Problem Number 1

A spring is attached to the ceiling and allowed to hang vertically. The spring has an un-stretched length of 10 cm while hanging. A 4 kg mass is then attached to the bottom of the spring and the mass stretches the spring such that the spring now has a length of 15 cm. You may neglect the mass of the spring itself in this problem.

You now pull down on the mass, stretching the spring from 15 cm to 17 cm and then release the mass.

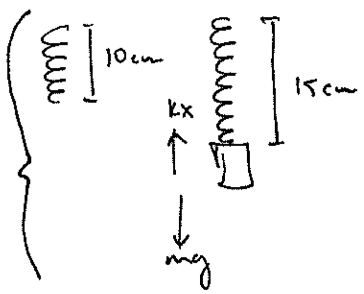
(a) In the resulting simple harmonic motion that takes place, what is the shortest length of the spring?

(3pts)

a) $A = 2\text{ cm}$

$\ell_{short} = 15 - 2 = \boxed{13\text{ cm}}$

(3pts)



$\Sigma F_y = kx - mg = 0$

$k(.05) = 4(9.8)$

$\boxed{k = 784\ N/m}$

(b) How many seconds does it take the spring to reach this shortest length?

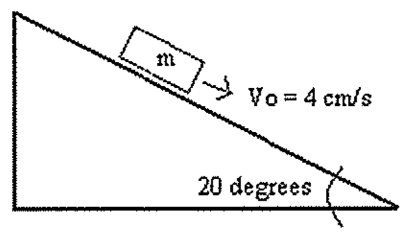
$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{4}{784}} \Rightarrow T = 0.45\text{ s}$ (3pts)

$T_{up} = \frac{1}{2}T = \boxed{.225\text{ s}}$ (1pt)

Do not write in this box: | Points Given = / 10 |

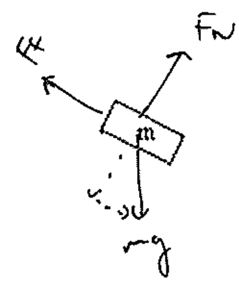
Problem Number 2

Mass M is sliding down the inclined plane, as shown in the diagram, with an initial velocity at time t=0 of 4 cm/sec. The coefficient of kinetic friction between the mass and the incline is $\mu_k = 0.2$. Assuming the mass does not reach the base of the incline before one second passes, complete the following:



a) Draw a free body diagram of the mass.

(3pb)



b) Calculate the speed of the mass after 1 second has passed.

$\Sigma F_{\parallel}$:

$mg\sin 20^\circ - F_f = ma_{\parallel}$

$\cancel{m}g\sin 20^\circ - \cancel{m}g\cos 20^\circ \cdot \mu = \cancel{m}a$

$a = 1.5\ m/s^2$

(4pb)

$v = v_0 + at$

$v = .04 + 1.5(1)$

$\boxed{v = 1.55\ m/s}$

(2pb)

c) Calculate how far from its initial position the mass has slid down the plane after one second.

$v^2 = v_0^2 + 2a(x - x_0)$

$1.55^2 = .04^2 + 2(1.5)(x)$

$x = 0.815\ m$

(2pb)

Do not write in this box: | Points Given = / 10

Problem Number 3

A lab manual asks students to mix 400 g of warm ethanol at 60 degrees Celsius with 300 grams of room temperature water at 20 degrees Celsius. The specific heat of ethanol is 3140 $\frac{J}{kg*°C}$ and the specific heat of water is 4186 $\frac{J}{kg*°C}$.

Calculate the final temperature of the mixture after it has been allowed to reach thermal equilibrium.

GAINS — H_2O

LOSSES — Ethanol

$$m_w c_w (T - 20) = m_E c_E (60 - T)$$

$$3\cancel{0}\cancel{0}(4186)(T - 20) = 4\cancel{0}\cancel{0}(3140)(60 - T)$$

$$T - 20 = 60 - T$$

$$2T = 80$$

$$\boxed{T = 40\,°C}$$

Do not write in this box: | Points Given = / 10

Problem Number 4

An ideal gas is kept inside a cylinder with a piston. The gas is argon and therefore each molecule contains only one atom. There are 20 moles of gas in the container.

a) The temperature of the gas is increased from $T_1 = 27°C$ to $T_2 = 200°C$. Calculate the change in internal energy of the gas.

300 K 473 K

(2pts) $\Delta U = \frac{3}{2} n R (\Delta T)$

(2pts) $= \frac{3}{2}(20)(8.31)(173)$

(1pt) $\boxed{\Delta U = 43{,}129 \text{ J}}$

b) During the process in part (a) the gas does 5000 J of work in lifting a mass M that was placed on the piston. Determine how much heat energy was put into the gas.

(2pts) $\Delta U = Q \pm W$

(2pts) $43{,}129 = Q - 5000$

(1pt) $\boxed{Q = 48{,}129 \text{ J}}$

Do not write in this box: | Points Given = / 10

Problem Number 5

In a football game, a receiver is standing still, having just caught a pass. Before he can move, a tackler running at a velocity of 4.5 m/sec east grabs on to the receiver. The two players continue to move together with a velocity of 2.6 m/sec, east, after the collision.

If the mass of the tackler is 115 kg, what was the mass of the receiver?

1: Receiver

2: Tackler

$$m_1 \cancel{v_{1o}}^{0} + m_2 v_{2o} = (m_1 + m_2) v \quad (5 \text{ pts})$$

$$m_2 (v_{2o}) = (m_1 + m_2) v$$

$$115 (4.5) = (m_1 + 115)(2.6) \quad (3 \text{ pts})$$

$$2.6\, m_1 = 218.5$$

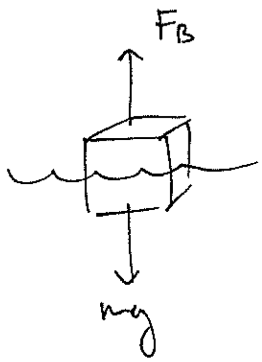
$$\boxed{m_1 = 84 \text{ kg}} \quad (2 \text{ pts})$$

Do not write in this box: | Points Given = / 10

Problem Number 6

A cube shaped, pine block measures 3 m on each edge. The density of pine wood is 550 kg/m^3 and the density of water is 1000 kg/m^3.

When the block is floating in water, what fraction of the 3 m height is below the surface?



(3pts)

$$F_B = mg \quad (2pts)$$

$$\rho_{H_2O} V_{disp} \cancel{g} = \rho_{wood} V_{block} \cancel{g} \quad (2pts)$$

$$\frac{V_{disp}}{V_{block}} = \frac{\rho_{wood}}{\rho_{H_2O}}$$

$$(2pts) \quad = \frac{550}{1000} = .55$$

(1pt) $\boxed{\text{55\% BELOW SURFACE}}$

SHORT CUT

$$\frac{\rho_{wood}}{\rho_{H_2O}} = \frac{V_{disp}}{V_{block}} \quad (5pts)$$

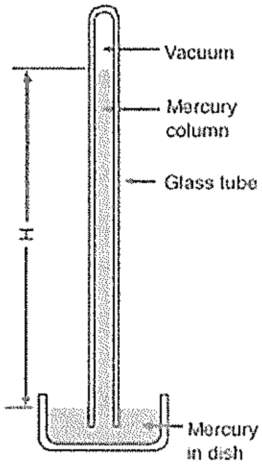
$$\frac{550}{1000} = \boxed{.55} \quad (5pts)$$

Do not write in this box: Points Given = / 10

Problem Number 7

The density of water is 1000 kg/m^3 and the density of mercury is 13,600 kg/m^3.

The discovery of the barometer may have gone something like this:



- A long, vertical test tube was filled with mercury with the top of the tube facing up.
- The top of the tube was sealed with a horizontal plate.
- The tube was inverted upside down with the base inside a pool of mercury.
- The horizontal plate was removed

It was then observed that the mercury level fell leaving an evacuated region at the top of the test tube. The height of the mercury in the test tube was found to be 76 cm above the surface of the mercury pool outside the test tube when the barometer was near sea level. (See diagram to right).

a) If the barometer were to be carefully held steady while a scientist walked up a mountain, the height of the mercury column would:

(3pts) _____ Increase ✓ Decrease _____ Remain the same

Justify your answer:

P_{air} decreases so less pressure to push Hg up the tube

(2pts)

b) In principal you could make a barometer using water instead of mercury. Describe a practical disadvantage of a water barometer by considering the expected height of the water column while near sea level.

$P_{air} = 100{,}000 \frac{N}{m^2} \Rightarrow P_{H_2O} = \rho g h$

(5pts)

$10\cancel{0{,}000} = 1\cancel{000}(9.\cancel{8})(h)$

$h = 10$ m

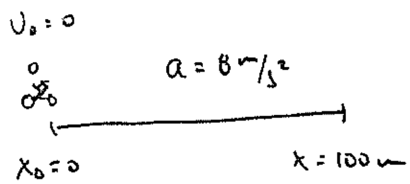
The barometer would have to be 10 m tall.

Do not write in this box: | Points Given = / 10 |

Problem Number 8

The famous X-Games motorcyclist Travis Pastrana, drives his motorcycle along the top of a level cliff that is 70 m high. After starting from rest Travis accelerated at a rate of 8.0 m/s^2 for a distance of 100 m before leaving the cliff horizontally.

a) Calculate the speed of the motorcycle at the end of 100 m as he left the edge of the cliff?



$$v^2 = v_0^2 + 2a(x - x_0)$$

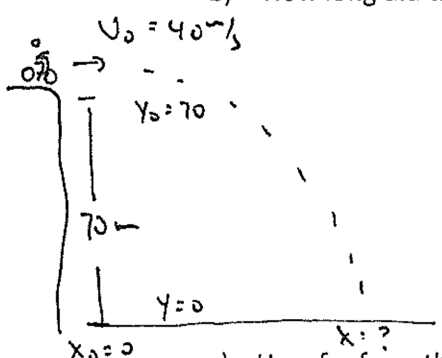
$$v^2 = 0 + 2(8)(100)$$

$$\boxed{v = 40\ m/s}$$

(3pt)

(1pt)

b) How long did the motorcyclist spend in the air after leaving the cliff?



$$y = y_0 + \cancel{v_{0y}t} + \frac{1}{2}gt^2$$

$$0 = 70 + 0 - 4.9t^2$$

$$\boxed{t = 3.78\ s}$$

(3pt)

c) How far from the base of the cliff did he land, assuming the face of the cliff was vertical?

$$x = x_0 + v_x t$$

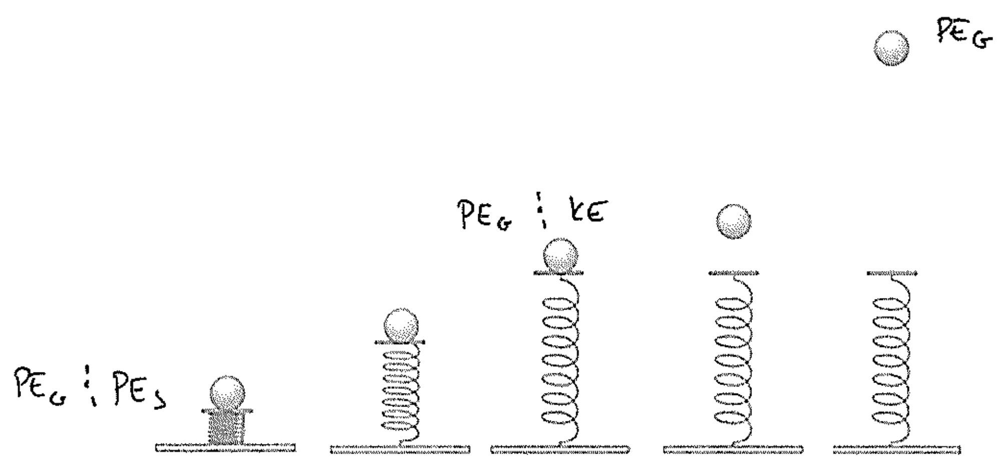
$$x = 0 + 40(3.78) \Rightarrow \boxed{x = 151\ m}$$

3pt

Do not write in this box: | Points Given = / 10

Problem Number 9

A ball of mass 25.0 grams is launched vertically by using a compressed spring with k = 3 N/m. The spring is originally of a length of 50.0 cm, but was compressed to a length of 10.0 cm prior to launching.



(a) Calculate the speed at which the ball leaves the spring.

$$mgh_0 + \frac{1}{2}kx^2 = mgh + \frac{1}{2}mv^2 \quad \text{(2pts)}$$

$$(.025)(9.8)(.1) + \frac{1}{2}(.4)^2(3) = (.025)(9.8)(.5) + \frac{1}{2}(.025)v^2 \quad \text{(2pts)}$$

$$\boxed{v = 3.37\ m/s} \quad \text{(1pt)}$$

(b) Calculate the maximum height above ground level that the ball reaches.

Kinematics

$y_0 = .5m$
$y = ?$
$v_0 = 3.37\ m/s$
$v = 0$
$a = -9.8\ m/s^2$
$t = ?$

(2pts) $v^2 = v_0^2 + 2g(y - y_0)$

(2pts) $0 = 3.37^2 - 19.6(y - .5)$

(1pt) $\boxed{y = 1.08\ m}$

Energy

(2pt) $mgh_0 + \frac{1}{2}kx^2 = mgh_f$

(2pt) $.025(9.8)(.1) + \frac{1}{2}(3)(.4)^2 = (.025)(9.8)(h)$

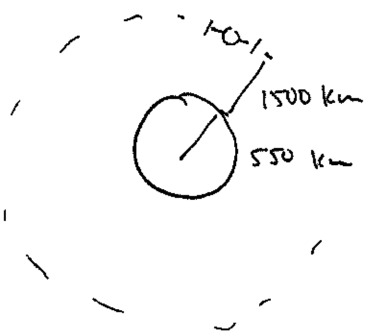
(1pt) $\boxed{h = 1.08\ m}$

Do not write in this box: Points Given = / 10

Problem Number 10

A small space probe, with a mass of 100 kg, is put into circular orbit about a newly discovered moon of Saturn. The moon's radius is known to be 550 km. The probe orbits at a height of 1500 km above the moon's surface and takes 2.00 Earth days to make one orbit.

a) Determine the speed of the space probe as it orbits the moon of Saturn.



(2pts) $V = \frac{2\pi r}{T} = \frac{2(\pi)(2{,}050{,}000)}{(2 \times 86{,}400)}$ (2pts)

$\boxed{\vec{v} = 74.5 \text{ m/s}}$ (1pt)

b) Determine the moon's mass.

$$\Sigma F_c = \frac{mv^2}{r}$$

$$\frac{G M_{moon} \cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m} v^2}{\cancel{r}}$$

$$\frac{(6.67 \times 10^{-11})(M_{moon})}{(2{,}050{,}000)} = (74.5)^2 \Rightarrow \boxed{M_{moon} = 1.7 \times 10^{20} \text{ kg}}$$

Do not write in this box: | Points Given = / 10 |