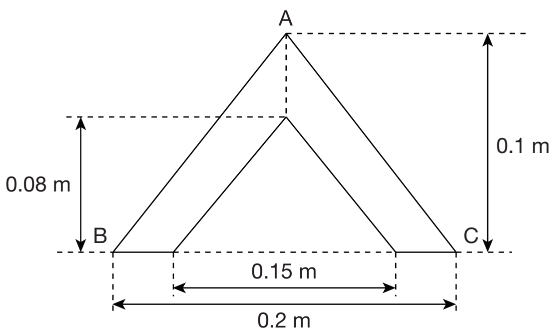
ENGINEERING MECHANICS TEST 3

Number of Questions: 25 **Time:60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. A belt wrapped around a pulley 400 mm in diameter has a tension of 800 N on the tight side and a tension of 200 N on the slack side. If the pulley is rotating at 200 rpm then the power being transmitted (in kW) will be
(A) 3351 (B) 3.35
(C) 32 (D) 3.2

2. A hollow triangular section is symmetrical about its vertical axis. The moment of inertia of the section about the base *BC* will be



(A) 1.02×10^{-5} m^4 (B) 1.11×10^{-6} m^4
(C) 1.02×10^{-6} m^4 (D) 1.11×10^{-5} m^4

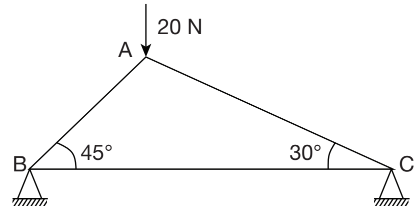
3. The force of friction between two bodies in contact
(A) depends upon the area of their contact
(B) depends upon the relative velocity between them
(C) is always normal to the surface of their contact
(D) All of the above

4. A ball is thrown with a velocity of 12 m/s at an angle of 60° with the horizontal. How high the ball will rise?
(A) 6 m (B) 6.35 m
(C) 11 m (D) 5.5 m

5. The equation for angular displacement of a particle, moving in a circular path of radius 300 m is given by : $\theta = 20t + 5t^2 - 3t^3$ where θ is the angular displacement at the end of t seconds. The maximum angular velocity of the particle (in rad/s) will be
(A) 20.34 (B) 22.78
(C) 23.63 (D) 24.39

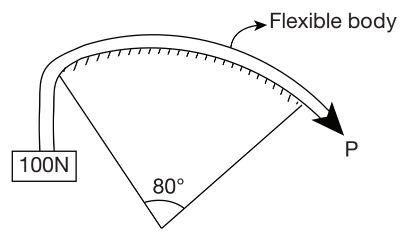
6. The velocity of piston in a reciprocating pump mechanism depends upon
(A) Angular velocity of crank
(B) Radius of the crank
(C) Length of the connecting rod
(D) All of the above

7. Consider a truss *ABC* loaded at *A* with a force 20 N as shown in figure.



The load in member *AB* will be approximately
(A) 21 N (B) 19 N
(C) 17 N (D) 18 N

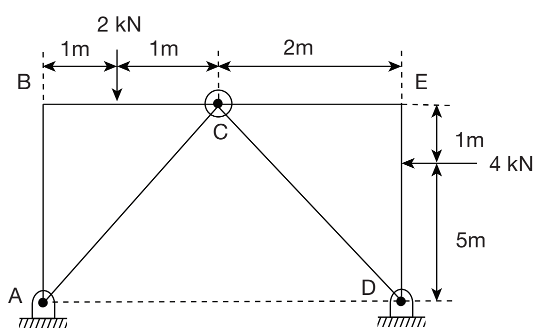
8. A flexible body is used to lift 100 N from a curved surface is as shown in the figure. What is the force *P* required to just lift 100 N weight? (Take coefficient of friction as 0.25.)



(A) 132.34 N (B) 121.36 N
(C) 70.53 N (D) 141.77 N

9. The supports which apply force on the body in only one direction and the direction is always normal to the contacting surface is known as
(A) Fixed support (B) Hinged support
(C) Roller support (D) All of these

10. Triangular plate *ABC* is connected by means of pin at *C* with another triangular plate *CDE* as shown in the figure. The vertical reaction at point *D* will be

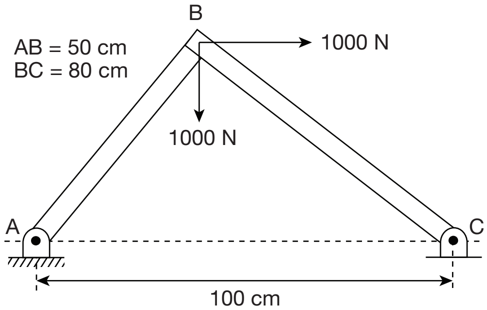


(A) 4.5 kN (B) 6 kN
(C) 2 kN (D) 4 kN

11. A beam 5 m long weighing 400 N is suspended in a horizontal position by two vertical strings, each of which can withstand a maximum tension of 450 N only. How far a body of 300 N weight be placed on the beam from the left end, so that one of the string may just break?

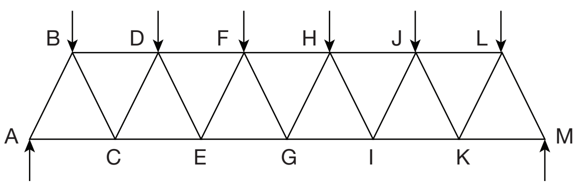
(A) 1.81 m (B) 1.43 m
(C) 0.834 m (D) 2.12 m

12. A figure is shown below. Solve for the force in member *AB* under the actions of the horizontal and vertical force of 1000 N.



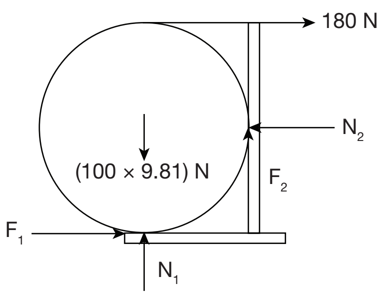
(A) 377.5 N (Tension)
(B) 377.5 N (Compression)
(C) 1415.9 N (Tension)
(D) 1415.9 N (Compression)

13. A truss is shown in the figure. Each load is 5 kN and all triangles are equilateral with sides of 4 m. Determine the force on member *GI*.



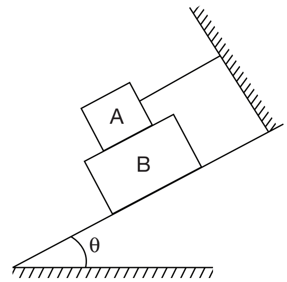
(A) 35 kN (Compression)
(B) 35 kN (Tension)
(C) 26 kN (Compression)
(D) 26 kN (Tension)

14. A cylinder is shown in the figure. The coefficient of friction between the cylinder and wall is 0.25. Will the 180 N force cause the 100 kg cylinder to slip?



(A) No slip (B) Slip will occur
(C) Insufficient data (D) None of these

15. Two blocks *B* and *A* of mass 40 kg and 13.5 kg respectively is kept as shown in the figure. The coefficient of friction μ for all surface is 1/3. The value of the angle θ so that the motion of 40 kg block impends down the plane will be

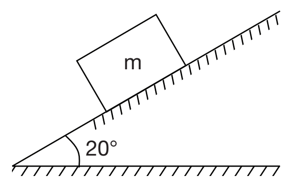


(A) 25.4° (B) 32.6°
(C) 29.2° (D) 34°

16. A flywheel 2 m in diameter accelerates uniformly from rest to 2000 rpm in 25 seconds. 0.6 second after it has started from rest, the linear acceleration of a point on the rim of the flywheel (in m/s^2) will be

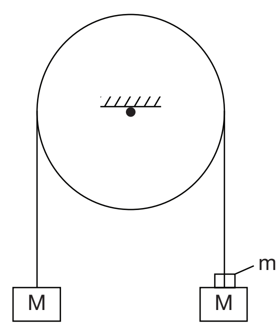
(A) 24.6 (B) 15.96
(C) 21.34 (D) 26.73

17. A mass of 2 kg is projected with a speed of 3 m/s up a plane inclined 20° with the horizontal as shown in the figure. After travelling 1 m, the mass comes to rest. The speed of the block as the block return to its starting position will be



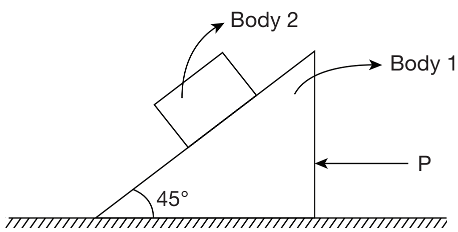
(A) 1.2 (B) 2.103
(C) 1.63 (D) 1.31

18. In a device, two equal masses of 100 kg are connected by a very light (negligible mass) tape passing over a frictionless pulley as shown in the figure. A mass of 10 kg is added to one side, causing that mass to fall and the other to rise. The acceleration (in m/s^2) of the masses will be



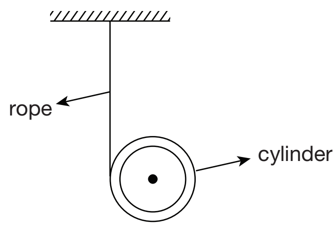
(A) 0.49 (B) 0.817
(C) 0.621 (D) 0.467

19. Find the force '*P*' required to prevent sliding of body 2 on body 1. Assume both the bodies have equal mass '*m*' and all the surfaces are smooth.



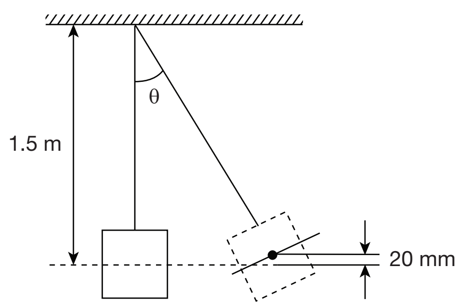
(A) mg Sin45° (B) mg
(C) 2 mg (D) 2 mg Cos45°

20. A rope is wound around a 30 kg solid cylinder of radius 50 cm as shown. Find the speed of its mass centre after it has drop by 2 m from the rest position.



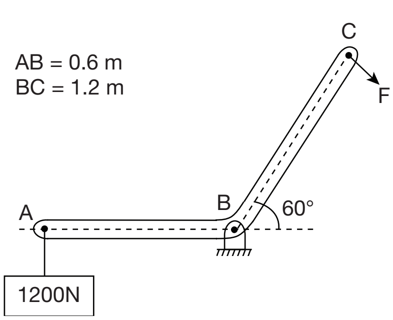
(A) 5.11 (B) 7.23
(C) 6.09 (D) 5.89

21. A 0.08 N bullet was fired horizontally into a 60 N sand bag suspended on a rope 1.5 m long as shown in the figure. It was found that the bag with the bullet embedded in it swung to a height of 20 mm. Determine speed of the bullet as it entered the bag?



(A) 470.42 m/s (B) 450 m/s
(C) 469.8 m/s (D) 474.34 m/s

22. A mass of 1200 N is supported by means of a bell crank as shown in the figure. The magnitude of resultant at *B* (in N) will be
AB = 0.6 m
BC = 1.2 m

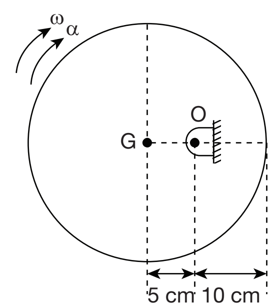


(A) 1588 N (B) 1500 N
(C) 520 N (D) 1600 N

23. A wheel accelerates uniformly from rest to a speed of 500 rpm in 0.5 seconds. It then rotates at that speed for 2 seconds before decelerating (uniformly) to rest in 0.34 seconds. How many revolutions does it make during the entire time travel?

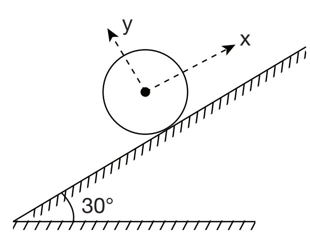
(A) 29.1 rev (B) 20.17 rev
(C) 22.34 rev (D) 26.33 rev

24. An eccentric cylinder used in a vibrator weights 198 N and rotates about an axis 5 cm from its geometric centre and perpendicular to the top view as shown in the figure. If the magnitudes of angular velocity and angular acceleration are 10 rad/s and 2 rad/s^2 in the phase shown, the resultant reaction of the vertical shaft on the cylinder (in N) and couple applied on the cylinder by the shaft (in N-m) will be



(A) 111 and 0.278 (B) 101 and 0.278
(C) 111 and 0.413 (D) 101 and 0.413

25. A sphere, rolling with an initial velocity of 12 m/s, starts up a plane inclined 30° with the horizontal as shown in the figure. What is the distance upto which the sphere will roll up the plane?



(A) 10.21 m (B) 12.31 m
(C) 11.86 m (D) 9.63 m

Answer Keys

1. B	**2.** A	**3.** C	**4.** D	**5.** B	**6.** D	**7.** D	**8.** D	**9.** C	**10.** A
11. C	**12.** B	**13.** D	**14.** A	**15.** C	**16.** D	**17.** B	**18.** D	**19.** C	**20.** A
21. A	**22.** A	**23.** B	**24.** B	**25.** C					

Hints and Explanations

1. Torque, $T = 800 \times 0.2 = 160$ N

Power $= T \times \omega = \dfrac{160 \times 2\pi \times 200}{60 \times 1000} = 3.35$ kW

Choice (B)

2. $I_{BC} = \dfrac{BH^3}{12} - \dfrac{bh^3}{12} = \dfrac{0.2 \times 0.1^3}{12} - \dfrac{0.15 \times 0.08^3}{12}$

$\Rightarrow \quad I_{BC} = 1.0267 \times 10^{-5}$ m^4

Choice (A)

3. Choice (C)

4. $H = \dfrac{u^2 \text{Sin}^2 \alpha}{2g} = \dfrac{12^2 \times \text{Sin}^2 (60^o)}{2 \times 9.81} = 5.5$ m Choice (D)

5. $\theta = 20t + 5t^2 - 3t^3$

$\omega = \dfrac{d\theta}{dt} = 20 + 10t - 9t^2$

For maximum angular velocity, $\dfrac{d\omega}{dt} = 0$

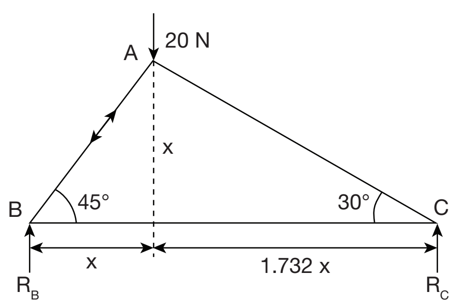
$\therefore \quad \dfrac{d\omega}{dt} = 10 - 18t = 0$

$\therefore t = \dfrac{10}{18} = 0.556$ seconds

$\therefore \quad \omega_{max} = 20 + 10(0.556) - 9(0.556)^2$
$= 22.78$ rad/sec Choice (B)

6. $V_{piston} = \omega[l \text{ Cos } \Phi + r \text{ Cos } \theta \tan \Phi]$
ω = angular velocity of crank
l = length of connecting rod
r = radius of crank Choice (D)

7.



$\Sigma M_B = 0$
$\Rightarrow \quad 20 \times x = R_C \times 2.732x$
$R_c = 7.32$ N
$\therefore \quad R_B = 20 - 7.32 = 12.68$ N
Now $F_{AB} \times \text{Sin}45^o = R_B$

$\Rightarrow \quad F_{AB} = \dfrac{12.68}{\text{Sin } 45^o} = 17.93$ N Choice (D)

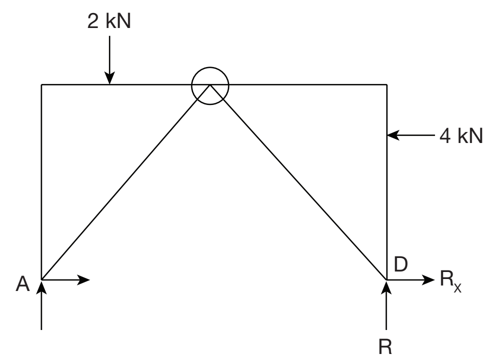
8. P = Tight side tension
W = Slack side tension

Now, $\dfrac{P}{W} = e^{\mu_s \theta} \Rightarrow \dfrac{P}{100} = e^{\left(0.25 \times 80 \times \frac{\pi}{180}\right)}$

$\Rightarrow \quad P = 141.77$ N Choice (D)

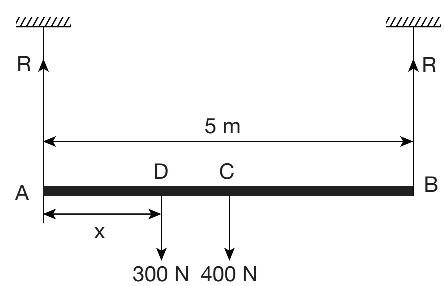
9. Choice (C)

10.



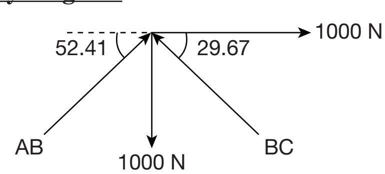
$\Sigma M_A = 0$
$\Rightarrow \quad 2 \times 1 - 4 \times 5 - R_y \times 4 = 0$
$\Rightarrow \quad R_y = 4.5$ kN Choice (A)

11.



x = Distance between the body of weight 300 N and support A (from the left end)
We know that one of the string will just break, when the tension will be 450 N (i.e., $R_A = 450$ N)
Now $\Sigma M_B = 0$
$450 \times 5 = 300\,(5 - x) + (400 \times 2.5)$
$\Rightarrow \quad x = 0.834$ m Choice (C)

12. **<u>Free body diagram</u>**



Now $\Sigma F_x = 0$

$\Rightarrow$ AB Cos(52.41) – BC Cos(29.67) + 1000 = 0 $\rightarrow$ (1)

and $\Sigma F_y = 0$

$\Rightarrow$ AB Sin(52.41) + BC Sin(29.67) – 1000 = 0 $\rightarrow$ (2)

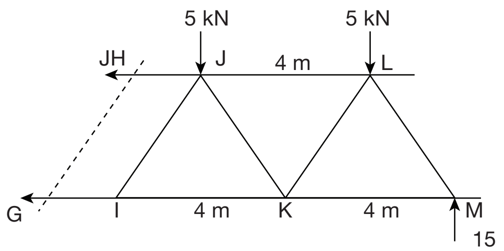
From equations (1) and (2) we get

AB = 377.5 N and BC = 1415.91 N

$\therefore$ Force in member AB is 377.5 N compression

Choice (B)

13. Taking section passes through JH and GI.



Taking moment about point H we get

$\Sigma M_H = 0 = -(GI) \times 2 \tan 60^\circ - (5 \times 4) - (5 \times 8) + 15 \times 10$

$\Rightarrow$ GI = 25.98 kN (Tension) Choice (D)

14. Since it is unknown whether or not the cylinder slips it is not possible to $F_1 = \mu N_1$ and $F_2 = \mu N_2$

$\Sigma F_h = 0 = F_1 - N_2 + 180 \rightarrow (1)$

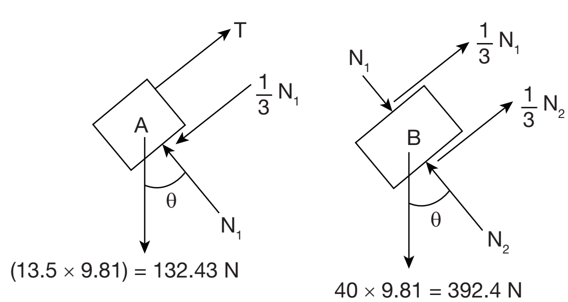
$\Sigma F_v = 0 = N_1 + F_2 - 980 \rightarrow (2)$

$\Sigma M_A = 0 = -180 \times 2r + F_2 + r + N_2 \times r \rightarrow (3)$

$\therefore$ $N_1 = 980 - F_2$, $N_2 = 360 - F_2$ and $F_1 = 180 - F_2$

Let us assume F_2 is at its maximum value that is 0.25 N_2 and solve for N_2, N_1 and F_1 using equations (1), (2) and (3). Then N_2 = 288 N, N_1 = 908 N, F_1 = 108 N. This means that if F_2 assumes its maximum static value then F_1 must be 108 N to hold the system in equilibrium. Since the maximum value of F_1 obtainable is 0.25 N_1 = 227 N, the cylinder will not rotate. Choice (A)

15.



From free body diagram of B.

$\Sigma F_x = 0 = -392.4 \text{ Sin } \theta + \frac{1}{3} N_1 + \frac{1}{3} N_2$ $\rightarrow$ (1)

$\Sigma F_y = 0 = N_2 - 392.4 \text{ Cos } \theta - N_1$ $\rightarrow$ (2)

Free body diagram of A.

$N_1 = 132.43 \text{ Cos } \theta$ $\rightarrow$ (3)

From equation (1), (2) and (3)

$\theta = 29.2^\circ$ Choice (C)

16. $\omega = \omega_o + \alpha t$

and $\omega_o = 0$ and $\omega = \dfrac{2\pi N}{60} = \dfrac{2 \times \pi \times 2000}{60}$

$\Rightarrow$ ω = 209.44 rad/sec

Now $\alpha = \dfrac{\omega - \omega_o}{t} = \dfrac{209.44 - 0}{25}$ = 8.4 rad/s²

Now velocity after 0.6 seconds

$\omega = \omega_o + \alpha t = 0 + (8.4 \times 0.6)$

= 5.04 rad/s

Normal component of acceleration, $a_n = r\,\omega^2$

$= 1 \times 5.04^2$

= 25.4 m/s²

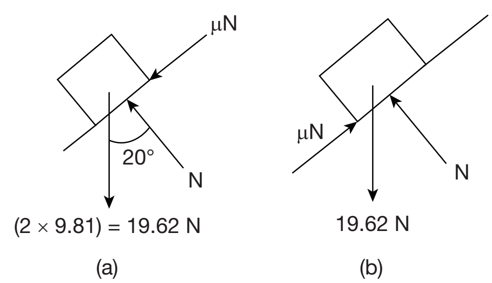
Tangential component of acceleration, $a_t = r\alpha$

= 1 × 8.4 = 8.4 m/s²

Total acceleration, $a = \sqrt{a_n^2 + a_t^2}$

$\Rightarrow a = \sqrt{25.4^4 + 8.4^2} = 26.753 \text{ m/s}^2$ Choice (D)

17.



From figure (a), N = 19.62 Cos20° = 18.44 N

Now $V^2 = V_o^2 + 2as \Rightarrow$ $a = \dfrac{0-(+3)^2}{2 \times 1} = -4.5 \text{ m/s}^2$

Now from figure (a), $\Sigma F_x = ma_x$

$\therefore$ +19.62 × Sin20° + (μ × 18.44) = 2(4.5)

$\Rightarrow$ μ = 0.124

To solve for return speed, refer figure (b)

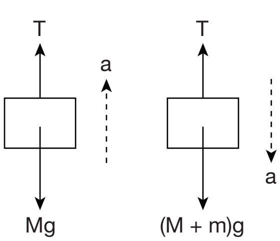
19.62 Sin 20° – 0.124 (18.44) = 2a

$\Rightarrow$ a = 2.212 m/s²

Finally $V^2 = V_o^2 + 2as$ or $V^2 = 0 + 2(2.212)(1)$

$\Rightarrow$ V = 2.103 m/s² Choice (B)

18.



$\Sigma F = T - Mg = Ma \rightarrow (1)$

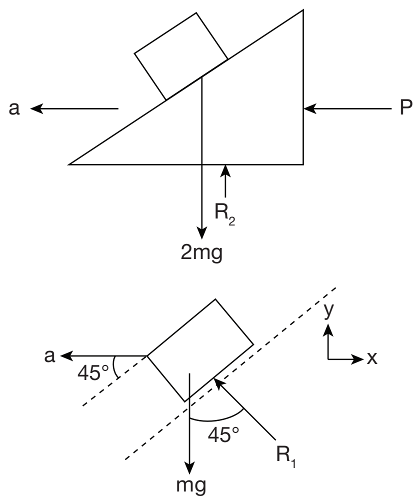
$\Sigma F = Mg + mg - T = (M + m)a$ $\rightarrow$ (2)

From equation (1) and (2)

$$a = \frac{m}{2M+m} g \Rightarrow a = \frac{10}{(2\times100)+10} \times 9.81 = 0.467 \text{ m/s}^2$$

Choice (D)

19.



$\Sigma F_x = ma_x \Rightarrow -P = 2m(-a)$

$\Rightarrow$ $P = 2ma$

$\Sigma F_x = ma_x$

$\Rightarrow$ $m(-a) = -R_1 \text{ Sin}45^o$ $\rightarrow (1)$

$\Sigma F_y = \text{ma}_y \Rightarrow R_1 \text{ Cos}45^o = mg$

$\Rightarrow$ $R_1 = mg/\text{Cos}45^o$ $\rightarrow (2)$

From equation (1) and (2) we get,

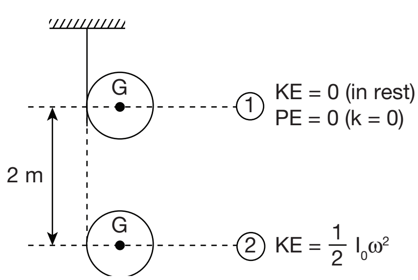
$$ma = \frac{mg}{\text{Cos}\,45^o} \times \text{Sin}\,45^o$$

$\Rightarrow$ $a = g \tan 45^o$

$\Rightarrow$ $a = g$

Now $P = 2\ ma \Rightarrow P = 2mg$ Choice (C)

20.



$$\frac{1}{2} \text{I}_o\, \omega^2 = mg(2)$$

$$\Rightarrow \frac{1}{2}\left[\frac{mr^2}{2} + mr^2\right] \omega^2 = 30 \times 9.81 \times 2$$

$$\Rightarrow \frac{1}{2}[1.5 \times 30 \times 0.5^2] \times \omega^2 = 30 \times 9.81 \times 2$$

$\Rightarrow$ $\omega = 10.23$ rad/s

$V_G = \omega \times r = 10.23 \times 0.5 = 5.115$ m/s Choice (A)

21. Let V_1 = Velocity of bullet before impact

V_2 = Velocity (bag + bullet) after impact

$= \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.02}$

= 0.6264 m/s

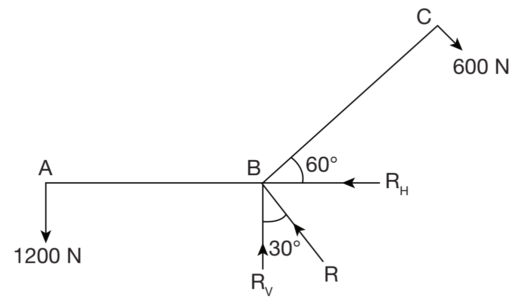
Now momentum before impact = momentum after impact

$\therefore$ $(0.08 \times V_1) + 0 = [0.08 + 60] \times 0.6264$

$\Rightarrow$ $V_1 = 470.4264$ m/s Choice (A)

22. $\Sigma`M_B = 0 \Rightarrow 1200 \times 0.6 = {}_F \times 1.2$

$\Rightarrow$ $F = 600$ N



$R_H = F \text{ Cos } 30^o = 600 \times \text{Cos } 30^o$

= 519.615 N

and $R_v = F \text{ Sin}30^o + 1200$

$= 600 \times \text{Sin}30^o + 1200$

= 1500 N

$\therefore$ Resultant reaction, $R = \sqrt{R_H^2 + R_V^2}$

$= \sqrt{519.615^2 + 1500^2}$

= 1587.45 N Choice (A)

23. From t = 0 to t = 0.5:

$$\theta_1 = \frac{1}{2}(\omega_o + \omega)t = \frac{1}{2}(0 + 500/60) \times 0.5$$

$\Rightarrow$ $\theta_1 = 2.0834$ rev

From $t = 0.5$ to $t = 2.5$ s:

$$\theta_2 = \omega t = \frac{500}{60} \times 2 = 16.67 \text{ rev}$$

From $t = 2.5$ to rest

$$\theta_3 = \frac{1}{2}(\omega_o + \omega)\, t = \frac{1}{2}\left[\frac{500}{60} + 0\right] \times 0.34$$

= 1.42 rev

Total number of revolutions $\theta = \theta_1 + \theta_2 + \theta_3$

= 2.0834 + 16.67 + 1.42

= 20.17 rev Choice (B)

24. $\Sigma F_n = m\bar{r}\,\omega^2 = \frac{198}{9.81} \times 0.05 \times 10^2 = 101$ N

$$\Sigma F_t = m\bar{r}\,\alpha = \frac{198}{9.81} \times 0.05 \times 2 = 2.02 \text{ N}$$

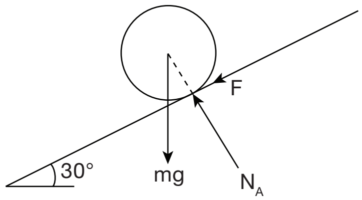
$$\Sigma M_o = I_o\, \alpha = \left[\frac{1}{2} \times \frac{198}{9.81} \times 0.15^2 + \frac{198}{9.81} \times 0.05^2\right]$$

= 0.278 N–m

Resultant of forces = $\sqrt{101^2 + 2.02^2}$ = 101.02 N

Choice (B)

25.



The initial kinetic Energy ($K.E_1$) decreases to final $K.E_2$ = 0 at the top of the travel. The only force that does work in the component (negative) of the weight W along the plane.

Work done = –[mg Cos30°] × x

Where, x is the required distance

Initial kinetic energy, $k.E_1 = \frac{1}{2}mV_1^2 + \frac{1}{2}I_o\omega_1^2$

Now $I_o = \frac{2}{5}mR^2$ and $V_1 = \omega_1 R$

$\therefore \quad K.E_1 = \frac{1}{2}\text{m}V_1^2 + \frac{1}{5}\text{m}V_1^2 = \frac{7}{10}m(12)^2$

Now work done = $K.E_2 - K.E_1$

$\Rightarrow \quad -mg\text{ Cos}30^o \times x = 0 - \frac{7}{10}\text{m}(12)^2$

$$\Rightarrow x = \frac{7\times 12^2}{10\times 9.81\times \text{Cos}\,30^o} = 11.86 \text{ m}$$

Choice (C)