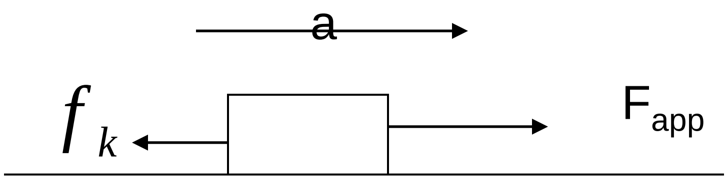
Solutions to
Exam II
Term 052

1. A horizontal force (F) is applied on a 100-kg box. The box accelerates along the positive x direction with constant acceleration of 1.0 m/s^2. If the coefficient of kinetic friction is 0.50 between the box and the surface then the work done by F as the box moves 100 m is:

A) 5.9×10^4 J
B) 2.5×10^4 J
C) 3.8×10^4 J
D) 1.0×10^4 J
E) -3.8×10^4 J



$$ma = F - \mu_k mg$$

$$F = m(a + \mu_k g) = 100(1.0 + 0.50 \times 9.8) = 590\ N$$

$$W = Fd = 590 \times 100 = 5.9 \times 10^4\ J$$

2. An object of mass 1.0 kg is whirled in a horizontal circle of radius 0.50 m at a constant speed of 2.0 m/s. The work done on the object during one revolution is:

A) 0 J
B) 12 J
C) -320 J
D) 320 J
E) 8.0 J

centripetal is not doing work

3. A boy holds a 40-N weight at arm's length for 10 s. His arm is 1.5 m above the ground. The work done by the force of the boy on the weight while he is holding it is:

A) 120 J
B) 40 J
C) 20 J
D) 0 J
E) 10 J

no distance traveled no work

4. A 40-N force is the only force applied on a 2.0-kg crate which is originally at rest. At the instant the object has traveled 2.5 m, the rate at which the force is doing work is:

A) 500 W
B) 300 W
C) 400 W
D) 25 W
E) 75 W

$$a = \frac{40}{2.0} = 20\ m/s$$

$$v^2 = v^2_0 + 2ad \Rightarrow v^2 = 2ad$$

$$v = \sqrt{2ad} = \sqrt{2 \times 20 \times 2.5} = 10 m/s$$

$$P_{ave} = Fv = 40 \times 10 = 400\ W$$

5. A 4.0 kg block starts up a 30° incline with 128 J of kinetic energy. How far will it slide up the incline if the coefficient of kinetic friction between the block and the incline is 0.50?

A) 5.5 m
B) 1.5 m
C) 2.5 m
D) 4.5 m
E) 3.5 m

$$\Delta E = -E_{th} = -f_k d$$

$$E_f - E_i = -\mu_k mgd\cos 30^o$$

$$E_i = K_i + U_i = 128 + 0 = 128\ J$$

$$E_f = K_f + U_f = 0 + mgd\sin 30^o$$

$$mgd\sin 30^o - 128 = -\mu_k mgd\cos 30^o$$

$$find\ d$$

6. A ball of mass 2.0-kg is kicked with an initial speed of $5(m/s)\hat{i} + 5(m/s)\hat{j}$. The ratio of the potential energy (relative to ground level) to the kinetic energy of the projectile at its highest point is:

A) 0.50
B) 2.0
C) 1.5
D) 1.0
E) 0

$$v_i = \sqrt{5^2 + 5^2} = 5\sqrt{2} = 7.1\, m/s$$

$$v_f = 5\, m/s$$

$$K_i = \frac{1}{2} m v^2 = \frac{1}{2} \times 2.0 \times 7.1^2 = 50.4\, J$$

$$K_f = \frac{1}{2} m v^2 = \frac{1}{2} \times 2.0 \times 5^2 = 25\, J$$

$$U_i = 0,$$

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f$$

$$50.4 + 0 = 25 + U_f$$

$$U_f = 25.4$$

$$\frac{U_f}{K_f} = \frac{25.4}{25} = 1.0$$

7. A block is released from rest at a height h = 6.0 m along a frictionless loop-the-loop with a diameter of 3.0 m (see Fig 1). The speed at the top of the loop is:

A) 3.6 m/s
B) 4.3 m/s
C) 7.7 m/s
D) 5.4 m/s
E) 2.9 m/s

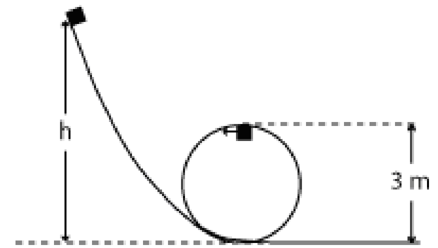


Figure 1

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f$$

$$0 + mgh_i = \frac{1}{2}mv^2 + mgh_f$$

$$v = \sqrt{2g(h_i - h_f)} = \sqrt{2 \times 9.8 \times (6.0 - 3.0)} = 7.7\ m/s$$

8. A 2.0-kg block slides on a rough horizontal table top (see Fig 2). Just before it hits a horizontal ideal spring its speed is 5.0 m/s. It hits the spring and compresses it 10.0 cm before coming momentarily to rest. If the spring constant is 1200 N/m, the work done by friction is:
A) 0
B) -2.6 J
C) -19 J
D) -0.70 J
E) -6.5 J

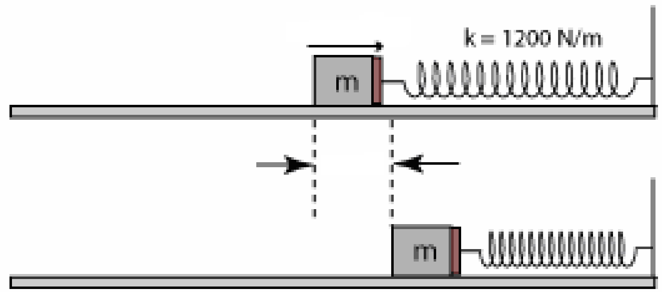


Figure 2

$$\Delta E = W_{fr}$$

$$W_{fr} = E_f - E_i$$

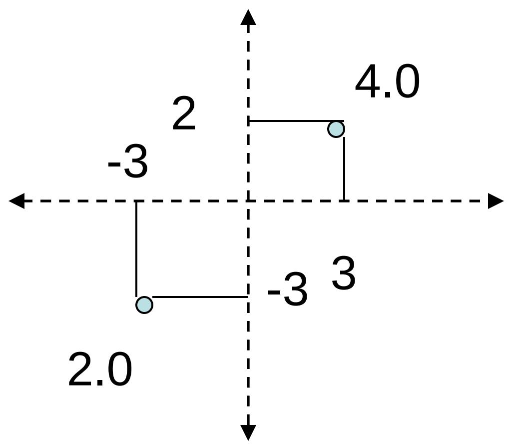
$$E_i = K_i + U_i = \frac{1}{2}mv^2_i + 0 = \frac{1}{2}\times 2.0\times 5.0^2 = 25\,J$$

$$E_f = K_f + U_f = 0 + \frac{1}{2}kx^2 = \frac{1}{2}\times 1200\times 0.100^2 = 6\,J$$

$$W_{fr} = 6 - 25 = -19\,J$$

9. The location of two thin flat objects of masses $m_1 = 4.0$ kg and $m_2 = 2.0$ kg are shown in Fig. 3, where the units are in m. The *x* and *y* coordinates of the center of mass of this system are:

A) 0, 0
B) 1.3 m, 1.7 m
C) 1.0 m, -0.33 m
D) 1.0 m, 0.33 m
E) 6.0 m, 2.0 m



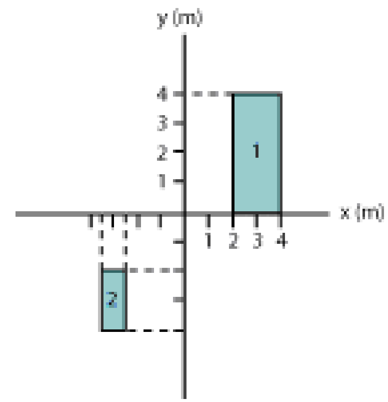


Figure 3

$$x_{com} = \frac{\sum m_i x_i}{\sum m_i} = \frac{4.0\times 3 - 2.0\times 3}{4.0+2.0} = \frac{12-6.0}{6.0} = 1.0\ m$$

$$y_{com} = \frac{\sum m_i y_i}{\sum m_i} = \frac{4.0\times 2 - 2.0\times 3}{4.0+2.0} = \frac{8.0-6.0}{6.0} = 0.33\ m$$

10. The impulse which will change the velocity of a 2.0-kg object from $\vec{v}_1 = +30\hat{j}\,(m/s)$ to $\vec{v}_2 = -30\hat{i}\,(m/s)$ is:

A) $(30\hat{i} - 30\hat{j})\,N\cdot s$

B) $(-60\hat{i} - 60\hat{j})\,N\cdot s$

C) $(-30\hat{i} + 30\hat{j})\,N\cdot s$

D) $(-15\hat{i} - 15\hat{j})\,N\cdot s$

E) $0\,N\cdot s$

$$\vec{J} = \Delta\vec{P} = \vec{P}_f - \vec{P}_i$$

$$\vec{P}_f = 2.0\times(-30i) = -60i\ kgm/s$$

$$\vec{P}_i = 2.0\times(30j) = 60j\ kgm/s$$

$$\vec{J} = -60i - 60j\ N.s$$

11. A 2.00 kg pistol is loaded with a bullet of mass 3.00 g. The pistol fires the bullet at a speed of 400 m/s. The recoil speed of the pistol when the bullet was fired is:

A) 0.500 m/s
B) 0.400 m/s
C) 1.75 m/s
D) 1.60 m/s
E) 0.600 m/s

$$P_i = P_f$$

$$0 = p_b + p_p$$

$$p_p = -p_b$$

$$m_p v_p = -m_b v_b$$

$$2.00 v_p = -0.0030 \times 400$$

$$v_p = -0.600\ m/s$$

12. Sphere A has mass $3m$ and is moving with velocity v in the positive the x direction. Sphere B has a mass m and is moving with velocity v in the negative x direction. The two spheres make a head-on elastic collision. After the collision the velocity of A (v_A) is:

A) 0
B) v
C) $-2v/4$
D) $-v/4$
E) $-5v/3$

$$v_{Af} = \frac{m_A - m_B}{m_A + m_B} v_{Ai} + \frac{2m_B}{m_A + m_B} v_{Bi}$$

$$v_{Af} = \frac{3m - m}{3m + m} v + \frac{2m}{3m + m}(-v)$$

$$= \frac{2}{4} v - \frac{2}{4} v = 0$$

13. The angular position of a particle is given as $\theta = 2 + t - t^3$ where θ is in *rad* and t is in *s*. The angular acceleration when the particle is momentarily at rest is:

A) 16 rad/s^2 clockwise
B) 0 rad/s^2
C) 3.5 rad/s^2 counterclockwise
D) 3.5 rad/s^2 clockwise
E) 16 rad/s^2 counterclockwise

$$\theta = 2 + t - t^3$$

$$\omega = \frac{d\theta}{dt} = 1 - 3t^2 = 0 \Rightarrow t = \frac{\sqrt{3}}{3} = 0.577\ s$$

$$\alpha = \frac{d\omega}{dt} = -6t = -3.5\ rad/s^2\ \left(3.5 rad/s^2 clockwise\right)$$

14. A disk of rotational inertia 5.0 kg m^2 starts rotating from rest and accelerates with a constant angular acceleration of 1.0 rad/s^2. During the first 4.0 s, the work done on the disk is:

A) 5.0 J
B) 40 J
C) 320 J
D) 2.5 J
E) 1800 J

$$W = \tau\Delta\theta = I\alpha\Delta\theta$$

$$\Delta\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2}\times 1.0\times 4.0^2 = 8.0\ rad$$

$$W = I\alpha\Delta\theta = 5.0\times 1.0\times 8.0 = 40\ J$$

15. The rotational inertia of a solid sphere (mass M and radius R_1) about an axis parallel to its central axis but at a distance of $2R_1$ from it is equal to I_1. The rotational inertia of a cylinder (same mass M but radius R_2) about its central axis is equal to I_2. If $I_1 = I_2$, the radius of the cylinder R_2 must then be:

A) 4.9 R_1
B) 9.0 R_1
C) 8.8 R_1
D) R_1
E) 3.0 R_1

$$I_1 = \frac{2}{5}MR^2{}_1 + M(2R_1)^2 = \frac{22}{5}MR_1{}^2$$

$$I_2 = \frac{1}{2}MR_2{}^2$$

$$I_1 = I_2$$

$$\frac{22}{5}MR_1{}^2 = \frac{1}{2}MR_2{}^2$$

$$\frac{R_2}{R_1} = \sqrt{\frac{44}{5}} = 3.0$$

16. A rope pulls a 1.0-kg box on a frictionless surface through a pulley as shown in Fig 4. The pulley has a rotational inertia of 0.040 kg.m^2 and radius of 20 cm. If the force F is 10 N, then the acceleration of the box is:

A) 10.0 m/s^2
B) 0 m/s^2
C) 1.0 m/s^2
D) 0.50 m/s^2
E) 5.0 m/s^2

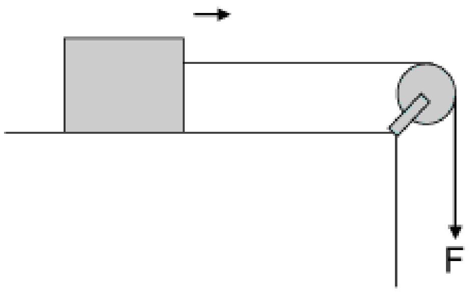


Figure 4

$$T = ma \Rightarrow TR^2 = maR^2$$

$$(F - T)R = I\frac{a}{R} \Rightarrow FR^2 - TR^2 = Ia$$

$$FR^2 - maR^2 = Ia \Rightarrow FR^2 = (mR^2 + I)a$$

$$a = \frac{FR}{(mR^2 + I)} = \frac{10 \times 0.20^2}{(1.0 \times 0.20^2 + 0.040)} = 5.0\ m/s^2$$

17. A ring is given an initial speed of 7.0 m/s at its center of mass (see Fig 5). It then rolls smoothly up the incline. At the height 5.0 m the speed of the center of mass of the ring is:

A) 7.0 m/s
B) 0 m/s
C) 2.0 m/s
D) 3.5 m/s
E) 4.1 m/s

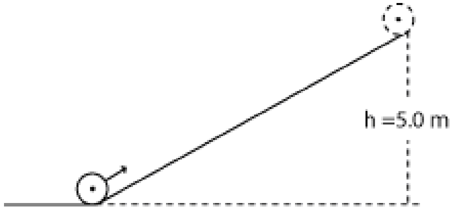


Figure 5

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f \qquad (1)$$

$$K_i = \frac{1}{2} I\omega_i^2 + \frac{1}{2} mv^2{}_i = \frac{1}{2}(mR^2)(\frac{v_i}{R})^2 + \frac{1}{2} mv^2{}_i = mv^2{}_i,$$

$$U_i = 0$$

$$K_f = \frac{1}{2} I\omega_f{}^2 + \frac{1}{2} mv^2{}_f = \frac{1}{2}(mR^2)(\frac{v_f}{R})^2 + \frac{1}{2} mv^2{}_f = mv^2{}_f$$

$$U_f = mgh$$

$$substitute\ in\ (1)$$

$$mv^2{}_i = mv^2{}_f + mgh$$

$$v_f = \sqrt{v^2{}_i - gh} = \sqrt{49-49} = 0$$

18. The angular momentum of an object about the origin is given as functions of time as follows: $\vec{L} = (2t - 1)\hat{i}\ kg \cdot m^2 \cdot s$ where t is in s. The torque about the origin at $t = 2.0\ s$ is:

A) (2.0 i) N.m
B) (8.0 k) N.m
C) (4.0 i – 2.0 j) N.m
D) (2.0i + 4.0 j) N.m
E) (4.0 k) N.m

$$\vec{\tau} = \frac{d\vec{L}}{dt} = 2.0i\ N.m$$

19. Two identical thin rods of mass M and length d are attached together in the form of a plus sign "+" (see Fig 6). The whole structure is rotating counterclockwise with angular velocity of ω about the z axis (which is at the point of attachment). The angular momentum about the z axis is:

A) (1/12) $M \omega d^2$ clockwise
B) (1/24) $M \omega d^2$ counterclockwise
C) (1/2) $M \omega d^2$ counterclockwise
D) (1/6) $M \omega d^2$ counterclockwise
E) $M \omega d^2$ clockwise

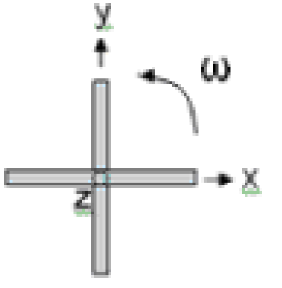


Figure 6

$$I = \frac{1}{12}Md^2 + \frac{1}{12}Md^2 = \frac{1}{6}Md^2$$

$$L = I\omega = \frac{1}{6}Md^2\omega\left(counterclockwise\right)$$

20. A solid sphere of mass $M = 1.0$ kg and radius $R = 10$ cm rotates about a frictionless axis at 4.0 rad/s (see Fig 7). A hoop of mass $m = 0.10$ kg and radius $R = 10$ cm falls onto the ball and sticks to it in the middle exactly. The angular speed of the whole system about the axis just after the hoop sticks to the sphere is:

A) 0.80 rad/s
B) 4.3 rad/s
C) 3.2 rad/s
D) 5.4 rad/s
E) 0.66 rad/s

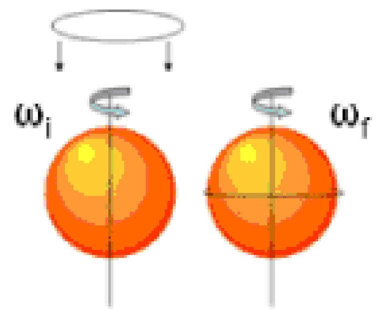


Figure 7

$$\tau_{ext} = 0 \Rightarrow$$

$$L_i = L_f$$

$$I_i \omega_i = I_f \omega_f \quad (1)$$

$$I_i = \frac{2}{5} M R^2 = \frac{2}{5}(1.0) \times (0.10)^2 = 0.004\ kg.m^2$$

$$I_f = I_i + mR^2 = 0.004 + 0.10 \times 0.10^2 = 0.005\ kg.m^2$$

$$(substitute\ in\ 1)$$

$$0.004 \times 4.0 = 0.005 \omega_f$$

$$\omega_f = \frac{0.004 \times 4.0}{0.005} = 3.2\ rad/s$$