Unit 5 Parent Guide: Work, Power, Energy

Part I: Types of Energy

Kinetic energy: Kinetic energy is the energy of motion. It is given by the equation:

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

Where *KE* represents Kinetic Energy, *m* is mass, and *v* is velocity. The symbol for Kinetic Energy is also commonly written as just *K*. Any moving object has kinetic energy. It is important to note that because velocity is squared, kinetic energy cannot be a negative value. Velocity is a vector quantity that can be positive or negative. But in the equation above, the direction of velocity does not matter because velocity squared doesn't have a positive or negative designation. So kinetic energy is a scalar quantity.

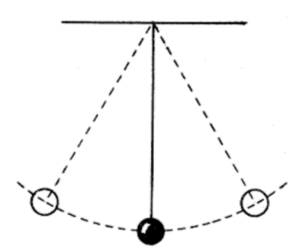
Potential Energy: Potential energy is said to be "stored" energy. It is the energy that a system has because of the arrangement of objects in the system. Objects in a system can exert forces on one another and those forces can potentially change the arrangement of the objects. So energy is stored in the system by nature of the arrangement, or location, of the interacting objects. Because potential energy depends on position, it is important to define a reference position in which the potential energy is equal to 0. Electric potential energy, Chemical energy, nuclear energy, gravitational energy, and spring energy are all forms of potential energy stored in a system because of the arrangement of objects within the system.

Gravitational potential energy is the energy that a system of objects has because there is a gravitational force between them. For example, if a ball resting on the ground is raised up to shelf, its location relative to earth has changed. On the shelf, the ball has more potential energy. The energy that the ball now has can potentially be converted into kinetic energy, so it is energy stored in the ball-earth system. On the ground, the ball-earth system has less potential energy. Gravitational potential energy at the surface is given by:

$$PE = mgh$$

where *PE* is the gravitational potential energy (often labeled as *U*), *m* is mass, *g* is acceleration of gravity, and *h* is height. The h is defined as displacement from a reference position which has a height of 0. It is often convenient to define the reference height as the ground. Sometimes, such as a swinging pendulum, it is convenient to define the reference height as the lowest point of the object's possible motion.

Part II: Conservation of Energy



In a closed system, energy is conserved. For example in the pendulum shown, the bob's velocity and height are both changing as it swings. As it swings downward, potential energy is being transformed into kinetic energy. The height is decreasing, but the velocity is increasing. In a closed system, consisting of the bob and the earth, the total amount of energy, called the mechanical energy, remains constant. In reality, the system is not closed, and mechanical energy decreases as the pendulum swings because the energy is lost to heat or work outside the system. Air molecules exert force on the bob. The string is attached to a support, resulting in friction. The molecules inside the bob and string warm up because of the contact with their surroundings. These objects exert external forces that can change the amount of mechanical energy in the system. Thus we see that the pendulum swings with less and less amplitude until it eventually stops. Because the system is not fully closed, the energy in the system does not remain constant. A closed system is an ideal situation, but not observable in everyday life. Nonetheless, it is a useful construct for understanding energy transformations.

Part III: Work and power

Work in physics has a special meaning. When a force is exerted on an object and the object is displaced as a result of the force being parallel to the displacement, we say that work has been done on the object by the force. When an object is pushed while not moving, no work is done. When an object moves without being pushed, no work is done. When an object moves perpendicular to the direction of a force, no work is done by the force. This is summarized in the equation for work, given here:

$$W = Fdcos\theta$$

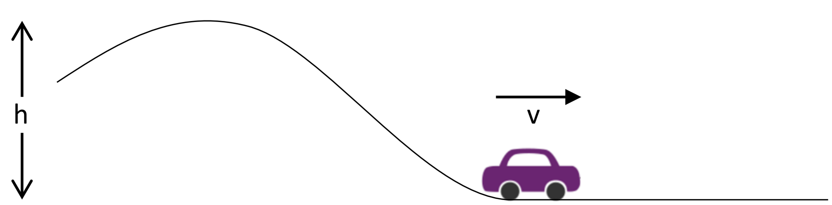
Where *W* is work, *F* is force doing the work, *d* is the displacement while the force is applied, and $cos\theta$ is the cosine of the angle between the force vector and displacement vector. It is important to note the following about the angle between the force and displacement vectors:

Orientation of F and d	Angle θ (degrees)	Work
Same direction	0	Positive
Opposite direction	180	Negative
Perpendicular	90	Zero

When you do work on an object, you change the object's energy. This is important in the relationship known as the **work-kinetic energy theorem**:

$$W = \Delta KE$$

Consider this example: suppose a car rolls down a hill, then slams on the brakes at the bottom. While rolling down, the car's potential energy is transformed into kinetic energy, while the total energy remains constant. But we also know that during braking, the car slows down because of friction between the tires and the road. The friction is a force pushing left on the car as the car is displaced to the right. So the road will do negative work on the car. The amount of work that the road performs on the car will be equal to the amount that the car's kinetic energy changes.



<u>Power</u>: The rate that work is done is called *power*.

$$P = \frac{W}{t}$$

The unit of power is Joules per second, also called Watts.

When energy is transformed from one form to another, work is done. How quickly that work is done is known as power. Suppose two students lift a 10 kg brick from the ground to a 2 m shelf. Student A does this task in 1.6 seconds and student B does it in 1.0 seconds. The students will both do 200 J of work on the brick. Student A's power will be 125 Watts student B's power will be 200 Watts.