CH 10: WORK

When a force acts upon an object to cause a displacement of the object, it is said that **work** was done upon the object. There are three key *ingredients* to work - force, displacement, and cause. In order for a force to qualify as having done *work* on an object, there must be a displacement and the force must *cause* the displacement. There are several good examples of work that can be observed in everyday life - a horse pulling a plow through the field, a father pushing a grocery cart down the aisle of a grocery store, a freshman lifting a backpack full of books upon her shoulder, a weightlifter lifting a barbell above his head, an Olympian launching the shot-put, etc. In each case described here there is a force exerted upon an object to cause that object to be displaced.

Define what work is.

When does work only occur?

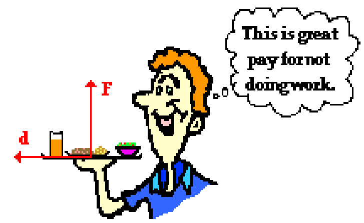
Work Equation

Mathematically, work can be expressed by the following equation.

$$W = F \cdot d \cdot \cos \Theta$$

To Do Work, Forces Must *Cause* Displacements

Let's consider a waiter who carried a tray full of meals above his head by one arm straight across the room at constant speed. The force supplied by the waiter on the tray is an upward force and the displacement of the tray is a horizontal displacement. A vertical force can never cause a horizontal displacement; thus, a vertical force does not do work on a horizontally displaced object!



It can be accurately noted that the waiter's hand did push forward on the tray for a brief period of time to accelerate it from rest to a final walking speed. But once *up to speed*, the tray will stay in its straight-line motion at a constant speed without a forward force. And if the only force exerted upon the tray during the constant speed stage of its motion is upward, then no work is done upon the tray. Again, a vertical force does not do work on a horizontally displaced object.

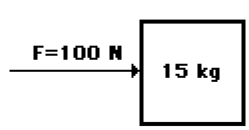
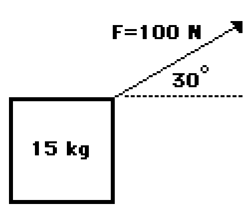
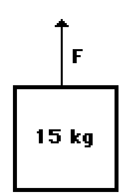
Why was no work done on the tray by the person?

Units of Work

Whenever a new quantity is introduced in physics, the standard metric units associated with that quantity are discussed. In the case of work (and also energy), the standard metric unit is the **Joule** (abbreviated **J**). One Joule is equivalent to one Newton of force causing a displacement of one meter. In other words,

The Joule is the unit of work. = **1 Joule = 1 Newton * 1 meter** **1 J = 1 N * m**

Apply the work equation to determine the amount of work done by the applied force in each situation below.

Diagram A	Diagram B	Diagram C
		
A 100 N force is applied to move a 15 kg object a horizontal distance of 5 meters at constant speed.	A 100 N force is applied at an angle of 30º to the horizontal to move a 15 kg object at a constant speed for a horizontal distance of 5 m.	An upward force is applied to lift a 15 kg object to a height of 5 meters at constant speed.

CH 10: POWER

The quantity work has to do with a force causing a displacement. Work has nothing to do with the amount of time that this force acts to cause the displacement. Sometimes, the work is done very quickly and other times the work is done rather slowly. For example, a rock climber takes an abnormally long time to elevate her body up a few meters along the side of a cliff. On the other hand, a trail hiker (who selects the easier path up the mountain) might elevate her body a few meters in a short amount of time. The two people might do the same amount of work, yet the hiker does the work in considerably less time than the rock climber. The quantity that has to do with the rate at which a certain amount of work is done is known as the power. The hiker has a greater *power rating* than the rock climber.

What variable does work not care about?

Define Power.

Power is the rate at which work is done. It is the work/time ratio. Mathematically, it is computed using the following equation. **Power = Work / time** or **P = W / t**

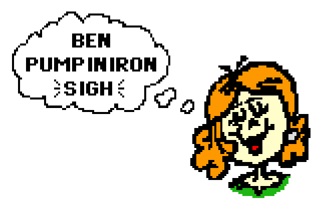
The standard metric unit of power is the **Watt**. As is implied by the on for power, a unit of power is equivalent to a unit of work divided by a time. Thus, a Watt is equivalent to a Joule/second. For historical s, the *horsepower* is occasionally used to describe the power delivered machine. One horsepower is equivalent to approximately 750 Watts.

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force} \cdot \text{Displacement}}{\text{Time}}$$

$$\text{Power} = \text{Force} \cdot \frac{\text{Displacement}}{\text{Time}}$$

$$\boxed{\text{Power} = \text{Force} \cdot \text{Velocity}}$$

A person is a machine that has a *power rating*. Some people are more power-full than others. That is, some people are capable of doing the same amount of work in less time or more work in the same amount of time. A common physics lab involves quickly climbing a flight of stairs and using mass, height and time information to determine a student's personal power. Despite the diagonal motion along the staircase, it is often assumed that the horizontal motion is constant and all the force from the steps is used to elevate the student upward at a constant speed. Thus, the weight of the student is equal to the force that does the work on the student and the height of the staircase is the upward displacement. Suppose that Ben Pumpiniron elevates his 80-kg body up the 2.0-meter stairwell in 1.8 seconds. If this were the case, then we could calculate Ben's *power rating*. It can be assumed that Ben must apply an 800-Newton downward force upon the stairs to elevate his body. By so doing, the stairs would push upward on Ben's body with just enough force to lift his body up the stairs. With these two approximations, Ben's power rating could be determined as shown below.



Ben's power rating is 871 Watts. He is quite a *horse*.

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{784\ \text{N} \cdot 2.0\ \text{m}}{1.8\ \text{seconds}}$$

$$\text{Power} = 871\ \text{Watts}$$

What was Ben's P.E.?

What was Ben's K.E.?