PHYS 105 Spring 2018

Quiz 1

Walking across a bridge, I find myself 60 m above the water. If I throw a stone straight down as hard as I can, I find it hits the water 2 seconds later. What is the speed of my throw? (g =9.8 m/s^2)

$V_0 = ?$, $t = 2s$, $a = +9.8\, m/s^2$, $\Delta y = +60$ m

↓+ positive down

$\Delta y = V_0 t + \frac{1}{2} a t^2$

$60 = V_0 \cdot 2 + \frac{1}{2} 9.8 \cdot 2^2$

$\frac{60 - \frac{1}{2} 9.8\, 2^2}{2} = V_0 = 20.2\, m/s$

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Quiz 2

An eagle is flying horizontally at a speed of 3 m/s when the fish in her talons wiggles loose and falls into the lake 5 m below. Calculate the velocity (magnitude and direction) of the fish relative to the water when it hits the water.

$v_x = v_{0x} = 3\,m/s$ always

↓ + positiv down

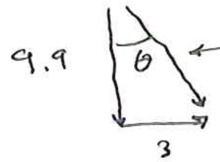
$v_{0y} = 0$ $\quad a = +9.8\,m/s^2$

$v_y = ?$ $\quad \Delta y = +5\,m$

$v_y^2 - v_{0y}^2 = 2a\Delta y$

$v_y^2 - 0^2 = 2 \cdot 9.8 \cdot 5$

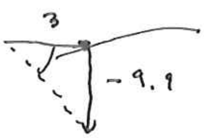
$v_y = \sqrt{2 \cdot 9.8 \cdot 5} = 9.90\,m/s$



← magnitude $= \sqrt{9.9^2 + 3^2} = 10.3\,m/s$

$\tan\theta = \frac{3}{9.9} \Rightarrow \theta = 16.9°$

Note in terms of "standard angle"



$\theta = -73.1°$

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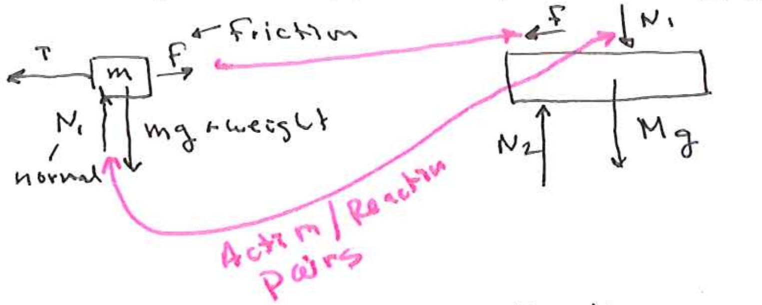
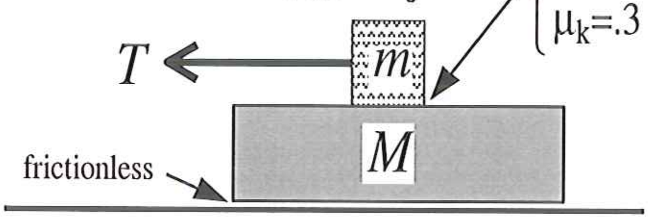
Quiz 3

A large slab (M=10 kg) floats frictionlessly on a flat surface. A block (m=1 kg) rests on top of the slab. The surface between the slab and the block has a coefficient of static friction of μ_s=0.4 and a coefficient of kinetic friction μ_k=0.3. The block is pulled with a horizontal force T. If T is sufficiently small the block+slab will move together as one object; if T is larger, there will be slippage and the block will accelerate faster than the slab (and will eventually be pulled off the slab). (A) Draw free body diagrams for each mass separately. Show and name all forces acting each mass. (B) If T=15 N, there will be slippage. Find the acceleration of each mass in this case.



Kinetic Friction $= \mu_K N_1 = \mu_K mg$



$T - f = m a_1$

$N_1 - mg = 0$

so $N_1 = mg$

& $f = \mu_K N_1 = \mu_K mg$

$f = M a_2$

$N_2 - N_1 - Mg = 0$

$\mu_K mg = M a_2$

$\frac{m}{M}\mu_K g = a_2 = .294\ m/s^2$

$T - \mu_K mg = m a_1$

$\frac{T}{m} - \mu_K g = a_1 = 12.1\ m/s^2$

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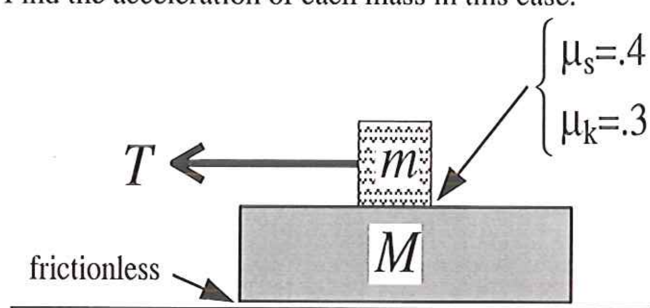

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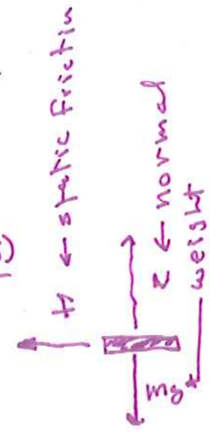
Quiz 4

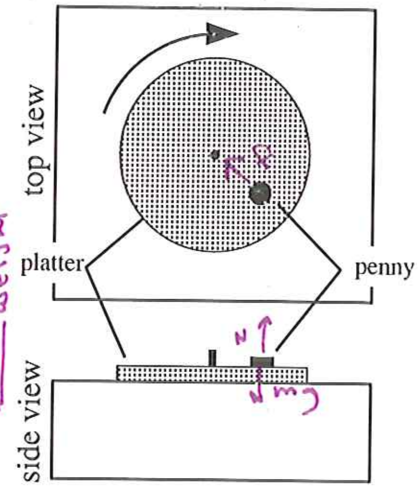
A record player is set for 33 1/3 revolutions per minute (rpm). It is found that a penny will stick with the platter as long as its distance from the platter center is less than 15 cm. (A) Draw a free body diagram of the penny sitting on the rotating platter. Show and name all forces acting on the penny. Show the direction of the acceleration (if there is any). (B) Calculate the coefficient of static friction for the penny on the platter.

$\omega = 33\frac{1}{3}\,\frac{rev}{min}\cdot\frac{1\,min}{60\,s}\cdot\frac{2\pi\,rad}{1\,rev} = 3.49\,\frac{rad}{sec}$

$N = mg$ $\quad f = \mu_s N$ (usually ≤ but in this problem at limit) $= ma$

$\mu_s mg = m\omega^2 r \Rightarrow \mu_s = \frac{\omega^2 r}{g} = \frac{(3.49)^2(.15)}{9.8} = .187$ ← unitless





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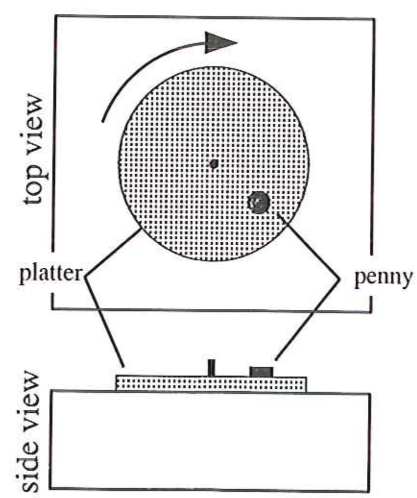

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Quiz 5

Stuntman Rupert has decided his Terminator+bike (mass = 100 kg) should have a horizontal velocity of 14 m/s for the crack-jump scene of Godzilla vs. Terminator. Since he's not really the Terminator, he could not achieve the required speed using his own muscles. So he's decided to build a frictionless ramp out of view of the camera to provide all the required energy. However, the movie frame will include 3 m on the rough surface before the crack (which has a frictional force of 800 N). (A) Calculate the work done by the frictional force as the bike travels over the rough surface. (B) Calculate the bike+rider kinetic energy (at the crack edge) required for a successful jump. (C) Calculate the height *h* at which Rupert should start.

A: $W = Fd\cos\Theta = Fd(-1) = -800 \cdot 3 = -2400\ J$

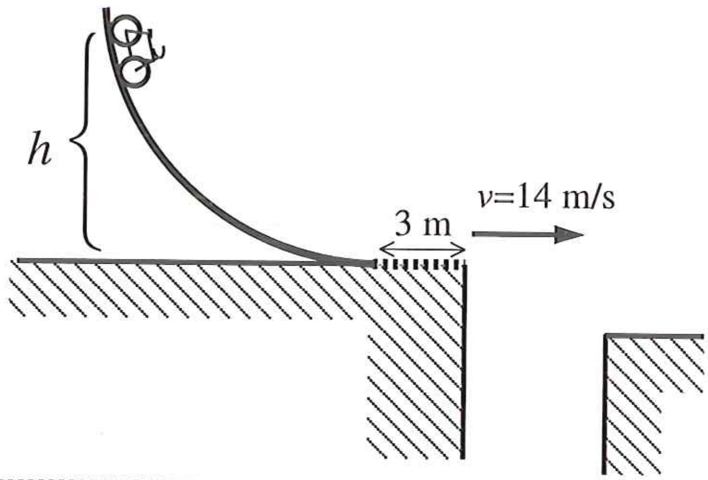
B $KE = \frac{1}{2}mv^2 = \frac{1}{2} \cdot 100 \cdot 14^2 = 9.80 \times 10^3\ J$

$W_{nc} = (KE_f + PE_f) - (KE_i + PE_i)$

$-2400 \qquad 9.8\times10^3 \qquad 0 \qquad 0 \qquad mgh$

$mgh = +2400 + 9.8\times10^3$

$h = \frac{(2400 + 9800)}{100 \cdot 9.8} = 12.5\,m$



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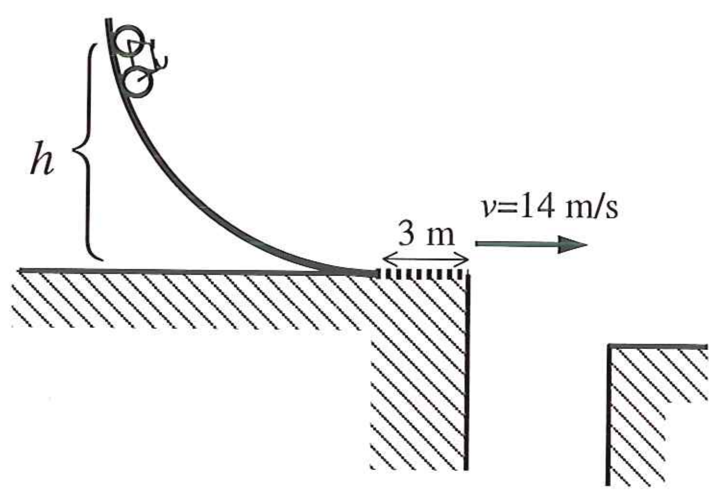

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Quiz 6

A 5.5 kg bowling ball moving 9 m/s makes an elastic, head-on collision with a .85 kg bowling pin which moves straight ahead (i.e., everything remains in a line). Find the post collision velocities of the bowling ball and bowling pin.

(m_1 = 5.5 kg, v_1 = 9 m/s, m_2 = .85 kg, $v_2 = 0$; v_1' = ball, v_2' = pin)

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2' \quad \text{momentum}$$

$$m_1v_1 = m_1v_1' + m_2v_2'$$

KE conservation is equivalent to

$$(v_1 - v_2) = -(v_1' - v_2')$$

$$v_1 = v_2' - v_1'$$

$$v_1 + v_1' = v_2'$$

$$m_1v_1 = m_1v_1' + m_2(v_1 + v_1')$$

$$(m_1 - m_2)v_1 = (m_1 + m_2)v_1'$$

$$\frac{(m_1 - m_2)}{(m_1 + m_2)} v_1 = v_1'$$

$$\frac{5.5 - .85}{5.5 + .85} 9 = v_1'$$

$$6.59 \text{ m/s} = v_1'$$

$$9 + 6.59 = v_2'$$

$$15.6 \text{ m/s} = v_2'$$

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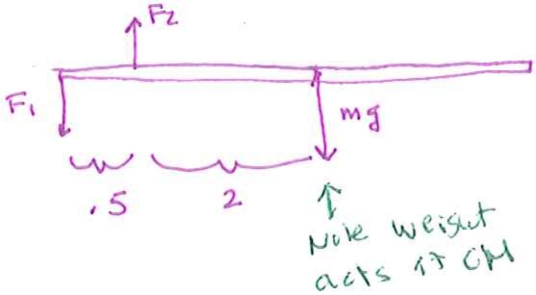
Quiz 7

A straight, uniform pole vault pole is 5 m long and has a mass of 10 kg. A pole vaulter places one hand at the end of the pole and the other hand 50 cm from the pole's end and holds the pole horizontal with no support other than his two hands. Draw a free body diagram showing the pole and where every force is applied. Calculate the force applied by each hand (your diagram should display the direction of these hand forces).



$F_2 - F_1 - mg = 0$

origin F_2: $\rightarrow F_2 \cdot 0 + F_1(.5) - mg(2) = 0$

$F_1 = \frac{2}{.5} mg = 4 \cdot 10 \cdot g$

$= 392$ N

origin F_1: $F_1 \cdot 0 + F_2(.5) - mg(2.5) = 0$

$F_2 = \frac{2.5}{.5} mg = 5 \cdot 10 \cdot g$

$= 490$ N

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Quiz 8

An old stone well consists of a bucket (mass M=2 kg) and a reel with crank (moment of inertia I= 0.9 kg m^2 and radius R=.3 m) to pull the bucket up. The bucket is released from the top of the well; as it falls it pulls the rope down and, as a result, the crank assembly runs backward. Find the acceleration of the bucket. Of course, your answer will include two free body diagrams: one of the forces on the bucket and one of the torques on the reel.

T

mg

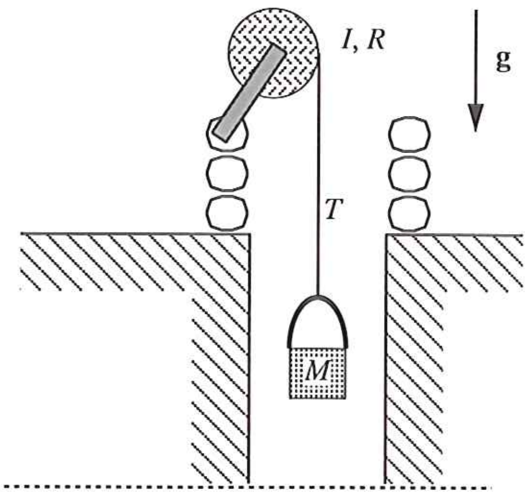
$Mg - T = Ma$

$TR = I\alpha = I\frac{a}{R}$

$T = \frac{I}{R^2}a$

$Mg = \left(M + \frac{I}{R^2}\right)a$

$\frac{Mg}{M + I/R^2} = a = \frac{2 \cdot 9.8}{2 + .9/.3^2} = 1.63\ m/s^2$



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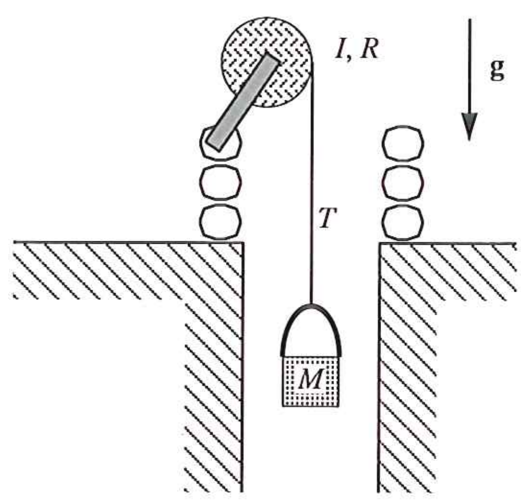

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Quiz 9

(area = $\frac{\pi}{4} dia^2$)

On a Lake Superior fire-fighting boat, a pump below decks provides the pressure to squirt water from the nozzle 10 m vertically above the pump. A 15 cm diameter hose connects the pump to the nozzle which has an end diameter of 1 cm. The velocity of the water as it leaves the nozzle is 20 m/s. The density of lake water is 1000 kg/m^3.

(A) How much water must the pump suck from the lake (in m^3/s)?

(B) What pressure does the pump produce, given that atmospheric pressure is 100 kPa?

A) $\frac{\pi}{4}(.01)^2 \cdot 20\,\text{m/s} = 1.57\times10^{-3}\ \text{m}^3/\text{s}$

B) $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

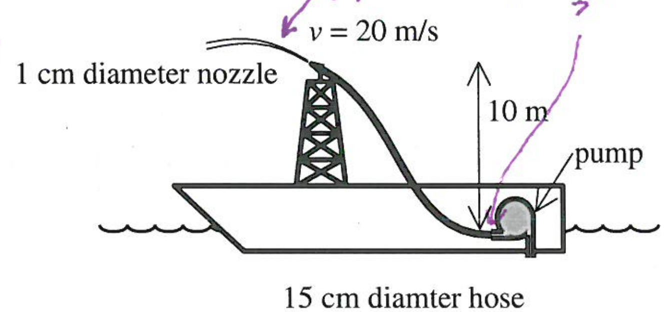
($P_1 = 10^5$, $v_1 = 20$, $y_1 = 10$, $v_2 = 8.89\times10^{-2}$, $y_2 = 0$)

$v_2 = \frac{v_1 A_1}{A_2} = 20\left(\frac{1}{15}\right)^2 = 8.89\times10^{-2}$ m/s

$10^5 + \frac{1}{2}\cdot1000\left(20^2 - [8.89\times10^{-2}]^2\right) + 1000\cdot9.8\cdot10 = P_2$

$3.98\times10^5 = P_2$ ← this is absolute; if seeking gauge, subtract 10^5 Pa

$P_1 = 10^5$ Pa



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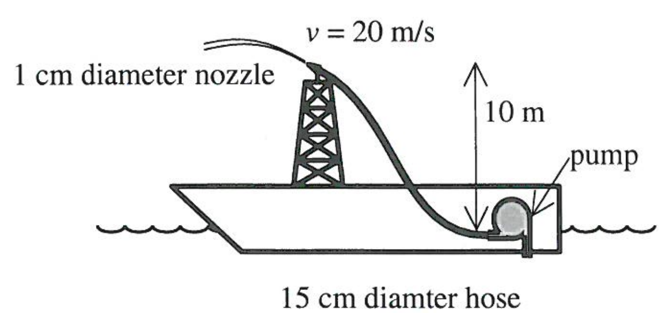

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Quiz 10

50 g of ice (from the freezer at –20°C), is used to cool 250 g of water (at room temperature: 22°C) in an insulated container. The final mixture is all liquid. What is the final temperature?

water heat of fusion = 334 J/g,
ice specific heat = 2.09 J/(g·K), water specific heat = 4.186 J/(g·K)

$$\underbrace{50\cdot 2.09\cdot(0-{-20})}_{\text{ice to }0^\circ C} + \underbrace{50\cdot 334}_{\text{melt ice}} + \underbrace{50\cdot 4.186\,(x-0)}_{\text{was ice to }x} + \underbrace{250\cdot 4.186\,(x-22)}_{\text{water to }x} = 0$$

$$300\cdot 4.186\cdot x = 250\cdot 4.186\cdot 22 - 50\cdot 334 - 50\cdot 2.09\cdot 20$$

$$x = \frac{4233}{1256} = 3.37^\circ C$$

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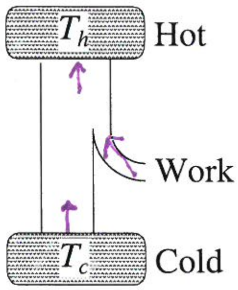
→ Note engine runs reverse!

We have discussed two conceptual maps for a Carnot refrigerator: (A) an abstract map that shows net energy flows to/from thermal reservoirs and (B) a more detailed P-V diagram of the working fluid. Select one of these maps and answer the corresponding questions. Use the following definitions:

Q_h = heat added to (+) or removed from (–) the hot ($T = T_h$) reservoir
Q_c = heat added to (+) or removed from (–) the cold ($T = T_c$) reservoir
Q = heat added to (+) or removed from (–) the working fluid of the machine itself
W = work done by (+) or on (–) the working fluid of the machine itself

1. A. For a Carnot refrigerator report the signs of Q_h : + , Q_c : – , W : –

   B. Add three arrows to the below left diagram showing the directions of the energy flows.



	hot	cold	fluid
ΔU	+	–	0
ΔS	+	–	0

   C. Enter in the above table (+,–,0) to denote the sign of the energy and entropy changes for the: hot reservoir, cold reservoir, and working fluid (for one complete cycle of the refrigerator).

   D. Write down the formula for the total entropy change (i.e., including everything) in terms of the symbols defined above. What does the second law of thermodynamics say about this total entropy change in general? For a Carnot cycle what is the numerical value of this total entropy change?

positive or zero

zero

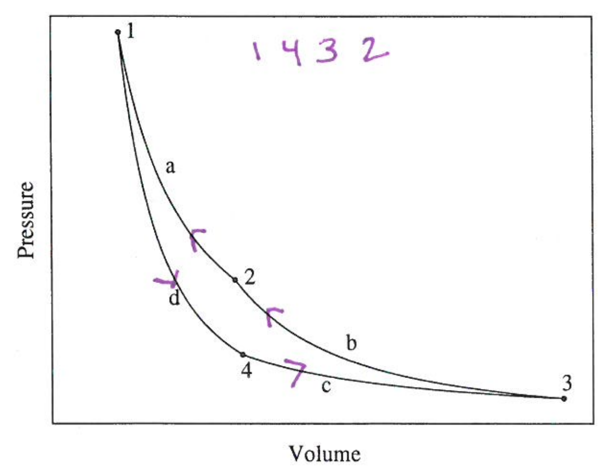
$$\frac{Q_h}{T_h} + \frac{Q_c}{T_c} \geq 0$$

$$\frac{Q_h}{T_h} - \frac{|Q_c|}{T_c} \geq 0$$

2. A. Report which way the cycle turns for a Carnot refrigerator by reporting the order the points are traversed. Put little arrows on the below plot to confirm your answer.

   B. Assume the working fluid is an ideal gas, and report in the below table the sign (+,–,0) of the corresponding quantity for each segment of the path (abcd).

	path	ΔT	ΔU	ΔS	Q	W
isotherm →	a	0	0	–	–	–
adiabat →	b	+	+	0	0	–
isotherm →	c	0	0	+	+	+
adiabat	d	–	–	0	0	+



PHYS 105 Spring 2018

Quiz 12

Rupert (mass = 80 kg) decides to bungie jump out of a tall building. The bungie has a spring constant of 160 N/m and a length such that it will start taking effect after Rupert has fallen 3 m. What is the extension of the bungie cord when Rupert's fall is temporarily stopped?

$E_i = PE_i = mgy_i = mgh$ where $h = 3\,m$

$E_f = PE_f = mgy + \frac{1}{2}ky^2$ ← seek solution where $y < 0$

Conservation of Energy: $mgh = mgy + \frac{1}{2}ky^2$

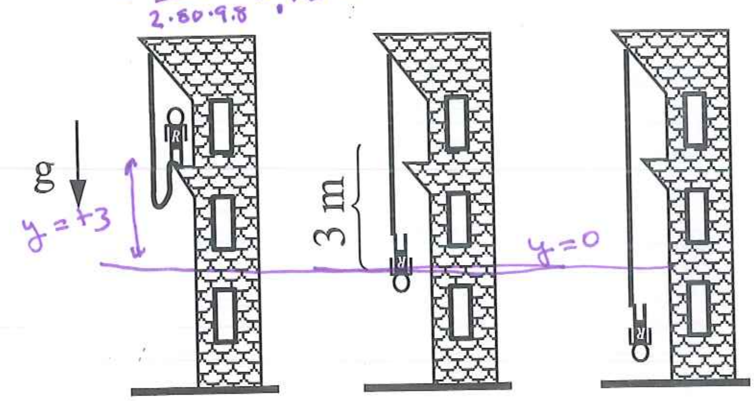
$h = y + \frac{1}{2}\frac{k}{mg}y^2$

$0 = \left(\frac{k}{2mg}\right)y^2 + y\,(-h)$

$a = \frac{160}{2\cdot 80\cdot 9.8} = .102$, $b = 1$, c

$y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-1 \pm \sqrt{1^2 + 4ha}}{2a} \approx \frac{-1 \pm 1.5}{2a}$ use (−)

$= -12.2\,m$



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