now using the principle of virtual work done, if C.G. of beam AB shifts by an amount 'y' then end B must shift by '$2y$' (using similar triangles).

$\therefore$ $$100 \times y - P \sin 45° \times 2y = 0$$

$\Rightarrow$ $$P = 70.71 \text{ kN}$$

23. (d)



The potential energy of $\frac{l}{3}$ of the chain that overhangs is

$$u_1 = \int_0^{l/3} -\frac{mgx}{l} dx = \frac{-mgl}{18}$$

The potential energy of the full chain when it completely slips off the table is

$$u_2 = \int_0^{l} -\frac{mgx}{l} dx = \frac{-mgl}{2}$$

$$\text{The loss in } PE = \frac{-mgl}{18} - \left(\frac{-mgl}{2}\right) = \frac{4mgl}{9}$$

This should be equal to gain in kinetic energy, but the initial kE is zero. Hence this is the kE when the chain completely falls off the table.

24. (a)

Given: $P = 250$ N; $BF_1 = 25$ mm; $F_1A = 325$ mm; $CD = 360$ mm; $DF_2 = 40$ mm

$$\text{Leverage of the upper lever, } AB = \frac{AF_1}{BF_1} = \frac{325}{25} = 13$$

$$\text{Leverage of the lower lever, } CF_2 = \frac{CF_2}{DF_2} = \frac{360+40}{40} = 10$$

Total leverage of the compound lever = 13 × 10 = 130

$$\text{We know that, Total leverage} = \frac{W}{P} = \frac{W}{250}$$

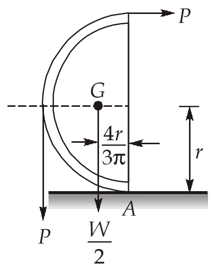
$$130 = \frac{W}{250}$$

$$W = 130 \times 250 = 32500 \text{ N} = 32.5 \text{ kN}$$

25. (b)

Taking one halve of cylinder. Centre of gravity of a semicircle is at a distance of $\frac{4r}{3\pi}$ from centre.

Taking moment about A,



$$P \times 2r = P \times r + \left(\frac{W}{2}\right) \times \left(\frac{4r}{3\pi}\right)$$

$$P \times r = W\left(\frac{2r}{3\pi}\right)$$

$$P = \frac{2W}{3\pi}$$

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