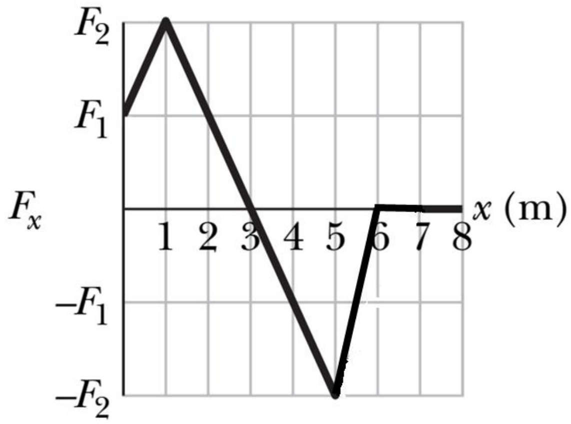
Q1.

Figure 1 gives the *x* component F_x of a single force that acts on a particle. If the particle begins at rest at *x* = 0, what is its coordinate when it has its greatest kinetic energy?

Figure 1



A) 3 m
B) 1 m
C) 6 m
D) 5 m
E) 8 m

Ans:

$\Delta K = K - 0 = K = W = xF_x = Area\ under\ the\ curve$

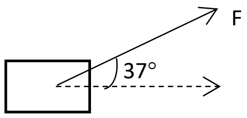
$Area\ is \max at\ x = 3\ m$

Q2.

A 100 kg block is pulled at a constant speed of 5.0 m/s across a horizontal floor by an applied force of 122 N directed 37° above the horizontal. What is the rate at which the force does work on the block?

A) 4.9×10^2 W
B) 3.7×10^2 W
C) 5.6×10^2 W
D) 1.8×10^3 W
E) 2.4×10^1 W

Ans:

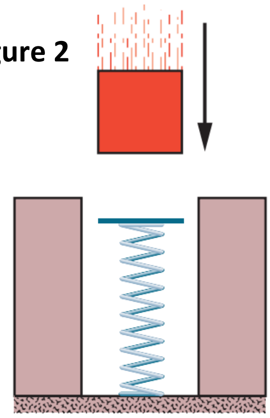


$$P = \frac{W}{t} = \frac{\vec{x}\cdot\vec{F}}{t} = v_x F cos\theta = 5 \times 122 \times cos37° = 4.9 \times 10^2\ W$$

Q3.

A 0.80 kg block is dropped onto a relaxed vertical spring that has a spring constant of k = 250 N/m as shown in **Figure 2**.The block compresses the spring 0.12 m before momentarily stopping. Find the maximum speed of the block just before it hits the spring. (Assume that friction and air resistance are negligible.)

Figure 2



A) 1.5 m/s
B) 2.1 m/s
C) 3.2 m/s
D) 4.6 m/s
E) 5.0 m/s

Ans:

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

$$\left(0 - \frac{1}{2}mv_0^2\right) + (0 - mgx) + \left(\frac{1}{2}kx^2 - 0\right) = 0$$

$$v_0 = \sqrt{\frac{kx^2}{m} - 2gx} = 1.5\, m/s$$

Q4.

A single force $\vec{F}$ acts on a 0.40-kg particle and changes its velocity from $\vec{\mathbf{v}}_i = \left(4.0\,\hat{\mathbf{i}} - 3.0\,\hat{\mathbf{j}}\right)$m/s at time t_i to $\vec{\mathbf{v}}_f = \left(5.0\,\hat{\mathbf{i}} + 3.0\,\hat{\mathbf{j}}\right)$ m/s at time t_f. What is the work done by $\vec{F}$ on the particle during this interval of time?

A) 1.8 J
B) 0.14 J
C) 1.2 J
D) zero
E) 5.0 J

Ans:

$$W_a = \Delta K = K - K_0 = \frac{1}{2}m(v^2 - v_0^2) = \frac{1}{2} \times 0.4(5^2 + 3^2 - 4^2 - 3^2) = 1.8 \text{ J}$$

Q5.

At time t = 0, a 1.0 kg ball is thrown from the top of a 100 m tall tower with initial velocity $\vec{\mathbf{v}}_0 = \left(16\,\hat{\mathbf{i}} + 24\,\hat{\mathbf{j}}\right)$ m/s. At what height from the ground will the kinetic energy of the ball be three times its initial kinetic energy? (Ignore the air resistance)?

A) 15 m
B) 10 m
C) 20 m
D) 25 m
E) 40 m

Ans:

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

$$U - U_0 + K - K_0 = 0$$

$$mgh - mg \times 100 + 3K_0 - K_0 = 0$$

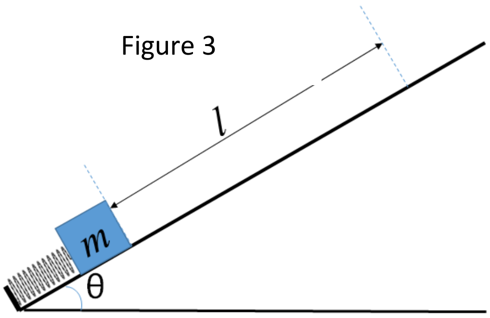
$$mgh - mg100 + 2 \times \frac{1}{2} m v_0^2 = 0$$

$$h = 100g - v_0^2 = 15\ m$$

Q6.

A block with mass m = 2.00 kg is placed against a spring on a rough incline with angle θ = 30.0° and coefficient of kinetic friction μ_k = 0.215 as shown in **Figure 3** (The block is not attached to the spring). The spring, which is compressed 20.0 cm from its relaxed position, is then released from rest and the block travels distance l = 1.20 m from the release point on the incline before coming to rest. Find the value of spring constant k of the spring.

Figure 3



A) 807 N/m
B) 578 N/m
C) 256 N/m
D) 980 N/m
E) 663 N/m

Ans:

$$\cancel{\Delta K}^{\,0} + \Delta U_g + \Delta U_s = W_f$$

$$U_g - U_{0g} + U_s - U_{0s} = -\mu_k F_N l$$

$$mgh - 0 + 0 - \frac{1}{2} k x^2 = -\mu_k mgcos\theta l$$

$$mglsin\theta - \frac{1}{2} k x^2 = -\mu_k mgcos\theta l \Rightarrow k = \frac{2mgl(sin\theta + \mu_k cos\theta)}{x^2} = 807\ N/m$$

Q7.

If only conservative forces are acting on a body then the work done by conservative forces

A) does not change the total mechanical energy.
B) does not change the potential energy.
C) does not change the kinetic energy.
D) is always equal to zero.
E) is always negative.

Ans:

A

Q8.

An 18-kg object is released from rest and moves vertically downward from a height of 80 m above the ground. It reaches the ground with a speed of 15 m/s. How much work was done by the non-conservative forces on the object?

A) – 12 kJ
B) – 16 kJ
C) + 12 kJ
D) + 16 kJ
E) – 14 kJ

Ans:

$$W_f = \Delta K + \Delta U_g = K - \cancelto{0}{K_0} + \cancelto{0}{U} - U_0$$

$$W_f = \frac{1}{2}mv^2 - mgh = m\left(\frac{1}{2}v^2 - gh\right) = -12k\,\mathrm{J}$$

Q9.

A stone is dropped at time t = 0. A second stone, with twice the mass of the first, is dropped from the same point at t = 0.10 s. How far below the release point is the center of mass of the two stones at t = 0.30 s? Ignore air resistance. (Both stones are dropped from rest and none of the stones has reached the ground.)

A) 0.28 m
B) 0.12 m
C) 0.45 m
D) 0.31 m
E) 0.63 m

Ans:

Stone 1

$$\Delta y_1 = \cancel{v_0 t_1}^{\,0} + \frac{1}{2}at_1^2$$

$$= \frac{1}{2}(-9.8) \times 0.3^2$$

$$\Delta y_1 = -0.491 \Longrightarrow y_1 = 0.441$$

Stone 2

$$\Delta y_2 = \frac{1}{2}at_2^2$$

$$= \frac{1}{2}(-9.8) \times 0.2^2$$

$$y_2 = 0.196$$

Stone 3

$$\frac{\mathrm{m_1y_1 + m_2y_2}}{\mathrm{m_1 + m_2}} = y_{com}$$

$$\frac{m\mathrm{y_1 + 2my_2}}{\mathrm{m + 2m}} = y_{com}$$

$$\frac{\mathrm{y_1 + 2y_2}}{3} = y_{com} \Rightarrow y_{com} = 0.28\ m$$

Q10.

A 2.4-kg ball that is falling vertically downward hits a horizontal floor with a speed of 2.5 m/s and rebounds with a speed of 1.5 m/s. What is the magnitude of the impulse exerted on the ball by the floor?

A) 9.6 N.s
B) 2.4 N.s
C) 3.5 N.s
D) 6.7 N.s
E) 7.1 N.s

Ans:

$$|J| = |\Delta p| = |p - p_0| = |-mv - mv_0| = 2.4(1.5 + 2.5) = 9.6\ \mathrm{N\cdot s}$$

Q11.

A cart, with mass 340 g and moving on a horizontal frictionless surface with an initial speed of 1.2 m/s, undergoes an elastic collision with an initially stationary cart of unknown mass. After the collision, the first cart continues in its original direction at 0.66 m/s. What is the mass of the second cart?

A) 0.099 kg
B) 0.061 kg
C) 0.036 kg
D) 0.018 kg
E) 0.075 kg

Ans:

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_1} v_{1i} + \cancelto{0}{\frac{2m_2}{m_1 + m_2}} v_{2t}$$

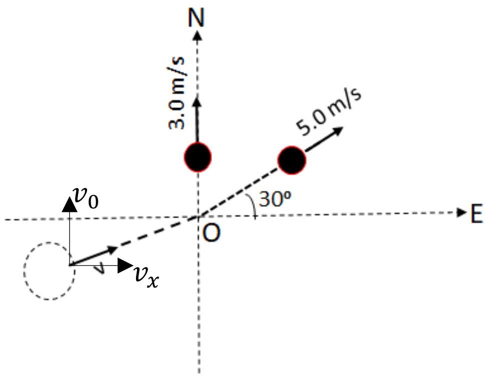
$$0.66 = \frac{0.34 - m_2}{0.34 + m_2} \times 1.2 \Longrightarrow 0.66 \times 0.34 + 0.66 \times m_2 = 0.34 \times 1.2 - 1.2m_2$$

$$\Longrightarrow m_2 = \frac{0.34 \times (1.2 - 0.66)}{(0.66 + 1.2)} = 0.099\ kg$$

Q12.

A 4.0 kg mass, moving with constant speed *v*, explodes at point O into two equal parts, as shown in **Figure 4**. The first part moves with speed 3.0 m/s due north, and the second part moves with speed 5.0 m/s, 30° north of east. Find the value of *v*.

Figure 4



A) 3.5 m/s
B) 8.0 m/s
C) 5.0 m/s
D) 2.0 m/s
E) 4.5 m/s

Ans:

East (x):

$$2mv_x = m \times 5cos30°$$

$$v_x = 2.5cos30°$$

North (y):

$$2mv_y = m \times 3 + m \times 5sin30°$$

$$v_y = 1.5 + 2.5sin30°$$

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{2.5^2cos^2 30° + (1.5 + 2.5sin30)^2} = 3.5\ m/s$$

Q13.

A rotating wheel requires 3.00 s to rotate through 37.0 revolutions. Its angular speed at the end of the 3.00 s interval is 98.0 rad/s. What is the constant angular acceleration of the wheel?

A) 13.7 rad/s^2
B) 10.5 rad/s^2
C) 11.2 rad/s^2
D) 17.1 rad/s^2
E) 29.3 rad/s^2

Ans:

$$\omega = \omega_0 + \alpha t$$

$$98 = \omega_0 + \alpha \times 3$$

$$\omega_0 = 98 - 3\alpha$$

$$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$37 = \omega_0 3 + \frac{1}{2}\alpha 9$$

$$37 \times 2\pi = 3\omega_0 + 4.5\alpha$$

$$232 = 3(98 - 3\alpha) + 4.5\alpha$$

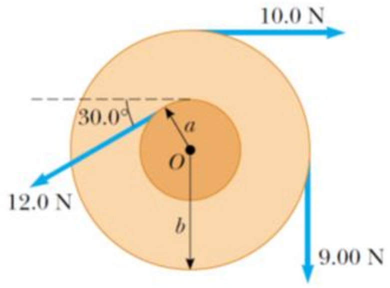
$$\Rightarrow \alpha = 13.7\ rad/s^2$$

Q14.

Find the net torque on the wheel in **Figure 5** about the axle through O if *a* = 10.0 cm and *b* = 25.0 cm.

A) – 3.55 N.m
B) – 1.27 N.m
C) +1.27 N.m
D) + 3.55 N.m
E) –7.16 N.m

Figure 5



Ans:

$$-10 \times b - 9 \times b + 12 \times a = \tau$$

$$-10 \times 0.25 - 9 \times 0.25 + 12 \times 0.1 = \tau$$

$$\tau = -3.55\ N.m$$

Q15.

A 32.0 kg wheel, essentially a thin hoop with radius 1.20 m, is rotating about its axis at 280 rev/min. It must be brought to a stop in 15.0 s. What is the magnitude of the required average power to stop it?

A) 1.32×10^3 W
B) 2.53×10^3 W
C) 6.14×10^3 W
D) 3.51×10^3 W
E) 4.96×10^3 W

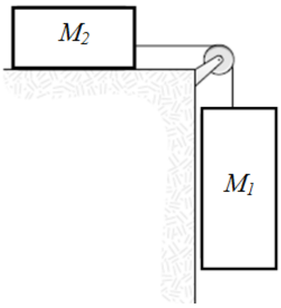
Ans:

$$\mathrm{P}_a = \frac{W_{av}}{t} = \frac{\Delta K}{t} = \frac{\frac{1}{2}I\omega^2}{t} = \frac{1}{2}\frac{MR^2\omega^2}{t} = \frac{32\times1.2^2(280\times2\pi/60)^2}{2\times15} = 1.3\times10^3 W$$

Q16.

A mass (M_1 = 5.0 kg) is connected by a massless cord to another mass (M_2 = 4.0 kg) which slides on a horizontal frictionless surface, as shown in **Figure 6**. The pulley (radius = 0.20 m) rotates about a frictionless axle. If the acceleration of M_2 is 3.5 m/s^2, what is the rotational inertia of the pulley?

Figure 6



A) 0.20 kg.m^2
B) 0.50 kg.m^2
C) 0.10 kg.m^2
D) 0.35 kg.m^2
E) 0.75 kg.m^2

Ans:

$$(\mathrm{T}_2-\mathrm{T}_1)R = I\alpha \quad --- (1)$$

$$\mathrm{T}_1 - m_1 g = -m_1 a$$

$$\mathrm{T}_2 = m_2 a$$

$$(\mathrm{T}_2-\mathrm{T}_1) = (m_2+m_1)a - m_1 g --- (2)$$

$$\text{solving } (1) and\ (2)$$

$$(m_2+m_1)aR - m_1 gR = I\,\frac{a}{R}$$

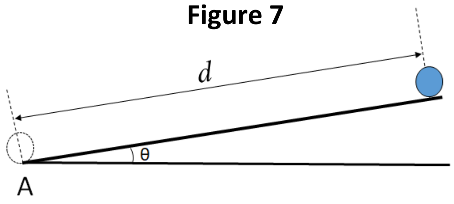
$$I = (m_1+m_2)R^2 - \frac{m_1 g R^2}{a}$$

$$I = 0.2\ kg\cdot m^2$$

Q17.

A uniform solid sphere of radius 0.10 m started to roll up without slipping with a center of mass speed of 2.0 m/s from the bottom of a ramp (point A in **Figure 7**) that is inclined at an angle θ = 10°. Find the maximum distance (*d*) travelled by the ball before it comes to rest.

Figure 7



A) 1.6 m
B) 2.8 m
C) 3.9 m
D) 4.1 m
E) 6.3 m

Ans:

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

$$\Delta K_R + \Delta K_T + +\Delta U_g = 0$$

$$\cancel{K_R}^{0} - K_{oR} + \cancel{K_T}^{0} - K_{oT} + U_g - \cancel{V_{og}}^{0} = 0$$

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

$$-\frac{1}{2}\frac{2}{5}mr^2\frac{v^2}{r^2} - \frac{1}{2}mv^2 + mgdsin\theta = 0$$

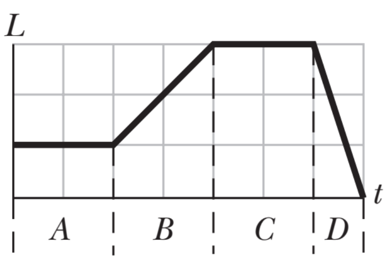
$$-\frac{7}{10}v^2 = -gdsin\theta = 0$$

$$d = \frac{7}{10}\frac{v^2}{gsin\theta} = 1.6\,m$$

Q18.

Figure 8 gives the angular momentum magnitude *L* of a wheel versus time *t*. Rank the four lettered time intervals according to the magnitude of the torque acting on the wheel, **greatest first**.

Figure 8



A) D, B, (A and C) tie
B) B, (A and C) tie, D
C) D, (A and C) tie, B
D) (A and C) tie, B , D
E) B, D, (A and C) tie

Ans:

$$|\tau| = \left|\frac{\Delta L}{\Delta t}\right| = magnitude\ of\ slope\ of\ L - t\ curve$$

Q19.

A 2.0 kg particle-like object moves in an *xy*-plane with velocity components $\boldsymbol{v_x}$ = 20 m/s and $\boldsymbol{v_y}$ = 60 m/s as it passes through the point with (*x*, *y*) coordinates of (3.0, – 4.0) m. At this time, what are the magnitude (in SI units) and direction of its angular momentum relative to the point located at (– 2.0, – 2.0) m?

A) $+680\,\hat{\mathbf{k}}$
B) $-680\,\hat{\mathbf{k}}$
C) Zero
D) $+540\,\hat{\mathbf{k}}$
E) $-540\,\hat{\mathbf{k}}$

Ans:

$$\vec{L} = \overrightarrow{\Delta r} \times \vec{P} = (\vec{r} - \vec{r}_0) \times m\vec{v}$$

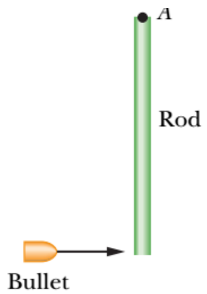
$$\vec{L} = (3i - 4j + 2i + 2j) \times 2(20i + 60j)$$

$$\vec{L} = 2(5i - 2j)(20i + 60j) = 2\left(300\hat{k} + 40\hat{k}\right) = 680\ \hat{k}$$

Q20.

A 50 g bullet is fired horizontally at one end of a 0.60 m long uniform rod of mass 0.50 kg, which is originally at rest and is pivoted at another end at point A in a vertical plane, as shown in **Figure 9**. If the angular speed of the system (bullet + rod assumed to stick together) about A just after impact is 4.5 rad/s, what is the bullet's speed just before impact?

Figure 9



A) 12 m/s
B) 10 m/s
C) 14 m/s
D) 17 m/s
E) 20 m/s

Ans:

$$m_b v_b L + 0 = (I_R + I_b)\omega$$

$$\omega = \frac{m_b v_b L}{I_R + I_b} = \frac{m_b v_b L}{\frac{1}{3}M_R L^2 + m_b L^2} = \frac{m_b v_b}{L\left(\frac{M_R}{3} + m_b\right)} = 12\ m/s$$