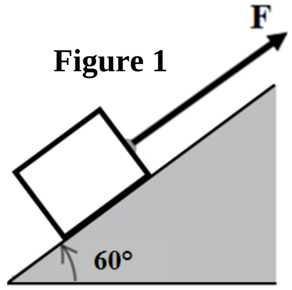
Q1.

A 50-kg box is pulled at constant speed 12 m up a plane 60° above the horizontal by a force parallel to the plane (see **Figure 1**). The coefficient of kinetic friction between the box and the plane is 0.30. How much work is done by the applied force?

Figure 1



A) 6.0 kJ
B) 3.5 kJ
C) 5.3 kJ
D) 0.57 kJ
E) 4.2 kJ

Ans:

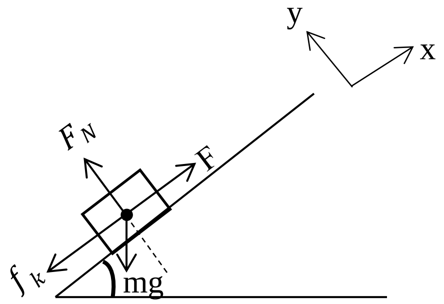
$m\cancel{a} = F - mg\sin\theta - f_k$ (a = 0)

$F = mg\sin\theta + f_k$

$mg\sin\theta + \mu_k mg\cos\theta$

$mg(\sin\theta + \mu_k\cos\theta) = 497.85 \text{ N}$

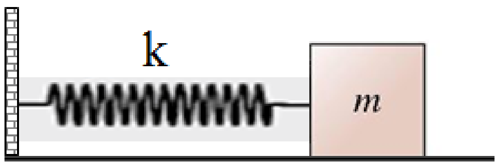
$W_F = F \cdot d = 497.85 \times 12 = 6.0 \text{ kJ}$



Q2.

A 3.0-kg block is attached to a massless spring of force constant 20 N/m (see **Figure 2**) and rests on a frictionless surface. The block is pulled 2.0 m to the right and released from rest. What is its kinetic energy when it is 1.0 m to the right of the equilibrium position?

Figure 2



A) 30 J
B) 10 J
C) 40 J
D) 50 J
E) 25 J

Ans:

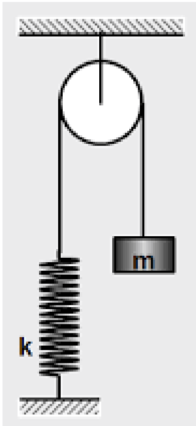
$W_s = \frac{1}{2}k(x_i^2 - x_f^2) = \frac{1}{2} \times 20 \times (4.0 - 1.0) = 30 \text{ J}$

$\Delta K = W_s$: $K_f - \cancel{K_i} = W_s \Rightarrow K_f = 30 \text{ J}$ (K_i = 0)

Q3.

A 20-kg mass is attached to a massless spring (k = 380 N/m) that passes over a frictionless massless pulley, as shown in **Figure 3**. The mass is released from rest with the spring unstretched. What is the speed of the mass at the instant when it has dropped a vertical distance of 0.40 m?

Figure 3



A) 2.2 m/s
B) 2.8 m/s
C) 1.5 m/s
D) 4.8 m/s
E) 3.6 m/s

Ans:

$$\Delta K = K_f - \cancel{K_i}^{\,0} = K_f = \frac{1}{2}mv^2$$

$$\Delta U_g = -mgh$$

$$\Delta U_s = \frac{1}{2}kh^2$$

$$\Delta K + \Delta U_s + \Delta U_g = 0$$

$$\frac{1}{2}mv^2 + \frac{1}{2}kh^2 - mgh = 0$$

$$v^2 = 2gh - \frac{k}{m}h^2$$

$$= (2 \times 9.8 \times 0.4) - \left(\frac{380}{20} \times 0.16\right) = 4.8\ (m/s)^2$$

$$\Rightarrow v = 2.2\ m/s$$

Q4.

A particle moves from the point (1.0, 2.0) m to the point (– 4.0, – 2.0) m while being acted on by a constant force $\vec{F} = 4.0\,\hat{\mathbf{i}} + 2.0\,\hat{\mathbf{j}}$ (N). What is the work done on the particle by this force?

A) – 28 J
B) + 10 J
C) + 23 J
D) + 17 J
E) – 78 J

Ans:

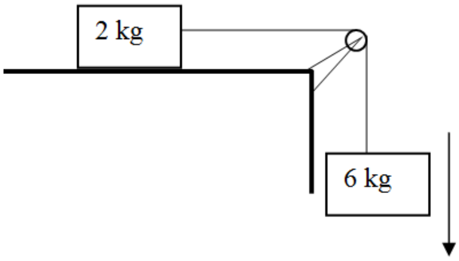
$$\vec{d} = \vec{r}_f - \vec{r}_i = -5\hat{\imath} - 4\hat{\jmath} \quad (\mathrm{m})$$

$$W = \vec{F}\cdot\vec{d} = (4\hat{\imath} + 2\hat{\jmath})\cdot(-5\hat{\imath} - 4\hat{\jmath}) = -20 - 8 = -28\,\mathrm{J}$$

Q5.

Two masses are connected and move as shown in **Figure 4**. The coefficient of kinetic friction between the 2.00-kg mass and the surface is 0.400. The system starts from rest. What is the speed of the 6.00-kg mass at the instant when it has fallen 1.50 m? Assume that the pulley is massless and frictionless.

Figure 4



A) 4.37 m/s
B) 3.54 m/s
C) 6.00 m/s
D) 5.05 m/s
E) 5.42 m/s

Ans:

Let $m_1 = 2\mathrm{kg}, m_2 = 6\mathrm{kg}, M = m_1 + m_2$

$$\Delta K = K_f - K_i = \frac{1}{2}mv^2 \quad (K_i = 0)$$

$$\Delta U_g = -m_2 gh$$

$$W_{ext} = W_f = -f_k \cdot d = -\mu_k m_1 gh$$

$$\Delta K + \Delta U_g = W_{ext}:$$

$$\frac{1}{2}mv^2 - m_2 gh = -\mu_k m_1 gh$$

$$4v^2 - 88.2 = -11.76 \Rightarrow v = 4.37\ \mathrm{m/s}$$

Q6.

A block is pushed on a rough horizontal surface by a 12-N force acting parallel to the surface. If the block moves with a constant speed of 1.5 m/s, how much power is lost due to the frictional force?

A) 18 W
B) 11 W
C) 29 W
D) 54 W
E) 31 W

Ans:

Constant speed: $f_k = F_{app} = 12\text{ N}$

$P = f_k \cdot v = 12 \times 1.5 = 18\text{ W}$

Q7.

Which of the following bodies has the largest kinetic energy?

A) Mass 2*M* and speed 3*V* $\rightarrow K = \frac{1}{2} \times 2M \times 9V^2 = 9MV^2$

B) Mass 3*M* and speed *V* $\rightarrow K = \frac{1}{2} \times 3M \times V^2 = 1.5MV^2$

C) Mass 3*M* and speed 2*V* $\rightarrow K = \frac{1}{2} \times 3M \times 4V^2 = 6MV^2$

D) Mass *M* and speed 4*V* $\rightarrow K = \frac{1}{2} \times M \times 16V^2 = 8MV^2$

E) Mass 4*M* and speed 2*V* $\rightarrow K = \frac{1}{2} \times 4M \times 4V^2 = 8MV^2$

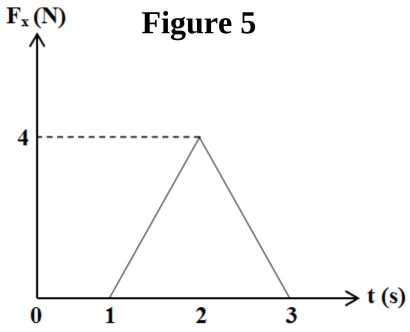
Ans:

A

Q8.

The only force acting on a 5.0-kg object moving along the *x*-axis is shown in **Figure 5**. What is the change in the speed of the object between *t* = 1.0 s and *t* = 3.0 s?

Figure 5



A) 0.80 m/s
B) 1.1 m/s
C) 1.6 m/s
D) 2.3 m/s
E) 4.0 m/s

Ans:

$J = \text{area} = \frac{1}{2} \times 2 \times 4 = 4\ \text{(N.s)}$

$P = mv \rightarrow \Delta P = m\,\Delta v \rightarrow J = m\,\Delta v$

$\Delta v = \frac{J}{m} = \frac{4}{5} = 0.8\text{ m/s}$

Q9.

A 2.0-kg object moving with a velocity of 5.0 m/s in the positive *x*-direction collides and sticks to a 3.0-kg object originally moving with a velocity of 2.0 m/s in the positive *x*-direction. What is the final speed of the composite object?

A) 3.2 m/s
B) 5.0 m/s
C) 2.0 m/s
D) 7.0 m/s
E) 1.2 m/s

Ans:

$$MV = m_1 v_1 + m_2 v_2$$

$$V = \frac{1}{M}(m_1 v_1 + m_2 v_2)$$

$$V = \frac{1}{5}[(2 \times 5) + (3 \times 2)] = 3.2\ m/s$$

Q10.

Three particles are placed in the *xy* plane. A 4-kg particle is located at (3, 4) m, and a 6-kg particle is located at (– 2, – 6) m. Where must a 2-kg particle be placed so that the center of mass of this three-particle system is at the origin?

A) (0, 10) m
B) (6, – 2) m
C) (5, 10) m
D) (9, 16) m
E) (– 2, 4) m

Ans:

$$M x_{com} = m_1 x_1 + m_2 x_2 + m_3 x_3$$

$$0 = 12 - 12 + 2x_3 \Rightarrow x_3 = 0$$

Q11.

A 2.0-kg particle has a velocity of 4.0 m/s in the positive *x*-direction, and a 3.0-kg particle has a velocity of 5.0 m/s in the positive *y*-direction. What is the speed of their center of mass?

A) 3.4 m/s
B) 3.8 m/s
C) 5.0 m/s
D) 4.4 m/s
E) 4.6 m/s

Ans:

$$\vec{V}_{com} = \frac{1}{M}(m_1 \vec{v}_1 + m_2 \vec{v}_2) = \frac{1}{5}(8\hat{i} + 15\hat{j})$$

$$= 1.6\hat{\imath} + 3\hat{\jmath}\ (m/s)$$

$$V_{com} = \sqrt{(1.6)^2 + (3)^2} = 3.4\ m/s$$

Q12.

A block of mass *m* slides on a frictionless surface with speed *v*. At one instant, it separates into two equal pieces. One piece is at rest just after the separation. What is the kinetic energy of the second piece immediately after the separation?

A) mv^2
B) zero
C) $2\,mv^2$
D) ¼ mv^2
E) ½ mv^2

Ans:

$$P_i = \cancel{p_{1f}}^{\,0} + p_{2f}$$

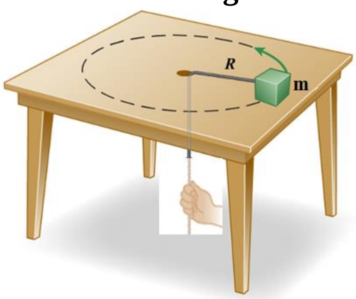
$$mv = \frac{m}{2} v_f \Rightarrow v_f = 2v$$

$$K_f = \frac{1}{2} \cdot \frac{m}{2} (2v)^2 = mv^2$$

Q13.

A mass *m* is attached to a rope passing through a small hole in a horizontal frictionless surface (**Figure 6**). The mass is initially rotating with a linear speed of 2.25 m/s in a circle of radius *R*. The rope is slowly pulled from below, decreasing the radius to *R*/2. What is the new linear speed of the mass?

Figure 6



A) 4.50 m/s
B) 1.13 m/s
C) 2.25 m/s
D) 1.50 m/s
E) 9.00 m/s

Ans:

Conservation of angular momentum:

$$l_i = l_f$$

$$\cancel{m} v_i r_i = \cancel{m} v_f r_f$$

$$v_f = \left(\frac{r_i}{r_f}\right) v_i = \left(\frac{R}{R/2}\right) v_i = 2v_i$$

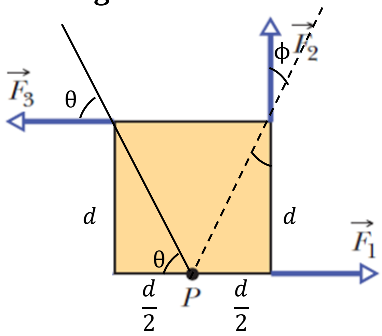
$$v_f = 2 \times 2.25 = 4.50 \text{ m/s}$$

Q14.

In the overhead view of **Figure 7**, three forces of the same magnitude act on a square that is pivoted at point *P* (midpoint of the lower side of the square). Rank the forces according to the magnitude of the torque they produce about point *P*, greatest first.

A) F_3, F_2, F_1
B) F_2, F_3, F_1
C) F_3, F_1, F_2
D) F_2, F_1, F_3
E) All tie

Figure 7



Ans:

$$\sin\theta = \frac{d}{r}, \qquad \sin\phi = \frac{d}{2r}$$

$$\tau_1 = 0$$

$$\tau_2 = F_2 \cdot r \cdot \sin\phi = F \cdot r \cdot \frac{d}{2r} = \frac{Fd}{2}$$

$$\tau_3 = F_3 \cdot r \cdot \sin\theta = F \cdot r \cdot \frac{d}{r} = \frac{Fd}{r}$$

Q15.

A wheel, starting from rest, turns through 8.0 revolutions in a time interval of 17 s. Assuming constant angular acceleration, what is the angular speed of the wheel at the end of this time interval?

A) 5.9 rad/s
B) 8.5 rad/s
C) 3.0 rad/s
D) 0.90 rad/s
E) 1.7 rad/s

Ans:

$$\theta = 8 \text{ rev} = 8 \times 2\pi = 50.26 \text{ rad}$$

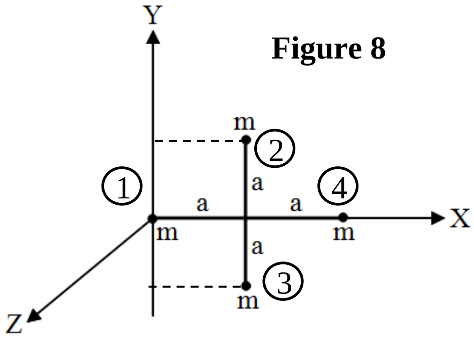
$$\theta = \cancelto{0}{\omega_i} t + \frac{1}{2} \times t^2 \Rightarrow \alpha = \frac{2\theta}{t^2} = 0.348 \text{ rad/s}^2$$

$$\omega = \cancelto{0}{\omega_i} + \alpha t = 0.348 \times 17 = 5.9 \text{ rad/s}$$

Q16.

Four identical particles, each of mass *m*, are arranged in the *xy* plane as shown in **Figure 8**. They are connected by massless rods to form a rigid body. If *m* = 2.0 kg and *a* = 1.0 m, the rotational inertia of this system about the *y*-axis is

A) 12 kg.m^2
B) 16 kg.m^2
C) 4.0 kg.m^2
D) 9.6 kg.m^2
E) 4.8 kg.m^2



Ans:

$$I_y = \sum m_i r_i^2 = m_2 a^2 + m_3 a^2 + m_4 (2a)^2$$

$$= 2ma^2 + 4ma^2$$

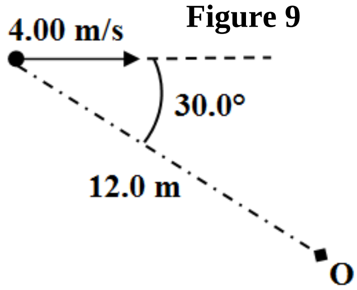
$$= 6ma^2$$

$$= 6 \times 2 \times 1 = 12\ \mathrm{kg.m^2}$$

Q17.

A 6.00-kg particle moves to the right with a speed of 4.00 m/s, as shown in **Figure 9**. The magnitude of its angular momentum about the origin O is

A) 144 kg.m^2/s
B) 288 kg.m^2/s
C) 543 kg.m^2/s
D) 249 kg.m^2/s
E) Zero



Ans:

$$l = r.p.\sin\phi = r.mv.\sin\phi$$

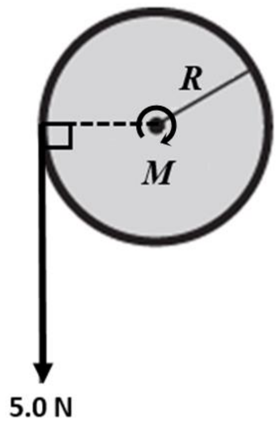
$$l = 12 \times 6 \times 4 \times \sin 30° = 144\ \mathrm{kg.m^2/s}$$

Q18.

A 5.0 N force is applied tangentially to a uniform solid disk, as shown in **Figure 10**. The disk has mass M = 1.0 kg and radius R = 0.50 m, and rotates without friction about an axis through its center. What is the magnitude of the angular acceleration of the disk?

A) 20 rad/s^2
B) 10 rad/s^2
C) 5.0 rad/s^2
D) 40 rad/s^2
E) 15 rad/s^2

Figure 10



Ans:

$$\tau = I\alpha$$

$$\alpha = \frac{\tau}{I}$$

$$\tau = r.F.\sin\phi = R.F$$

$$I = \frac{1}{2}MR^2$$

$$\Rightarrow \alpha = \frac{R.F}{MR^2/2} = \frac{2F}{MR} = \frac{2\times 5}{1\times 0.5} = 20\ \text{rad/s}^2$$

Q19.

A uniform solid sphere of mass of 4.00 kg rolls without slipping on a horizontal surface. The linear speed of its center of mass is 4.00 m/s. Its total kinetic energy is

A) 44.8 J
B) 32.0 J
C) 12.8 J
D) 19.2 J
E) 57.6 J

Ans:

$$K = K_{rot} + K_{trans} = \frac{1}{2}I_{com}\omega^2 + \frac{1}{2}MV_{com}^2$$

$$K = \left(\frac{1}{2}\right)\left(\frac{2}{5}MR^2\right)\left(\frac{V_{com}}{R}\right)^2 + \frac{1}{2}MV_{com}^2 = 0.7MV_{com}^2$$

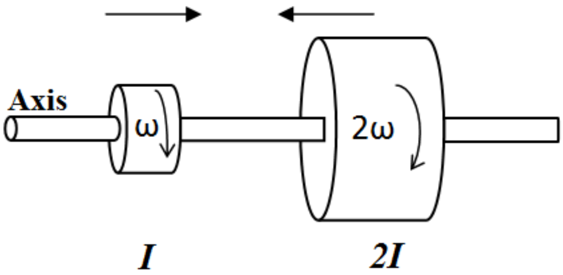
$$K = 0.7\times 4\times 16 = 44.8\ \text{J}$$

Q20.

Two disks are mounted on a frictionless axis as shown in **Figure 11**. The first disk has a rotational inertia *I* and is rotating with an angular speed of 6.00 rad/s. The second disk has a rotational inertia 2*I* and is rotating with an angular speed of 12.0 rad/s. They then couple and stick together. What is their common angular speed after coupling?

Figure 11

A) 10.0 rad/s
B) 11.4 rad/s
C) 9.17 rad/s
D) 6.00 rad/s
E) 18.0 rad/s



Ans:

$L_{1i} = I_1\omega_{1i} = I\omega_{1i} = 6\ I$

$L_{2i} = I_2\omega_{2i} = (2I)(12) = 24\ I$

$L_i = L_{1i} + L_{2i} = 30\ I$

$L_f = (I_1 + I_2)\omega_f = 3\ I\ \omega_f$

$L_i = L_f:\ 30\ I = 3\ I\omega_f \Rightarrow \omega_f = 10\ \text{rad/s}$