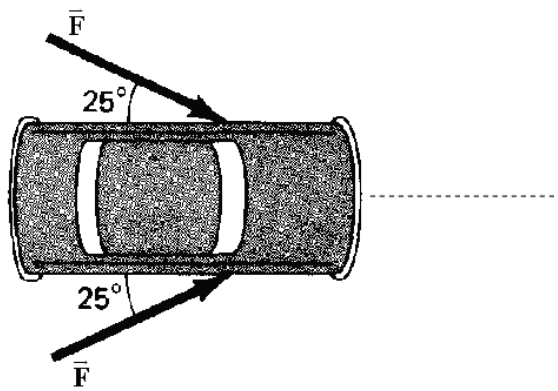
Q1. Two persons pushed a car initially at rest at its front doors, each applying a force with magnitude $|\vec{F}| = 300$ N at 25.0° to the forward direction, as shown in **Figure 1**. How much average power does **each person** requires in pushing the car 10.0 m for 10.0 seconds?
Fig#



Answer:

$$W = 300 \times 10 \times \cos 25^o = 2719$$

$$P = W / t = \frac{300 \times 10 \times \cos 25^o}{10} = 271.8 \text{ W} \approx 272 \text{ W}$$

A) 272 W
B) 145 W
C) 710 W
D) 424 W
E) 299 W

Q2. A spring has a spring constant k . If the work done in stretching the spring a distance $x = L$ from the equilibrium position is *W*, the work required to stretch the spring from $x_i = L$ to $x_f = 2L$ will be:

Answer:

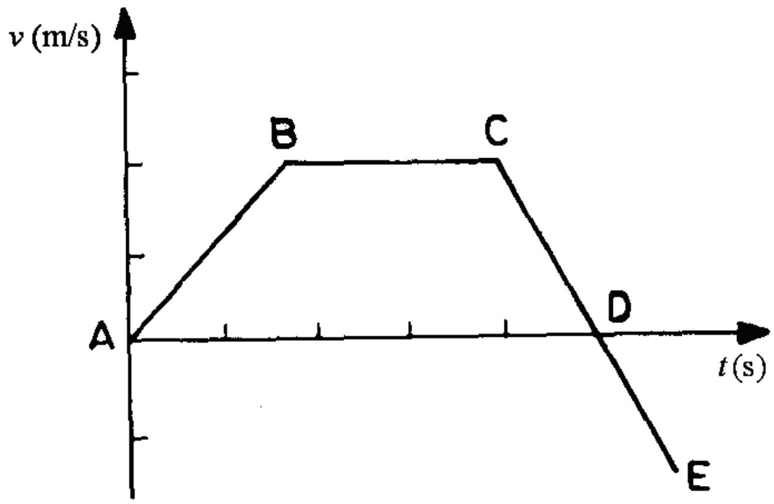
$$W = \frac{1}{2} k (L^2 - 0) = \frac{1}{2} k L^2$$

$$W_1 = \frac{1}{2} k \left[(2L)^2 - L^2 \right] = 3W$$

A) 3 *W*
B) 5 *W*
C) 4 *W*
D) 2 *W*
E) 1 *W*

Q3. A single force acts on the body causing the body to move in a straight line. A plot of the body's velocity v (m/s) versus time t (s) is shown in the Fig 2. The **correct** statement among the following is:

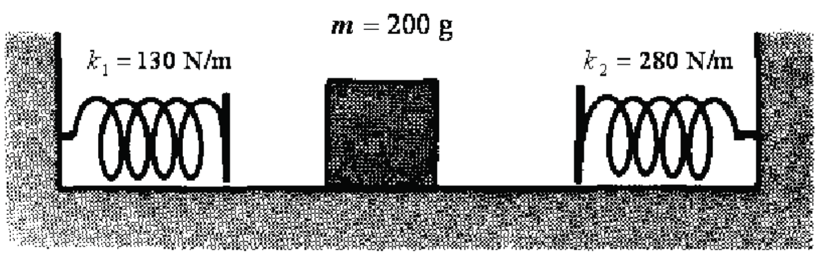
Fig#



A) in moving from D to E, the work done by the force on the body is positive.
B) in moving from B to C no work is done on the body but the body does work on the system.
C) in moving from C to D, the work done by the force on the body is positive.
D) in moving from A to B, the work done by the force on the body is negative.
E) in moving from A to D, the work done by the force on the body is positive.

Q4. A block, of mass $m = 200$ g, slides back and forth on a **frictionless surface** between two springs, as shown in **Figure 3**. The left-hand side spring has $k_1 = 130$ N/m and its maximum compression is 16 cm. The right-hand side spring has $k_2 = 280$ N/m. Find the maximum compression of the right-hand side spring.

Fig#



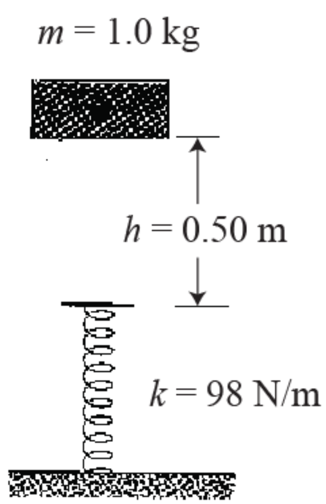
Answer:

$$\frac{1}{2}k_1x_1^2 = \frac{1}{2}k_2x_2^2 \quad \Rightarrow \quad \frac{x_2^2}{x_1^2} = \frac{k_1}{k_2}$$

$$\Rightarrow \quad x_2 = \sqrt{\left(\frac{k_1}{k_2}\right)x_1^2} = \sqrt{\left\{\frac{130}{280}\right\}(16)^2} = 10.9 \text{ cm.}$$

A) 11 cm.
B) 14 cm.
C) 2.0 cm.
D) 30 cm.
E) 8.0 cm.

Q5. A block, of mass $m = 1.0$ kg, initially at rest, falls from a height of h = 0.50 m, on a vertical spring fastened to a horizontal board placed on the floor, as shown in **Figure 4**. If the spring constant is $k = 98$ N/m, the maximum compression that the spring undergoes is:
Fig#



Answer:

$$mgh = mg(-x) + \frac{1}{2}kx^2$$

$$\Rightarrow \quad 1.0g(0.5) = 1.0g(-x) + \frac{1}{2}(98)x^2 \quad \Rightarrow \quad 1 = -2x + 10x^2$$

$$x = 0.43 \text{ m}$$

A) 0.43 m
B) 0.17 m
C) 0.34 m
D) 0.86 m
E) 0.54 m

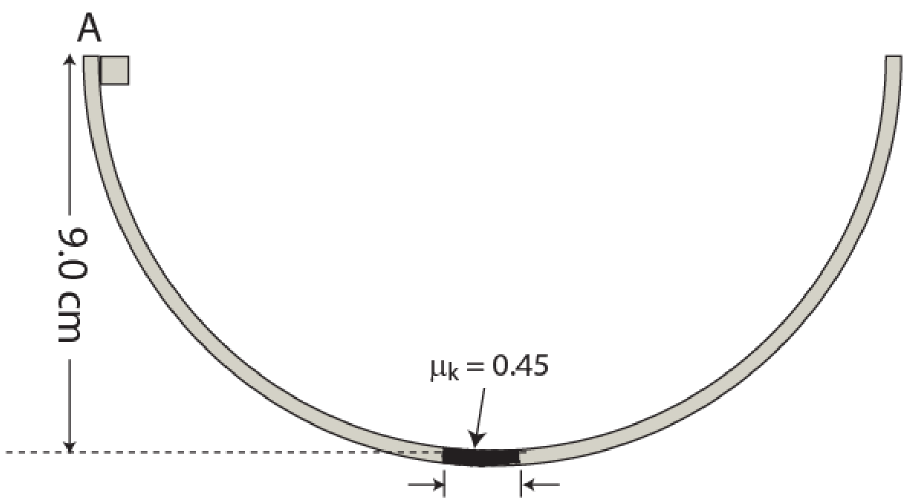
Q6. A single force F, of magnitude 10.0 N, accelerates an object of mass 5.00 kg for three seconds starting from rest at t = 0. What is the work done on the object in the time interval from t = 2.00 sec to t = 3.00 sec.

Answer:

$$d_3 - d_2 = \tfrac{1}{2} a\left(3^2 - 2^2\right) = 0 + \tfrac{1}{2}\tfrac{10}{5} 5 = 5.00$$
$$\Rightarrow \quad W = Fd = 10.0 \times 5.00 = 50.0 \text{ J}$$

A) 50.0 J.
B) 40.0 J.
C) 20.0 J.
D) 10.0 J.
E) 25.0 J.

Q7. A block slides back and forth in a hemispherical bowl, starting from rest at the top point A, as shown in **Figure 5**. The bowl is frictionless except for a 2.0 cm-wide rough flat surface at the bottom, where coefficient of kinetic friction is $\mu_k = 0.45$. How many times does the block cross the rough region before coming to rest?
Fig#

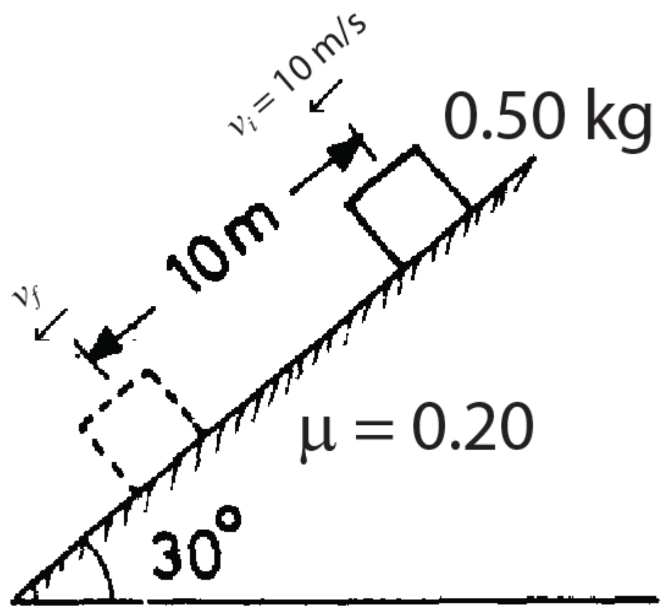


Answer:

$$mgh = N\,\mu mgd \quad \Rightarrow \quad N = \frac{h}{\mu d} = \frac{9}{0.45 \times 2.0} = 10 \text{ times}$$

A) 10 times.
B) 14 times.
C) 13 times.
D) 3 times.
E) 4 times.

Q8. **Figure 6** shows a block, of mass $m = 0.50$ kg with an initial speed of $v_i = 10$ m/s, moving down an inclined rough plane of angle 30°. The coefficient of kinetic friction between the block and the plane is $\mu = 0.20$. The speed, v_f, of the block after it travels a distance of 10 m is:
Fig#



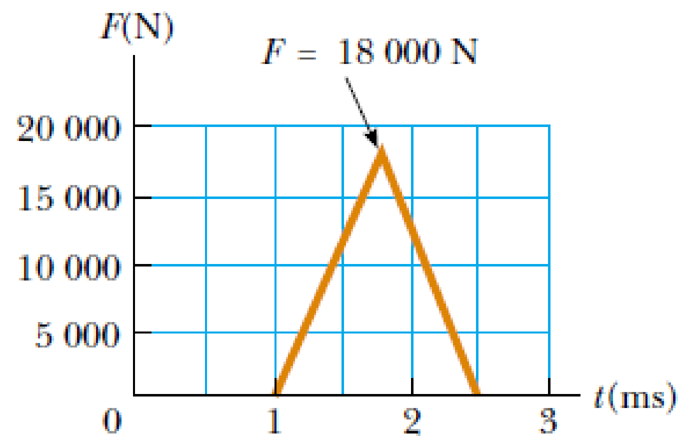
Answer:

$$\frac{1}{2}m\left(v_f^2 - 10^2\right) = \left(mg\sin 30^\circ - \mu mg\cos 30^\circ\right)d = mg\left(\sin 30^\circ - \mu\cos 30^\circ\right)10$$

$$\Rightarrow\ v_f^2 = 100 + 64.1 \qquad \Rightarrow\ v_f = \sqrt{164.1} = 12.8 \text{ m/s}$$

A) 13 m/s
B) 24 m/s
C) 8 m/s
D) 17 m/s
E) 36 m/s

Q9. A force $F(t)$ (pointing in the + x-direction) acts on a ball with mass m = 0.060 kg initially at rest at $t = 1.00$ ms. **Figure 7** shows a plot of $F(t)$ vs t. Find the speed of the ball at t = 2.50 ms.
Fig#



Answer:

$$p = \int F dt = \frac{1}{2} F dt$$

$$\Rightarrow \quad v_f = \frac{1}{2}\frac{Fdt}{m} = \frac{1}{2}\frac{18000 \times (2.5-1) \times 10^{-3}}{0.06} = 225 \text{ m/s}$$

A) 225 m/s
B) 375 m/s
C) 400 m/s
D) 153 m/s
E) 642 m/s

Q10. A system consists of two particles m_1 and m_2, where the mass of m_2 = 0.10 kg. At t = 0 s, the particle m_1 was at $x_1 = 0.0$ m and has a velocity $\vec{v}_1$, and the other particle m_2 was at rest at $x_2 = 8.0$ m. At t = 0 s, the center of mass of the system was at x_{com} = 2.0 m, and has a velocity of $\vec{v}_{com} = 5.0\,\hat{i}$ m/s. What was the velocity $\vec{v}_1$?

Answer:
All the velocities are in x-direction
Location of the center of mass system implies:

$$m_1 x_1 + m_2 x_2 = (m_1 + m_2) x_{cm} \quad \Rightarrow \quad 0 + 8 \times 1 = (m_1 + m_2) 2 \qquad (1)$$

Velocity of the center of mass system implies

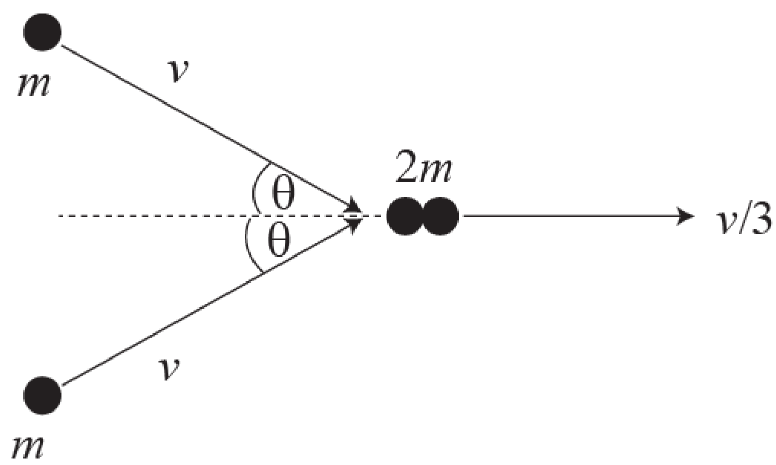
$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_{cm} \quad \Rightarrow \quad m_1 v_1 = (m_1 + m_2) 5 \qquad (2)$$

From (1) and (2) one finds:

$$m_1 = 0.3 \text{ kg}, \quad \vec{v}_1 = 6.7\ \hat{i} \text{ m/s}$$

A) $\vec{v}_1 = 6.7\ \hat{i}$ m/s
B) $\vec{v}_1 = 2.7\ \hat{i}$ m/s
C) $\vec{v}_1 = 1.8\ \hat{i}$ m/s
D) $\vec{v}_1 = 3.4\ \hat{j}$ m/s
E) $\vec{v}_1 = 9.2\ \hat{i}$ m/s

Q11. After a completely inelastic collision between two objects of equal mass *m*, each having an initial speed *v*, the two move off together with a speed *v*/3, see **Figure 8**. What was the angle (2θ) between their initial velocities?
Fig#



Answer:

Conservation of momentum implies:

$$mv\cos\left(\frac{\theta}{2}\right) + mv\cos\left(\frac{\theta}{2}\right) = 2m\left(\frac{v}{3}\right)$$

$$\Rightarrow \theta = 2\cos^{-1}\left(\frac{1}{3}\right) = 141^\circ$$

A) 141°
B) 134°
C) 102°
D) 163°
E) 127°

Q12. A ball of mass m_1 makes a head on elastic collision with second ball, of mass m_2, initially at rest. If m_1 rebounds in the opposite direction with a speed equal to one-fourth its original speed, what is the mass m_2?

Answer:
Conservation of momentum implies:

$$m_1 v_1 + 0 = m_1\left(\frac{-v_1}{4}\right) + m_2\left(\frac{3v_1}{4}\right)$$

$$\Rightarrow m_1(1+\frac{1}{4}) = \frac{3}{4}m_2 \Rightarrow \boxed{m_2 = \frac{5}{3}m_1}$$

A) $\frac{5}{3}m_1$
B) $\frac{1}{2}m_1$
C) $\frac{1}{3}m_1$
D) $\frac{3}{4}m_1$
E) $\frac{7}{2}m_1$

Q13. A uniform disk of 1.0 m radius is rotating about its symmetry axis with a constant angular speed of 2.0 rad/s. What are the magnitude of the tangential acceleration a_t and centripetal acceleration a_r of a point on the rim of the disk?

Answer:

$$\omega = 2 \text{ rad/s}, \ \text{r} = 1 \text{ m},$$

$$a_r = \frac{v^2}{2} = r\omega^2 = 1\times 2^2 = 4 \text{ m/s}^2,$$

$$a_t = \frac{d\omega}{dt} = 0$$

A) a_t = 0.0 m/s^2 , a_r = 4.0 m/s^2
B) a_t = 1.0 m/s^2 , a_r = 2.0 m/s^2
C) a_t = 0.0 m/s^2 , a_r = 1.0 m/s^2
D) a_t = 2.0 m/s^2 , a_r = 4.0 m/s^2
E) a_t = 4.0 m/s^2 , a_r = 0.0 m/s^2

Q14. A disk, subjected to a constant net torque, rotates around a fixed axis starting from rest. The ratio of work done by the torque during the (0 – 5.0 s) interval to the work done during the (5.0 s-10 s) interval is:

Answer:

$$W = \tau\,\Delta\theta \Rightarrow \frac{W_1}{W_2} = \frac{\Delta\theta_1}{\Delta\theta_2}$$

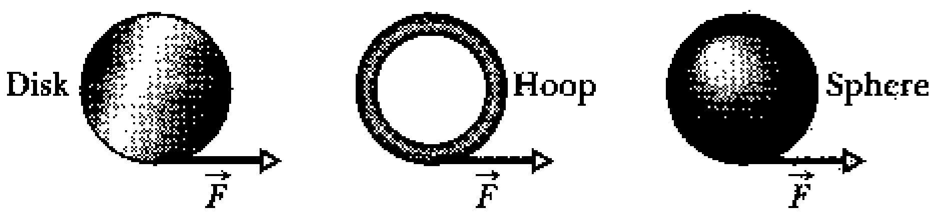
$$\Delta\theta_1 = 0 + 1/2\,\alpha(5)^2 \quad \text{and } \Delta\theta_1 + \Delta\theta_2 = 0 + 1/2\,\alpha(10)^2$$

$$\frac{W_1}{W_2} = \frac{\Delta\theta_1}{\Delta\theta_2} = \frac{25}{75} = \frac{1}{3}$$

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

Q15. A uniform disk, a thin hoop, and a uniform solid sphere, all with the same mass and same outer radius, are each free to rotate about a fixed axis through their centers. Identical forces are simultaneously applied to the rims of the objects, as shown in **Figure 9**. If the objects start from rest, rank the objects according to their angular speeds achieved after a given time (*t* sec), **least to greatest**.

Fig#



A) hoop, disk, sphere
B) All tie.
C) hoop, sphere, disk
D) disk, hoop, sphere
E) sphere, disk, hoop

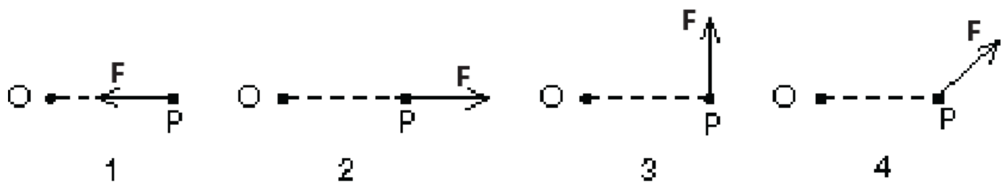
Q16. An engine applies a constant torque of 5.00 N·m on a wheel, with moment of inertia I_o = 10.0 kg.m^2, to rotate it about its symmetry axis O. How much power is required by the engine to rotate the wheel at $t = 5.00$ s, if the wheel starts from rest?

Answer:

$$P_{av} = \vec{\tau} \cdot \vec{\omega}. = \tau \alpha t = \frac{\tau^2 t}{I} = \frac{5^2 \times 5}{10} = 12.5 \text{ W.}$$

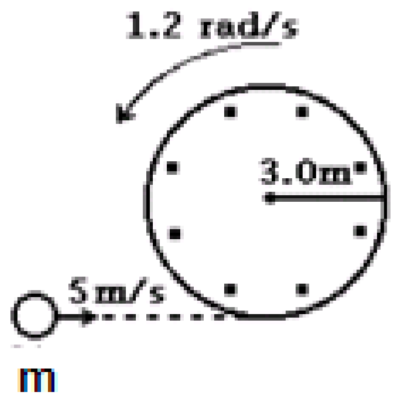
A) 12.5 W
B) 3.06 W
C) 6.20 W
D) 2.53 W
E) 1.62 W

Q17. A single force **F** acts on a particle P. Rank each of the orientations of the force shown in **Figure 10** according to the magnitude of the time rate of change of the particle's angular momentum about the point O, **least to greatest**.
Fig#



A) 1 and 2 tie, then 4, 3
B) 1, 2, 3, 4
C) 1 and 2 tie, then 3, 4
D) 1 and 2 tie, then 3 and 4 tie
E) All are the same

Q18. A disk with radius of 3.0 m and a moment of inertia of 8000 kg·m^2 is rotating about its central axis without friction with an angular velocity of 1.2 rad/s. Initially a man with mass **m** is moving with a velocity of 5.0 m/s, on a line tangent to the edge of the disk, as shown in **Figure 11**. The man jumps onto the edge of the disk. The final angular velocity of the disk and the man is 1.24 rad/s. The mass of the man **m** is:
Fig#



Answer:
Conservation of angular momentum implies:

$$I_1\omega_1 + mvr = I_1\omega_1' + mr^2\omega$$

$$\Rightarrow I_1(\underbrace{1.2-1.24}_{-0.04}) = m_1\left(r^2\omega - vr\right) = m(3)(3\times1.24-5) = 3m(-1.28)$$

$$\Rightarrow m = \frac{8000\times0.04}{3\times1.28} = 83.3 \text{ kg}$$

A) 83 kg
B) 61 kg
C) 75 kg
D) 53 kg
E) 94 kg

Q19. A disk starts from rest and rotates with a constant angular acceleration. If the angular velocity is ω rad/s at the end of the first two revolutions, then at the end of the first eight revolutions, the angular velocity will be:

Answer:

$$\omega^2 = \omega_0^2 + 2\alpha\,\Delta\theta$$

$$\omega_2^2 = 0 + 2\alpha\left(2\times2\pi\right) \text{ and } \omega_8^2 = 0 + 2\alpha\left(8\times2\pi\right)$$

$$\frac{\omega_2^2}{\omega_8^2} = \frac{2}{8} \quad\Rightarrow\quad \frac{\omega_2}{\omega_8} = \frac{1}{2} \quad\Rightarrow\quad \omega_8 = 2\omega_2 = 2\omega \text{ rad/s}$$

A) 2 ω rad/s
B) $\sqrt{2}$ ω rad/s
C) 3 ω rad/s

D) 4 ω rad/s
E) 5 ω rad/s

Q20. A hoop rolls without sliding along a horizontal floor. The ratio of its translational kinetic energy to its rotational kinetic energy (about an axis through its center of mass) is:

Answer:

$$K_r = \frac{1}{2} I\omega^2, K_t = \frac{1}{2}mv^2 = \frac{1}{2}mr^2\frac{v^2}{r^2} = \frac{1}{2}I\omega^2$$

$$\Rightarrow \quad \frac{K_t}{K_r} = 1.$$

A) 1
B) 2
C) 3
D) 1/2
E) 1/3