

# Work and Energy

- one of the most central concepts in science is energy; the combination energy and matter makes up our universe
- matter is the substance of the universe, while energy is what moves the substance
- matter is what we can see, touch and feel; energy is somewhat more elusive to categorize; energy is not typically seen or felt



# Work

- work is the product of the force and distance and is a scalar measurement  $Work = Force \times Distance$   $W = Fd$
- the unit of work is the joule (J); where  $1 J = 1 N \cdot m$
- when you lift an object off the ground you are doing work; the heavier the load ( $\uparrow F$ ) or the higher you lift the object ( $\uparrow d$ ), the more work you are performing
- there are two things that must occur if work is being done:
  - a force must be exerted
  - the object must move



# Power

- What if we can do the same work in shorter time!!??
- the time it takes to perform work makes a difference, indeed.
- this difference in how fast the work is done is called power
- **power** is equal to the **amount of work done per unit time**
- **Power = Work/time interval**

$$P = W/t$$

- one of the original units of power called horsepower was developed by Scottish engineer James Watt (1736 – 1819); Watt was famous for the development of the steam engine
- Watt wanted to know how the steam engine compared to horses in pumping out water out of coal mines; he found that a horse could lift 150 pounds 220 feet in one minute;
- **1 horsepower is equal to 745.2 watts**
- the SI unit of power is the watt (W); **1 W = 1 J/s**
- engines are valued because they can perform a lot of work very quickly



# Mechanical Energy

- energy is that which enables objects to do work
- there are many types of energy; like work, energy is measure in joules (J)
- we will focus of mechanical energy; mechanical energy is separated into two categories; potential and kinetic



# Potential Energy

- an object may store energy because of its position; this is called potential energy (PE)
- a book on a shelf, a rock tossed into the sky, and compressed spring, all have potential energy; work was done to all of these objects which stored the energy
- work is required to elevate objects against Earth's gravity; the amount of gravitational potential energy possessed by an object is equal to the amount of work done against gravity in lifting it

- Gravitational Potential Energy = Weight × Height

$$U_g = mgd$$

the unit of potential energy (as with any type of energy) is the joule (J)



# Kinetic Energy

- if we perform work on a moving object, then we can change its energy of motion
- if an object is in motion, then by virtue of that motion, it is capable of performing work
- kinetic energy (KE) is energy of motion; the kinetic energy of an object depends on its mass and speed

$$\text{Kinetic Energy} = \frac{1}{2} \text{ mass} \times \text{speed}^2$$

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

- as a result:

$$\text{Net force} \times \text{distance} = \text{kinetic energy}$$

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

$$\text{Work} = \Delta KE$$



# Example (1)

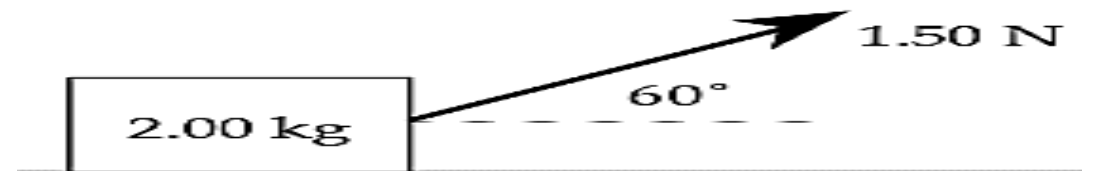
## (Work)

- A constant force of 1.50 N is applied at an angle of  $60^\circ$  above the horizontal to a 2.00 kg block in contact with a horizontal frictionless surface (Figure below). The block moves a distance of 0.500 m along the surface. Calculate the work done by the agent of the force during this movement

### Solution

$$W = F \cdot \Delta r \cdot \cos\theta = (1.50\text{N})(0.500\text{m})\cos 60^\circ = 0.375\text{ J}.$$

It is useful to note that the work done is independent of the mass of the object.



# Example (2)

## Work done by spring

- A mass is connected to the end of a spring. The spring constant is  $k = 0.020 \text{ N} \cdot \text{m}^{-1}$ . The mass is released from a position  $x_i = 0.25 \text{ m}$ . How much work is done by the spring when the mass moves to the position  $x_f = -0.10 \text{ m}$ ?

### Solution:

$$\begin{aligned} W &= \frac{1}{2} k (x_i^2 - x_f^2) \\ &= \frac{1}{2} (0.020 \text{ N} \cdot \text{m}^{-1}) [(0.25 \text{ m})^2 - (-0.10 \text{ m})^2] \\ &= 5.25 \times 10^{-4} \text{ J.} \end{aligned}$$

The spring does a positive amount of work.





# Example (3)

## Power

- The source of a force applied to an object does 2.00 J of work in an elapsed time of 0.500 s. Calculate the average power.

Solution:

$$\bar{P} = \frac{\Delta W}{\Delta t} = \frac{2.00(J)}{0.500(s)} = 4.00 \text{ Watts.}$$

In the elapsed time given, energy is being transferred from the agent of the force to the object at the average rate of 4.00 joules per second.

