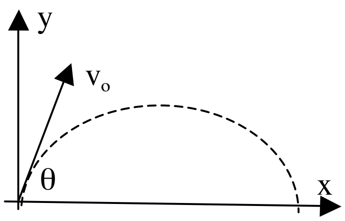
Name:____ Posting Code ____ ____ ____
(only if you want your grade posted on the web.)

Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 10 points. You <u>must</u> show your work in a logical fashion <u>starting</u> with the correctly applied physical principles shown on the last page. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. In 1940, Emanuel Zacchini set the record for distance by a "human cannonball" at 53.0m. His initial speed was 24.0m/s and he was launched at 30.0° above horizontal. Find (a)the time he spent in the air and (b)his maximum height above the ground.



$x_o = 0$
$x = 53.0\text{m}$
$v_{ox} = 24.0\cos 30.0°$
$v_x = 24.0\cos 30.0°$
$a_x = 0$
$t = ?$

(a)Use the kinematic equation,

$$x = x_o + v_{ox}t + \tfrac{1}{2}a_x t^2 \Rightarrow t = \frac{x}{v_{ox}}$$

Plugging in the numbers,

$$t = \frac{53.0}{24.0\cos 30.0°} \Rightarrow \boxed{t = 2.55s}.$$

$y_o = 0$
$y = ?$
$v_{oy} = 24.0\sin 30.0°$
$v_y = 0$
$a_y = -9.80\text{m/s}^2$
$t = ?$

(b)Using the kinematic equation,

$$v_y^2 = v_{oy}^2 + 2a_y(y - y_o) \Rightarrow y = -\frac{v_{oy}^2}{2a_y}$$

Plugging in the numbers,

$$y = -\frac{v_{oy}^2}{2a_y} = -\frac{(24.0\sin 30.0°)^2}{2(-9.80)} \Rightarrow \boxed{y = 7.35m}.$$

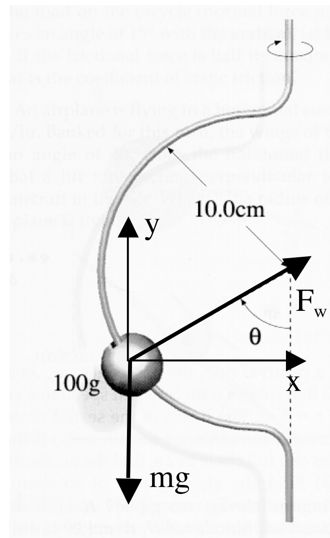
2. Looking at the apples in the grocery store, the following questions enter your (physics obsessed) mind: (a)Which has a larger mass, an apple or a watermelon? (b)Which feels a larger gravitational force when dropped? (c)Which accelerates toward Earth at a higher rate? Fortunately, your instructor asks you to answer these very questions on your final exam. Unfortunately, he expects you to explain your answers.

(a)The [watermelon] has a larger mass because it is harder to accelerate (or it has more inertia) than an apple.

(b)The force of gravity is proportional to the mass according to the mass/weight rule or the Universal Law of Gravitation, so the [watermelon] feels more gravitational force.

(c)Using Newton's Second Law, they both wind up having [the same] acceleration. The watermelon has a bigger mass, but more force while the apple has less mass and less force. Rule of Falling Bodies could also be cited.

3. The device shown at the right consists of a 100g bead that is free to move along a frictionless wire bent in the shape of a circle of radius 10.0cm. The device is rotated at just the right rate so that the angle is 37.0˚. Find (a)the magnitude of the force that the wire exerts on the bead and (b)the angular speed of the bead.



Using the Second Law and centripetal acceleration,

$$\Sigma F_x = ma_x \Rightarrow F_w \sin\theta = m\frac{v^2}{r}$$

$$\Sigma F_y = ma_y \Rightarrow F_w \cos\theta - mg = 0 \Rightarrow F_w \cos\theta = mg$$

(a)Solving the y equation,

$$F_w = \frac{mg}{\cos\theta} = \frac{(0.100)(9.80)}{\cos 37.0^\circ} \Rightarrow \boxed{F_w = 1.23N}.$$

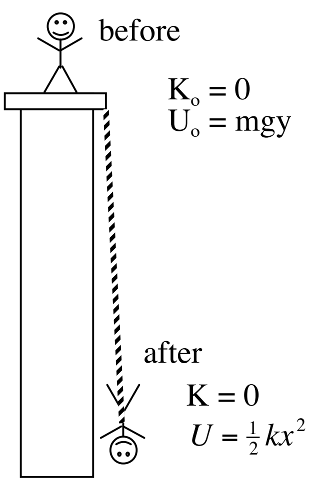
(b)Note that $v = r\omega$ and that $r = R\sin\theta$. The x equation becomes,

$$F_w \sin\theta = m\frac{(r\omega)^2}{r} = m\omega^2 r = m\omega^2 R\sin\theta \Rightarrow F_w = m\omega^2 R \Rightarrow \omega = \sqrt{\frac{F_w}{mR}}$$

Plugging in the numbers,

$$\omega = \sqrt{\frac{1.23}{(0.100)(0.100)}} \Rightarrow \boxed{\omega = 11.1 rad/s}.$$

4. A 60.0kg nut-case jumps off a 45.0m high bridge attached to a bungee-cord. The unstretched length of the cord is 25.0m. Find the minimum spring constant of the cord so that the jumper does not collide with the ground.



Using the Law of Conservation of Energy,

$$\Delta K + \Delta U = 0 \Rightarrow (K - K_o) + (U - U_o) = 0 \Rightarrow U = U_o$$

Putting in the potential energies,

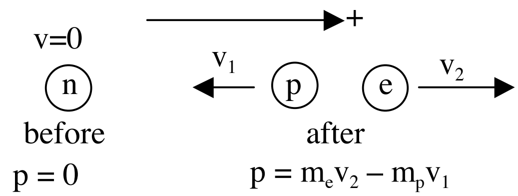
$$\tfrac{1}{2}kx^2 = mgy \Rightarrow k = \frac{2mgy}{x^2}$$

Note that the stretch of the cord is 45-25=20.0m,

$$k = \frac{2(60.0)(9.80)(45.0)}{(20.0)^2} \Rightarrow \boxed{k = 132 N/m}.$$

5. It turns out that neutrons are not stable particles. A neutron will decay into a proton and an electron. The mass of a proton is 1833 times the mass of an electron. Suppose a neutron, initially at rest, breaks apart into an electron and a proton. Find (a)the net momentum of the electron and the proton as a system and (b)the ratio of kinetic energy of the electron to the kinetic energy proton.

(a)Since the neutron is initially at rest, the total momentum of the system is zero before the decay. By the Law of Conservation of Momentum, the momentum of the proton plus the electron will also be zero after the decay.

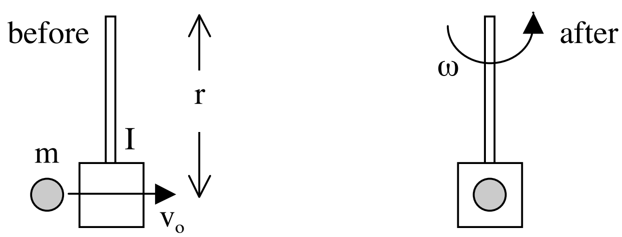


(b)Applying the Law of Conservation of Momentum, $0 = m_e v_2 - m_p v_1 \Rightarrow \frac{v_2}{v_1} = \frac{m_p}{m_e}$

The ratio of the kinetic energies is,

$$\frac{K_e}{K_p} = \frac{\frac{1}{2}m_e v_2^2}{\frac{1}{2}m_p v_1^2} = \frac{m_e}{m_p}\left(\frac{v_2}{v_1}\right)^2 = \frac{m_e}{m_p}\left(\frac{m_p}{m_e}\right)^2 = \frac{m_p}{m_e} \Rightarrow \boxed{\frac{K_e}{K_p} = 1833}.$$

6. In lab you examined the collision of a 75.0g ball with a catching device that had a rotational inertia of $0.0150 kg\cdot m^2$. The ball was caught 30.0cm below the pivot point. As a result, the arm and ball took off with an angular speed of 8.00rad/s. Find the initial speed of the ball.



$L_o = mv_o r$ $L = mvr + I\omega$

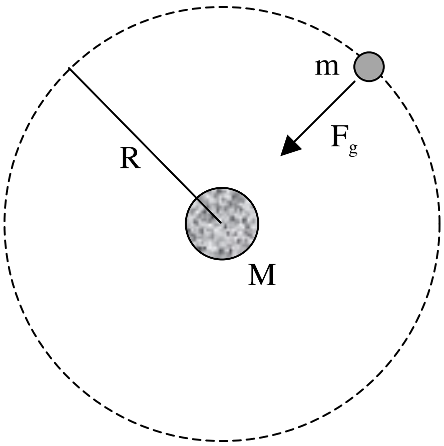
Using the Law of Conservation of Angular Momentum,

$$L_o = L \Rightarrow mv_o r = mvr + I\omega.$$

Note that v = rω,

$$mv_o r = mr^2\omega + I\omega \Rightarrow v_o = \left(r + \frac{I}{mr}\right)\omega = \left(0.300 + \frac{0.0150}{(0.0750)(0.300)}\right)(8.00) \Rightarrow \boxed{v_o = 7.73 m/s}.$$

7. Find the period of orbit for the moon using the data on the equation sheet.



Using Newton's Second Law and the Universal Law of Gravitation,

$$\Sigma F = ma \Rightarrow G\frac{mM}{R^2} = ma \Rightarrow G\frac{M}{R^2} = a$$

Using the centripetal acceleration and the speed as the circumference divided by the time,

$$G\frac{M}{R^2} = \frac{v^2}{R} \Rightarrow G\frac{M}{R} = \left(\frac{2\pi R}{T}\right)^2 \Rightarrow T = \sqrt{\frac{4\pi^2 R^3}{GM}}$$

Plugging in the numbers,

$$T = \sqrt{\frac{4\pi^2(3.82x10^8)^3}{(6.67x10^{-11})(5.98x10^{24})}} \Rightarrow \boxed{T = 2.35x10^6 s = 27.2 days}.$$

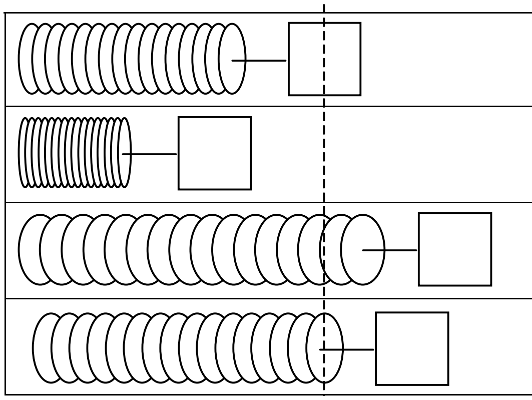
8. The pendulum of any grandfather clock is roughly 1.00m long. Explain.

The period of a simple pendulum is given by,

$$T = 2\pi\sqrt{\frac{\ell}{g}}.$$

For a 1.00m long pendulum, the period is about 2.00s. Since the pendulum is at its amplitude twice each oscillation, you can set the gears in the clock so that each time the pendulum is at its amplitude it moves the clock forward one second.

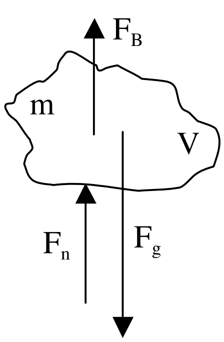
9. Shown below is a mass, m, is oscillating at the end of a spring with spring constant, k with an amplitude, A. For each time shown, fill in the missing information. Explain your reasoning for full credit.



x	v	U	K	E
0	$\sqrt{\frac{k}{m}}A$	0	$\frac{1}{2}kA^2$	$\frac{1}{2}kA^2$
-A	0	$\frac{1}{2}kA^2$	0	$\frac{1}{2}kA^2$
A	0	$\frac{1}{2}kA^2$	0	$\frac{1}{2}kA^2$
$\frac{1}{2}A$	$\sqrt{\frac{3k}{4m}}A$	$\frac{1}{8}kA^2$	$\frac{3}{8}kA^2$	$\frac{1}{2}kA^2$

The Law of Conservation of Energy requires the total energy to remain fixed.
First row: Since the spring is unstretched, all the energy is kinetic, $\frac{1}{2}mv^2 = \frac{1}{2}kA^2 \Rightarrow v = \sqrt{\frac{k}{m}}A$.
Second and third rows: The speed is zero and so is the kinetic energy, so the potential energy equals the total energy. Since the potential energy is given by $\frac{1}{2}kx^2$, x must equal A at these two points.
Fourth row: From the position we can get the potential energy, $U = \frac{1}{2}k\left(\frac{A}{2}\right)^2 = \frac{1}{8}kA^2$. Subtracting from the total energy gives the kinetic energy and then the speed, $\frac{1}{2}mv^2 = \frac{3}{8}kA^2 \Rightarrow v = \sqrt{\frac{3k}{4m}}A$.

10. A1000kg boulder with a volume of 0.700m^3 rests on the bottom of a lake. Draw a sketch showing the forces that act on the boulder and find the magnitude of each one.



The weight can be found from the mass/weight rule,
$F_g = mg = (1000)(9.80) \Rightarrow \boxed{F_g = 9800N}$.

The buoyant force can be found using Archimedes' Principle,

$F_B = m_f g = \rho g V = (1000)(9.80)(0.700) \Rightarrow \boxed{F_B = 6860N}$.

The normal force can be found using the Second Law,

$\Sigma F = ma \Rightarrow F_B + F_n - F_g = 0 \Rightarrow F_n = F_g - F_B = 9800 - 6860 \Rightarrow \boxed{F_n = 2940N}$.