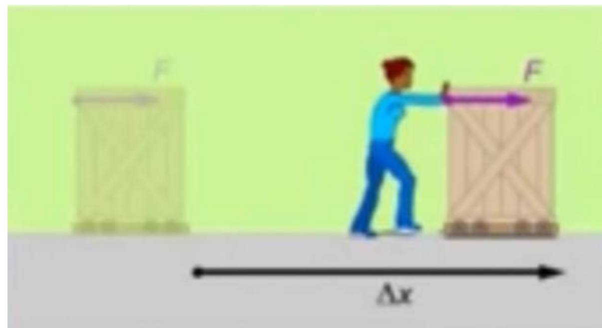
Work: the product of displacement and the force in the direction of displacement.

- When the force on an object is the same direction as the displacement, the magnitude of the force and the object's displacement can be multiplied together to calculate the work done by the force.

$W = F. \Delta X$



Where:

W = work

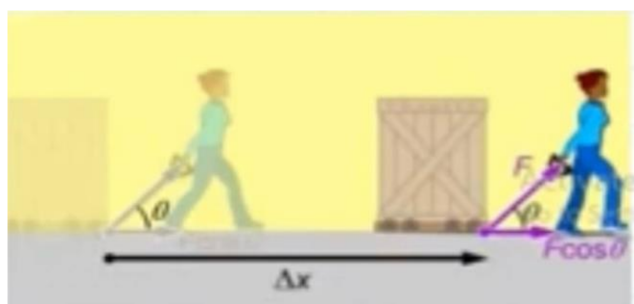
F = force

ΔX= displacement

Units = joules

Note: if the force at angle to displacement as shown in the below figure, only force component along displacement contributes to work.

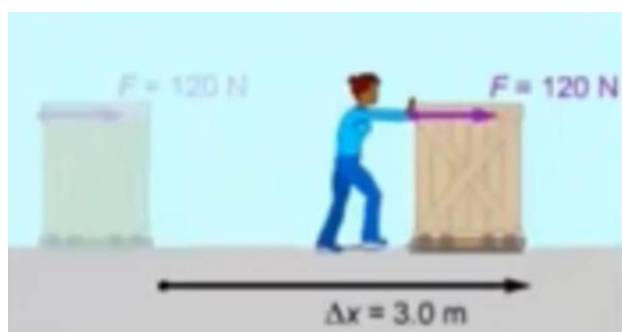
$W = (F \cos\theta)\ \Delta X$



Where:

θ: angle between force and displacement.

Example: how much work does the woman do on the crate as shown below?



Sol.:

$W = F. \Delta X$

$= 120 * 3 = 360J$

Example: now the woman is pulling the crate at an angle. If she does the same amount of work as before (W= 360J), how much force must the woman create?

Sol.:

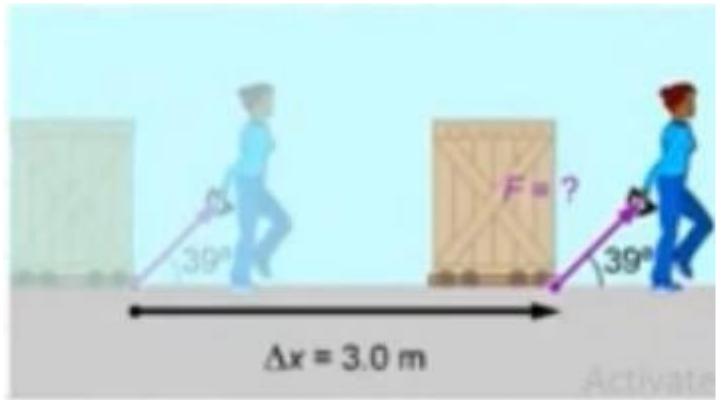
$W = (F \cos\theta)\, \Delta X$

$= F \cos 39° * 3$

$360 = 3 F \cos 39°$

$F = \frac{360}{3 \cos 39°}$

F= 154.4 N

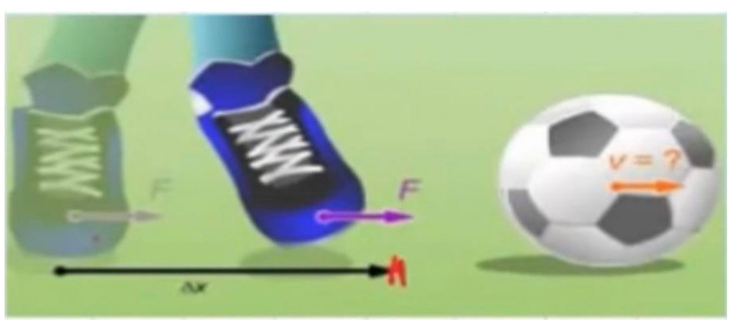


Energy: in physics, energy is the quantitative property that must transferred to an object in order to perform work on, or to heat the object.

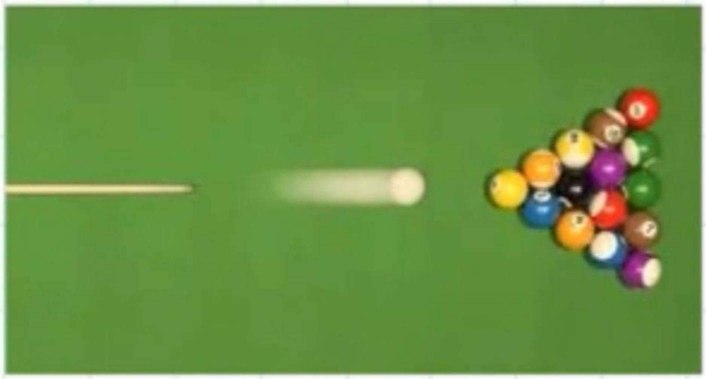
- Energy is a conserved quantity; the law of conservation of energy states that energy can be converted in form, but not created or destroyed.
- Many forms of energy exist; electric, atomic, chemical, kinetic, potential, and so on.

  There are important principles that concern all forms of energy:

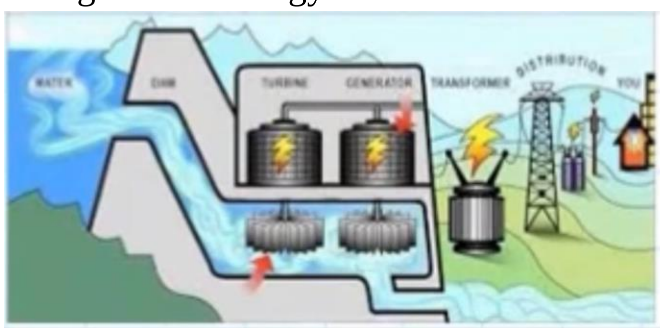
  1. There is a relationship between work and energy. For instance, if you do work by kicking a stationary soccer ball, you increase a form of its energy called kinetic energy, the energy of motion.



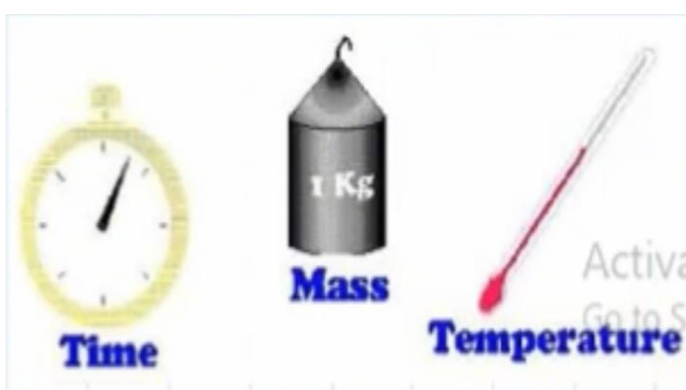
  2. Energy can transfer between objects. When a cue ball in the game of pool strikes another ball, the cue ball slows or stops, and the other ball begins to roll. The cue ball's loss of energy is the other ball's gain.



3. Energy can change forms. When water falls over a dam, its energy of position becomes the energy of motion (kinetic energy). The kinetic energy from the moving water can cause a turbine to spin in a dam, generating electric energy.



4. Energy is a scalar. Objects can have more or less energy, and some forms of energy can be positive or negative, but energy does not have a direction, only a value.
5. The joule is the unit of for energy, just as it is for work. The fact that work and energy share the same unit is another indication that a fundamental relationship exists between them.



Kinetic energy (KE): the energy of motion.

- Physicists describe the energy of objects in motion using the concept of kinetic energy (KE).

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

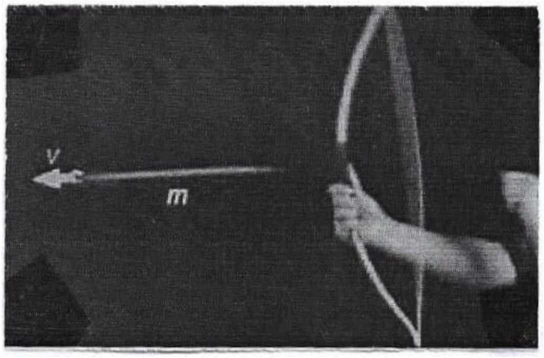
Where

KE: kinetic energy.

m: mass

v: speed

Unit: joule (J)



- Kinetic energy is proportional to mass and square of speed.
- The kinetic energy of an object increases with mass and the square of speed.
- Objects never have negative kinetic energy, only zero or positive kinetic energy.

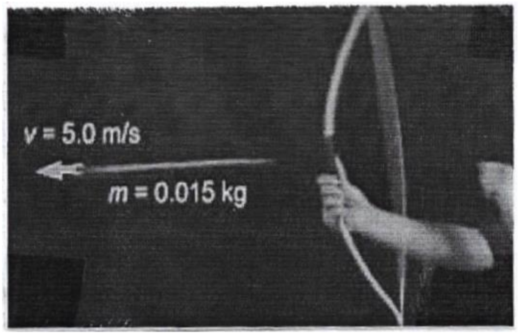
Example: - what is the kinetic energy of the arrow for the below figure?

Sol.:

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

$$KE = \frac{1}{2} (0.015)\ (5)^2$$

$$KE = 0.19\ J$$



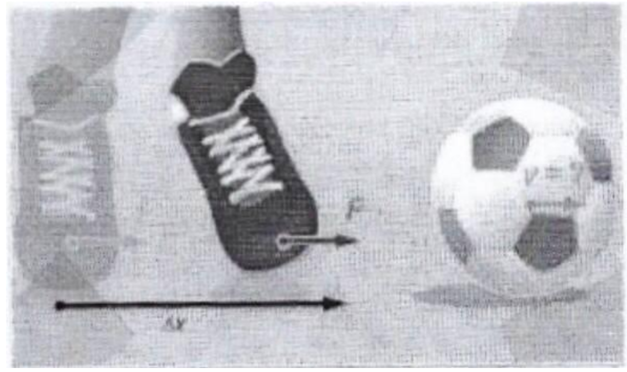
Work – Kinetic energy theorem: the net work done on a particle equals its change in kinetic energy.

$W = \Delta KE$

Where

W: net work, J

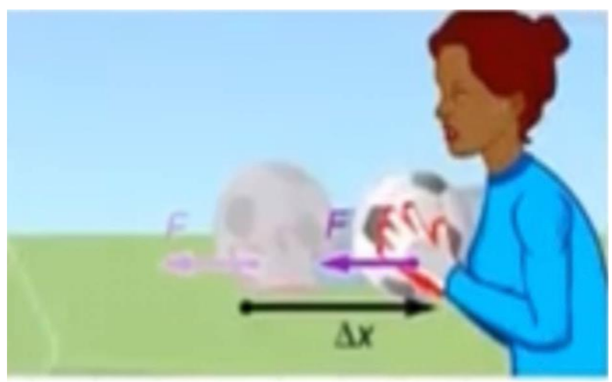
KE: kinetic energy, J



According to this figure, the ball is stationary. It has zero kinetic energy because it has zero speed. The foot applies a force to the ball as it moves through a short displacement.

This force accelerates the ball. The ball now has a speed greater than zero, which means it has kinetic energy. The work – kinetic energy theorem states that the work done by the foot on the ball equals the change in the ball's kinetic energy. In this example, the work is positive (the force is in the direction of the displacement), so the work increases the kinetic energy of the ball.

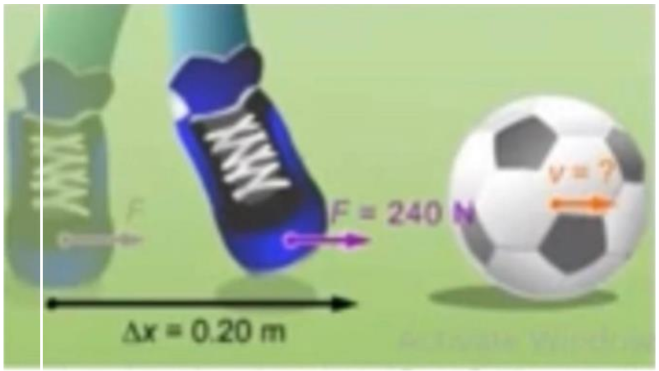
According to the right picture, a goalie catches a ball kicked directly at her. The goalie's hands apply a force to the ball, slowing it. The force on the ball is opposite the ball's displacement, which means the work is negative. The negative work done on the ball slows and then stops it, reducing its kinetic energy to zero. Again, the work equals the change in energy; in this case, negative work on the ball decreases its energy.



Note:

- Positive work on an object increases its kinetic energy.
- Negative work on an object decreases the object's kinetic energy.

Example: What is the soccer ball's speed immediately after being kicked? Its mass is 0.42 kg. Consider the below figure.



Sol.:

W = ΔKE

W = KE f- KE i

$W = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$ ($v_i = 0$)

$W = \frac{1}{2} m v_f^2$

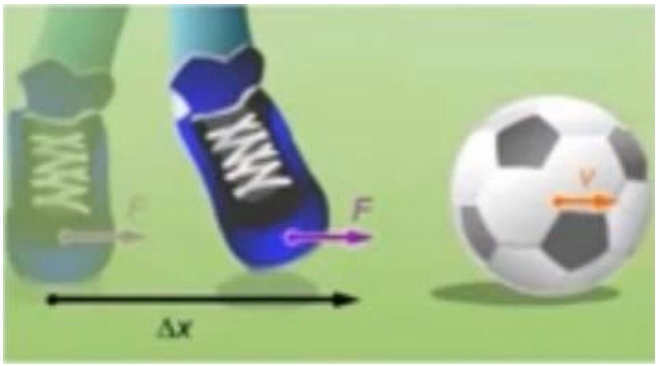
$F.\Delta X = \frac{1}{2} m v_f^2$

$$v_f^2 = \frac{2\,F.\Delta X}{m} = \frac{2 * 240 * 0.2}{0.42}$$

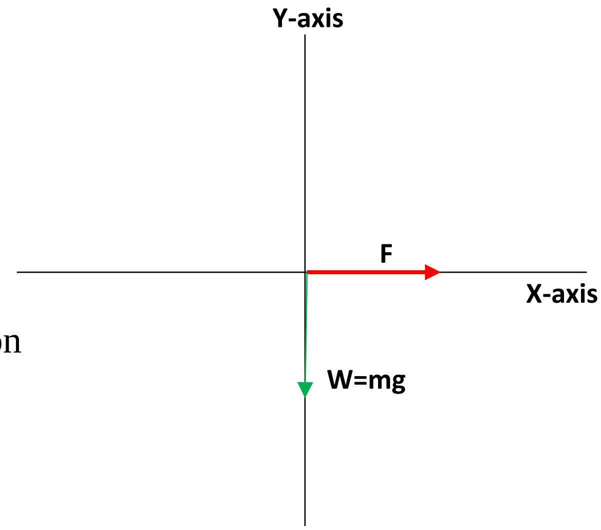
$v_f = 16.1$ m/s

Derivation: work-kinetic energy theorem

- In this section, we show that the net work done on an object and its change in kinetic energy are equal by using the definition of work and Newton's second law.
- We will again use the illustration of a soccer ball being kicked and model the ball as a particle. The ball starts at rest and we assume the force applied by the foot equals the net force on the ball, and that the ball moves without rotating.



$W=F.\ \Delta X$ … (1)



By applying 2nd law of Newton along X-axis

$\Sigma Fx = ma$

$F= ma$ sub. Into (1)

$W= m\ a.\ \Delta X$ … (2)

Since $V_f^2 = v_i^2 + 2a\Delta X$, linear motion equation

$V_f^2 - v_i^2 = 2a\Delta X$

$a\Delta X = \frac{Vf2 - vi2}{2}$ sub. In (2)

$W= m\ (\frac{Vf2 - vi2}{2})$

$W = \frac{1}{2}\ m\ v_f^{\ 2} - \frac{1}{2}\ m\ v_i^{\ 2}$

W = KE f- KE i

$W = \Delta KE$