Q1.

A car, of mass 2300 kg, reaches a speed of 29.0 m/s in 6.10 s starting from rest. What is the average power used by the engine during the period of acceleration?

A) 159 kW
B) 52.3 kW
C) 267 kW
D) 352 kW
E) zero

Ans:

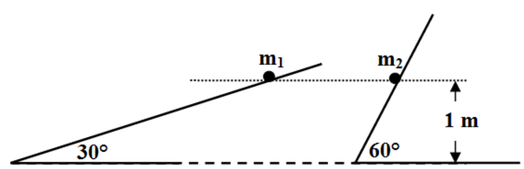
$$W = \Delta K = K_f - \cancelto{0}{K_i} = \frac{1}{2} m v_f^2$$

$$P_{avg} = \frac{W}{\Delta t} = \frac{m v_f^2}{2\Delta t} = \frac{2300 \times (29)^2}{2 \times 6.10} = 159 \text{ kW}$$

Q2.

Two masses m_1 and $m_2 = 2m_1$ start from rest from the same height from the top of two frictionless inclines of angles 30° and 60° (see **Figure 1**). When the masses reach the bottom of the inclines:

Figure 1



A) Both masses are moving with the same speed.
B) m_1 moves faster than m_2.
C) m_2 moves faster than m_1.
D) Both masses have the same kinetic energy.
E) m_1 has more kinetic energy than m_2.

Ans:

$$\Delta K + \Delta U_g = \cancelto{0}{W_{ext}}$$

$$\Delta K = -\Delta U_g$$

$$\frac{1}{2} m v^2 = -(-mgh)$$

$$\Rightarrow v = \sqrt{2gh}$$

Independent of mass

Q3.

A 500 kg elevator is pulled upward with a constant force of 5500 N for a distance of 50 m. What is the net work done on the elevator by all forces acting on it?

A) $+3.0 \times 10^4$ J
B) -5.2×10^5 J
C) -3.6×10^5 J
D) $+2.1 \times 10^5$ J
E) $+1.7 \times 10^4$ J

Ans:

$$W_F = 5500 \times 50 = 275 \times 10^3 \text{ J}$$

$$W_g = -500 \times 9.8 \times 50 = -245 \times 10^3 \text{ J}$$

$$W_{net} = W_F + W_g = +30 \times 10^3 \text{ J} = +3.0 \times 10^4 \text{ J}$$

Q4.

A simple pendulum is 1.30 m long. The mass at its end is pulled to one side until the pendulum makes an angle of 29.0° with the vertical and then released from rest. If the kinetic energy of the mass at the lowest point of its motion is 0.360 J, what is the value of the mass?

A) 0.225 kg
B) 0.106 kg
C) 0.140 kg
D) 0.980 kg
E) zero

Ans:

Take the lowest point as the reference of gravitational potential energy.

$$U_i + \cancelto{0}{K_i} = \cancelto{0}{U_f} + K_f \quad \{i \longrightarrow \text{release};\ f \longrightarrow \text{lowest point}\}$$

$$mgh = K_f \Longrightarrow mgL\,(1 - cos\theta_i) = K_f$$

$$m = \frac{K_f}{gL(1 - cos\theta_i)} = \frac{0.36}{9.8 \times 1.3 \times (1 - \cos 29^o)} = 0.225 \text{ kg}$$

Q5.

A ball falls from the top of a building to the floor. At the moment when it is 0.70 m above the floor, its gravitational potential energy equals its kinetic energy. What is the speed of the ball at that moment? Take the floor as the reference of gravitational potential energy.

A) 3.7 m/s
B) 6.9 m/s
C) 9.8 m/s
D) 14 m/s
E) zero

Ans:

$$\left.\begin{aligned} U_g &= mgh \\ K &= \frac{1}{2}mv^2 \end{aligned}\right\} U_g = K: \cancel{m}gh = \frac{1}{2}\cancel{m}v^2$$

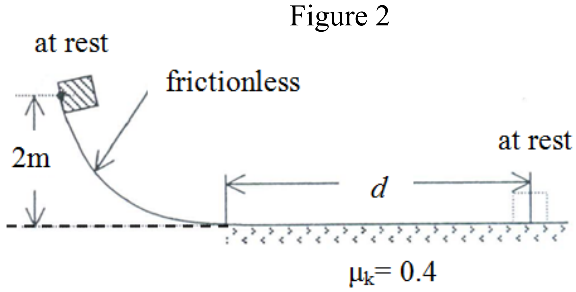
$$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.7} = 3.7\ \text{m/s}$$

Q6.

A block slides along the track shown in **Figure 2**. The curved portion of the track is frictionless, but for the horizontal part the coefficient of kinetic friction is 0.40. The block is released from rest from a height of 2.0 m above the horizontal part of the track. Find the distance *d* that the block moves on the horizontal part before it stops. Treat the block as a particle.

A) 5.0 m
B) 0.80 m
C) 2.4 m
D) 7.5 m
E) 1.5 m

Figure 2



Ans:

$$\Delta U_g + \cancelto{0}{\Delta K} = W_{ext}$$

$$-mgh = W_f = -f_k \cdot d$$

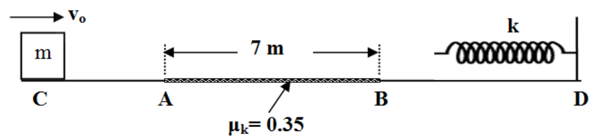
$$mgh = \mu_k mg \cdot d$$

$$d = \frac{h}{\mu_k} = \frac{2.0}{0.40} = 5.0\ \text{m}$$

Q7.

As shown in **Figure 3**, a 4.0-kg block has speed 8.5 m/s at point C. Tracks CA and BD are frictionless, but track AB (of length 7.0 m) is rough (μ_k = 0.35). The block runs into and compresses a spring (k = 2400 N/m) until it momentarily stops. By what distance is the spring compressed when the block stops?

Figure 3



A) 0.20 m
B) 0.45 m
C) 0.35 m
D) 0.57 m
E) 0.15 m

Ans:

$$\Delta K + \Delta U_s = W_{ext}$$

$$\cancelto{0}{K_f} - K_i + \frac{1}{2}kd^2 = W_f$$

$$-\frac{1}{2}mv^2 + \frac{1}{2}\,kd^2 = -\mu_k mgx$$

$$1200\,d^2 = -96.04 + 144.5 \Longrightarrow d = 0.2 \text{ m}$$

Q8.

A 6.0-kg object, initially at rest, explodes into three pieces A, B, and C. After the explosion, A (2.0 kg) has velocity $+3.0\,\hat{\mathrm{i}}$ (m/s), and B (3.0 kg) has velocity $-1.0\,\hat{\mathrm{j}}$ (m/s). Find the velocity of C.

A) $-6.0\,\hat{\mathrm{i}} + 3.0\,\hat{\mathrm{j}}$ (m/s)
B) $+3.0\,\hat{\mathrm{i}} + 6.0\,\hat{\mathrm{j}}$ (m/s)
C) $+6.0\,\hat{\mathrm{i}} - 3.0\,\hat{\mathrm{j}}$ (m/s)
D) $+6.0\,\hat{\mathrm{i}} + 3.0\,\hat{\mathrm{j}}$ (m/s)
E) $+3.0\,\hat{\mathrm{i}} - 6.0\,\hat{\mathrm{j}}$ (m/s)

Ans:

$$\vec{P}_i = \vec{P}_f$$

$$0 = \vec{p}_A + \vec{p}_B + \vec{p}_C$$

$$\vec{p}_C = -\vec{p}_A - \vec{p}_B$$

$$(1)\vec{v}_C = -(2 \times 3\hat{\mathbf{i}}) - (3 \times -\hat{\mathbf{j}}) = -6\,\hat{\mathbf{i}} + 3\,\hat{\mathbf{j}}\,(\mathrm{m/s})$$

Q9.

A 0.15 kg ball, moving along a straight line, has a velocity of $+20\hat{\mathrm{i}}$ (m/s). It collides with a wall and rebounds with a velocity of $-10\hat{\mathrm{i}}$ (m/s). If the ball is in contact with the wall for 0.005 s, what is the average force exerted by the wall on the ball?

A) $-900\hat{\mathrm{i}}$ (N)
B) $+900\hat{\mathrm{i}}$ (N)
C) $-300\hat{\mathrm{i}}$ (N)
D) $+300\hat{\mathrm{i}}$ (N)
E) zero

Ans:

$$\vec{p}_i = 0.15 \times 20\,\hat{\mathbf{i}} = 3\,\hat{\mathbf{i}}\,(\mathrm{N.s})$$

$$\vec{p}_f = 0.15 \times (-10\,\hat{\mathbf{i}}) = -1.5\,\hat{\mathbf{i}}\,(\mathrm{N.s})$$

$$\vec{F}_{avg} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\vec{p}_f - \vec{p}_i}{\Delta t} = -\frac{1.5\,\hat{\mathbf{i}} - 3\,\hat{\mathbf{i}}}{0.005} = -900\,\hat{\mathbf{i}}\,(\mathrm{N})$$

Q10.

Figure 4 shows an overhead view of four particles on which external forces act as shown. What are the *x* and *y* components of the force acting on the fourth particle if the center of mass of the system moves with constant velocity?

A) $F_x = +5\,\mathrm{N},\ F_y = -2\,\mathrm{N}$
B) $F_x = +5\,\mathrm{N},\ F_y = +8\,\mathrm{N}$
C) $F_x = 0,\ F_y = 0$
D) $F_x = -5\,\mathrm{N},\ F_y = -8\,\mathrm{N}$
E) $F_x = -5\,\mathrm{N},\ F_y = -2\,\mathrm{N}$

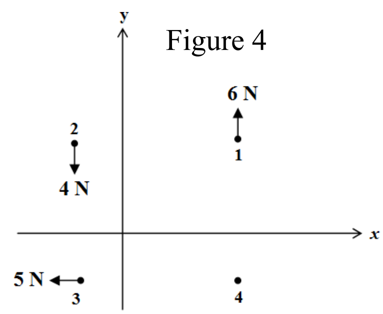


Figure 4

Ans:

$$\text{Constant Velocity} \Rightarrow \vec{\mathbf{a}}_{com} = 0 \Rightarrow \vec{\mathbf{F}}_{net} = 0$$

$$\vec{\mathbf{F}}_{net} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \vec{\mathbf{F}}_3 + \vec{\mathbf{F}}_4 = 0$$

$$\Rightarrow \vec{\mathbf{F}}_4 = -\left(\vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \vec{\mathbf{F}}_3\right)$$

$$= -(6\,\hat{\mathbf{j}} - 4\hat{\mathbf{j}} - 5\hat{\mathbf{i}})$$

$$= 5\hat{\mathbf{i}} - 2\,\hat{\mathbf{j}}\,(\mathrm{N})$$

Q11.

Block 1 of mass 1 kg slides along a frictionless surface and undergoes a one dimensional elastic collision with stationary block 2 of mass 3 kg. Before the collision, the center of mass of the two-block system had a speed of 3 m/s. After the collision, what is speed of block 2?

A) 6 m/s
B) 2 m/s
C) 4 m/s
D) 8 m/s
E) 3 m/s

Ans:

Before Collison: $v_{1i} = ?, \qquad v_{2i} = 0$

$$V_{com} = \frac{m_1 v_{1i} + m_2 v_{2i}}{m_1 + m_2}$$

$$3 = \frac{(1)(v_{1i}) + 0}{1 + 3} \Longrightarrow v_{1i} = 12 \ \text{m/s}$$

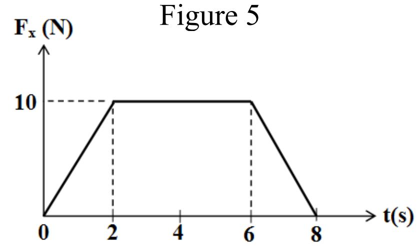
After Collison: $v_{2f} = \dfrac{2m_1}{m_1 + m_2} v_{1i} = \dfrac{2}{4} \times 12 = 6 \ \text{m/s}$

Q12.

The force F_x on a 5.0-kg particle varies with time as shown in **Figure 5**. If the particle is initially ($t = 0$) moving along the x-axis with a velocity of – 3.0 m/s, find its velocity at $t = 8.0$ s.

A) + 9.0 m/s
B) + 5.0 m/s
C) + 3.0 m/s
D) – 15 m/s
E) – 3.0 m/s

Figure 5



Ans:

$\Delta p = J =$ area under $(F - t)$ curve

$$= \left(\frac{1}{2} \times 2 \times 10\right) + (4 \times 10) + \left(\frac{1}{2} \times 2 \times 10\right)$$

$$= 10 + 40 + 10 = 60 \ (\text{N} \cdot \text{s})$$

$$\Delta p = p_f - p_i = p_8 - p_0$$

$$p_8 = p_0 + \Delta p$$

$$m v_8 = m v_0 + \Delta p$$

$$v_8 = v_0 + \frac{\Delta p}{m} = -3.0 + \frac{60}{5} = +9.0 \ \text{m/s}$$

Q13.

A disk, initially rotating at 42 rad/s, stops after 10 s (assume constant angular acceleration). Through what angle does the disk turn during this time?

A) 210 rad
B) 320 rad
C) 150 rad
D) 440 rad
E) 900 rad

Ans:

$$\cancelto{0}{\omega_f} = \omega_i - \alpha t \Longrightarrow \alpha = \frac{\omega_i}{t} = \frac{42}{10} = 4.2\ \mathrm{rad/s^2}$$

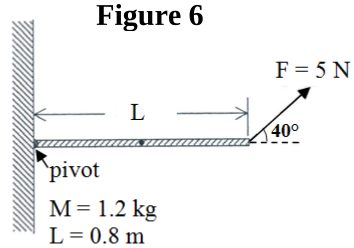
$$\theta = \omega_i t - \frac{1}{2} \times \alpha t^2 = (42)(10) - \left(\frac{1}{2} \times 4.2 \times 100\right) = 420 - 210 = 210\ \ \mathrm{rad}$$

Q14.

A uniform rod, of mass 1.2 kg and length 0.80 m, is free to rotate in a vertical plane about one end, where a force F = 5.0 N acts on the rod as shown in **Figure 6**. What is the net torque on the rod about the pivot at the instant shown in the figure?

A) 2.1 N.m, clockwise
B) 2.6 N.m, counterclockwise
C) 4.7 N.m, clockwise
D) 7.3 N.m, clockwise
E) 7.3 N.m, counterclockwise

Figure 6



Ans:

$$\tau_g = -\frac{1}{2} \times mg = -0.4 \times 1.2 \times 9.8 = -\ 4.70\ \ \mathrm{N \cdot m}$$

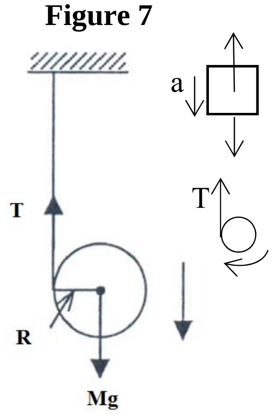
$$\tau_F = L \cdot F \cdot sin\theta = 0.8 \times 5 \times \sin 40° = +\ 2.57\ (\mathrm{N \cdot m})$$

$$\tau_{net} = \tau_g + \tau_F = -\ 2.13\ \mathrm{N \cdot m}$$

Q15.

A massless string is wound around a uniform disk (see **Figure 7**). The disk is released from rest with the string vertical. Find the magnitude of the acceleration of the center of mass of the disk.

Figure 7



A) 6.53 m/s^2
B) 3.23 m/s^2
C) 8.34 m/s^2
D) 1.13 m/s^2
E) 9.25 m/s^2

Ans:

$$ma = mg - T \longrightarrow (1)$$

$$\tau = I\,\alpha$$

$$\cancel{R}T = \frac{1}{2}mR^{\cancel{2}} \cdot \frac{a}{\cancel{R}}$$

$$T = \frac{ma}{2} \longrightarrow (2)$$

Adding (1) and (2):

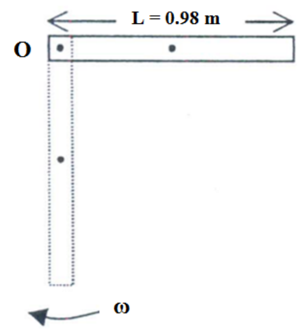
$$ma = mg - \frac{ma}{2} \Longrightarrow \frac{3ma}{2} = mg$$

$$a = \frac{2g}{3} = \frac{2}{3} \times 9.8 = 6.53 \ \mathrm{m/s^2}$$

Q16.

A uniform rod of length 0.98 m is free to rotate in a vertical plane about a frictionless pin through one end (point O in **Figure 8**). The rod is released from rest when it is in the horizontal position. What is the angular speed of the rod at its lowest position?

Figure 8



A) 5.5 rad/s
B) 3.4 rad/s
C) 6.8 rad/s
D) 4.0 rad/s
E) 7.9 rad/s

Ans:

$i \longrightarrow$ horizontal position

$f \longrightarrow$ vertical position

Conservation of mechanical energy:

$$\overset{0}{\cancel{K_i}} + \overset{0}{\cancel{U_i}} = K_f + U_f$$

$$K_f = -U_f$$

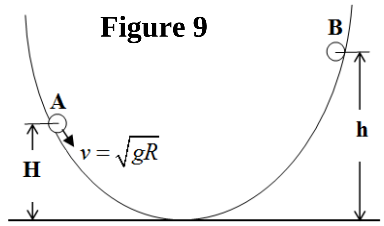
$$\frac{1}{2} I\,\omega^2 = -(-mg\,\frac{L}{2})$$

$$\frac{1}{2} \times \frac{1}{3} mL^2\omega^2 = mg\,\frac{L}{2}$$

$$\omega = \sqrt{\frac{3g}{L}} = 5.5 \text{ rad/s}$$

Q17.

A solid sphere, of radius R, rolls without slipping, as shown in **Figure 9**. As the sphere passes point **A** of height $H = 5.3\ R$, the speed of its center of mass is $\sqrt{gR}$. If the sphere comes momentarily to rest at point **B**, then the height h of point **B** is



A) $6\ R$
B) $2\ R$
C) $8\ R$
D) $9\ R$
E) $10\ R$

Ans:

$$K_A + U_A = \overset{0}{\cancel{K_B}} + U_B$$

$$K_A + mgH = mgh$$

$$K_A = K_{tr} + K_{rot}$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}I_{com}\omega^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{\cancel{2}} \times \frac{\cancel{2}}{5}M\cancel{R^2} \times \frac{v^2}{\cancel{R^2}}$$

$$= 0.7\ mv^2 = 0.7\ mgR$$

$$0.7\ \cancel{mg}R + \cancel{mg}H = \cancel{mg}h$$

$$0.7\ R + 5.3\ R = h$$

Q18.

The torque about the origin on a particle located at (0, – 4.0, 3.0) m due to the force $\vec{F} = 6.0\,\hat{\imath}\,(N)$ is:

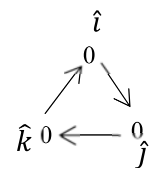
A) $+18\hat{j}+24\hat{k}$ (N.m)

B) $-18\hat{j}+24\hat{k}$ (N.m)

C) $-18\hat{j}-24\hat{k}$ (N.m)

D) $+18\hat{j}-24\hat{k}$ (N.m)

E) zero



Ans:

$$\vec{\boldsymbol{\tau}} = \vec{\mathbf{r}} \times \vec{\mathbf{F}} = \left(-4\hat{\mathbf{j}} + 3\hat{\mathbf{k}}\right) \times (6\hat{\mathbf{i}})$$

$$= 24\hat{\mathbf{k}} + 18\,\hat{\mathbf{j}}\,(\mathrm{N} \cdot \mathrm{m})$$

Q19.

A particle Q with a mass of 2.00 kg has a position vector $\hat{r}$(of magnitude 5.00 m) and velocity $\vec{v}$ (of magnitude 4.00 m/s) oriented as shown in **Figure 10**. Calculate the angular momentum of the particle (in units of kg.m^2/s) about the origin.

A) $-37.6\hat{k}$

B) $+17.6\hat{k}$

C) $+37.6\hat{k}$

D) $-17.6\hat{k}$

E) $+7.68\hat{j}$

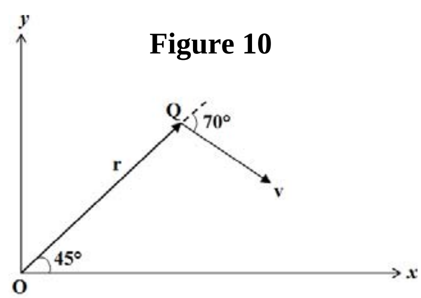


Figure 10

Ans:

From the right-hand rule:

$$\vec{\boldsymbol{l}} \rightarrow (-\hat{\mathbf{k}})$$

$$l = r \cdot p \cdot \sin\phi = r\,m\,v\,\sin\phi$$

$$= 5 \times 2 \times 4 \times sin70° = 37.6$$

$$\Rightarrow \vec{\boldsymbol{l}} = -\,37.6\,\hat{\mathbf{k}}$$

Q20.

A man stands at the center of a frictionless rotating disk. His arms are extended and he holds a weight in each hand. The rotational inertial of the system (man + weights + disk) about the central axis is 6.0 kg.m^2. The man pulls the weights toward himself, reducing the rotational inertia of the system to 2.0 kg.m^2, and changing the angular speed to 3.6 rad/s. What was the initial angular speed of the system?

A) 1.2 rad/s
B) 2.5 rad/s
C) 3.6 rad/s
D) 7.2 rad/s
E) 0.36 rad/s

Ans:

$$L_i = L_f : I_i\omega_i = I_f\omega_f$$

$$\Rightarrow \omega_i = \frac{I_f}{I_i}\,\omega_f = \frac{2}{6} \times 3.6 = 1.2\ \mathrm{rad/s}$$