Physics November 24, 2009

KINETIC ENERGY

Physics is sometimes described as the study of matter and energy. We know how we measure matter. We indicate its mass. Energy is less tangible but we can measure how much energy there is by measuring the amount of work that can be done. This measurement will be made in various ways for different types of energy such as electrical, thermal or light. For now we will concentrate on mechanical energy. There are basically two kinds of mechanical energy and that is what we will consider today.

Clearly things that are in motion have energy and we can measure it by the amount of work that can be done by virtue of their motion. This type of energy is called kinetic energy.

Lets calculate how much more kinetic energy an object of mass *m* has when it is moving at a velocity v_i. then it would have if it were at rest. All we have to do is imagine how much work it could accomplish. As you know the equation for work is $W = \vec{F} \cdot \vec{d}$

To make this derivation simple we will consider that the force the object exerts is constant and in the direction of its motion. The formula then becomes ***W =Fd.*** Suppose the situation is as shown below.

The object's energy that is to be measure is moving to the right at v_i and exerting a force *F* on the large block shown. It does this until both objects stop as shown to the right. The amount of work done will simply be *F d.* Unfortunately we don't know either of these quantities, however we do know, from Newton's third law an and equal and opposite force will be exerted by the large block on our object. We can find that force as follows. Newton's second law tells us this force will cause the block to accelerate according to the equation *F=ma* and we know $a = \frac{\Delta v}{\Delta t}$ so we have $F = m\frac{\Delta v}{\Delta t} = m\frac{v_f - v_i}{\Delta t}$.

Now in our case we want $v_f = 0$ so the force on the object comes out $F = -m\frac{v_i}{\Delta t}$ and the force the object exerts on the block is $F = +m\frac{v_i}{\Delta t}$. We are almost there now so hold on. The distance traveled is the average velocity times the time but the average velocity for the object starting at v_i and coming to a stop is given by $v_{av} = \frac{v_i + v_f}{2} = \frac{v_i + 0}{2} = \frac{v_i}{2}$ so the distance is just $d = \frac{v_i}{2}\Delta t$. Putting the force and distance together to calculate the work we get: $W = m\frac{v_i}{\Delta t}\frac{v_i}{2}\Delta t = \frac{1}{2}mv_i^2$. The amount of work that can be done by this moving object is called its kinetic energy and we can write the general expression:

$$K = \frac{1}{2}mv^2$$

This is general expression for the energy a object has as the result of its motion. Because we measure energy by its ability to do work it has the same unit, **joules**, as work.

Do the following problems neatly one separate paper so they can be turned in at the end of the period. In each case show your work and clearly indicate your answers. Since this is a learning exercise you may seek help if you have trouble. In some cases the answers will be provided in brackets at the right in order to make sure you are on the right track.

1) Calculate the kinetic energy of a 40. kg person running at 3.5 m/s. [245 J]

2) What is the kinetic energy of a 1 200 kg car traveling at 45 km/h? (Don't forget you need to convert km/h to m/s before you begin.) [93 800 J]

3) A 0.0015 bullet traveling at 420 m/s penetrates 0.14 m into a stationary tree trunk.
   a) What was the kinetic energy of the bullet? [132 J]
   b) How much work could the bullet do on the wood? [132 J]
   c) If there were no other energy losses, how much average force did the bullet exert on the wood? [950 N]
   d) Again if there were no other energy losses, how much average force did the tree exert on the bullet? [950 N]

4) A car skidding on ice runs into a barrier and exerts an average force of 3 500 N moving the barrier a distance of 0.45 m before coming to a stop.
   a) How much work is done by the car? [1575 J]
   b) How much kinetic energy did the car have? [1575 J]
   c) If the mass of the car was 1 000 kg, what must have been the velocity of the car? [1.8 m/s]

The Work-Energy Theorem states that **the net work done on an object is equal to the change in its kinetic energy**. Use this theorem to evaluate the work done by net external forces in the following cases.

5) In a old-fashioned pin ball machine the spring ejects a 0.010 kg ball with a speed of 2.0 m/s. How much work was done by the spring?

6) Does it take more, less, or the same amount of energy to accelerate a 1 500 kg car from 0 m/s to 15 m/s or from 15 m/s to 30 m/s? Support your answer with calculations.

Your copies of these solutions are to be turned in at then end of the period. Your homework is to read in the text pages 177 – 180.