Name:_____

Chapter 5- Forces **Regents Physics**

Friction

- The force that **opposes the relative motion** of two objects in contact is called **friction**. Friction is a **vector** quantity and is **always parallel** to the two surfaces in contact. The force of friction ($\mathbf{F_f}$) is **directly proportional to the magnitude of the normal force, $\mathbf{F_N}$**.

- As you already know, the **normal force** is the force pressing the two contacting surfaces together. On a **horizontal surface, the normal force is equal in magnitude and opposite in direction to the weight**, F_g (or *mg*), of the object resting on the surface. The normal force is **always perpendicular to the surface**. Therefore, **on an incline**, the normal force will not be equal to the weight but rather $\mathbf{F_g \cos \theta}$ **or** $\mathbf{mg \cos \theta}$. (We'll deal with hills later on).

- The force of friction also depends on the **coefficient of friction (μ)** which is a constant that has **no units**. The coefficient of friction is unique to the surface that an object is moving on. The **higher the coefficient of friction, the rougher the surface**, and thus the more force of friction. The coefficient of friction is **usually a decimal**.

The formula for force of friction is:

$$\mathbf{F_f = \mu F_N}$$

For Example:

1.) What will have a higher coefficient of friction. A dry road or a wet road? (Which will have the rougher surface?)

2.) As the coefficient of friction increases, the force of friction (increases/decreases).

3.) As the normal force decreases, the force of friction (increases/decreases).

$F_f = \mu F_N$

4.) Julie pushes a 20 kg goat across the highway with a force of 100 N. The coefficient of friction between the goat's hooves and the highway is 0.30.

a. Draw a free body diagram to represent the situation.

b. Determine the **weight** of the goat.

c. What is the **normal force** acting on the goat?

d. Determine the force of friction acting on the goat.

e. Will Julie be able to push the goat? If so, with what acceleration?

5.) Tom wishes to push a basketball hoop to the other side of a street. Tom knows that the force of friction between the basketball hoop and the street is 100 N. If the basketball hoop as a mass of 30 kg, determine the **coefficient of friction** between the hoop and the street.

6.) The coefficient of friction between a shopping cart and the parking lot is 0.2. When Jillian is finished shopping for her family's holiday feast, the force of friction between the cart and the parking lot is 70 Newtons. Determine the **mass** of the shopping cart and its items.

Static vs. Kinetic Friction

Now that we've covered the basics of friction, let's look at the **two types of friction**.

Static Friction: the force that opposes the **start of motion**.

Kinetic Friction: the friction between objects in contact when they **are in motion**.

The force of kinetic friction for two surfaces in contact **is less** than the force of static friction for the same two surfaces (meaning the **coefficient of kinetic friction is less than the coefficient of static friction**). For example, the coefficient of kinetic friction for copper on steel is 0.36 and the coefficient of static friction for copper on steel is 0.53.

Note: it is harder to push an object **to start** moving than it is to push an object already in motion.

For Example:

7.) What is harder to push: a refrigerator at rest or a refrigerator that is already moving?

8.) During a heist, Ray tries to push a 100-kg safe out of a third story window (30 meters high) into the back of his pick-up truck down below. The static coefficient of friction is 0.80 while the kinetic coefficient of friction is 0.40.

   a. How much force is required to overcome the static force of friction?

   b. Once the safe begins to move, how much force will Ray apply to move it at a constant velocity?

   c. Once out the window, how much time before the safe hits the pick-up truck?

   d. What will be the safe's velocity right before it hits the pick-up truck?

9.) A 40-kg bookshelf requires a 200 N force to begin its motion. Once moving, it only requires a force of 50 N.

a. What is the normal force?

b. Determine the static coefficient of friction.

c. Determine the kinetic coefficient of friction

10.) A 10-kg computer tower is pushed to the right with an acceleration of 5 m/s^2 using a force of 100 N.

a. Draw a FBD for the situation.

b. Determine the force of friction acting on the computer tower.

c. Determine the kinetic coefficient of friction.