

Kinetic and Potential Energy/Conservation of Energy

Intro

Associate energy usually with activity or motion:
Falling stone possesses energy, energetic person constantly doing things
Foods are rich in energy, the Earth receives radiant energy from the sun

Relation between piece of pie and a falling stone:
The ability to do **work**

Work

Changes that take place in physical world are result of forces. Forces are needed to pick things up, move things, squeeze things, stretch things, etc. If push against a stone wall, nothing happens. However, if we apply the same force to one of the stones that make up the wall, the stone flies through the air for some distance - something has been accomplished from our push. The difference between the two situations is that our hand did not move when it pushed against the wall. The force was stationary. In the second case, when we throw the stone, our hand moved while the force was being applied, and before the stone actually left our grasp. The motion of the force is what constitutes the difference between the two cases and is responsible for the difference in the two results.

Almost all forces that produce effects such as motion or distortions in an object undergo displacements in doing so - a moving force accomplishes something, while a stationary force does not, which we define as **work**. Work done by a force is equal to the magnitude of the force multiplied by the distance through which the force acts. If the distance is zero, no work is done by the force, no matter how great it is. If something moves a distance, it does not do work unless it exerts a force on something else.

W = Fd

F is assumed to be in the same direction as d. If not, $W = F \cdot d \cdot \cos\theta$. Thus, a force that is perpendicular to the motion of an object can do no work upon it (at 90 degrees). Therefore, gravity does no work on objects moving along the Earth's surface. However, if we drop an object, as it falls to the ground work is done upon it.

In the metric system, work is measured in Joules, 1 Joule is the amount of work done by a force of 1 Newton that acts through a distance of 1m.

$$1 \text{ J} = 1 \text{ N} \cdot \text{m}$$

$$1 \text{ J} = 0.738 \text{ ft} \cdot \text{lb}$$

$$1 \text{ ft} \cdot \text{lb} = 1.36 \text{ J}$$

Power

Power is the rate at which work is being done by some force.

$$P = W / t$$

Metric System, unit of power is the watt:

$$1 \text{ watt} = 1 \text{ J / sec}$$

Origin: in order to see the steam engines he had invented, James Watt was usually compelled to compare its power output with that of a horse. After various tests he found that a typical horse could perform works at the rate of 22,000 ft *lb / min for as much as 10 hr / day. To avoid possible disputes about full measure, Watt increased this figure by one-half in establishing the unit that he called the horsepower. Watt's horse power represents a rate of doing work of 33,000 (ft *lb) / min or 550 (ft * lb) / sec.

$$1 \text{ hp} = 746 \text{ W}$$

Kinetic Energy

What makes it possible for a force to do work? The answer is **energy**. Energy may be thought of as the property of something which enables it to do work. When we say that something has energy, we suggest that it is capable of exerting a force on something else and performing work on it. When work is done something, energy has been added to it. Energy is measured in Joules, the same units as work.

Energy takes on many forms. One type is the energy a moving body possesses by virtue of its motion. Every moving object has the capacity to do work. By striking another object that is free to move, the moving object can exert a force and cause the second object to shift its position. While the object is moving, it has the capacity for doing work. **Energy means the ability to do work**, so all moving things have energy by virtue of their motion. This type of energy is called **kinetic energy**.

The energy that an object possesses because it is moving, it's kinetic energy, is defined as :

$$KE = 1/2 mv^2$$

Potential Energy

Many objects possess energy because of their position, potential energy is energy due to an object's position or configuration - stored energy.

Book on a table has potential energy since it can fall to the floor; skier poised at top of a slide, water at brink of a cataract, car at top of hill, anything capable of moving toward the Earth under the influence of gravity has energy because of its position.; planet has potential energy with respect to the sun since it can do work in falling toward the sun, nail placed near a magnet has potential because it can do work in moving to the magnet.

$W = mgh = PE$ -> work required to raise a body of mass m to height h above its original position. When we specify weight w of a body instead of mass -

$$PE = wh \text{ since mass is related by } w = mg$$

PE is a relative quantity, meaningful only in terms of a specific reference location - ex. 10 g pencil 10 cm above table whose top is 1 m above floor. Pencil has PE of 0.0098 J relative to table and PE of 0.108 J relative to floor.

If we drop a pencil and want to compute its speed upon hitting floor, we equate KE with its loss of PE in falling the 1.1 m.

$$PE = KE$$

$$v = 4.6 \text{ m/sec}$$

the height is always the vertical distance (not necessarily the total distance the body may travel) between the starting point and the lowest point of fall.

Energy Transformations

Nearly all mechanical processes consist of interchanges of energy among its kinetic and potential forms and work. When a car drives to top of hill, its engine must do work in order to lift the car up. At top the car has an amount of PE equal to the work done in getting it up there. If the engine is turned off, the car can still coast down the hill, and its KE at the bottom of the hill will be the same as its potential energy at the top - PE -> KE as it goes downhill, KE -> PE as it climbs the second hill.

Law of conservation of Energy:

Energy can never be created or destroyed. Energy may be transformed from one form to another. The total energy of a system remains constant in any isolated system of objects.

Ex. Swinging pendulum:

Pull the bob over to the right side at 65 degrees - bob contains its maximum PE and its minimum Kinetic Energy (zero). If we let go, the PE or stored energy has been lost, but it has gained in KE due to its motion. At bottom of arc swing, its PE is zero and its kinetic energy is max (max velocity). KE causes the bob to swing upward to left. As

complete the swing, KE decreases and PE increases - KE changing into PE - Sum of the KE and the PE of bob at any instant is constant - assuming no friction or air resistance the bob would swing forever uniformly.

The only force that does work on the mass is the force of gravity, since the force of tension is always perpendicular to each element of the displacement and hence does no work. Since the force of gravity is a conservative force, the total mechanical energy is constant. Therefore, as the pendulum swings, there is a continuous transfer between potential and kinetic energy:

$$E = K + U$$

$$K_i + U_i = K_f + U_f$$

$$0 - mgL \cos\theta = (0.5)mv_f^2 - mgL$$

Orbit of planets around the sun:

The orbits of the planets are ellipses with the sun at one focus, and each planet is therefore at a constantly varying distance from the sun. At all time the total of its potential and kinetic energies remain the same. When the planet is close to the sun, its potential energy is low and its kinetic energy high. The additional speed due to the increased kinetic energy keeps the planet from being pulled into the sun by the greater gravitational force it experiences at this point in its path. When the planet is far from the sun, its potential energy is high and its kinetic energy low, reduced speed keeping pace with gravitational force.

Drop a ball:

Since the ball is in free-fall, the only force acting on it is gravity. Therefore, we can use the principle of conservation of mechanical energy - initially the ball has potential energy and no kinetic energy. As it falls, its total energy (the sum of the KE and the PE) remains constant and equal to its initial PE.

$$0 + mgh = (0.5) mv_f^2 - mgy$$

- 1) "Introduction to Physics and Chemistry," Arthur Beiser and Konrad Krauskopf, McGraw-Hill Book Company, 1964, p.70-87.
- 2) "Physics For scientists and Engineers," Raymond A. Serway, Saunders College Publishing, 1996, p.207-218