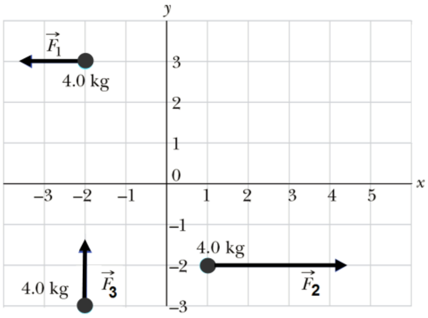
Q1.

The three particles in **Figure 1** are initially at rest. Each experiences an external force, with their directions as indicated, and the magnitudes are F_1 = 6.0 N, F_2 =14 N and F_3 = 6.0 N. In what direction θ does the center of mass move? The angle θ is measured counterclockwise from the + *x* axis.

A) 37°
B) 21°
C) 330°
D) 110°
E) 290°

Figure 1



Ans:

$$\left.\begin{aligned}\vec{F}_1 &= -6\hat{\imath}\\ \vec{F}_2 &= 14\hat{\imath}\\ \vec{F}_3 &= 6\hat{\jmath}\end{aligned}\right\}\begin{aligned}\vec{F}_{net} &= 8\hat{\imath} + 6\hat{\jmath}\\ M &= 12\text{ kg}\end{aligned}$$

$$\vec{a}_{com} = \frac{\vec{F}_{net}}{M} = \frac{2}{3}\,\hat{\imath} + \frac{1}{2}\,\hat{\jmath}$$

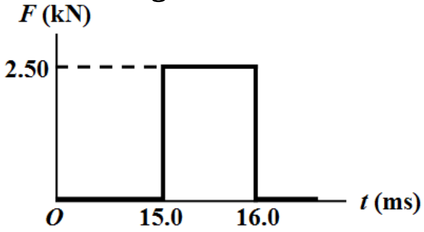
$$\tan\theta = \frac{a_y}{a_x} = \frac{1}{2} \div \frac{2}{3} = \frac{1}{2}\cdot\frac{3}{2} = \frac{3}{4}$$

$$\theta = 36.9°$$

Q2.

A 2.00-kg ball is initially sliding to the right on a frictionless surface with a speed of 4.00 m/s. It is suddenly struck by an object that exerts a large horizontal force directed to the left. The graph in **Figure 2** shows the variation of the magnitude of the force with time. What is the final velocity of the ball?

Figure 2



A) 2.75 m/s, to the right
B) 2.75 m/s, to the left
C) 1.25 m/s, to the left
D) 1.25 m/s, to the right
E) 5.25 m/s, to the left

Ans:

$$J = F\cdot\Delta t = 2.50 \times 10^3 \times 1.0 \times 10^{-3} = 2.50\ (N\cdot s)$$

$$\Delta p = -2.5\ (N.s)$$

$$\Delta p = p_f - p_i$$

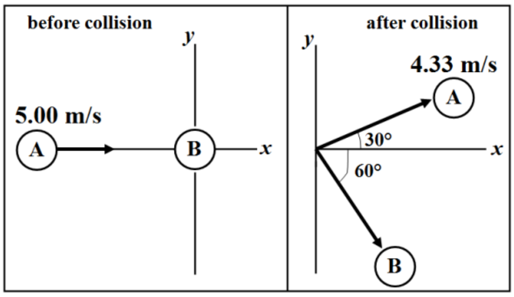
$$p_f = \Delta p + p_i = -2.5 + 8.0 = +5.5\ \ N\cdot s$$

$$v_f = \frac{p_f}{m} = +\frac{5.5}{2} = +2.75\ m/s$$

Q3.

Ball (A), of mass 0.300 kg, initially moving at 5.00 m/s strikes a stationary ball (B) of the same mass initially at the origin. Just after the collision, ball A moves at 4.33 m/s, at an angle of 30.0° with respect to the original line of motion, and ball B moves along a line that makes an angle of 60.0° with respect to the original line of motion of A (See **Figure 3**). What is the kinetic energy of ball B just after the collision?

Figure 3



A) 0.937 J
B) 2.81 J
C) 1.88 J
D) 0.372 J
E) 0.173 J

Ans:

Consider the y − comp:

$$\not{m} \times 4.33 \times \sin 30° = \not{m} \times v_{2f} \times \sin 60°$$

$$v_{2f} = \frac{\sin 30}{\sin 60} \times 4.33 = 2.5\ m/s$$

$$K_{2f} = \frac{1}{2} m v_{2f}^2 = \frac{1}{2} \times 0.3 \times 2.5^2 = 0.937\ \text{J}$$

Q4.

An initially stationary object is located at the origin. It suddenly explodes into two pieces. Piece A, of mass m_A, travels off to the right with speed v_A. Piece B of mass m_B, travels off to the left with speed v_B. The ratio of the kinetic energies K_A/K_B is:

A) m_B/m_A
B) m_A/m_B
C) 1
D) ½
E) 2

Ans:

$$m_A v_A = m_B v_B \rightarrow v_B = \frac{m_A}{m_B} v_A$$

$$K_A = \frac{1}{2} m_A v_A^2$$

$$K_B = \frac{1}{2} m_B \cdot v_B^2 = \frac{1}{2} m_B \cdot \frac{m_A^2 v_A^2}{m_B^2} = \frac{1}{2} \frac{m_A^2 v_A^2}{m_B}$$

$$\frac{K_A}{K_B} = \frac{m_A v_A^2}{2} \cdot \frac{2 m_B}{m_A^2 v_A^2} = \frac{m_B}{m_A}$$

Q5.

If a wheel turns with constant angular speed about a fixed axis then:

A) the wheel turns through equal angles in equal time intervals
B) each point on its rim moves with constant velocity
C) each point on its rim moves with constant acceleration
D) the angle through which the wheel turns in each second increases as time goes on
E) the angle through which the wheel turns in each second decreases as time goes on

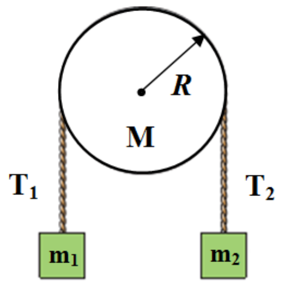
Ans:

$$\omega = \frac{\Delta\theta}{\Delta t};\ \Delta\theta = \omega \cdot \Delta t$$

Q6.

In **Figure 4**, block 1 has mass m_1 and block 2 has mass m_2. The pulley is in the shape of a solid cylinder, has radius R = 5.0 cm and mass M = 1.0 kg, and is mounted on a horizontal frictionless axle. When released from rest, block 2 falls 75 cm in 5.0 s without the cord slipping on the pulley. What is the magnitude of the net torque on the pulley?

Figure 4



A) 1.5×10^{-3} N.m
B) 3.8×10^{-3} N.m
C) 3.0×10^{-3} N.m
D) 7.6×10^{-3} N.m
E) 4.3×10^{-3} N.m

Ans:

$$\text{Consider } m_2:\ Y = \frac{1}{2}at^2 \rightarrow a = \frac{2y}{t^2} = \frac{2\times0.75}{25} = 0.06\ m/s^2$$

$$a = \frac{2y}{t^2} = \frac{2\times0.75}{25} = 0.06\ m/s^2$$

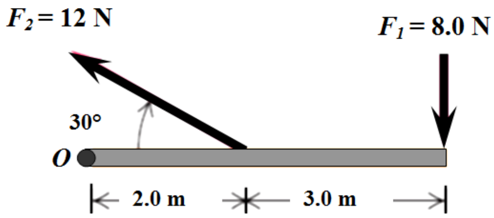
$$\alpha = \frac{a}{R} = \frac{0.06}{0.05} = 1.2\ rad/s^2$$

$$\tau_{net} = I\alpha = \frac{1}{2}MR^2\cdot\alpha = \frac{1}{2}\times1\times25\times10^{-4}\times1.2 = 1.5\times10^{-3}\ N\cdot m$$

Q7.

A rod is pivoted at point O and is free to rotate in a horizontal plane, as shown in **Figure 5**. Calculate the net torque on the rod about point O due to the two forces applied to the rod as shown in the figure. The rod and both forces are in the plane of the page.

Figure 5



A) 28 N.m, clockwise
B) 28 N.m, counterclockwise
C) 52 N.m, counterclockwise
D) 52 N.m, clockwise
E) 40 N.m, clockwise

Ans:

$$\tau_1 = 8 \times 5 = 40 \text{ N} \cdot \text{m} \qquad \text{Clockwise}$$

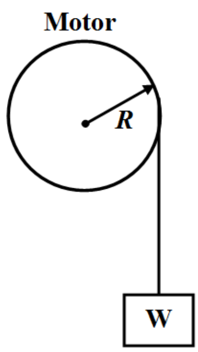
$$\tau_2 = 12 \times 2 \times \frac{1}{2} = 12 \text{ N} \cdot \text{m} \qquad \text{Counterclockwise}$$

$$\tau_{net} = 40 - 12 = 28 \cdot \text{N} \cdot \text{m} \qquad \text{Clockwise}$$

Q8.

A motor, in the shape of a disk of radius R = 0.2000 m, is used to lift a weight W, as shown in **Figure 6**. The motor is rotating about a frictionless axle with a constant angular speed of 420.0 rad/s, and its power output is 150.0 kW. What weight can the motor lift at constant speed?

Figure 6



A) 1786 N
B) 1023 N
C) 4192 N
D) 3104 N
E) 2527 N

Ans:

$$P = \tau \cdot \omega$$

$$\tau = RW$$

$$P = RW\omega$$

$$W = \frac{P}{R\omega} = \frac{150 \times 10^3}{0.2 \times 420} = 1786\ N$$

Q9.

A uniform solid ball, of mass 4.0 kg, rolls smoothly along a horizontal floor at a linear speed of 4.0 m/s. What is its total kinetic energy?

A) 45 J
B) 32 J
C) 13 J
D) 64 J
E) 39 J

Ans:

$$K_t = \frac{1}{2} M v^2 = 0.5\, M v^2$$

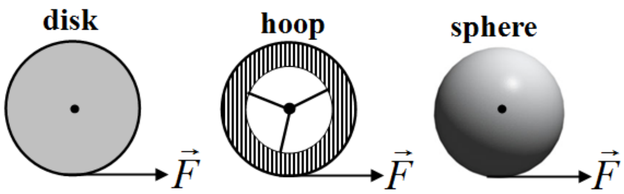
$$K_r = \frac{1}{2} I \omega^2 = \frac{1}{2} \cdot \frac{2}{5}\, M R^2 \cdot \frac{V^2}{R^2} = 0.2\, M v^2$$

$$K = K_t + K_r = 0.7\, M v^2 = 0.7 \times 4.0 \times 16 = 44.8 \text{ J} \cong 45 \text{ J}$$

Q10.

A uniform disk, a thin hoop, and a uniform sphere, all with the same mass and same outer radius, are each free to rotate about a fixed axis through their centers. With the objects starting from rest, **identical** forces are simultaneously applied to the rims, as shown in **Figure 7**. Rank the objects according to their angular momenta after a given time *t*, least to greatest.

Figure 7



A) all tie
B) disk, hoop, sphere
C) hoop, disk, sphere
D) hoop, sphere, disk
E) disk, sphere, hoop

Ans:

$\tau = R \cdot F \rightarrow$ same for all

$$\tau = \frac{\Delta L}{\Delta t}$$

$$\Delta L = \tau \cdot \Delta t$$

$L = \tau \cdot t \longrightarrow$ same for all

Q11.

A 2.00-kg particle-like object moves in a plane with velocity components v_x = 15.0 m/s and v_y = 12.0 m/s as it passes through the point with (x, y) coordinates of (4.00, –5.00) m. At that instant, what is the angular momentum of the object about the origin (in units of kg.m^2/s)?

A) $246\,\hat{k}$
B) $-246\,\hat{k}$
C) Zero
D) $54.0\,\hat{k}$
E) $-54.0\,\hat{k}$

Ans:

$\vec{r} = 4\hat{\imath} - 5\hat{\jmath}\ (m)$

$\vec{v} = 15\hat{\imath} + 12\hat{\jmath}\ (m/s)$

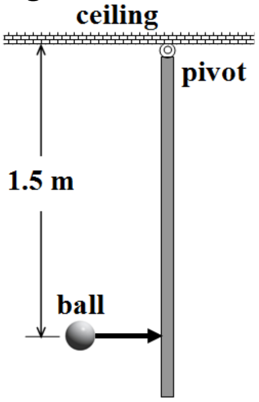
$\vec{r} \times \vec{v} = 48\,\hat{k} + 75\,\hat{k} = 123\,\hat{k}$

$\vec{l} = \vec{r} \times \vec{p} = \vec{r} \times (m\vec{v}) = m\,(\vec{r} \times \vec{v}) = 246\,\hat{k}$

Q12.

A thin, uniform metal rod, of length 2.0 m, is hanging vertically from the ceiling by a frictionless pivot, as shown in **Figure 8**. Its rotational inertia about the pivot is 4.0 kg.m^2. It is struck 1.5 m below the ceiling by a small 0.050 kg ball, initially travelling horizontally at 10 m/s. The ball rebounds in the opposite direction with a speed of 5.0 m/s. Find the angular speed of the rod just after the collision.

Figure 8



A) 0.28 rad/s
B) 0.34 rad/s
C) 0.45 rad/s
D) 0.057 rad/s
E) 0.31 rad/s

Ans:

$\vec{l}_{ib} = (mrv)\,\hat{k} = 0.05 \times 1.5 \times 10\,\hat{k} = 0.75\,\hat{k}$

$\vec{l}_{fb} = -0.05 \times 1.5 \times 5\,\hat{k} = -0.375\,\hat{k}$

$\vec{l}_{fr} = I\omega\hat{k}$

$\vec{L}_f = \vec{L}_i : 0.75\,\hat{k} = I\omega\hat{k} - 0.375\hat{k}$

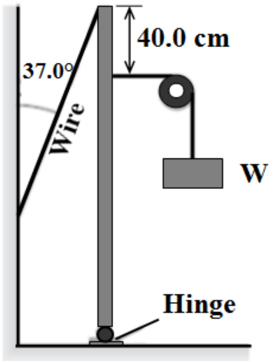
$I\omega = 0.75 + 0.375 = 1.125$

$\Rightarrow \omega = \dfrac{1.125}{4} = 0.281 \quad rad/s$

Q13.

A weight W = 100 N is supported by attaching it to a vertical uniform metal rod by a thin cord passing over a massless frictionless pulley, as shown in **Figure 9**. The cord is attached to the rod 40.0 cm below the top of the rod. The rod has a length of 1.70 m and its top is connected by a thin wire to a vertical wall. If the system is in equilibrium, what is the magnitude of the tension in the wire?

Figure 9



A) 127 N
B) 95.8 N
C) 39.1 N
D) 29.5 N
E) 166 N

Ans:

$\sum \tau_0 = 0$: where point O is the hinge

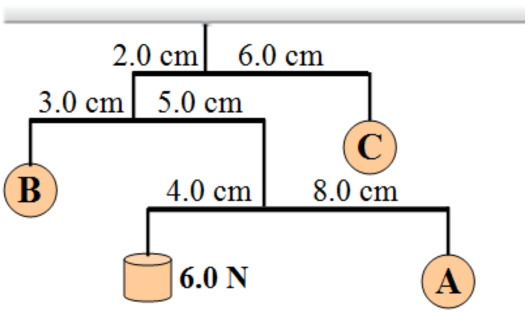
$W \times 1.3 = T \times 1.7 \times \sin 37°$

$\Rightarrow T = 127\ N$

Q14.

Consider the assembly shown in **Figure 10**, where four objects are held in equilibrium by horizontal massless rods. What is the weight of ball C?

Figure 10



A) 8.0 N
B) 3.0 N
C) 15 N
D) 9.0 N
E) 18 N

Ans:

$$6 \times 4 = 8\,A \longrightarrow A = \frac{24}{8} = 3\ N$$

$$5 \times 9 = 3\,B \longrightarrow B = \frac{45}{3} = 15\ N$$

$$2 \times 24 = 6\,C \longrightarrow C = \frac{48}{6} = 8\ N$$

Q15.

A wire has a length of 2 m, a cross sectional area of 0.01 cm^2, and is made of a material whose Young modulus is 5×10^{10} N/m^2. A force of 50 N is applied perpendicular to the cross section of the wire. What is the change in the length of the wire?

A) 2 mm
B) 3 mm
C) 1 mm
D) 4 mm
E) 5 mm

Ans:

$$\frac{F}{A} = E \cdot \frac{\Delta L}{L}$$

$$\Delta L = \frac{F \cdot L}{E \cdot A} = \frac{50 \times 2}{5 \times 10^{10} \times 0.01 \times 10^{-4}} = 2 \times 10^{-3}\ m$$