CHAPTER 4 REVIEW QUESTIONS

SECTION I: MULTIPLE CHOICE

1. **A** Since the force **F** is perpendicular to the displacement, the work it does is zero.

2. **B** By the work–energy theorem,

$$W = \Delta K = \tfrac{1}{2}m(v^2 - v_0^2) = \tfrac{1}{2}(4\text{ kg})[(6\text{ m/s})^2 - (3\text{ m/s})^2] = 54\text{ J}$$

3. **B** Since the box (mass m) falls through a vertical distance of h, its gravitational potential energy decreases by mgh. The length of the ramp is irrelevant here.

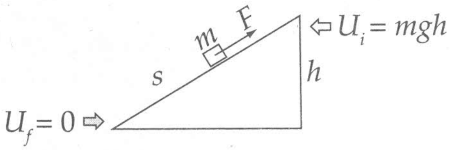
4. **C** Since the centripetal force always points along a radius toward the center of the circle, and the velocity of the object is always tangent to the circle (and thus perpendicular to the radius), the work done by the centripetal force is zero. Alternatively, since the object's speed remains constant, the work–energy theorem tells us that no work is being performed.

5. **A** The gravitational force points downward while the book's displacement is upward. Therefore, the work done by gravity is $-mgh = -(2\text{ kg})(10\text{ N/kg})(1.5\text{ m}) = -30\text{ J}$.

6. **D** The work done by gravity as the block slides down the inclined plane is equal to the potential energy at the top (mgh).

$$mgh = W = \Delta K = \tfrac{1}{2}m(v^2 - v_0^2) = \tfrac{1}{2}mv^2 \quad \Rightarrow \quad v = \sqrt{2gh} = \sqrt{2(10)(6.4)\sin 30^\circ)} = 8\text{ m/s}$$

7. **D** Since a nonconservative force (namely, friction) is acting during the motion, we use the modified Conservation of Mechanical Energy equation.



$$K_i + U_i + W_{friction} = K_i + U_f$$
$$0 + mgh - Fs = K_f + 0$$
$$mgh - Fs = K_f$$

8. **E** Apply Conservation of Mechanical Energy (including the negative work done by $\mathbf{F}_r$, the force of air resistance):

$$K_i + U_i + W_r = K_f + U_f$$
$$0 + mgh - F_r h = \tfrac{1}{2}mv^2 + 0$$
$$v = \sqrt{\frac{2h(mg - F_r)}{m}}$$
$$= \sqrt{\frac{2(40\text{ m})[(4\text{ kg})(10\text{ N/kg}) - 20\text{ N}]}{4\text{ kg}}}$$
$$= 20\text{ m/s}$$

9. **E** Because the rock has lost half of its gravitational potential energy, its kinetic energy at the half-way point is half of its kinetic energy at impact. Since K is proportional to v^2, if $K_{\text{at halfway point}}$ is equal to $\frac{1}{2}K_{\text{at impact}}$, then the rock's speed at the halfway point is $\sqrt{1/2} = 1/\sqrt{2}$ its speed at impact.

10. **D** Using the equation $P = Fv$, we find that $P = (200\text{ N})(2\text{ m/s}) = 400\text{ W}$.

Section II: Free Response

1. (a) Applying Conservation of Energy,

$$K_A + U_A = K_{\text{at }H/2} + U_{\text{at }H/2}$$
$$0 + mgH = \tfrac{1}{2}mv^2 + mg(\tfrac{1}{2}H)$$
$$\tfrac{1}{2}mgH = \tfrac{1}{2}mv^2$$
$$v = \sqrt{gH}$$

(b) Applying Conservation of Energy again,

$$K_A + U_A = K_B + U_B$$
$$0 + mgH = \tfrac{1}{2}mv_B^2 + 0$$
$$v_B = \sqrt{2gH}$$

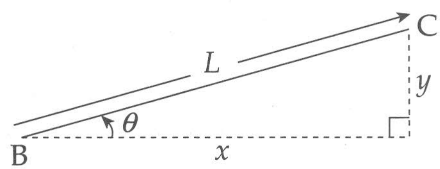
(c) By the work–energy theorem, we want the work done by friction to be equal (but opposite) to the kinetic energy of the box at Point B:

$$W = \Delta K = \tfrac{1}{2}m(v_C^2 - v_B^2) = -\tfrac{1}{2}mv_B^2 = -\tfrac{1}{2}m(\sqrt{2gH})^2 = -mgH$$

Therefore,

$$W = -mgH \quad \Rightarrow \quad -F_f x = -mgH \quad \Rightarrow \quad -\mu_k mgx = -mgH \quad \Rightarrow \quad \mu_k = H/x$$

(d) Apply Conservation of Energy (including the negative work done by friction as the box slides up the ramp from B to C):



$$K_B + U_B + W_f = K_C + U_C$$

$$\tfrac{1}{2}m(\sqrt{2gH})^2 + 0 - F_f L = 0 + mgy$$

$$mgH + 0 - F_f L = 0 + mgy$$

$$mg(H - y) - (\mu_k mg\cos\theta)(L) = 0$$

$$\mu_k = \frac{H - y}{L\cos\theta} = \frac{H - y}{x}$$

(e) The result of part (b) reads $v_B = \sqrt{2gH}$. Therefore, by Conservation of Mechanical Energy (with the work done by the frictional force on the slide included), we get

$$K_A + U_A + W_f = K_B' + U_B$$

$$0 + mgH + W_f = \tfrac{1}{2}m\left(\tfrac{1}{2}v_B\right)^2 + 0$$

$$mgH + W_f = \tfrac{1}{2}m\left(\tfrac{1}{2}\sqrt{2gH}\right)^2$$

$$mgH + W_f = \tfrac{1}{4}mgH$$

$$W_f = -\tfrac{3}{4}mgH$$

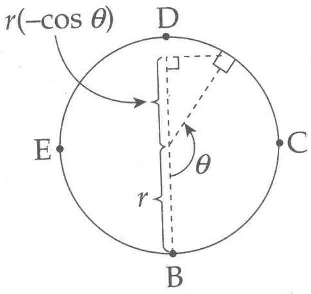
2. (a) The centripetal acceleration of the car at Point C is given by the equation $a = v_C^2/r$, where v_C is the speed of the car at C. To find v_C^2, we apply Conservation of Energy:

$$\begin{aligned} K_A + U_A &= K_C + U_C \\ 0 + mgH &= \tfrac{1}{2}mv_C^2 + mgr \\ mg(H - r) &= \tfrac{1}{2}mv_C^2 \\ v_C^2 &= 2g(H - r) \end{aligned}$$

Therefore,

$$a_c = \frac{v_C^2}{r} = \frac{2g(H - r)}{r}$$

(b) In terms of θ, the car's height above the bottom of the track (Point B) is given by the equation $h = r + (-r\cos\theta)$,



so we get

$$\begin{aligned} K_A + U_A &= K + U \\ 0 + mgH &= \tfrac{1}{2}mv^2 + mg(r - r\cos\theta) \\ mg[H - r(1 - \cos\theta)] &= \tfrac{1}{2}mv^2 \\ v &= \sqrt{2g[H - r(1 - \cos\theta)]} \end{aligned}$$

(c) When the car reaches Point D, the forces acting on the car are its weight, $\mathbf{F}_w$, and the downward normal force, $\mathbf{F}_N$, from the track. Thus, the net force, $\mathbf{F}_w + \mathbf{F}_N$, provides the centripetal force. In order for the car to maintain contact with the track, F_N must not vanish. Therefore, the cut-off speed for ensuring that the car makes it safely around the track is the speed at which F_N just becomes zero; any greater speed would imply that the car would make it around. Thus,

$$F_w + F_N = m\frac{v^2}{r} \quad \Rightarrow \quad F_w + 0 = m\frac{v_{\text{cut-off}}^2}{r} \quad \Rightarrow \quad v_{\text{cut-off}} = \sqrt{\frac{rF_w}{m}} = \sqrt{gr}$$