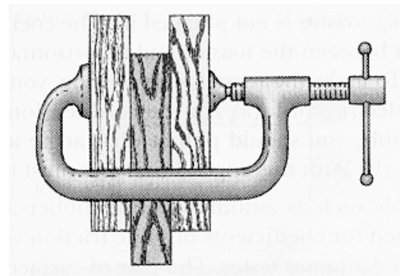
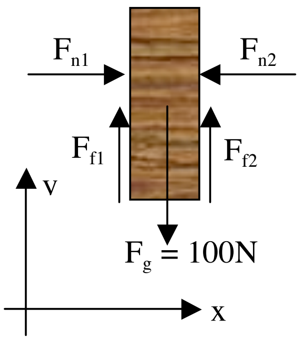
Name:_______________________________________

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. The equations you need are on the equation sheet. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. A 100N board is sandwiched between to other boards using a clamp as shown. The clamp is very loose so that the board is just barely held in place. The coefficient of friction between boards is 0.875. (a)Draw the forces that act on the 100N board. (b)Find the magnitude of each force.





Applying Newton's Second Law,

$$\Sigma F_x = ma_x \Rightarrow F_{n1} - F_{n2} = 0 \Rightarrow F_{n1} = F_{n2}$$
$$\Sigma F_y = ma_y \Rightarrow F_{f1} + F_{f2} - F_g = 0 \Rightarrow F_{f1} + F_{f2} = F_g$$

Using the definition of COF, $F_{f1} = \mu F_{n1}$ and $F_{f2} = \mu F_{n2}$.
Plugging into the equation from the y-direction,
$\mu F_{n1} + \mu F_{n2} = F_g \Rightarrow \mu(F_{n1} + F_{n2}) = F_g$.

Since the normal forces are equal, $2\mu F_{n1} = F_g \Rightarrow F_{n1} = \dfrac{F_g}{2\mu} = \dfrac{100}{2(0.875)} \Rightarrow \boxed{F_{n1} = F_{n2} = 57.1N}$.

The frictional forces must also be equal,

$$F_{f1} = F_{f2} = \mu F_{n1} = \mu\frac{F_g}{2\mu} = \tfrac{1}{2}F_g = (0.500)(100) \Rightarrow \boxed{F_{f1} = F_{f2} = 50.0N}.$$

2. The moon is in a nearly circular orbit about Earth at a nearly constant speed. Describe the moon's motion from the point of view of each of Newton's Laws of Motion. For full credit you must be able to at least paraphrase each law.

Newton's First Law: Objects move with a constant velocity unless a force acts.
The moon has a constant speed, but since the direction of motion is changing, the moon's velocity is changing. Therefore, a force is acting on the moon.

Newton's Second Law: The net force is equal to the mass times the acceleration.
The moon's changing velocity means that it has a centripetal acceleration. The force acting on the moon causes this centripetal acceleration. Its size could be found by knowing the acceleration and the mass of the moon.

Newton's Third Law: Objects exert equal and opposite forces on each other.
The force exerted on the moon is caused by Earth. According to the Third Law, the moon must exert an equal but opposite force back upon Earth.

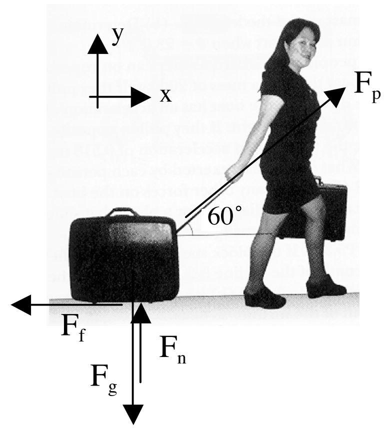
3. Determine (a)the acceleration of the moon in its 27.4 day orbit around Earth and (b)the force that Earth exerts on the moon.

(a)Using the definition of speed, $v \equiv \frac{\Delta x}{\Delta t} = \frac{2\pi r}{T} = \frac{2\pi(3.82x10^8)}{(27.4)(24)(3600)} \Rightarrow v = 1010 m/s$.

The centripetal acceleration is, $a_c = \frac{v^2}{r} = \frac{(1010)^2}{3.82x10^8)} \Rightarrow \boxed{a_c = 2.69x10^{-3} m/s^2}$.

(b)Using Newton's Second Law, $\Sigma F = ma \Rightarrow F_g = ma = (7.36x10^{22})(2.69x10^{-3}) \Rightarrow \boxed{F_g = 1.98x10^{20} N}$.

4. A woman at the airport pulls her 20.0kg suitcase, initially at rest, with a force of 60.0N at an angle of 60.0° above horizontal for a distance of 2.00m. The frictional force on the suitcase is 20.0N. Find (a)the work done by each force on the suitcase and (b)the speed of the suitcase at the end of the two meters.



(a)The only forces that do work are the pull and friction because gravity and the normal force are perpendicular to the motion. So,

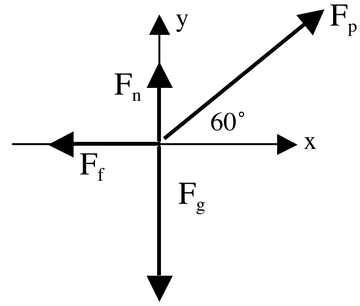
$$\boxed{W_g = 0} \text{ and } \boxed{W_n = 0}$$

Using the Definition of Work, $W \equiv \int \vec{F} \bullet d\vec{s}$, for a constant force,

$$W = Fs\cos\theta.$$

For the pull, $W_p = F_p s\cos 60° = (60.0)(2.00)\cos 60° \Rightarrow \boxed{W_p = 60.0J}$.

For the friction, $W_{fr} = F_{fr} s\cos 180° = (20.0)(2.00)\cos 180° \Rightarrow \boxed{W_{fr} = -40.0J}$.



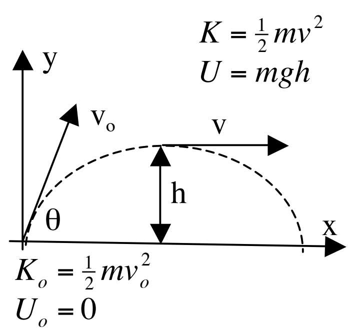
(b)Using the Work-Energy Theorem and the Definition of Kinetic Energy,

$$W_{net} = \Delta K \Rightarrow W_{net} = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_o^2 \Rightarrow W_{net} = \tfrac{1}{2}mv^2.$$

Solving for the final speed,

$$v = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{2(60.0 - 40.0)}{20.0}} \Rightarrow \boxed{v = 1.41 m/s}.$$

5. In 1940, Emanuel Zacchini set the record for distance by a "human cannonball" at 53.0m. His mass was 65.0kg and his initial speed was 24.0m/s. He was launched at 30.0° above horizontal. Find his (a)initial kinetic energy, (b)speed at the top of his flight, (c)kinetic energy at the top of his flight, and (d)maximum height above the ground. You may assume that air resistance is negligible.



(a)Using the Definition of Kinetic Energy,

$$K_o = \tfrac{1}{2}mv_o^2 = \tfrac{1}{2}(65.0)(24.0)^2 \Rightarrow \boxed{K_o = 18.7kJ}.$$

(b)From our knowledge of projectile motion the velocity at the top of the flight is all in the x-direction. Furthermore, the x-component of the velocity doesn't change throughout the motion. Therefore,

$$v = v_o\cos\theta = 24.0\cos 30.0° \Rightarrow \boxed{v = 20.8 m/s}.$$

(c) Using the Definition of Kinetic Energy,

$$K = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(65.0)(20.8)^2 \Rightarrow \boxed{K_o = 14.0kJ}.$$

(d)Using the Law of Conservation of Energy, $\Delta K + \Delta U = 0 \Rightarrow (K - K_o) + (mgh - 0) = 0$.

Solving for the height,

$$h = \frac{K_o - K}{mg} = \frac{18700 - 14000}{(65.0)(9.80)} \Rightarrow \boxed{h = 7.38m}.$$