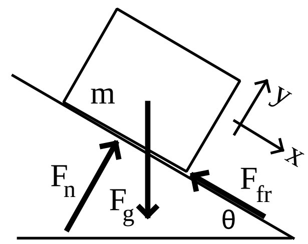
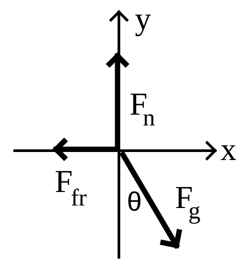
Name:______________________________________

Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 20 points. You must show your work in a logical fashion starting with the correctly applied physical principles which are on the last page. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. A 50.0kg crate skids down a 30.0˚ ramp. The coefficient of friction is 0.450. Find the acceleration.



Free Body Diagram



The three forces on the crate are gravity, normal force and friction. Choose the acceleration along the x axis. Using the free body diagram carefully apply the Second Law to each direction separately,

$\Sigma F_x = ma_x \qquad F_g \sin\theta - F_{fr} = ma \qquad mg\sin\theta - F_{fr} = ma \qquad (1),$

$\Sigma F_y = ma_y \qquad F_n - F_g \cos\theta = 0 \qquad F_n = mg\cos\theta \qquad (2),$

where the mass/weight rule has been used.

Using the definition of coefficient of friction and eq. 2,

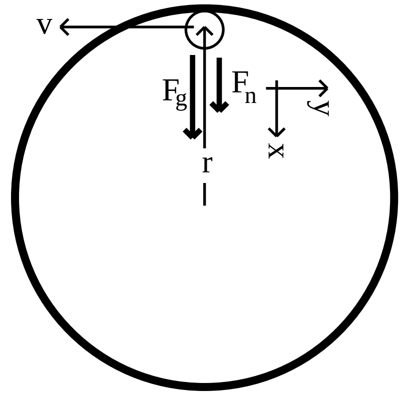
$$\mu \equiv \frac{F_{fr}}{F_n} \qquad F_{fr} = \mu F_n = \mu mg\cos\theta \qquad (3).$$

Substituting eq. 3 into eq. 1,

$$\not{m}g\sin\theta - \mu\not{m}g\cos\theta = \not{m}a \qquad a = g(\sin\theta - \mu\cos\theta).$$

Plugging in the numbers,

$$a = (9.80)\left[\sin 30^\circ - (0.45)\cos 30^\circ\right] \qquad \boxed{a = 1.08\ \mathrm{m/s^2}}.$$



2. In my office is a toy in which a 100g ball rolls around on the inside of a circular track with a radius of 20.0cm as shown at the right. Find the forces that act on the ball at the top of the circle if the speed of the ball at this point is 3.00m/s.

The forces that act on the ball are the weight and the normal force from the track.

The weight can be found from the mass/weight rule,

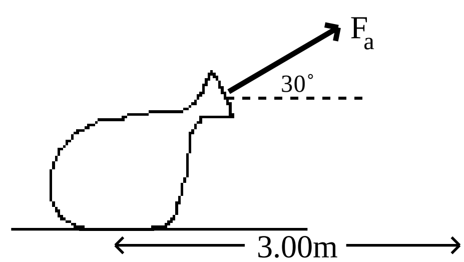
$$F_g = mg = (0.100)(9.8) \qquad \boxed{F_g = 0.980\text{N}}.$$

The normal force can be found by applying the Second Law to the ball,

$$\Sigma F = ma \qquad \Sigma F_x = ma_x \qquad F_g + F_n = m\frac{v^2}{r},$$

where the expression for centripetal force has been used. Solving for the normal force,

$$F_n = m\frac{v^2}{r} - F_g = (0.100)\frac{(3.00)^2}{0.20} - 0.980 \qquad \boxed{F_n = 3.52\text{N}}.$$



3. A 10.0kg laundry bag is dragged 3.00m across a floor at a constant speed by an applied force of 120N exerted at an angle of 30.0° above the horizontal. Find (a)the net work done on the laundry bag, (b)the work done by the applied force on the laundry bag, and (c)the work done by the frictional force on the laundry bag.

(a)Since the bag moves at a constant velocity, the kinetic energy of the bag isn't changing. According to the work-energy theorem, the net work is equal to the change in kinetic energy. Therefor, the net work done is zero,

$$W_{net} = \Delta K \qquad \boxed{W_{net} = 0}.$$

(b)Using the definition of work and the fact that the applied force is constant,

$$W \equiv \int \vec{F} \cdot d\vec{s} \qquad W_a = \vec{F}_a \cdot \vec{d} = F_a d \cos\theta.$$

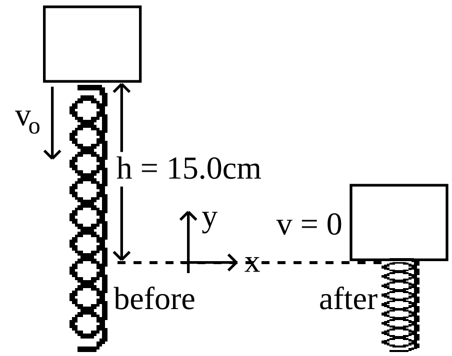
Plugging in the numbers,

$$W_a = (120)(3.00)\cos 30.0° \qquad \boxed{W_a = 312\text{J}}.$$

(c)Since the only other force doing work on the bag is the friction and the net work is zero,

$$W_{net} = W_a + W_{fr} = 0 \qquad W_{fr} = -W_a \qquad \boxed{W_{fr} = -312\text{J}}.$$

4. A 250g block is dropped onto a vertical spring with a spring constant of 5.00N/cm. The block attaches to the spring and drops 15.0cm more before coming to rest. Find the speed of the block just as it hits the spring.



Using the coordinates shown, the initial kinetic and potential energies are,

$$K_o = \tfrac{1}{2} m v_o^2 \text{ and } U_o = mgh.$$

When the block comes to rest the gravitational potential energy is gone, but spring potential has been created,

$$K = 0 \text{ and } U = \tfrac{1}{2} k h^2.$$

Using the Law of Conservation of Energy,

$$\Delta K + \Delta U = 0 \qquad (0 - \tfrac{1}{2} m v_o^2) + (\tfrac{1}{2} k h^2 - mgh) = 0 \qquad \tfrac{1}{2} m v_o^2 = \tfrac{1}{2} k h^2 - mgh \qquad v_o = \sqrt{\frac{k}{m} h^2 - 2gh}\,.$$

Putting in the values,

$$v_o = \sqrt{\frac{500}{0.250}(0.150)^2 - 2(9.80)(0.150)} \qquad \boxed{v_o = 6.49\text{m/s}}.$$

5. Every month Pacific Gas & Electric Company sends me a bill for the energy I "used." As a physicist I find their choice of words to be irritating because I still have to pay the bill! Explain why I object to paying for the energy I "used" and explain what I am really paying for.

According to the Law of Conservation of Energy, energy can be transformed from one type to another, but the total energy remains the same. I don't really "use up" any of the energy from PG&E, I just convert it from a convenient form, like electricity or natural gas, to a less convenient form like heat, light or sound. So I guess I'm really paying for the privilege of having energy delivered in an easy to use form.