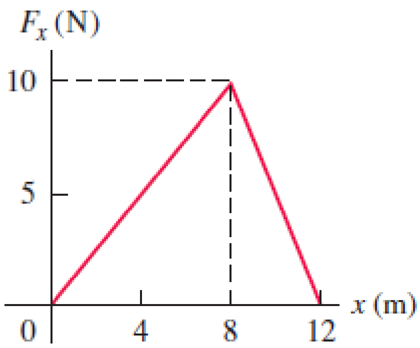
Q1.

A force F_x is applied to a 5.0-kg box moving it along the x-axis. The force varies with distance as shown in **FIGURE 1**. If the box starts from rest at the origin, what is its speed at x = 12 m?



A) 4.9 m/s
B) 4.0 m/s
C) 2.8 m/s
D) zero
E) 3.9 m/s

Answer:

$W = \text{area under the curve} = \frac{1}{2} \times 12 \times 10 = 60\ \text{J}$

$\Delta k = W : K_{12} - K_0 = W$

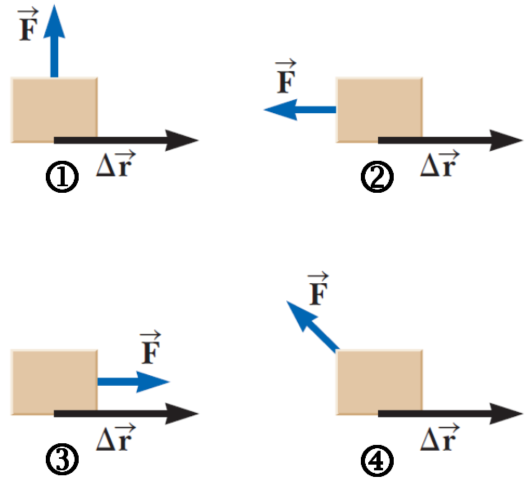
$\frac{1}{2} m v^2 - 0 = W$

$\Rightarrow v = \frac{\sqrt{2W}}{m}$

$= \sqrt{\frac{2 \times 60}{5.0}} = 4.9\ \text{m/s}$

Q2.

FIGURE 2 shows four situations in which a force is applied to an object. In all four cases, the force has the same magnitude, and the displacement of the object is to the right and of the same magnitude. Rank the situations in order of the work done by the force, from most positive to most negative.



A) 3, 1, 4, 2
B) 2, 4, 1, 3
C) 3, 2, 4, 1
D) 1, 4, 2, 3
E) 4, 1, 2, 3

Answer:

$W = \vec{F}.\Delta\vec{r}$
$W_1 = 0$
$W_2 = -F.\Delta r$
$W_3 = +F.\Delta r$
$W_4 = F.\Delta r.\cos\phi \;\; (-)$
Ranking : $3, 1, 4, 2$

Q3.
A rough inclined plane has a height of 1.00 m, and makes an angle of 45.0^{o} above the horizontal. An object of mass 1.00 kg is released from rest at the top of the incline, and has a speed of 3.50 m/s at the bottom of the incline. Calculate the magnitude of the work done by the frictional force.

A) 3.68 J
B) 5.31 J
C) 8.21 J
D) 2.50 J
E) 4.94 J

Answer:

$\Delta K = K_f - K_i = \frac{1}{2}m\left(v_f^2 - v_i^2\right) = \frac{1}{2} \times 1.00 \times (12.25 - 0) = 6.125 \text{ J}$
$\Delta U_g = -mgh = -1.00 \times 9.8 \times 1.00 = -9.8 \text{ J}$
$\Delta K + \Delta U_g = W_{ext}: W_f = \Delta K + \Delta U_g = 6.125 - 9.8 = -3.675 \text{ J}$

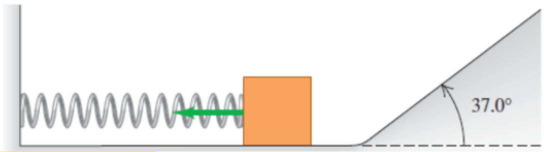
Q4.
A 15.0-kg box slides on a rough horizontal surface with an initial speed of 8.00 m/s and finally stops due to friction after moving for 3.10 s. What average power is produced by friction as the box stops?

A) 155 W
B) 480 W
C) 131 W
D) 326 W
E) 271 W

Answer:

$$W_{ext} = \Delta K + \Delta U_g$$
$$W_f = \Delta K + 0 = K_f - K_i = 0 - K_i = -\frac{1}{2}mv_i^2 = -\frac{1}{2} \times 15.0 \times 64 = -480 \text{ J}$$
$$P_{avg} = \frac{W}{\Delta t} = \frac{480}{3.1} = 154.8 \text{ W} \longrightarrow 155 \text{ W}$$

Q5.
A 3.0-kg block is pushed against a spring of force constant k = 500 N/m, compressing it 0.25 m. When the block is released from rest, it moves along a frictionless horizontal surface and then up a frictionless plane inclined at 37^{o} above the horizontal (see **FIGURE 3**). What is the speed of the block after it has moved 0.50 m up along the incline? Ignore air resistance. The block is not connected to the spring.



A) 2.1 m/s
B) 0.79 m/s
C) 4.1 m/s
D) 4.5 m/s
E) 2.9 m/s

Answer:

$$\Delta K + \Delta U_g = 0$$
$$\frac{1}{2}mv^2 - \frac{1}{2}kx^2 + mgh = 0$$
$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 - mgh$$
$$v^2 = \frac{k}{m}x^2 - 2gh = \left(\frac{500}{3}\right)(0.25)^2 - (19.6)(0.30) = 4.2 \Longrightarrow v = 2.1 \text{ m/s}$$

Q6.
The only force acting on a particle is conservative force $\vec{F}$. If the particle is at point A, the potential energy of the system is + 40 J, If the particle moves from point A to point B, the

work done on the particle by $\vec{F}$ is + 15 J. What is the potential energy of the system at point B?

A) + 25 J
B) – 25 J
C) + 55 J
D) – 55 J
E) – 15 J

Answer:

For a conservative force : $\Delta U = -W$

$\Delta U = -W$

$U_B - U_A = -W$

$U_B = U_A - W = 40 - 15 = +25$ J

Q7.

An object is initially at rest at the origin. It explodes into three equal-mass pieces (X, Y, Z), which slide along a frictionless surface. Piece X moves in the negative *x*-direction, and piece Y moves in the negative *y* direction. Which piece has the highest speed?

A) Z
B) Y
C) X
D) X and Y
E) All move with the same speed

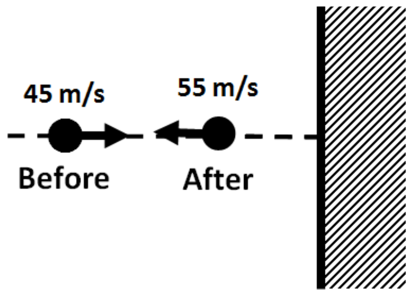
Answer:

Piece Z must move in the first quadrant with velocity:

$\vec{v}_z = v_x\,\hat{\imath} + v_y\hat{\imath} \Longrightarrow$ speed: $v_z = \sqrt{v_x^2 + v_y^2}$

Q8.

A ball of mass 0.20 kg, moving initially horizontally to the right with a speed of 45 m/s, strikes a wall, as shown in **FIGURE 4**. After the collision, the ball rebounds to the left with a speed 55 m/s. If the ball is in contact with the wall for 2.0 ms, what is the magnitude of the average force exerted by the wall on the ball?



A) 10 kN
B) 19 kN
C) 39 kN
D) 17 kN

E) 21 kN

Answer:

$\vec{\boldsymbol{p}}_{\boldsymbol{i}} = 0.2 \times 45\,\hat{\mathbf{i}} = 9\,\hat{\mathbf{i}}$
$\vec{\boldsymbol{p}}_{\boldsymbol{f}} = -0.2 \times 55\,\hat{\mathbf{i}} = -11\,\hat{\mathbf{i}}$
$\Delta\vec{\boldsymbol{p}} = \vec{\boldsymbol{p}}_{\boldsymbol{f}} - \vec{\boldsymbol{p}}_{\boldsymbol{i}} = -20\,\hat{\mathbf{i}}$
$\Delta\vec{\boldsymbol{p}} = \vec{\boldsymbol{p}}_{\boldsymbol{f}} - \vec{\boldsymbol{p}}_{\boldsymbol{i}} = -20\,\hat{\mathbf{i}}$
$\vec{\boldsymbol{F}}_{\boldsymbol{avg}} = \frac{\Delta\vec{\boldsymbol{p}}}{\Delta t} = \frac{-20\,\hat{\mathbf{i}}}{2\times10^{-3}} = -10 \times 10^{3}\,\hat{\mathbf{i}}\ \ (\mathrm{N})$
$\Rightarrow F_{avg} = 10\ \mathrm{kN}$

Q9.
Two cars move toward each other along a straight road and collide head-on. Just before the collision, Car A, of mass 2000 kg, is moving toward the west, while car B, of mass 1500 kg, is moving toward the east at 12 m/s. Just after the collision, the two cars stick together and move to the east as a unit at 1.5 m/s. What was the speed of car A just before the collision?

A) 6.4 m/s
B) 1.3 m/s
C) 8.4 m/s
D) 1.7 m/s
E) 7.3 m/s

Answer:

$m_A\vec{\boldsymbol{v}}_A + m_B\vec{\boldsymbol{v}}_B = M\vec{\boldsymbol{V}}$
$\vec{\boldsymbol{v}}_{\boldsymbol{A}} = \frac{M}{m_A}\vec{V} - \frac{m_B}{m_A}\vec{\boldsymbol{v}}_A = \left(\frac{3500}{2000}\right)(1.5\,\hat{\mathbf{i}}) - \left(\frac{1500}{2000}\right)\left(\frac{3500}{2000}\right)(12\,\hat{\mathbf{i}})$
$2.625\,\hat{\mathbf{i}} - 9\,\hat{\mathbf{i}} = -6.375\,\hat{\mathbf{i}}\ (\mathrm{m/s})$

Q10.
A system consists of two particles at rest. The first particle is at the origin. The second particle, which has a mass of 0.500 kg, is on the y-axis at y = 5.00 m. If the center of mass of the system is on the y-axis at y = 1.60 m, what is the mass of the first particle?

A) 1.06 kg
B) 4.11 kg
C) 0.345 kg
D) 3.13 kg
E) 2.16 kg

Answer:
$y_{com} = \frac{m_1y_1 + m_2y_2}{M} = \frac{m_2y_2}{M} \Rightarrow M = m_2\frac{y_2}{y_{com}} = 0.5 \times \frac{5}{1.6} = 1.5625\ \mathrm{kg}$
$m_1 = M - m_2 = 1.5625 - 0.5 = 1.0625\ \mathrm{kg}$

Q11.

Two balls (A of mass m_A = 10.0 g and B of mass m_B = 20.0 g) move toward each other along a line on a horizontal frictionless surface. Ball A has a velocity of $\vec{v}_A = 0.300\ \hat{\mathrm{i}}$ (m/s), while ball B has a velocity of $\vec{v}_B = -\ 0.200\ \hat{\mathrm{i}}$ (m/s). The two balls collide elastically. What is the change in the linear momentum of ball A due to the collision?

A) $-\ 6.67\times10^{-3}\ \hat{\mathrm{i}}$ (N.s)
B) $-\ 3.67\times10^{-3}\ \hat{\mathrm{i}}$ (N.s)
C) $-\ 1.67\times10^{-3}\ \hat{\mathrm{i}}$ (N.s)
D) $-\ 0.667\times10^{-3}\ \hat{\mathrm{i}}$ (N.s)
E) $+\ 1.67\times10^{-3}\ \hat{\mathrm{i}}$ (N.s)

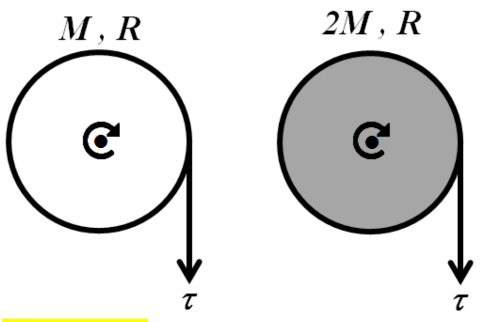
Answer:

$$v_{Af} = \frac{M_A - M_{AB}}{m_A + M_B} v_{Ai} + \frac{M_B}{M_A + M_B} v_{Bi}$$
$$= \left(\frac{10-20}{30} \times 0.3\right) + \left(\frac{40}{30} \times -0.2\right) = -0.1 - 0.267 = -\ 0.367\ \mathrm{m/s}$$

$$\vec{\boldsymbol{p}}_{\boldsymbol{Af}} = m_A \vec{\boldsymbol{v}}_{Ai} = 0.01 \times 0.3\ \hat{\mathbf{i}} = 3 \times 10^{-3}\ \hat{\mathbf{i}}\ (\mathrm{N.s})$$
$$\vec{\boldsymbol{p}}_{Af} = m_A \vec{\boldsymbol{v}}_{Af} = 0.01 \times (-0.367\ \hat{\mathbf{i}}) = -3.67 \times 10^{-3}\ \hat{\mathbf{i}}\ (\mathrm{N.s})$$
$$\Delta\vec{\boldsymbol{p}}_A = \vec{\boldsymbol{p}}_{Af} - \vec{\boldsymbol{p}}_{Ai} = -6.67 \times 10^{-3}\ \hat{\mathbf{i}}\ (\mathrm{N.s})$$

Q12.

Two cylinders are initially at rest: cylinder 1 has mass *M* and radius *R*, while cylinder 2 has mass 2*M* and radius *R*. A constant torque (τ) of the same magnitude is applied to each cylinder to rotate them about fixed axes through their centers, as shown in **FIGURE 5**. After one revolution, what can be said about their rotational kinetic energies?



A) $K_2 = K_1$
B) $K_2 = 2\ K_1$
C) $K_2 = 4\ K_1$
D) $K_2 = 8\ K_1$
E) $K_2 = K_1/2$

Answer

$\omega^2 = \omega_i^2 + 2\alpha\theta$

$K = \frac{1}{2} I\omega^2 = \left(\frac{1}{2}\right)\left(\frac{\tau}{\alpha}\right)(2\alpha\theta)$

$\therefore K = \tau\theta \Longrightarrow K$ is the same, since τ and θ are the same.

Q13.

A wheel with a radius of 0.40 m starts from rest and accelerates with a constant angular acceleration to a final angular speed of 1.2 rad/s after one revolution. Calculate the magnitude of the tangential acceleration of a point on the rim of the wheel.

A) 0.046 m/s^2
B) 0.042 m/s^2
C) 0.020 m/s^2
D) 0.064 m/s^2
E) 0.051 m/s^2

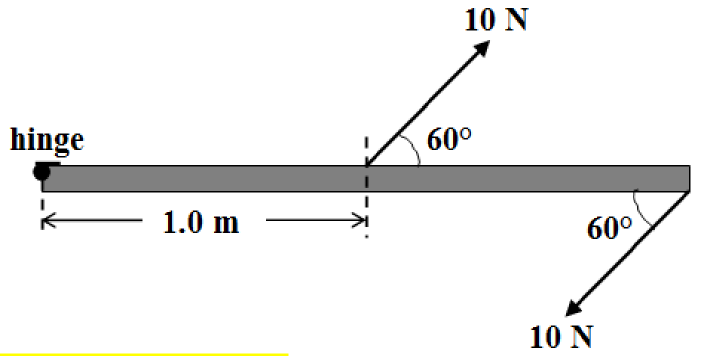
Answer:

$\omega^2 = \omega_i^2 + 2\alpha\theta \Longrightarrow \alpha = \frac{\omega^2}{2\theta} = \frac{(1.2)^2}{2 \times 2\pi} = 0.112 \text{ rad/s}$

$a_t = R\alpha \quad = 0.40 \times 0.114 = 0.0458 \text{ m/s}^2$

Q14.

FIGURE 6 shows the top view of a door that is 2.0 m wide. Two forces are applied to the door as indicated. What is the net torque on the door with respect to the hinge?



A) 8.7 N.m, clockwise
B) 8.7 N.m, counterclockwise
C) 26 N.m, counterclockwise
D) 26 N.m, clockwise
E) zero

Answer

$\tau = r.F.\sin\theta$

$\tau_1 = 1.0 \times 10 \times \sin 60° = 8.66 \text{ N.m}$, counterclockwise (+)

$\tau_2 = 2.0 \times 10 \times \sin 60° = 17.32 \text{ N.m}$, clockwise(−)

$\Longrightarrow \tau_{net} = \tau_1 + \tau_2 = 8.66 - 17.32 = -8.66 \text{ N.m}$

Q15.
A solid cylinder of radius 0.150 m and mass 1.50 kg is accelerated from rest to 126 rad/s using a constant torque. Calculate the work done by the torque.

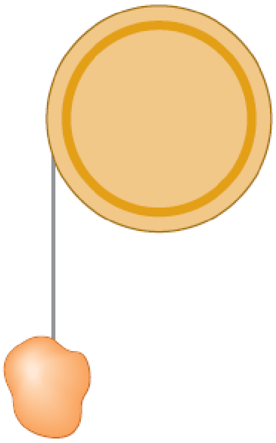
A) 134 J
B) 145 J
C) 189 J
D) 315 J
E) 196 J

Answer:

$$I = \frac{1}{2}MR^2 = \frac{1}{2} \times 1.5 \ \times (0.15)^2 = 0.016875 \text{ kg.m}^2$$

$$W = \Delta K = K_f = \frac{1}{2}I\omega_f^2 = \frac{1}{2}I\omega_f^2 = \frac{1}{2} \times 0.016875 \times (126)^2 = 134 \text{ J}$$

Q16.
A frictionless pulley is in the form of a solid disk of mass 3.0 kg and radius 25 cm. A 1.5-kg stone is attached to a wire that is wrapped around the rim of the pulley (**FIGURE 7**), and the system is released from rest. How far must the stone fall for the pulley to have 5.0 J of kinetic energy?



A) 68 cm
B) 17 cm
C) 27 cm
D) 97 cm
E) 52 cm

Answer:

$$\text{pully}: K_p = \frac{1}{2}I\omega^2 = \frac{1}{2} \times \frac{MR^2}{2} \times \frac{v^2}{R^2} = 0.25\, Mv^2$$

$$\text{stone}: K_s = 0.5\, mv^2 = (0.5m)\left(\frac{4K_p}{M}\right) = K_p$$

$$\text{conservation of energy}: \Delta K_p + \Delta K_p + \ \Delta U_g = 0$$

$$K_p + K_p - mgh = 0$$
$$\Rightarrow h = \frac{2K_p}{mg} = \frac{2 \times 5}{1.5 \times 9.8} = 0.68 \text{ m}$$

Q17.
A hoop (ring) of radius 0.60 m and mass 2.5 kg is rolling without slipping on a horizontal surface with an angular speed of 3.0 rad/s. What is the total kinetic energy of the hoop?

A) 8.1 J
B) 4.1 J
C) 6.1 J
D) 2.7 J
E) 5.3 J

Answer:

$$K = K_{rot} + K_{trans} = \frac{1}{2} I_{com}\omega^2 + \frac{1}{2} M V_{com}^2$$
$$= \frac{1}{2} MR^2\omega^2 + \frac{1}{2} MR^2\omega^2 = MR^2\omega^2$$
$$= 2.5 \times (0.6 \times 3)^2 = 8.1 \text{ J}$$

Q18.
Calculate the friction force on a 2.0-kg solid sphere rolling without slipping up a 30° incline.

A) 2.8 N, up the incline
B) 2.8 N, down the incline
C) 7.8 N, up the incline
D) 7.8 N, down the incline
E) zero

Answer:

$$a_{com} = \frac{g \sin \theta}{1 + \frac{I_{com}}{MR^2}} = \frac{g \sin \theta}{1 + \frac{0.4\, MR^2}{MR^2}} = \frac{9.8 \times \frac{1}{2}}{1.4} = 3.5 \text{ m/s}^2$$
$$fR = I.\alpha \Rightarrow fR = 0.4MR^2 . \frac{a}{R} \Rightarrow f = 0.4Ma = 2.8 \text{ N}$$

The frictional force is up the incline (see the direction of α)

Q19.
A force $\vec{F} = 2.0\hat{j} + 4.0\hat{k}$ (N) acts on a particle located the point with coordinates (0, – 4.0, 2.0) m. What is the torque on the particle about the origin due to this force?

A) – 20 $\hat{i}$ (N.m)
B) + 20 $\hat{i}$ (N.m)
C) – 12 $\hat{i}$ (N.m)
D) + 12 $\hat{i}$ (N.m)
E) – 16 $\hat{i}$ (N.m)

Answer:

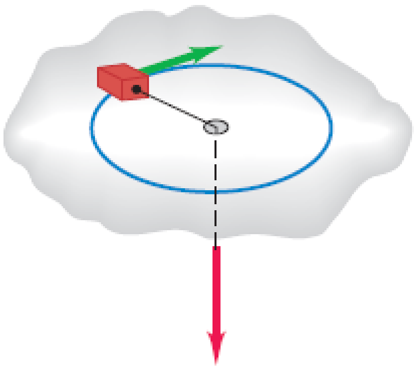
$\boldsymbol{\tau} = \vec{\boldsymbol{r}} \times \vec{\boldsymbol{F}}$

$= (-4\,\hat{\mathbf{j}} + 2\,\hat{\mathbf{k}}) \times (2\,\hat{\mathbf{j}} + 4\,\hat{\mathbf{k}})$

$= -16\,\hat{\mathbf{i}} - 4\,\hat{\mathbf{i}} = 20\,\hat{\mathbf{i}}\,(\mathrm{N.m})$

Q20.

A small block on a frictionless, horizontal surface has a mass of 0.030 kg. It is attached to a massless cord passing through a hole in the surface, as shown in **FIGURE 8**. The block is originally rotating at a distance of 0.30 m from the hole with an angular speed of 1.75 rad/s. The cord is then pulled from below, shortening the radius of the circle in which the block rotates to 0.15 m. What is the new angular speed of the block?



A) 7.0 rad/s
B) 3.5 rad/s
C) 7.4 rad/s
D) 4.7 rad/s
E) 5.7 rad/s

Answer:

$consrvation\ of\ anguar\ momentum$:

$L_i = L_f$

$I_i\omega_i = I_f\omega_f$

$mr_i^2\omega_i = mr_f^2\omega_f$

$\Rightarrow \omega_f = (\frac{r_i}{r_f})^2\omega_i$

$= \left(\frac{0.30}{0.15}\right)^2 (1.75)$

$= 7.0\ \mathrm{rad/s}$
