Q1.

A constant force $\vec{F} = (7.0\hat{i} - 2.0\hat{j})N$ acts on a 2.0 kg block, initially at rest, on a frictionless horizontal surface. If the force causes the block to be displaced by $\vec{d} = (4.0\hat{i} + 6.0\hat{j})m$, find the block's final speed.

A) 4.0 m/s
B) 5.0 m/s
C) 0 m/s
D) 3.0 m/s
E) 2.0 m/s

Ans:

$$W = \Delta K$$

$$\vec{F} \cdot \vec{d} = \frac{1}{2}mv_f^2 - \overset{0}{\cancel{\frac{1}{2}mv_i^2}}$$

$$28 - 12 = \frac{1}{2}(2)v_f^2$$

$$v_f = 4\ m/s$$

Q2.

A 15.0 N force with a fixed direction does work on a particle as the particle moves through the three-dimensional displacement $\vec{d} = (2.00\hat{i} - 4.00\hat{j} + 3.00\hat{k})m$. What is the angle between the force and the displacement if the change in the particle's kinetic energy is 50.0 J.

A) 51.8°
B) 62.3°
C) 43.9°
D) 69.1°
E) 37.2°

Ans:

$$W = \Delta K$$

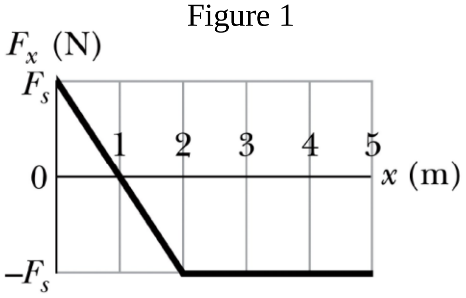
$$|\vec{F}||\vec{d}|\cos\theta = 50\,J$$

$$\cos\theta = \frac{50}{15\sqrt{29}} \Rightarrow \theta = 51.8°$$

Q3.

The only force acting on a 2.0 kg body as the body moves along an *x* axis varies as shown in **Figure 1**. The scale of the figure's vertical axis is set by F_s= 5.0 N. The speed of the body at *x* = 0 is 5.0 m/s. At what value of *x* will the body have a kinetic energy of 15 J?

Figure 1



A) 4.0 m
B) 1.0 m
C) 3.0 m
D) 5.0 m
E) 2.0 m

Ans:

$$\Delta K = W = \text{Area}$$

$$K_f = K_i + \text{Area}$$

$$15 = 25 - F(x - 2)$$

$$15 = 25 - 5x + 10$$

$$\Rightarrow x = 4\text{ m}$$

Q4.

The loaded cab of an elevator has a mass of 3.0×10^3 kg and moves 150 m upward in 10 s at constant speed. At what average rate does the force from the cable do work on the cab? [Ignore air resistance]

A) 4.4×10^5 W
B) 2.0×10^5 W
C) 2.7×10^5 W
D) 2.7×10^3 W
E) 0 W

Ans:

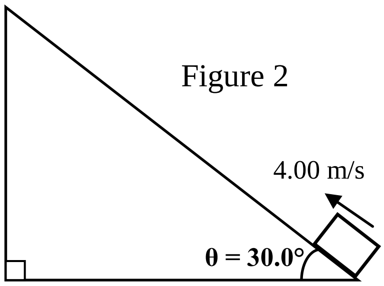
$$P = \frac{W}{t} = \frac{mgd}{t}$$

$$= \frac{3\times10^3\times9.8\times150}{10} = 4.4\times10^5\text{W}$$

Q5.

In **Figure 2,** a 6.00 kg block is projected up a frictionless plane at a speed of 4.00 m/s. The plane is inclined at an angle θ = 30.0° with the horizontal. How far up along the inclined plane does the block move before coming to stop? [Ignore air resistance]

A) 1.63 m
B) 0.850 m
C) 4.00 m
D) 1.00 m
E) 1.05 m



Ans:

$$\Delta E = 0$$

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

$$\Rightarrow h = \frac{v_i^2}{2g} = \frac{(4)^2}{(2)(9.8)} = 0.816 \text{ m}$$

$$d = \frac{h}{\sin 30} = 1.63 \text{ m}$$

Q6.

A man pushes a block up an incline at a constant speed. As the block moves up the incline, only one statement is true:

A) Its kinetic energy remains constant and the potential energy of block-earth system increases
B) Its kinetic energy and the potential energy of block-earth system both increase
C) Its kinetic energy increases and the potential energy of block-earth system remains constant
D) Its kinetic energy decreases and the potential energy of block-earth system remains constant
E) Its kinetic energy decreases and the potential energy of block-earth system decreases

Ans:

$$\Delta E = 0$$

$$\Delta K + \Delta U = 0$$

$$\Delta K = 0$$

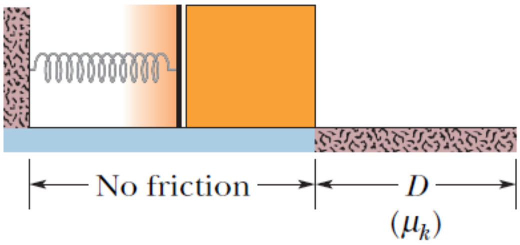
$$\Delta V = mg(h - h_0)$$

Q7.

As shown in **Figure 3**, a 3.50 kg block is accelerated from rest by compressing against a spring by a distance *x*. The other end of the spring is fixed to the wall and the spring has a spring constant of 134 N/m. The block leaves the spring and then travels over a rough horizontal floor with a coefficient of kinetic friction $\mu_k = 0.250$. The frictional force stops the block in distance *D* = 7.80 m. Find the distance *x*?

A) 1.00 m
B) 0.460 m
C) 1.20 m
D) 0.750 m
E) 2.30 m

Figure 3



Ans:

$$\frac{1}{2}kx^2 = \mu_k mgD$$

$$\frac{1}{2}(134)x^2 = (0.25)(3.5)(9.8)(7.8)$$

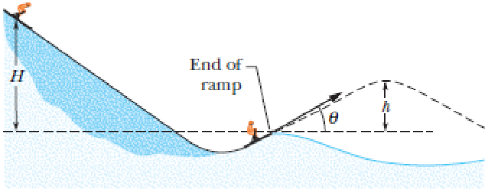
$$\Rightarrow x = 1.00 \text{ m}$$

Q8.

A 80 kg skier starts from rest at height *H* = 25 m above the end of a frictionless ski-jump ramp and leaves the ramp at angle θ= 30°, as shown in **Figure 4**. What is the maximum height *h* of his jump above the end of the ramp? Neglect the effects of air resistance.

A) 6.3 m
B) 5.6 m
C) 7.1 m
D) 4.3 m
E) 8.1 m

Figure 4



Ans:

$$\Delta E = 0 \;\Rightarrow \text{mgH} = \frac{1}{2}\text{mv}^2$$

$$v_o = \sqrt{2gH}$$

$$v_f^2 = v_o^2 - 2gh$$

$$0 = 2gH\sin^2(30) - 2gh$$

$$\Rightarrow \frac{H}{4} = h = \frac{25}{4} \cong 6.3 \text{ m}$$

Q9.

A completely inelastic collision occurs between two balls of clay that move directly toward each other along a vertical axis. Just before the collision, one ball, of mass 5.0 kg, is moving upward at 20 m/s and the other ball, of mass 2.0 kg, is moving downward at 15 m/s. After the collision the two balls stick together and move. How high do the combined two balls rise above the collision point? (Neglect air resistance.)

A) 5.1 m
B) 2.6 m
C) 7.3 m
D) 3.7 m
E) 4.5 m

Ans:

$$\vec{P}_{before} = \vec{P}_{after}$$

$$5 \times 20 \times \hat{j} - 2 \times 15 \times \hat{j} = (5 + 2)V$$

$$\Rightarrow V = 10\,\hat{j}$$

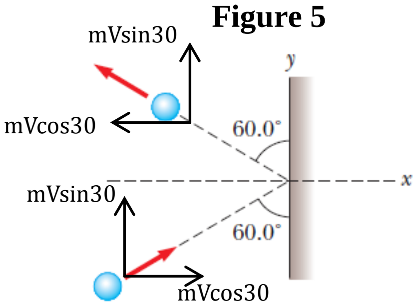
$$\frac{1}{2}(m_1 + m_2)V^2 = (m_1 + m_2)gh$$

$$\Rightarrow h = \frac{V^2}{2g} = \frac{(10)^2}{(2)(9.8)} = 5.1\text{ m}$$

Q10.

A 3.00 kg ball strikes a wall at 10.0 m/s at an angle of 60.0° with the plane of the wall. It bounces off the wall with the same speed and angle (See **Figure 5**). If the ball is in contact with the wall for 0.200 s, what is the magnitude of the average force exerted by the wall on the ball? [ignore air resistance]

Figure 5



A) 260 N
B) 150 N
C) 110 N
D) 390 N
E) 0

Ans:

$$\text{Impulse} = |\Delta\vec{P}| = \bar{F}\Delta t$$

$$2mV\cos 30 = F(0.2)$$

$$(2)(3)(10)(0.866) = F(0.2)$$

$$\Rightarrow |F_{avg}| = 260\text{ N}$$

Q11.

The center of mass of a two-particle system is at the origin. One particle has a mass of 2.0 kg and is located at (*x* = 3.0 m, *y* = 0.0 m). What is the location of the second particle if it has a mass of 4.0 kg?

A) (*x* = -1.5 m, *y* = 0.0 m)
B) (*x* = +1.5 m, *y* = -1.5 m)
C) (*x* = -1.5 m, *y* = +1.5 m)
D) (*x* = 0.0 m, *y* = -1.5 m)
E) (*x* = +1.5 m, *y* = 0.0 m)

Ans:

$$X_{cm} = 0 = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} = \frac{(2)(3) + 4x_2}{6}$$

$$\Rightarrow x_2 = -1.5 \text{ m}$$

$$Y_{cm} = 0 = (2)(0) + (4)(y_2) \Rightarrow y_2 = \ 0 \text{ m}$$

Q12.

Two metallic solid spheres approach each other head-on with the same speed of 3.00 m/s and collide elastically. After the collision, one of the spheres, whose mass is 600 g, remains at rest. What is the speed of the two-sphere center of mass?

A) 1.50 m/s
B) 3.55 m/s
C) 1.00 m/s
D) 2.75 m/s
E) 4.53 m/s

Ans:

$$V_{1f} = \frac{m_1 - m_2}{m_1 + m_2}V_{1i} - \frac{2m_2}{m_1 + m_2}V_{2i} = 0$$

$$\Rightarrow m_1 - m_2 - 2m_2 = 0 \ \Rightarrow m_2 = \frac{m_1}{3} = 200 \text{ g}$$

$$m_1|V_{1i}| - m_2|V_{2i}| = V_{com}(m_1 + m_2) \ \Rightarrow \ V_{com} = 1.5 \text{ m/s}$$

Q13.

Staring from rest, a disk takes 10 rev. to reach an angular velocity ω at constant angular acceleration. How many more revolutions are required by the disk to reach an angular velocity of 2ω?

A) 30 rev.
B) 10 rev
C) 20 rev.
D) 40 rev
E) 50 rev.

Ans:

$$\omega_{f1}^2 = 0 + 2\alpha(10) \Rightarrow \omega_{f1}^2 = 20\alpha$$

$$\omega_{f2}^2 = \omega_{f1}^2 + 2\alpha(\Delta B)$$

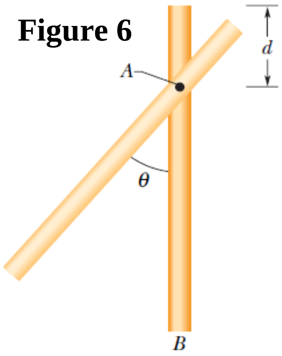
$$(4)(20\alpha) = 20\alpha + 2\alpha(\Delta B)$$

$$\Rightarrow \ \Delta\theta = 30 \text{ rev}$$

Q14.

A thin uniform rod (mass =5.0 kg and length = 6.0 m) rotates freely in a vertical plane about a horizontal axis that is perpendicular to the rod and passing through point *A*, as shown in **Figure 6**. Point *A* is at distance *d* = 1.5 m from the end of the rod. The kinetic energy of the rod as its other end *B* passes through the lowest vertical position is 25 J. What is the (linear) speed of the end *B* as the rod passes through the lowest vertical position?

Figure 6



A) 6.2 m/s
B) 2.6 m/s
C) 3.9 m/s
D) 7.9 m/s
E) 8.1 m/s

Ans:

$$I = \frac{mL^2}{12} + Md^2 = M\left(\frac{L^2}{12} + (1.5)^2\right)$$

$$= 5\left(\frac{36}{12} + (1.5)^2\right) = 26.25 \text{ kg} \cdot \text{m}^2$$

$$K = \frac{1}{2} I\omega^2 \Rightarrow \omega = \sqrt{\frac{2K}{I}}$$

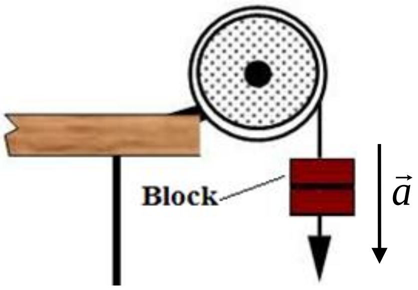
$$\Rightarrow \omega = \sqrt{\frac{(2)(25)}{26.25}} = 1.378 \text{ rad/s}$$

$$V = R\omega = (6 - 1.5)(1.378) = \ 6.2 \text{ m/s}$$

Q15.

A 45 N block is suspended by a massless light string from a 2.0 kg pulley, as shown in **Figure 7**. The block is released from rest and falls to the floor below as the pulley rotates. The pulley may be considered a solid disk of radius 1.5 m. What is the magnitude of acceleration $\vec{a}$ of the block? [Ignore air resistance]

Figure 7



- A) 8.1 m/s^2
- B) 15 m/s^2
- C) 9.4 m/s^2
- D) 5.5 m/s^2
- E) 7.3 m/s^2

Ans:

$$\tau = I\alpha = RT$$

$$\Rightarrow T = \frac{I\alpha}{R} = \frac{\frac{1}{2}MR^2}{R}\frac{a}{R}$$

$$\Rightarrow T = \frac{2.25\ a}{R^2} = \frac{2.25a}{(1.5)^2} = \frac{2.25}{(1.5)^2}\ a = a$$

$$\Rightarrow T - mg = \ -ma$$

$$a - 45 = \ -\frac{(45)}{9.8}\ a\ \Rightarrow a = 8.1\ \mathrm{m/s^2}$$

Q16.

A 2.0 kg solid cylinder of radius 0.50 m rotates about its cylindrical axis at a constant angular velocity of 40 rad/s. What average power is required to bring the cylinder to rest in 10 s?

- A) 20 W
- B) 10 W
- C) 50 W
- D) 30 W
- E) 40 W

Ans:

$$W = \Delta K = \frac{1}{2}I\omega^2 = \frac{1}{2}\left[\left(\frac{1}{2}\right)(2)(0.5)^2\right](40)^2 = 200\ \mathrm{J}$$

$$\Rightarrow P = \frac{W}{t} = \frac{200}{10} = 20\ \mathrm{W}$$

Q17.

A uniform solid sphere rolls without slipping along a horizontal surface. What percentage of its total kinetic energy is rotational kinetic energy?

- A) 29 %
- B) 50 %
- C) 12 %
- D) 75 %
- E) 33 %

Ans:

$$\frac{K_{rotational}}{K_{total}} = \frac{\frac{2}{10}\omega^2 R^2 M}{\frac{2}{10}M\omega^2 R^2 + \frac{1}{2}M\omega^2 R^2} = \frac{2}{7} = 0.29 = 29\ \%$$

Q18.

Force $\vec{F} = (3\hat{i} + \hat{j})N$ is acting on a particle with position vector $\vec{r} = (2\hat{i} + 4\hat{j})m$. What is resulting torque on the particle about a point (x = 0 m, y = 6 m)?

- A) $8\hat{k}$ N.m
- B) $-8\hat{k}$ N.m
- C) $5\hat{k}$ N.m
- D) $-5\hat{k}$ N.m
- E) $3\hat{k}$ N.m

Ans:

$$\vec{\tau} = \vec{r} \times \vec{F} = (2-0)\hat{\imath} + (4-6)\hat{\jmath} = 2\hat{\imath} - 2\hat{\jmath}$$

$$\vec{\tau} = \vec{r} \times \vec{F} = (2\hat{\imath} - 2\hat{\jmath}) \times (3\hat{\imath} + \hat{\jmath}) = 8\hat{k}\ \mathrm{N.m}$$

Q19.

A point object with 1.40 kg mass and position (x = 2.00 m, y = 3.10 m) moves at 4.62 m/s at an angle 45.0° north of east. What is magnitude of the object's angular momentum about the origin.

- A) 5.00 kg.m^2/s
- B) 3.60 kg.m^2/s
- C) 6.00 kg.m^2/s
- D) 7.00 kg.m^2/s
- E) 2.90 kg.m^2/s

Ans:

$$\vec{L} = \vec{r} \times \vec{P}$$

$$= (2\hat{\imath} + 3.1\hat{\jmath}) \times (4.62\cos 45\ \hat{\imath} + 4.62\sin 45\ \hat{\jmath})$$

$$\vec{L} = -5\hat{k} \Rightarrow |\vec{L}| = 5\ \mathrm{kg.m^2/s}$$

Q20.

Two uniform spheres A and B of equal masses, attached to two ends of a massless rod, can rotate about a frictionless pivot at the point P in horizontal plane on a tabletop. **Figure 8** shows top view of the rotating system. The system is made to rotate clockwise on the tabletop with angular speed *ω*. Sphere A collides with and sticks to another sphere C (with equal mass) that is at rest on the tabletop. What is the angular speed of the system immediately after the collision?

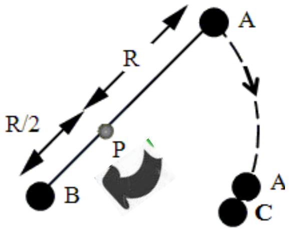


Figure 7

A) 0.56*ω*
B) 0.82*ω*
C) 0.60*ω*
D) *ω*
E) 0.29*ω*

Ans:

$$\vec{L}_{\text{before}} = \vec{L}_{\text{after}} \Rightarrow \left(mR^2 + m\frac{R^2}{4}\right)\omega = \left(2mR^2 + \frac{mR^2}{4}\right)\omega_f$$

$$\frac{\left(\frac{5}{4}\right)}{\left(\frac{9}{4}\right)} = \frac{\omega_f}{\omega} \Rightarrow \omega_f = 0.56\ \omega$$