Since the block is released from rest at 3.0 m, due to conservation of energy, it cannot climb up a vertical distance greater than 3.0 m. So hill #4 is the first one the block cannot climb.

(b) If it fails to cross that hill, it slides back down, picking up K.E. in the process and ends up at its initial starting point and then back again. If there is no friction, this process continues ad infinitum.

(c) Since we are told that the hills have identical circular tops, they have the same vertical radius R. The greatest centripetal acceleration occurs on the hill where \( \alpha \) is the greatest. Recall \( \alpha = \frac{v^2}{R} \), since the kinetic energy is the greatest on hill #1, \( \alpha \) is the greatest there. So \( \alpha \) is the largest on hill #1.

(d) The larger the speed of the block, the larger the net force pointing towards the center that must act on the block to keep it going in a circle. So since \( \text{Force, } y = mg - N \), we need N to be the smallest possible when \( \alpha \) is large. This can also be seen from \( \text{Net, } y = ma \):

\[
mg - N = \frac{mv^2}{R} \Rightarrow N = mg - \frac{mv^2}{R}
\]

Since \( N \) is largest on hill #1, that's where \( N \) is the smallest.
s21. \( t_0 \rightarrow t_1 \): As the block slides down to \( h = 0 \), its gravitational P.E decreases and its K.E increases. When it reaches \( h = 0 \), the grav. potential energy is completely converted to K.E.

\( t_1 \rightarrow t_2 \): Now the block starts compressing the spring. The gravitational P.E decreases further and so does its K.E. The block comes to rest at \( x \) (momentarily).

At that point, the K.E of the block is again zero. At this point, the change in the gravitation potential energy of the block is stored as spring potential energy of the spring-block-earth system.

a1. K.E increases from \( t_0 \rightarrow t_1 \), decreases to zero from \( t_1 \) to \( t_2 \).

b1. P.Eg of the earth-block system decreases from \( t_0 \) to \( t_2 \).

c) The elastic/spring potential energy is zero from \( t_0 \) to \( t_1 \), but increases from \( t_1 \) to \( t_2 \).
S31. Consider the earth - baseball system.

since \( \text{West} = 0 \),

\[\Delta E = \text{West}\]

\[\Rightarrow \Delta E = 0 \Rightarrow E_f - E_i = 0\]

\[\Rightarrow E_f = E_i\]

\[
\frac{1}{2}mv_o^2 = mgh + \frac{1}{2}mv_y^2
\]

\[\Rightarrow v_f = \sqrt{v_o^2 - g(h)} - \text{Does NOT depend on } \theta.
\]

b). To solve for \( v_f \) at \( y = h \), we would need to substitute the following: use \( y_f = y_i + v_{oy} t - \frac{1}{2} gt^2 \)

\[h = 0 + v_0 \sin \theta \cdot t - \frac{1}{2} gt^2
\]

Solve for \( t \) here and then use

\[v_{fy} = v_{iy} - gt \Rightarrow v_{fy} = v_0 \sin \theta - gt
\]

So we would need to know the angle \( \theta \).

\[\text{Note: } v_f = \frac{\sqrt{v_y^2 + v_{fx}^2}}, \text{but } v_{fx} = v_0 \cos \theta \text{ since } a_x = 0\]

e). The kinematic eqs give us information about exactly how the system behaves as a function of time - in other words, they tell us how a system evolves in time.

The energy relationships are more convenient to use if all we're interested in are the initial and final states of a system. For example, in the above problem of the baseball, the energy conservation equations tell us what the speed is at \( y_f = h \), if \( v_i \) & \( h_i \) are given.
The work needed to lift 10 people by some height \( h \) is: \( W = Mgh \) since the work we do gets stored as the gravitational P.E of the people-earth system. (Assuming \( \Delta K\!E = 0 \) which it is for an elevator ride.) Assume each person weighs \( \approx 50 \text{ N} \) (that's \( \approx 110 \text{ lbs} \)). so total weight \( mg = (10 \times 50 \text{ N}) = 500 \text{ N} \). weight to elevator \( = (500 \text{ kg})(10 \text{ m}) \) \( = 5000 \text{ N} \text{m} \).

Assume \( h = 10 \text{ m} \) so \( W = Mgh = (5500 \text{ N})(10 \text{ m}) \) \( = 55,000 \text{ Nm} \).

\[ W = 55 \text{ kJ} \]

To light a 100 watt bulb for an hour, the energy needed is \( (100 \text{ W})(3600 \text{ s}) = 360 \text{ kJ} \).

So it takes roughly 6.5 times more energy to keep a light bulb lit for an hour than to transport 10 people up to the 4th floor.

*Important Note:* This is assuming the ideal case in which there are no frictional forces present that convert part of the energy expended into Thermal Energy.
I set the river to be the \( h = 0 \) level. Let's take the system to be the bungee cord + earth + jumper. Then

\[
\Delta E = W_{\text{ext}}
\]

\[
\Delta P.E_{\text{g}} + \Delta P.E_{\text{sp}} + \Delta K.E = 0
\]

\[
\nu_i = \nu_f = 0 \quad \text{so} \quad \Delta K.E = 0
\]

\[
\implies P.E_{\text{fg}} + P.E_{\text{fsp}} = P.E_{\text{ig}} + P.E_{\text{isp}}
\]

\[
mgh_f + \frac{1}{2}kd^2 = mgh_i
\]

\[
\implies \frac{1}{2}kd^2 = mg(h_i - h_f)
\]

\[
\implies k = \frac{2mg(h_i - h_f)}{d^2}
\]

\[
= \frac{2(700 \text{ N})(32 \text{ m})}{(7 \text{ m})^2}
\]

\[
= k = 914 \text{ N/m}
\]
System = Earth + block.

The normal force is 1 to the displacement so it does not do work.

Since $F_{k1}$ on the ramp and $F_{k2}$ on the horizontal floor the total change in thermal energy is

$$\Delta E_{\text{thermal}} = f_{k1} d_1 + f_{k2} d_2.$$ \(\checkmark\)

$$u_1 = 0, \quad v_f = 0 \Rightarrow \Delta K_1 E = 0.$$ \(\checkmark\)

So using $\Delta E = W_{\text{ext}} + \Delta P_{E_g} + \Delta K_1 E + \Delta E_{\text{thermal}} = 0$

$$= \left( p.E^0_f - p.E^0_i \right) + f_{k1} d_1 + f_{k2} d_2 = 0$$

$$-mg h + \mu mg \cos \theta d_1 + \mu mg d_2 = 0$$

$$\Rightarrow \quad d_2 = \frac{mgh - \mu mg \cos \theta}{\mu mg \sin \theta} = 1.96 \text{ m}.$$ \(\checkmark\)

Note you also do this problem by splitting it into two parts, 1st calculate the $K_E$ of the block at the bottom of the ramp using $\Delta P_{E_g} + \Delta K_1 E + \Delta E_{\text{thermal}} = 0$ then use $\Delta K_1 E + \Delta E_{\text{thermal}} = 0$ on the horizontal floor where now $K_1 E = 0$ and $K_1 E_i$ is the $K_1 E$ of the block at the bottom of the ramp. $\Delta E_{\text{thermal}}$ for this part is just $\mu mg d_2$, and $\Delta E_{\text{thermal}}$ is $\mu mg \cos \theta d_1$. \(\checkmark\)
Energy is conserved in the swing of the pendulum, and the stationary peg does no work, so the ball's speed does not change when the string hits or leaves the peg, so the ball swings equally high on both sides.

\[ h = 0 \]

Note the string tension \( T \) does no work on the system because \( T \) is always perpendicular to the tangential displacement.

\[ \Delta E = W_{net} \]

\[ \Delta P.E + \Delta K.E = 0 \]

\[ P.E_f + K.E_f = P.E_i + K.E_i \]

(where \( P.E \) and \( K.E \) refer to potential and kinetic energy at the top of the swing.

We want the bob to have minimum speed for it to go in a circle.

\[ 2mg(l-d) + \frac{1}{2}mv^2 = mg l \]  

\( eq 1 \)

Using \( \Delta F \), \( F = ma \) \( \Rightarrow \)

\[ \frac{v^2}{R} + mg = \frac{mv^2}{R} \]

to find min. speed to go in a circle.

\[ \Rightarrow \frac{v^2}{R} + mg = \]

\[ \Rightarrow \frac{v^2}{R} = \frac{mg}{R} \]

Substitute \( v^2 = Rg \) \( \Rightarrow \) \( R = l-d \)

\[ 2mg(l-d) + \frac{1}{2}mg(l-d) = mg l \]

\[ \Rightarrow \frac{1}{2} (l-d) = l \]

\[ d = \frac{3}{5} l \]

\[ \frac{5}{7} l - l = \frac{5}{2} d \]
PS1. Consider the block-track-earth system, \( W_{ext} = 0 \) so \( \Delta E = 0 \).

\[ \Rightarrow \Delta K_i E + \Delta P_i E = 0 \]

\[ \Rightarrow \Delta K_i E = -\Delta P_i E \]

\[ K_i E_f - K_i E_i = -(P_i E_f - P_i E_i) \]

\[ \Rightarrow K_i E_f = -(mg(2R) - mg h) \]

\[ = mg h - 2mg R \]

\[ K_i E_f = mg(h - 2R) \quad \text{eq 1.} \]

b1. cannot have a tangential acceleration at the top since both the normal force and \( F_g \) point in the radial direction at the top. There is no force in the tangential direction (assuming no friction).

To find \( a_r \), we need \( \nu \) - using eq 1 above,

\[ \frac{1}{2} \nu^2 = mg(h - 2R) \]

\[ \Rightarrow \nu^2 = 2g(h - 2R) \]

\[ a_r = \frac{\nu^2}{R} \Rightarrow a_r = \frac{2g(h - 2R)}{R} \]

\( c \) For minimum speed, set \( N = 0 \). \( \Rightarrow \) \( \Sigma F_{net, r} = ma_r \)

\[ mg = \frac{mv^2}{R} \]

\( P_i E_i = P_i E_f + K_i E_f \)

To find minimum \( h \), use \( mgh = 2mg R + \frac{1}{2} mv^2 \)

\[ mgh = 2mg R + \frac{1}{2} mg R \]

\[ mgh = \frac{5}{2} mg R \Rightarrow h = \frac{5}{2} R \]

PAGES5
\( P61 \)

(a) \[ F_{\text{net}, r} = m a \]

\[ T - m g \cos \theta = \frac{m v^2}{R} \]

\[ T = m g \cos \theta + \frac{m v^2}{R} \]

Since \( \theta \) increases as \( \theta \to 0 \) and \( \cos \theta \to 1 \) as \( \theta \to 0 \),

\( \Rightarrow \) Tension \( T \) increases as the pendulum moves towards the bottom.

(b) Using conservation of energy,

\[ \Delta E = W_{\text{ext}} \]

Considering the earth-pendulum bob system (Note tension does no work.)

\[ \Delta E = 0 \]

\[ \Rightarrow \Delta P.E + \Delta K.E = 0 \]

\[ \Rightarrow P.E_i + K.E_i = P.E_f + K.E_f \]

\[ h_f = l - l \cos \theta_0 \]

\[ \begin{align*}
\text{mg} h_i &= m \text{gh}_f + \frac{1}{2} m v_f^2 \\
\text{mg} l(1 - \cos \theta_0) &= \text{mg} l(1 - \cos \theta) + \frac{1}{2} m v_f^2 \\
\Rightarrow g l - g l \cos \theta_0 &= g l - g l \cos \theta + \frac{1}{2} v_f^2 \\
\Rightarrow 2 g l (\cos \theta - \cos \theta_0) &= v_f^2 \\
\Rightarrow v_f &= \sqrt{2 g l (\cos \theta - \cos \theta_0)}
\end{align*} \]
\[ a_r = \frac{v^2}{l} \]

\[ a_r = \frac{2g \ell (\cos \theta - \cos \theta_0)}{x} \]

\[ a_r = 2g (\cos \theta - \cos \theta_0) \]

1. If \( \theta = 90^\circ \)

\[ v_f = \sqrt{2g \ell} \]

\[ v_f = \sqrt{2g \Delta h} \quad \text{since in this case} \]

\[ h_f = \ell (1 - \cos \theta) = 0 \quad \text{at the bottom and} \]

\[ h_i = \ell (1 - \cos \theta_0) = \ell (1 - \cos 90^\circ) = l. \]

\[ \Delta h = \]

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