A ball of mass $m$ falls from a height $h$ to the floor. (a) Write the appropriate version of Equation 8.2 for the system of the ball and the Earth and use it to calculate the speed of the ball just before it strikes the Earth. (b) Write the appropriate version of Equation 8.2 for the system of the ball and use it to calculate the speed of the ball just before it strikes the Earth.

(a) The system of the ball and the Earth is isolated. The gravitational energy of the system decreases as the kinetic energy increases.

$$\Delta K + \Delta U = 0$$

$$\left(\frac{1}{2}mv^2 - 0\right) + (-mgh - 0) = 0 \rightarrow \frac{1}{2}mv^2 = mgy$$

$$v = \sqrt{2gh}$$

(b) The gravity force does positive work on the ball as the ball moves downward. The Earth is assumed to remain stationary, so no work is done on it.

$$\Delta K = W$$

$$\left(\frac{1}{2}mv^2 - 0\right) = mgh \rightarrow \frac{1}{2}mv^2 = mgy$$

$$v = \sqrt{2gh}$$
8.5 A bead slides without friction around a loop-the-loop (Fig. P8.5). The bead is released from rest at a height \( h = 3.50R \). (a) What is its speed at point A? (b) How large is the normal force on the bead at point A if its mass is 5.00 g?

### P8.5

The speed at the top can be found from the conservation of energy for the bead-track-Earth system, and the normal force can be found from Newton’s second law.

(a) We define the bottom of the loop as the zero level for the gravitational potential energy.

Since \( v_i = 0 \),

\[
E_i = K_i + U_i = 0 + mgh = mg(3.50R)
\]

The total energy of the bead at point \( A \) can be written as

\[
E_A = K_A + U_A = \frac{1}{2}mv_A^2 + mg(2R)
\]

Since mechanical energy is conserved, \( E_i = E_A \), we get

\[
mg(3.50R) = \frac{1}{2}mv_A^2 + mg(2R)
\]

simplifying,

\[
v_A^2 = 3.00 \, gR
\]

\[
v_A = \sqrt{3.00gR}
\]

(b) To find the normal force at the top, we construct a force diagram as shown, where we assume that \( n \) is downward, like \( mg \). Newton’s second law gives \( \sum F = ma \), where \( a \) is the centripetal acceleration.

\[
\sum F_y = ma_y: \quad n + mg = \frac{mv^2}{r}
\]

\[
n = m \left[ \frac{v^2}{R} - g \right] = m \left[ \frac{3.00gR}{R} - g \right] = 2.00mg
\]

\[
n = 2.00(5.00 \times 10^{-3} \text{ kg})(9.80 \text{ m/s}^2)
\]

\[
= 0.0980 \text{ N downward}
\]
8.6 A block of mass $m = 5.00$ kg is released from point A and slides on the frictionless track shown in Figure P8.6. Determine (a) the block’s speed at points B and C and (b) the net work done by the gravitational force on the block as it moves from point A to point C.

(a) Define the system as the block and the Earth.
\[ \Delta K + \Delta U = 0 \]
\[ \left( \frac{1}{2} mv_B^2 - 0 \right) + (mgh_B - mgh_A) = 0 \]
\[ \frac{1}{2} mv_B^2 = mg(h_A - h_B) \]
\[ v_B = \sqrt{2g(h_A - h_B)} \]
\[ v_B = \sqrt{2(9.80 \text{ m/s}^2)(5.00 \text{ m} - 3.20 \text{ m})} = 5.94 \text{ m/s} \]

Similarly,
\[ v_C = \sqrt{2g(h_A - h_C)} \]
\[ v_C = \sqrt{2g(5.00 - 2.00)} = 7.67 \text{ m/s} \]

(b) Treating the block as the system,
\[ W_{\text{gr}}|_{A\rightarrow C} = \Delta K = \frac{1}{2} mv_C^2 - 0 = \frac{1}{2} (5.00 \text{ kg})(7.67 \text{ m/s})^2 = 147 \text{ J} \]
8.7 Two objects are connected by a light string passing over a light, frictionless pulley as shown in Figure P8.7. The object of mass \( m_1 = 5.00 \) kg is released from rest at a height \( h = 4.00 \) m above the table. Using the isolated system model, (a) determine the speed of the object of mass \( m_2 = 3.00 \) kg just as the 5.00-kg object hits the table and (b) find the maximum height above the table to which the 3.00-kg object rises.

**Figure P8.7**
Problems 7 and 8.

**P8.7**

We assign height \( y = 0 \) to the table top. Using conservation of energy for the system of the Earth and the two objects:

(a) Choose the initial point before release and the final point, which we code with the subscript \( f \), just before the larger object hits the floor. No external forces do work on the system and no friction acts within the system. Then total mechanical energy of the system remains constant and the energy version of the isolated system model gives

\[
(K_A + K_B + U_y)_i = (K_A + K_B + U_y)_f
\]

At the initial point, \( K_A \) and \( K_B \) are zero and we define the gravitational potential energy of the system as zero. Thus the total initial energy is zero, and we have

\[
0 = \frac{1}{2} (m_1 + m_2) v_{i}^2 + m_2 gh + m_1 g(-h)
\]

Here we have used the fact that because the cord does not stretch, the two blocks have the same speed. The heavier mass moves down, losing gravitational potential energy, as the lighter mass moves up, gaining gravitational potential energy. Simplifying,
\[(m_1 - m_2)gh = \frac{1}{2}(m_1 + m_2)v_{fs}^2\]

\[v_{fs} = \sqrt{\frac{2(m_1 - m_2)gh}{(m_1 + m_2)}} = \sqrt{\frac{2(5.00 \text{ kg} - 3.00 \text{ kg})g(4.00 \text{ m})}{5.00 \text{ kg} + 3.00 \text{ kg}}} = \sqrt{19.6 \text{ m/s}} = 4.43 \text{ m/s}\]

(b) Now we apply conservation of energy for the system of the 3.00-kg object and the Earth during the time interval between the instant when the string goes slack and the instant at which the 3.00-kg object reaches its highest position in its free fall.

\[\Delta K + \Delta U = 0 \quad \rightarrow \quad \Delta K = -\Delta U\]

\[0 - \frac{1}{2}m_2v^2 = -m_2g\Delta y \rightarrow \Delta y = \frac{v^2}{2g}\]

\[\Delta y = 1.00 \text{ m}\]

\[y_{\text{max}} = 4.00 \text{ m} + \Delta y = 5.00 \text{ m}\]
8.14 A crate of mass 10.0 kg is pulled up a rough incline with an initial speed of 1.50 m/s. The pulling force is 100 N parallel to the incline, which makes an angle of 20.0° with the horizontal. The coefficient of kinetic friction is 0.400, and the crate is pulled 5.00 m. (a) How much work is done by the gravitational force on the crate? (b) Determine the increase in internal energy of the crate–incline system owing to friction. (c) How much work is done by the 100-N force on the crate? (d) What is the change in kinetic energy of the crate? (e) What is the speed of the crate after being pulled 5.00 m?

\[ W_g = \vec{F} \cdot \Delta \vec{r} = mg \ell \cos(90.0° + \theta) \]
\[ = (98.0 \text{ N})(5.00 \text{ m}) \cos 110.0° = -168 \text{ J} \]

(b) We set the \( x \) and \( y \) axes parallel and perpendicular to the incline, respectively.

From \( \sum F_y = ma_y \), we have
\[ n - (98.0 \text{ N}) \cos 20.0° = 0 \]
so \( n = 92.1 \text{ N} \)
and
\[ f_k = \mu_k n = 0.400 (92.1 \text{ N}) = 36.8 \text{ N} \]
Therefore,
\[ \Delta F_{\text{int}} = f_k d = (36.8 \text{ N})(5.00 \text{ m}) = 184 \text{ J} \]

(c) \[ W_f = F \ell = (100 \text{ N})(5.00 \text{ m}) = 500 \text{ J} \]

(d) We use the energy version of the nonisolated system model.
\[ \Delta K = -f_k d + \sum W_{\text{other forces}} \]
\[ \Delta K = -f_k d + W_g + W_{\text{applied force}} + W_a \]
The normal force does zero work, because it is at 90° to the motion.

\[ \Delta K = -184 \text{ J} - 168 \text{ J} + 500 \text{ J} + 0 = 148 \text{ J} \]

(e) Again, \( K_f - K_i = -f_id + \sum W_{\text{other forces}} \), so

\[ \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = \sum W_{\text{other forces}} - f_id \]

\[ v_f = \sqrt{\frac{\frac{\Delta K}{m} + \frac{1}{2} mv_i^2}{\frac{2}{10.0 \text{ kg}} [148 \text{ J} + \frac{1}{2} (10.0 \text{ kg})(1.50 \text{ m/s})^2]} \]

\[ v_f = \sqrt{\frac{2[159 \text{ kg} \cdot \text{m}^2/\text{s}^2]}{10.0 \text{ kg}}} = [5.65 \text{ m/s}] \]
8.15 A block of mass \( m = 2.00 \text{ kg} \) is attached to a spring of force constant \( k = 500 \text{ N/m} \) as shown in Figure P8.15. The block is pulled to a position \( x_i = 5.00 \text{ cm} \) to the right of equilibrium and released from rest. Find the speed the block has as it passes through equilibrium if (a) the horizontal surface is frictionless and (b) the coefficient of friction between block and surface is \( m_k = 0.350 \).

**Figure P8.15**

\[ W_s = \frac{1}{2} kx_i^2 - \frac{1}{2} kx_f^2 \]

\[ W_i = \frac{1}{2} (500 \text{ N/m}) (5.00 \times 10^{-2} \text{ m})^2 - 0 \]

\[ = 0.625 \text{ J} \]

Applying \( \Delta K = W_s \):

\[ \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2 \]

\[ = W_s \rightarrow \frac{1}{2} mv_f^2 - 0 = W_s \]

so

\[
 v_f = \sqrt{\frac{2(W_s)}{m}}
\]

\[
 = \sqrt{\frac{2(0.625)}{2.00}} \text{ m/s} = 0.791 \text{ m/s}
\]
(b) Now friction results in an increase in internal energy $f_id$ of the block-surface system. From conservation of energy for a nonisolated system,

\[ W_s = \Delta K + \Delta E_{\text{int}} \]
\[ \Delta K = W_s - f_id \]
\[ \frac{1}{2} m_2 v_f^2 = W_s - f_id = W_s - \mu mgd \]

\[ \frac{1}{2} m_2 v_f^2 = 0.625 \text{ J} - (0.350)(2.00 \text{ kg})(9.80 \text{ m/s}^2)(0.050 \text{ m}) \]

\[ \frac{1}{2} (2.00 \text{ kg}) v_f^2 = 0.625 \text{ J} - 0.343 \text{ J} = 0.282 \text{ J} \]

\[ v_f = \sqrt{\frac{2(0.282)}{2.00}} \text{ m/s} = 0.531 \text{ m/s} \]
8.25 A 200-g block is pressed against a spring of force constant 1.40 kN/m until the block compresses the spring 10.0 cm. The spring rests at the bottom of a ramp inclined at 60.08 to the horizontal. Using energy considerations, determine how far up the incline the block moves from its initial position before it stops (a) if the ramp exerts no friction force on the block and (b) if the coefficient of kinetic friction is 0.400.

**P8.25** The spring is initially compressed by $x_i = 0.100$ m. The block travels up the ramp distance $d$.

The spring does work $W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2 = \frac{1}{2}kx_i^2 - 0 = \frac{1}{2}kx_i^2$ on the block.

Gravity does work $W_g = mgd\cos(90^\circ + 60.0^\circ) = mgd\sin(60.0^\circ)$ on the block. There is no friction.

(a) \[ \Sigma W = \Delta K: \quad W_s + W_g = 0 \]
\[ \frac{1}{2}kx_i^2 - mgd \sin(60.0^\circ) = 0 \]
\[ \frac{1}{2}\left(1.40 \times 10^3 \text{ N/m}\right)(0.100 \text{ m})^2 \]
\[ - (0.200 \text{ kg})(9.80 \text{ m/s}^2)d\sin(60.0^\circ) = 0 \]
\[ d = 4.12 \text{ m} \]

(b) Within the system, friction transforms kinetic energy into internal energy:
\[ \Delta E_{int} = f_d = (\mu_k n)d = \mu_k (mg \cos 60.0^\circ)d \]
\[ \Sigma W = \Delta K + \Delta E_{int}: \quad W_s + W_g - \Delta E_{int} = 0 \]
\[ \frac{1}{2}kx_i^2 - mgd \sin 60.0^\circ - \mu_k mg \cos 60.0^\circ d = 0 \]
\[ \frac{1}{2}\left(1.40 \times 10^3 \text{ N/m}\right)(0.100 \text{ m})^2 \]
\[ - (0.200 \text{ kg})(9.80 \text{ m/s}^2)d\sin(60.0^\circ) \]
\[ - (0.400)(0.200 \text{ kg})(9.80 \text{ m/s}^2)(\cos 60.0^\circ)d = 0 \]
\[ d = 3.35 \text{ m} \]
8.27 A child of mass \( m \) starts from rest and slides without friction from a height \( h \) along a slide next to a pool (Fig. P8.27). She is launched from a height \( h/5 \) into the air over the pool. We wish to find the maximum height she reaches above the water in her projectile motion. (a) Is the child–Earth system isolated or nonisolated? Why? (b) Is there a nonconservative force acting within the system? (c) Define the configuration of the system when the child is at the water level as having zero gravitational potential energy. Express the total energy of the system when the child is at the top of the waterslide. (d) Express the total energy of the system when the child is at the launching point. (e) Express the total energy of the system when the child is at the highest point in her projectile motion. (f) From parts (c) and (d), determine her initial speed \( v_i \) at the launch point in terms of \( g \) and \( h \). (g) From parts (d), (e), and (f), determine her maximum airborne height \( y_{\text{max}} \) in terms of \( h \) and the launch angle \( u \). (h) Would your answers be the same if the waterslide were not frictionless? Explain.

(a) Yes, the child-Earth system is isolated because the only force that can do work on the child is her weight. The normal force from the slide can do no work because it is always perpendicular to her displacement. The slide is frictionless, and we ignore air resistance.

(b) No, because there is no friction.

(c) At the top of the water slide,

\[ U_g = mgh \quad \text{and} \quad K = 0: \quad E = 0 + mgh \rightarrow E = mgh \]
(d) At the launch point, her speed is \( v_x \) and height \( h = h/5 \):
\[
E = K + U_g
\]
\[
E = \frac{1}{2} mv_i^2 + \frac{mgh}{5}
\]

(e) At her maximum airborne height, \( h = y_{\text{max}} \):
\[
E = \frac{1}{2} mv_x^2 + mgh = \frac{1}{2} m(v_{xI}^2 + v_{yI}^2) + mgy_{\text{max}}
\]
\[
E = \frac{1}{2} m(v_{xI}^2 + 0) + mgy_{\text{max}} \rightarrow E = \frac{1}{2} mv_{xI}^2 + mgy_{\text{max}}
\]

(f) \[
E = mgh = \frac{1}{2} mv_i^2 + mgh/5 \rightarrow v_i = \sqrt{\frac{8gh}{5}}
\]

(g) At the launch point, her velocity has components \( v_{xI} = v_i \cos \theta \) and \( v_{yI} = v_i \sin \theta \):
\[
E = \frac{1}{2} mv_i^2 + \frac{mgh}{5} = \frac{1}{2} mv_{xI}^2 + mgy_{\text{max}}
\]
\[
\rightarrow \frac{1}{2} mv_i^2 + \frac{mgh}{5} = \frac{1}{2} m(v_i \cos \theta)^2 + mgy_{\text{max}}
\]
\[
\rightarrow \frac{1}{2} v_i^2 (1 - \cos^2 \theta) + \frac{gh}{5} = g h_{\text{max}}
\]
\[
\rightarrow h_{\text{max}} = \frac{1}{2} g \left( \frac{8gh}{5} \right) (1 - \cos^2 \theta) + \frac{gh}{5g}
\]
\[
\rightarrow h_{\text{max}} = \left( \frac{4h}{5} \right) (1 - \cos^2 \theta) + \frac{h}{5} \rightarrow h_{\text{max}} = h \left( 1 - \frac{4}{5} \cos^2 \theta \right)
\]

(h) No. If friction is present, mechanical energy of the system would not be conserved, so her kinetic energy at all points after leaving the top of the waterslide would be reduced when compared with the frictionless case. Consequently, her launch speed, maximum height reached, and final speed would be reduced as well.
8.29 An 820-N Marine in basic training climbs a 12.0-m vertical rope at a constant speed in 8.00 s. What is his power output?

**P8.29** The Marine must exert an 820-N upward force, opposite the gravitational force, to lift his body at constant speed. The Marine’s power output is the work he does divided by the time interval:

\[ P = \frac{W}{t} \]

\[ P = \frac{mgh}{t} = \frac{(820 \text{ N})(12.0 \text{ m})}{8.00 \text{ s}} = 1230 \text{ W} = 1.23 \text{ kW} \]

8.40 A 650-kg elevator starts from rest. It moves upward for 3.00 s with constant acceleration until it reaches its cruising speed of 1.75 m/s. (a) What is the average power of the elevator motor during this time interval? (b) How does this power compare with the motor power when the elevator moves at its cruising speed?

**P8.38** (a) The distance moved upward in the first 3.00 s is

\[ \Delta y = \bar{v} \Delta t = \left[ \frac{0 + 1.75 \text{ m/s}}{2} \right] (3.00 \text{ s}) = 2.63 \text{ m} \]

The motor and the Earth’s gravity do work on the elevator car:

\[ W_{\text{motor}} + W_{\text{gravity}} = \Delta K \]

\[ W_{\text{motor}} + (mg \Delta y) \cos 180^\circ = \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2 \]

\[ W_{\text{motor}} = \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2 - mg \Delta y \]

\[ W_{\text{motor}} = \frac{1}{2} \left( 650 \text{ kg} \right) (1.75 \text{ m/s})^2 - 0 + (650 \text{ kg}) g (2.63 \text{ m}) \]

\[ = 1.77 \times 10^4 \text{ J} \]

Also, \( W = \bar{P} \Delta t \) so \( \bar{P} = \frac{W}{\Delta t} = \frac{1.77 \times 10^4 \text{ J}}{3.00 \text{ s}} = 5.91 \times 10^3 \text{ W} = 7.92 \text{ hp} \).

(b) When moving upward at constant speed \((v = 1.75 \text{ m/s})\), the applied force equals the weight = \((650 \text{ kg})(9.80 \text{ m/s}^2)\) = \(6.37 \times 10^3 \text{ N}\). Therefore,

\[ P = Fv = (6.37 \times 10^3 \text{ N})(1.75 \text{ m/s}) = 1.11 \times 10^4 \text{ W} = 14.9 \text{ hp} \]
8.37 A 3.50-kN piano is lifted by three workers at constant speed to an apartment 25.0 m above the street using a pulley system fastened to the roof of the building. Each worker is able to deliver 165 W of power, and the pulley system is 75.0% efficient (so that 25.0% of the mechanical energy is transformed to other forms due to friction in the pulley). Neglecting the mass of the pulley, find the time required to lift the piano from the street to the apartment.

P8.39 As the piano is lifted at constant speed up to the apartment, the total work that must be done on it is

\[ W_{nc} = \Delta K + \Delta U_g = 0 + mg(y_f - y_i) \]
\[ = (3.50 \times 10^3 \text{ N})(25.0 \text{ m}) \]
\[ = 8.75 \times 10^4 \text{ J} \]

The three workmen (using a pulley system with an efficiency of 0.750) do work on the piano at a rate of

\[ P_{net} = 0.750 \left( \frac{3P_{\text{single worker}}}{3} \right) = 0.750[3(165 \text{ W})] = 371 \text{ W} = 371 \text{ J/s} \]

so the time required to do the necessary work on the piano is

\[ \Delta t = \frac{W_{nc}}{P_{net}} = \frac{8.75 \times 10^4 \text{ J}}{371 \text{ J/s}} = \frac{236 \text{ s}}{1 \text{ min}} \times \left( \frac{1 \text{ min}}{60 \text{ s}} \right) = 3.93 \text{ min} \]
As the driver steps on the gas pedal, a car of mass 1160 kg accelerates from rest. During the first few seconds of motion, the car’s acceleration increases with time according to the expression

\[ a = 1.16t - 0.210t^2 + 0.240t^3 \]

where \( t \) is in seconds and \( a \) is in m/s\(^2\). (a) What is the change in kinetic energy of the car during the interval from \( t = 0 \) to \( t = 2.50 \) s? (b) What is the minimum average power output of the engine over this time interval? (c) Why is the value in part (b) described as the minimum value?

**P8.57**

(a) To calculate the change in kinetic energy, we integrate the expression for \( a \) as a function of time to obtain the car’s velocity:

\[
v = \int_0^t a \, dt = \int_0^t \left(1.16t - 0.210t^2 + 0.240t^3\right) dt
\]

\[
= \left[ \frac{1.16t^2}{2} - \frac{0.210t^3}{3} + \frac{0.240t^4}{4} \right]_0^t = 0.580t^2 - 0.070t^3 + 0.060t^4
\]

At \( t = 0 \), \( v_f = 0 \). At \( t = 2.50 \) s,

\[
v_f = (0.580 \text{ m/s}^3)(2.50 \text{ s})^2 - (0.070 \text{ m/s}^4)(2.50 \text{ s})^3
+ (0.060 \text{ m/s}^5)(2.50 \text{ s})^4 = 4.88 \text{ m/s}
\]

The change in kinetic energy during this interval is then

\[
K_i + W = K_f
\]

\[
0 + W = \frac{1}{2}mv_f^2 = \frac{1}{2}(1160 \text{ kg})(4.88 \text{ m/s})^2 = 1.38\times10^4 \text{ J}
\]

(b) The road does work on the car when the engine turns the wheels and the car moves. The engine and the road together transform chemical potential energy in the gasoline into kinetic energy of the car.

\[
P = \frac{W}{\Delta t} = \frac{1.38\times10^4 \text{ J}}{2.50 \text{ s}} = 5.52\times10^3 \text{ W}
\]

(c) The value in (b) represents only energy that leaves the engine and is transformed to kinetic energy of the car. Additional energy leaves the engine by sound and heat. More energy leaves the engine to do work against friction forces and air resistance.
A 10.0-kg block is released from rest at point A in Figure P8.63. The track is frictionless except for the portion between points B and C, which has a length of 6.00 m. The block travels down the track, hits a spring of force constant 2 250 N/m, and compresses the spring 0.300 m from its equilibrium position before coming to rest momentarily. Determine the coefficient of kinetic friction between the block and the rough surface between points B and C.

The easiest way to solve this problem about a chain-reaction process is by considering the energy changes experienced by the block between the point of release (initial) and the point of full compression of the spring (final). Recall that the change in potential energy (gravitational and elastic) plus the change in kinetic energy must equal the work done on the block by non-conservative forces. We choose the gravitational potential energy to be zero along the flat portion of the track.
There is zero spring potential energy in situation (A) and zero gravitational potential energy in situation (D). Putting the energy equation into symbols:

\[ K_D - K_A - U_{sA} + U_{sd} = -f_k d_{BC} \]

Expanding into specific variables:

\[ 0 - 0 - mg y_A + \frac{1}{2} k x_s^2 = -f_k d_{BC} \]

The friction force is \( f_k = \mu_k mg \), so

\[ m g y_A - \frac{1}{2} k x_s^2 = \mu_k m g d \]

Solving for the unknown variable \( \mu_k \) gives

\[ \mu_k = \frac{y_A}{d} - \frac{k x_s^2}{2 m g d} \]

\[ = \frac{3.00 \text{ m}}{6.00 \text{ m}} - \frac{(2.250 \text{ N/m})(0.300 \text{ m})^2}{2(10.0 \text{ kg})(9.80 \text{ m/s}^2)(6.00 \text{ m})} = 0.328 \]
This is the solution key for Tutorial #6 for PHYS 101. You can find all 13 questions in the book called "Physics for Scientists and Engineers with Modern Physics," John W. Jewett & Jr. Raymond A. Serway.

List of Questions to be Solved

1) Question 8.2
2) Question 8.5
3) Question 8.6
4) Question 8.7
5) Question 8.14
6) Question 8.15
7) Question 8.25
8) Question 8.27
9) Question 8.29
10) Question 8.40
11) Question 8.37
12) Question 8.49
13) Question 8.63
1) (a) Principle of conservation of energy states that the change in the total energy of the system is equal to the amount of energy transferred across the system boundary by some mechanism. This principle can mathematically be illustrated as follows:

\[ \Delta E_{\text{system}} = \sum T \]  \hspace{1cm} (1)

The ball-Earth system is isolated from the environment which means that one can write

\[ \Delta K + \Delta U = 0 \]  \hspace{1cm} (2)

\[ \Delta E_{\text{system}} \]

\[ \Delta K = K_{\text{final}} - K_{\text{initial}} \]

\[ = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \]

The ball "falls" from some height.

\[ \Rightarrow \quad v_i = 0 \text{ m/s} \]

\[ \therefore \Delta K = \frac{1}{2} m v_f^2 \]  \hspace{1cm} (3)
What about \( \Delta U \)?

\[ \Delta U = \text{CHANGE IN GRAVITATIONAL POTENTIAL ENERGY} \]

\[ \therefore \Delta U = mg y_f - mg y_i \]

\[ \text{Initially, the ball is at this point which means that } y_i = h. \]

\[ y_f = 0 \]

\[ \Delta U = mg (0) - mgh = -mgh \quad \text{--- (4)} \]

Substituting (3) & (4) into equation (2), we get

\[ \frac{1}{2} mv_f^2 = mg h \]

Rearrange for \( v_f \). (Multiply both sides by two and take the square root of both sides.)

\[ v_f = \sqrt{2gh} \]
In this part, we need only the system consisting of the ball itself. So, let us consider the conservation of energy equation for the ball.

\[ \Delta E_{\text{ball}} = \sum T \]

\[ \Delta K = W \quad \Rightarrow \quad \text{WHY?} \]

The ball is falling down so the work done on the ball by the gravitational force will be (+)ve.

Now, substitute the formulas for change in the kinetic energy of the ball and the work done by gravitational force on the ball.

\[ \frac{1}{2} m v_f^2 - 0 = m g h \]

Starts from rest.

Solve this equation for \( v_f \).

\[ v_f = \sqrt{2gh} \]
2) (a) Before you start solving your question numerically, make sure that you can summarize it with the given information, keywords & diagrams. It is necessary for you to understand the logic behind!

KEYWORDS

without friction \[\Rightarrow\] \[E_{\text{initial}} = E_{\text{final}}\]

bead released from rest \[\Rightarrow\] initial velocity is zero which implies that initial kinetic energy will be zero also!

\[K_i = \frac{1}{2}mv_i^2\]

\[= \text{zero}\]

GIVEN INFORMATION

\[h = 3.50R\]
\[v_i = 0 \text{ m/s}\]

FREE BODY DIAGRAM OF THE BEAD

Now, you may start!

\[\sum E_{\text{initial}} = \sum E_{\text{final}}\]

\[\sum E_i = \sum E_f\]

\[K_i + U_i = K_f + U_f\]
\[ k_i + u_i = k_f + u_f \]
\[ k_i + u_i = k_A + u_A \]
\[ \frac{1}{2} m v_i^2 + mgh_i = \frac{1}{2} m v_A^2 + mg(h_A) \]

This is equal to the diameter of the loop.
\[ h = 3.50R \]

"released from rest"

Therefore,
\[ mg(3.50R) = \frac{1}{2} m v_A^2 + mg(2R) \]

"Solve for \( v_A \)."
\[ v_A^2 + 2(2R)g = 2g(3.50R) \]
\[ v_A^2 = gR - 4gR \]

Taking the square-root of this expression gives
\[ v_A = \sqrt{3gR} \text{ m/s} \]
(b) How large is the normal force?

**FBD for the bead**

\[ + \mathbf{j} \]
\[ \downarrow \]
\[ n \]
\[ \downarrow \mathbf{j} \]
\[ mg \]

Newton's 2\textsuperscript{nd} Law states that \( \mathbf{F}_{\text{net}} = m\mathbf{a} \), in which we can express in terms of its components and obtain the two equations below.

\[ \sum F_x = ma_x \]

\[ \sum F_y = ma_y \rightarrow \text{For this specific question, we only need this one.} \]

One can clearly see that

\[ \sum F_y = \left( \frac{mv_1^2}{r} \right) \rightarrow \text{centripetal force} \]

\[ n + mg = \frac{mv_1^2}{r} \rightarrow \text{Rearrange for } n \]

\[ n = \frac{mv_1^2}{r} - mg \rightarrow \text{Now, plug in the numerical values.} \]

\[ n = \left( 5 \times 10^{-3} \right) \left( \sqrt{2gR^2} \right)^2 - (5 \times 10^{-3} g) = 0.098 \text{N} \]
KEYWORDS

(1) released from point A \rightarrow V_A = 0 \text{ m/s}

(2) frictionless track \rightarrow isolated system, \Delta K + \Delta U = 0

GIVEN INFORMATION

\[ m = 5.00 \text{ kg} \]
\[ v_i = V_A = 0 \text{ m/s} \]

(a)(i) Starting point \rightarrow A

Final point \rightarrow B

Since there is no force of friction,

\[ \Delta K + \Delta U = 0 \quad \ldots \quad (*) \]

How can I define \( \Delta K \) and \( \Delta U \)?

\[ \Delta K = K_f - K_i \]
\[ = \frac{1}{2} m v_B^2 - \frac{1}{2} m v_A^2 \]

\[ \Delta U = U_f - U_i \]
\[ = mgh_B - mgh_A \]

Substitute in (*)

\[ \frac{1}{2} m v_B^2 - \frac{1}{2} m v_A^2 + mgh_B - mgh_A = 0 \]

\[ \left( \text{released from rest!} \right) \]

\[ V_A = 0 \text{ m/s} \]
After writing your equation correctly, you can now substitute your numerical values. It is usually preferable to leave substitution of numbers to the last step.

\[
\frac{1}{2} m v_B^2 - 0 + \frac{1}{2} m g h_B - \frac{1}{2} m g h_A = 0
\]

\[
v_B = \sqrt{2 g (h_A - h_B)}
\]

\[
v_B = \sqrt{2 \times 9.81 \text{ m/s}^2 \times (5.00 \text{ m} - 3.20 \text{ m})}
\]

\[
v_B = 5.94 \text{ m/s}
\]

(ii) \( v_c = ? \)

Starting point \( \rightarrow A \)
Final point \( \rightarrow C \)

While moving from \( A \) to \( C \), there will be no energy loss to the surroundings, since the track is frictionless. If we had force of friction, we would have lost some energy during the motion (heat, sound, etc).

\[
\Delta K + \Delta U = 0
\]

\[
\frac{1}{2} m v_c^2 - \frac{1}{2} m v_A^2 + m g h_c - m g h_A = 0
\]

\[
\frac{1}{2} m v_c^2 = \frac{1}{2} m v_A^2
\]

\[
v_A = 0
\]

\[
v_c = \sqrt{2 g (h_A - h_c)}
\]

\[
v_c = \sqrt{2 \times 9.81 \text{ m/s}^2 \times (5.00 \text{ m} - 2.00 \text{ m})} = 7.67 \text{ m/s}
\]
(b) Using work–kinetic energy theorem, one can write

\[ W |_{g \; A \rightarrow C} = \Delta K \]

Work done on the mass by gravitational force = Change in the kinetic energy of the mass

\[ W |_{g \; A \rightarrow C} = \frac{1}{2} m v_c^2 - \frac{1}{2} m v_A^2 \]

\[ = \frac{1}{2} (5.00 \text{ kg}) (7.67 \text{ m/s}) \]

\[ = 147 \text{ Joules} \]

Hence, working out the change in kinetic energy of the system will directly give us the net work done by the gravitational force.

4) **KEYWORDS**

- m, released from rest
- isolated system model

**GIVEN INFORMATION**

\[ m_1 = 5.00 \text{ kg}, \quad v_{1i} = 0 \text{ m/s}, \quad v_{2i} = 0 \text{ m/s} \]

\[ h = 4.00 \text{ m}, \quad m_2 = 3.00 \text{ kg} \]
(a) Try to picturise your problem. Where are my blocks initially & finally?

**Initial Case**

\[ m_1 \]
\[ h = 4 \text{ m} \]
\[ m_2 \]
\[ \text{zero level} \]

**Final Case**

\[ m_2 \]
\[ h = 4 \text{ m} \]
\[ m_1 \]

This picture clearly shows us that initially ONLY \( m_1 \) has gravitational potential energy. Why? Because \( m_2 \) is situated on the floor itself. We also know that they are released from rest, i.e., initial total kinetic energy of the system is ZERO.

We can see that the situation is reversed. Now, only \( m_2 \) has gravitational potential energy, whereas \( m_1 \) is on the floor. However, be careful! Both objects are MOVING.

For an isolated system, \( \Delta K + \Delta U = 0 \), or alternatively \( K_i + U_i = K_f + U_f \).
\[ K_i = \frac{1}{2} m v_{1i}^2 + \frac{1}{2} m v_{2i}^2 \]

Knowing that they are both at rest initially, \( K_i = 0 \)

\[ U_i = m_1 g h_{1i} + m_2 g h_{2i} \]
\[ = m_1 g h + m_2 g (0) \]
\[ = m_1 g h \]

\[ K_f = \frac{1}{2} m_1 v_f^2 + \frac{1}{2} m_2 v_f^2 \]

\[ U_f = m_1 g h_{1f} + m_2 g h_{2f} \]
\[ = 0 + m_2 g h \]
\[ = m_2 g h \]

Our equation becomes, \( 0 + m_1 g h = \frac{1}{2} m_1 v_f^2 + \frac{1}{2} m_2 v_f^2 + m_2 g h \)

\[ m_1 g h - m_2 g h = \frac{1}{2} v_f^2 (m_1 + m_2) \]

Now, rearrange for \( v_f \) and substitute numbers.

\[ v_f = \sqrt{\frac{2 g h (m_1 - m_2)}{m_1 + m_2}} = 4.43 \text{ m/s} \]
b) After \( m_1 \) hits the ground, \( m_2 \) will move \( \Delta y \) upwards from point B.

\[ \Delta y \]

\[ h_{\text{max}} = (4 + \Delta y) \]

Take this to be zero potential \( \Delta y = ? \)

In an isolated system, \( \Delta K + \Delta U = 0 \). Hence, for \( m_2 \) we can write

\[ \Delta K \bigg|_{m_2} = -\Delta U \bigg|_{m_2} \]

\[ \frac{1}{2} m_2 v_f^2 - \frac{1}{2} m_2 v_i^2 = -\left[ m_2 g (h_f - h_i) \right] \]

At maximum height, \( v_f = 0 \text{ m/s} \).

\[ 0 - \frac{1}{2} m_2 v_8^2 = -\left[ m_2 g \right] \left[ \Delta h \right] \]

\[ \Delta y = \frac{0 - h_i}{h_f} \]

\[ \therefore \quad -\frac{1}{2} m_2 v_8^2 = -m_2 g \Delta y \]

we found in part (a)

\[ -\frac{1}{2} \left[ 4.43 \text{ m/s} \right]^2 = \left[ -9.81 \text{ m/s}^2 \right] \Delta y \]

\[ \Rightarrow \quad \Delta y = 1 \text{ m} \]

\[ \Rightarrow h_{\text{max}} = (4 + 1) \text{ m} \]
5) **KEYWORDS**

(*) pulled up

(*) rough incline

(*) pulling force parallel to incline

**GIVEN INFORMATION**

\[ m = 10 \text{ kg} \]

\[ v_i = 1.5 \text{ m/s} \]

\[ F = 100 \text{ N} \]

\[ \theta = 20.08^\circ \]

\[ \mu_k = 0.400 \]

\[ l = 5.00 \text{ m} \]

(a) \[ W \delta D | \delta g = ? \]

Let us draw the FBD for the crate.

In equilibrium,

1. \[ \Sigma F_x = 0 \]

2. \[ \Sigma F_y = 0 \]
For our question,

1. \[ \Sigma F_x = \max_0 \Rightarrow 100 - f_k - mg \sin \theta = 0 \]

2. \[ \Sigma F_y = 0 \Rightarrow n - mg \cos \theta = 0 \]

\[ W|_g = \vec{F} \cdot \Delta \vec{r} \]

Dot product (scalar product)

\[ \vec{F} \cdot \Delta \vec{r} = |\vec{F}| \cdot |\Delta \vec{r}| \cdot \cos \theta = \vec{F} \cdot \Delta \vec{r} \cdot \cos \theta \]

In general,

\[ \vec{A} \cdot \vec{B} = AB \cos \theta \]

\[ \theta \rightarrow \text{the angle between the 2 concerned vectors} \]

Hence,

\[ W|_g = F_g \Delta r \cos \theta = mg \Delta r \cos \theta \Rightarrow \frac{10 \times 2\text{ m/s}^2}{(9.81 \text{ m/s}^2) \times (5 \text{ m}) \times \cos (\theta + 90^\circ)} \]
You must ask yourself the questions below.

"What is the direction of motion?"

"What is the direction of the force I am interested in?"

Then, draw these two vectors.

Hence, while doing the scalar product
\[ \vec{F}_g \cdot \Delta \vec{r} = F_g \Delta r \cos \theta, \]
the angle we are interested in is \( \theta + 90^\circ \).

\[ \therefore W_g = (10 \text{ kg}) \times (9.81 \text{ m/s}^2) \times (5.00 \text{ m}) \times \cos (90^\circ + 25^\circ) \]
\[ = -168 \text{ Joules} \]
(b) Use equation II from page 14.

\[ n - mg \cos \theta = 0 \]

\[ n = 10 \text{ kg} \times 9.81 \text{ m/s}^2 \times \cos 20^\circ \]

\[ = 92.1 \text{ N} \]

We know that \( \vec{F}_k = \mu \vec{n} \). Hence, \( f_k = \mu_k n \).

\[ f_k = 0.400 \times (92.1 \text{ N}) = 36.8 \text{ N} \]

\[ \text{[Be careful! Do NOT use } n = mg. \text{ This is an INCLINED PLANE. Your normal reaction force will be perpendicular to the surface of contact, whereas the weight will be parallel to the ground. Therefore, } n = mg \cos \theta \text{ not } mg!} \]

\[ \therefore \Delta E_{inl} = f_k \lambda \]

\[ = 36.8 \text{ N} \times 5 \text{ m} \]

\[ = 184 \text{ Joules} \]
(c) \[ W_f = \vec{F} \cdot \Delta \vec{r} \]

**Direction of motion?**

**Direction of \( \vec{F} \)?**

\[ W_f = F \Delta r \cos \theta \]

\[ = (100 \text{ N}) \times 5 \text{ m} \times (1) \]

\[ = 500 \text{ Joules} \]

(d) Non-isolated system \{ Friction exists! \}

\[ \Delta K = W_{f_k} + \sum W_{\text{other forces}} \]

\[ \Delta K = -f_k d + W_{g_k} + W_f + W_n \]

\[ = -184 \text{ J} - 168 \text{ J} + 500 \text{ J} + 0 \]

\[ = 148 \text{ Joules} \]

(e) \[ \Delta K = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \]

Rearrange the equation for \( v_f \).

\[ v_f = \sqrt{\frac{2}{m} \left[ \Delta K + \frac{1}{2} m v_i^2 \right]} \]

\[ = \sqrt{\frac{2}{10 \text{ kg}} \left[ 148 \text{ J} + \frac{1}{2} (1 \text{ kg}) (1.5 \text{ m/s})^2 \right]} = 5.65 \text{ m/s} \]
\[ W|_s = \frac{1}{2} k x_i^2 - \frac{1}{2} k x_f^2 \]
\[ = \frac{1}{2} k \left[ x_i^2 - x_f^2 \right] \]
\[ = \frac{1}{2} \left( 500 \text{ N/m} \right) \left( 5.00 \times 10^{-2} - 0 \right) \]
\[ = 0.625 \text{ Joules} \]

If there is no friction, \( \Delta K = W|_s \). [Isolated system]

\[ \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = 0.625 \text{ J} \]

starts from rest

\[ v_f^2 = \frac{2(0.625)}{2.00 \text{ kg}} \]

\[ v_f = 0.791 \text{ m/s} \]

b) If friction exists, \( \Delta K + \Delta E_{\text{int}} = W|_s \).

\[ \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 + \int_0^L \mu_k \text{d}x = W|_s \]

\[ m v_f^2 + 2 \mu_k mg = 2 W|_s \]

\[ v_f^2 = 2 W|_s - 2 \mu_k mg \]

\[ v_f = \sqrt{2 \left[ \frac{W|_s - \mu_k mg}{m} \right]} \]

\[ v_f = \sqrt{2 \left[ \frac{0.625 - 0.350}{2.00 \text{ kg}} \right]} = 0.531 \text{ m/s} \]
\[ \sum W = \Delta K \quad \{ \text{NO FRICTION}\} \]
\[ \frac{1}{2} kx_i^2 - \frac{1}{2} kx_f^2 - W \bigg|_\theta = 0 \quad \text{(1)} \]

\[ W |_g = mgd \cos \alpha \quad \text{(4)} \]

\[ 90^\circ + 60^\circ \]

\[ \text{why? check page 15. Same reasoning!} \]

In general, \( \cos (\theta + 90^\circ) = \sin \theta \). Hence, using this property, eqn (4) becomes

\[ W |_g = mgd \sin 60^\circ \quad \rightarrow \text{substitute into (1)} \]

\[ \frac{1}{2} kx_i^2 - mgd \sin 60^\circ = 0 \]

\[ \therefore d = 4.12 \text{ m} \]

(b) \[ \sum W = \Delta K + \Delta E_{\text{int}} \]

\[ \frac{1}{2} kx_i^2 - mgd \sin 60^\circ - \frac{4k}{\mu_k} mgd \cos 60^\circ = 0 \]

Work done by force of friction

Rearrange for \( d \) & plug in numbers.

\[ d = 3.35 \text{ m} \]
(8)

\[ \theta = 90^\circ \quad \text{direction of motion} \]

\[ F \parallel \Delta F' \cos \theta \quad \text{at} \quad 90^\circ = \text{zero!} \]

No work done by \( \vec{n} \).

\( \star \) No FORCE OF FRICTION!

\( \star \) No AIR RESISTANCE \{negligible\}

Hence, isolated system!

(b) No. "slides without friction"

(c) At the top of waterslide,

\[ \sum \vec{E}_{\text{system}} = U_g + K \]

\[ = mg \cdot h + 0 \]

\[ = mg \cdot h \]

(d) \[ \sum \vec{E} = K + U_g \]

We are given that \( h = h/5 \) \& initial speed \( v_i \).

\[ \vec{E} = \frac{1}{2} \cdot mv_i^2 + \frac{mg \cdot h}{5} \]

(e) \[ \sum \vec{E} = \frac{1}{2} \cdot m(v_{x_i}^2 + v_{y_i}^2) + mg y_{max} \]

\[ E = \frac{1}{2} \cdot mv_{x_i}^2 + mg y_{0 \max} \]
(f) \[ E = \frac{1}{2} m v_i^2 + \frac{gh}{5} = \rho \text{gh} \]

Rearrange for \( v_i \).

Multiply the equation by 10.

\[ 5 v_i^2 + 2gh = 10 \rho \text{gh} \]

\[ v_i = \sqrt{\frac{8gh}{5}} \]

(g) \[ \frac{1}{2} m v_i^2 + \frac{gh}{5} = \frac{1}{2} m v_{xi}^2 + g y_{max} \]

\[ v_{xi} = v_i \cos \theta \]
\[ v_{yi} = v_i \sin \theta \]

Hence, \[ \frac{1}{2} v_i^2 + \frac{gh}{5} = \frac{1}{2} (v_i \cos \theta)^2 + g y_{max} \]

Rearrange for \( y_{max} \).

\[ y_{max} = h - \frac{4h}{5} \cos^2 \theta \]

(h) No, it would not be the same. In the case for existence of friction, we would need to think of a non-isolated system. The kinetic energy at all points would be less (hence launch speed, \( h_{max} \) & \( v_f \) also would be less).
9) \[ \text{Power} = \frac{\text{Work Done}}{\text{time}} \]

\[ W = \text{mgh} = \frac{820 \text{ N} \times 12.0 \text{ m}}{8.00 \text{ s}} = 1230 \text{ W} = 1.23 \text{ kW} \]

10) **KEYWORDS**

(a) \[ (v_i) \text{ start from rest} \rightarrow v_i = 0 \text{ m/s} \]
(b) \( v_f = 1.75 \text{ m/s} \)

**GIVEN INFORMATION**

\[ m = 650 \text{ kg} \]
\[ v_i = 0 \text{ m/s} \]
\[ \Delta t = 3 \text{ s} \]
\[ v_f = 1.75 \text{ m/s} \]

\[(a) \quad W = \bar{P} \Delta t \quad \Rightarrow \quad \bar{P} = \frac{W_{\text{motor}}}{\Delta t} \quad \text{(average power)} \]

First, we must find work done by the motor.

\[ \sum W = \Delta K \]
\[ W_{\text{motor}} + W_{\text{gravity}} = \Delta K \]
\[ W_{\text{motor}} = \Delta K - W_{\text{gravity}} \]

\[ = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 - mg Ay \cos 180^\circ \]

\[ = \frac{1}{2} (650 \text{ kg})(1.75 \text{ m/s})^2 \]

\[ = 1.77 \times 10^4 \text{ J} \]

\[ + \frac{650 \text{ kg} \cdot (2.62 \text{ m})}{5.91 \times 10^3 \text{ J}} \]

\[ \bar{P} = 1.42 \text{ kW} \]

\[ J = 5.91 \times 10^3 \text{ J} \]
\[ W = \Delta K + \Delta U_g \]
\[ = 0 + mgy_f - mgy_i \]
\[ = mg [y_f - y_i] \]
\[ = 8.75 \times 10^4 \text{ Joules} \]

Logically, \( P_{\text{net}} = \text{efficiency} \times 3 P_{\text{single water}} \)
\[ = 0.750 \times 3 \times 165 \text{ W} \]
\[ = 371 \text{ Watts} \]
\[ = 371 \frac{J}{s} \]

Since \( \text{Power} = \frac{W}{t} \), then \( \Delta t = \frac{W}{P_{\text{net}}} \)

Hence,
\[ \Delta t = \frac{8.75 \times 10^4 \frac{J}{s}}{371 \frac{J}{s}} = 236 \text{ s} \]

If you would like to convert into minutes:
\[ \text{236 seconds} \times \left( \frac{1 \text{ min}}{60 \text{ s}} \right) = 3.93 \text{ mins} \]

12) Accelerates from rest \( \Rightarrow v_i = 0 \text{ m/s} \)
\( m = 1160 \text{ kg} \)
\( a = 1.16t - 0.210t^2 + 0.240t^3 \)

(a) \( \Delta K = \frac{1}{2}m v_f^2 - \frac{1}{2}m v_i^2 \)

First, we must find \( v_f \).
Integral of \( a(t) \) with respect to time gives you the velocity:

\[
V(t) = \int_{0}^{t} a \, dt
\]

\[
= \int 1.16t - 0.210t^2 + 0.240t^3 \, dt
\]

\[
= \left[ \frac{1.16t^2}{2} - \frac{(0.210 \times 2)t^3}{3} + \frac{(0.240 \times 3)t^4}{4} \right]_{0}^{t}
\]

\[
= 0.580t^2 - 0.070t^3 + 0.060t^4
\]

We are asked to find \( \Delta K \) between \( t = 0 \) to \( t = 2.5 \) s. When \( t = 0 \), \( V = 0 \); and when \( t = 2.5 \),

\[
V = 0.580(2.5)^2 - 0.070(2.5)^3 + 0.060(2.5)^4 = 4.88 \text{ m/s}
\]

Hence,

\[
\Delta K = \frac{1}{2} (1160)(4.88)^2 = 1.38 \times 10^4 \text{ Joules}
\]

(b) \[
P = \frac{W}{\Delta t} = \frac{1.38 \times 10^4 \text{ J}}{2.50 \text{ s}} = 5.52 \times 10^3 \text{ Watts}
\]

(c) "\( P = 5.52 \times 10^3 \text{ W} \)" represents only energy that leaves the engine & is transformed to kinetic energy of the car. Additional energy leaves the engine by sound & heat. More energy leaves the engine to do work against friction forces & air resistance.
(*) released from rest at point A.
(*) frictionless except between points B and C.
(*) coming to rest momentarily.

**Given Information**

\[ m = 10.0 \text{ kg} \]
\[ v_i = v_A = 0 \text{ m/s} \]
\[ d_{BC} = 6.00 \text{ m} \]
\[ k = 2250 \text{ N/m} \]
\[ x_s = 0.300 \text{ m} \]
\[ v_f = v_D = 0 \text{ m/s} \]

"Point D is not labelled in the question. You can assume it is called D or any other symbol you wish."

Initial point \( \rightarrow A \)

Final point \( \rightarrow D \)

Total energy at final destination \( A \) will be equal to total energy at final destination \( D \) plus work done by friction.
\[ \Delta E_{\text{mech}} = \Delta K + \Delta U = -f_k d_{\text{BC}} \]

Initial Point \( \rightarrow \) A
Final Point \( \rightarrow \) D

\[ \Delta K + \Delta U = K_D - K_A + mg h_D - mg h_A + U_{SD} = -f_k d_{\text{BC}} \]

\[ \frac{1}{2} m v_D^2 - \frac{1}{2} m v_A^2 + mg h_D - mg h_A + U_{SD} = -f_k d_{\text{BC}} \]

\[ -mg h_A + \frac{1}{2} k x_s^2 = -f_k d_{\text{BC}} \]

Rearranging for \( \mu_k \) gives

\[ \mu_k = \frac{mg h_A - \frac{1}{2} k x_s^2}{mg d_{\text{BC}}} \]

Now, substitute the numerical values.

\[ \mu_k = \frac{(10 \text{ kg} \times 9.81 \text{ m/s}^2 \times 8.00 \text{ m}) - \frac{1}{2} (2250 \text{ N/m})(0.3 \text{ m})^2}{(10 \text{ kg} \times 9.81 \text{ m/s}^2 \times 6 \text{ m})} \]

\[ ; \mu_k = 0.328 \]