Lecture Notes

(Work & Energy)

Intro:

- 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

- it was so abstract that the idea of energy was largely unknown until the mid 1800's

- energy is both a thing and a process; people, places and things all have energy but we only see it when it is being transformed

- before we talk further about energy it is customary to talk about a related concept; work

Work:

- when discussing momentum and impulse in the previous lecture, we discussed how time played a factor in the motion of an object

- when discussing impulse, "How long" meant time; with work, however, "How long" means what distance

- work is the product of the force and distance and is a scalar measurement

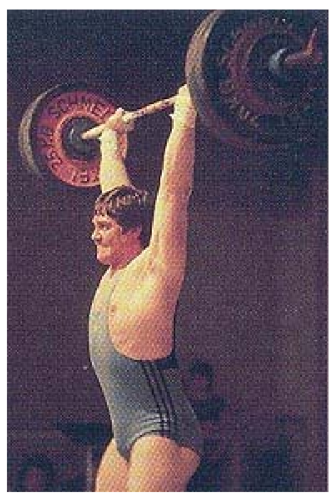
$$\text{Work} = \text{Force} \times \text{Distance}$$
$$W = \boldsymbol{F}d$$

- the unit of work is the joule (J); where 1 J = 1 N·m

- when you lift an object off the ground you are doing work; the heavier the load ($\uparrow \boldsymbol{F}$) 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:
  1. a force must be exerted
  2. the object must move

- sometimes there are situations that appear to be work, but are actually not; for example, if you hold a barbell steady over your head, you are not doing any work (remember, the object has to move in order to do work)



- lifting the same barbell up over your head is different however; in this case, work is being done

- no work is done if you push on a wall but it does not move

Power:

- the definition of work does not say anything about the time it takes to do the work

- we know from experience, however, that the time it takes to perform work makes a difference; for example, say you went to Sam's and bought 25 cases of soft drinks for a party; your job was to unload them from your mom's car

- you would obviously be much more tired (and unhappy) if you had to perform this task in 5 minutes rather than 30 minutes

- this difference in how fast the work is done is called power

- power is equal to the amount of work done per unit time

$$\text{Power} = \text{Work/time interval}$$
$$P = W/t$$

- 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, a compressed spring, and a drawn bow all have potential energy; work was done to all of these objects which stored the energy

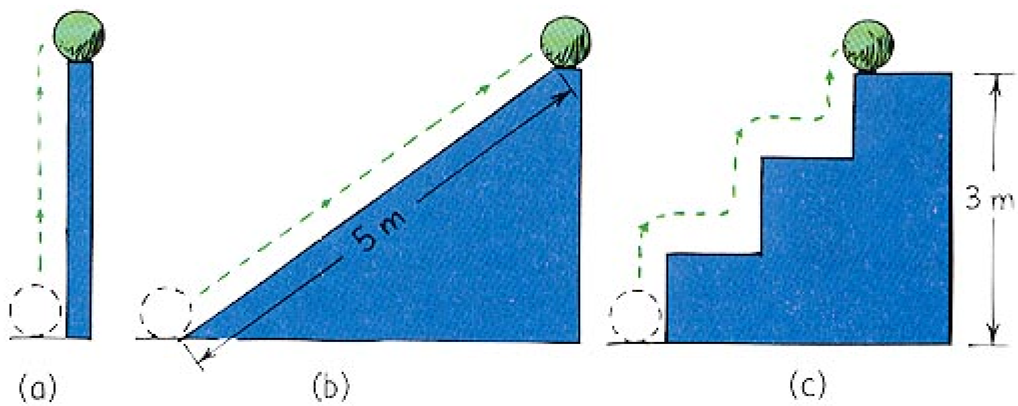
- work is required to elevate objects against Earth's gravity; the amount of gravitational potential energy possessed by an object is equal to the amount of work done against gravity in lifting it

$$\text{Gravitational Potential Energy} = \text{Weight} \times \text{Height}$$
$$U_g = mgd$$

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

- in the diagram below, we see three situations where a ball is raised three meters off the ground; in each case, the ball takes different paths to get to the three-meter position off the ground

- in each case, the same amount of work is being done



<u>Kinetic Energy</u>:

- 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

- <u>kinetic energy</u> (KE) is energy of motion; the kinetic energy of an object depends on its mass and speed

$$\text{Kinetic Energy} = \tfrac{1}{2}\,\text{mass} \times \text{speed}^2$$
$$\text{KE} = \tfrac{1}{2}mv^2$$

- notice that the speed variable is squared, so that if the speed is doubled, the KE is quadrupled; the change speed has a more dramatic effect on KE than a change in mass

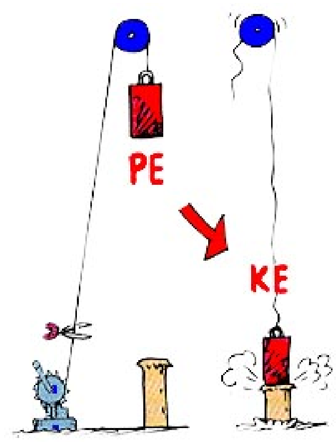
- when a ball is thrown, work is done on it, giving it KE; that moving ball can hit something and push against it and cause it to move; the ball can perform work equal to the amount of work put into the ball

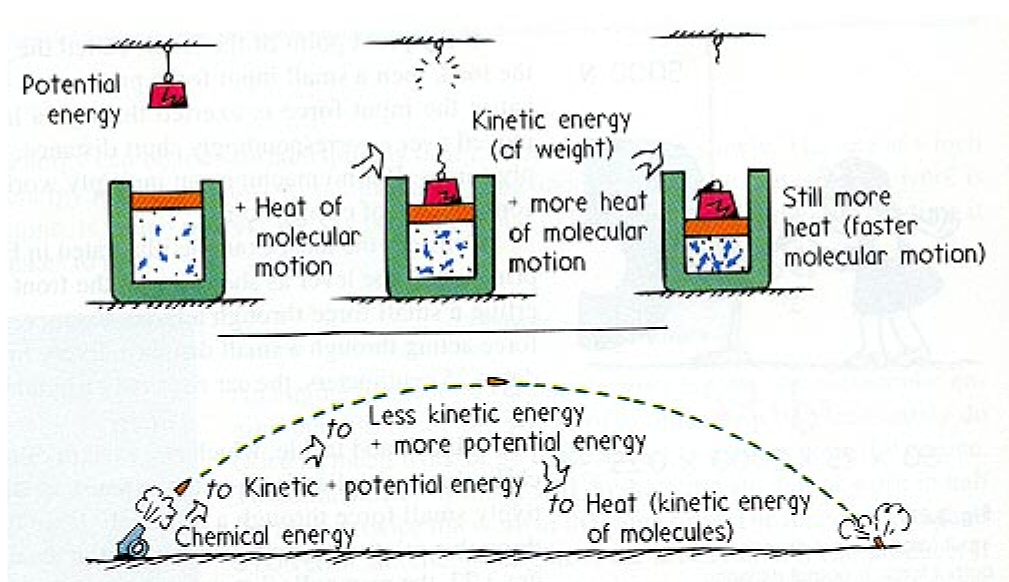
- as a result:

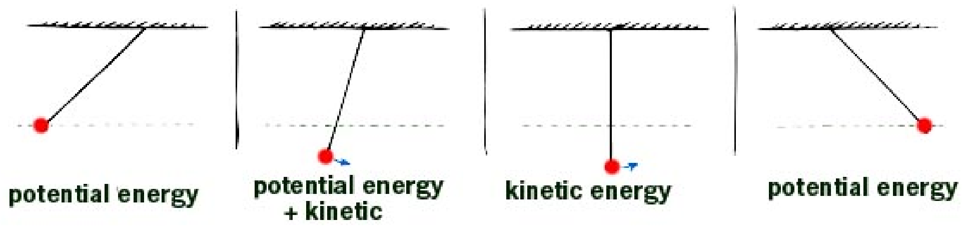
$$\text{Net force} \times \text{distance} = \text{kinetic energy}$$
$$\boldsymbol{F}d = \tfrac{1}{2}mv^2$$
$$\text{Work} = \Delta\text{KE}$$

<u>Conservation of Energy</u>:

- an important concept about energy is to understand how it can change from one form into another





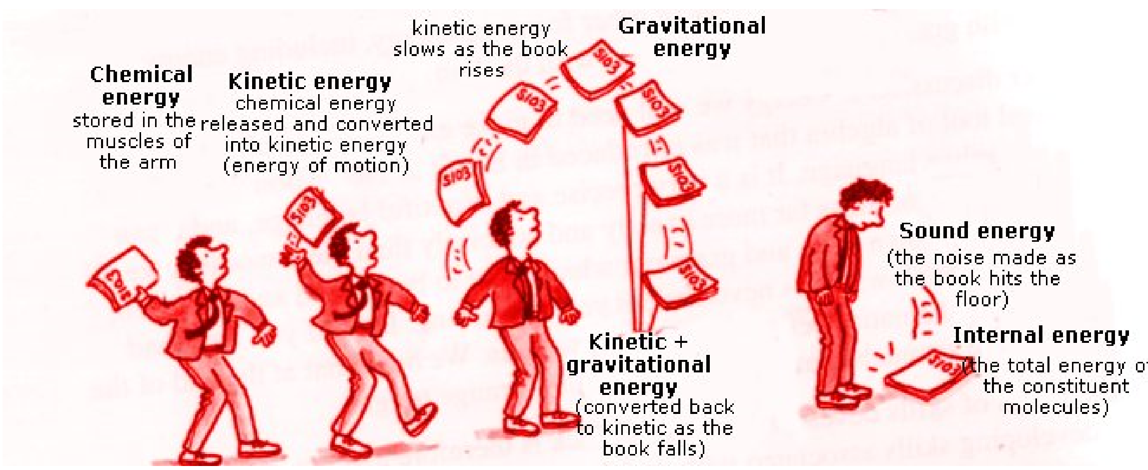


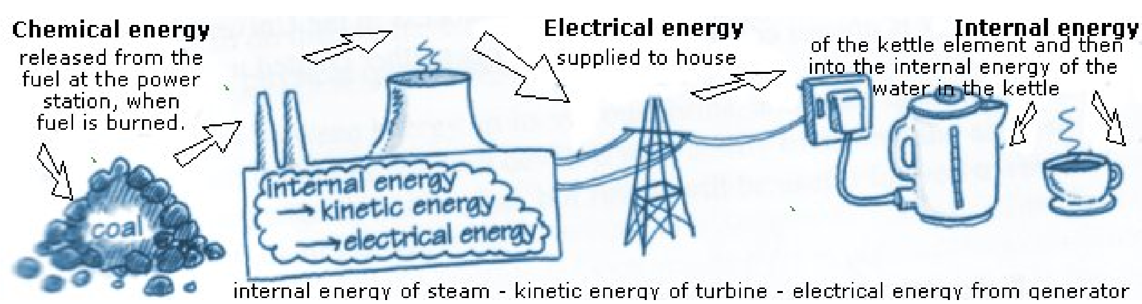
- for example, as you stretch a slingshot we perform work in stretching the rubber band; we give the slingshot potential energy

- when the rubber band is released, the potential energy of the slingshot is transformed into kinetic energy equal to the potential energy of the rubber band

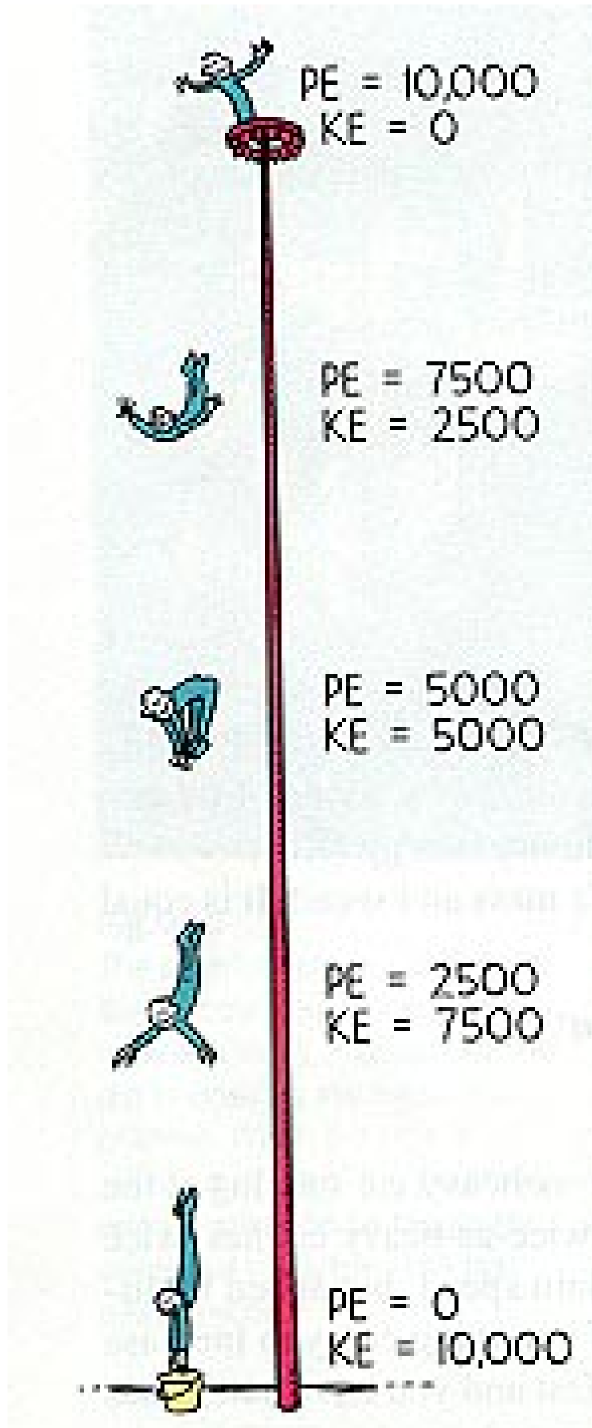
- the stone then transfers this energy to the object it hits; in each case the amount of energy being transformed remains the same

- the study of energy transformations led to another conservation law; the law of conservation of energy





- the <u>conservation of energy law</u> states that energy cannot be created nor destroyed; it may be transformed from one form into another, but the total amount remains the same



Summary:

Summary of Terms

- **Momentum** The product of the mass of an object and its velocity.
- **Impulse** The product of the force acting on an object and the time during which it acts.
- **Relationship** between impulse and momentum: Impulse is equal to the change in the momentum of the object that the impulse acts on. In symbol notation,

$$Ft = \Delta mv$$

- **Conservation of momentum** When no external net force acts on an object or a system of objects, no change of momentum takes place. Hence, the momentum before an event involving only internal forces is equal to the momentum after the event:

$$mv_{\text{(before event)}} = mv_{\text{(after event)}}$$

- **Elastic collision** A collision in which colliding objects rebound without lasting deformation or the generation of heat.
- **Inelastic collision** A collision in which the colliding objects become distorted, generate heat, and possibly stick together.
- **Work** The product of the force and the distance through which the force moves:

$$W = Fd$$

- **Energy** The property of a system that enables it to do work.
- **Potential energy** The stored energy that a body possesses because of its position.
- **Kinetic energy** Energy of motion, described by the relationship

$$\text{Kinetic energy} = \tfrac{1}{2} mv^2$$

- **Work-energy theorem** The work done on an object is equal to the energy gained by the object.

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

- **Conservation of energy** Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes. In an ideal machine, where no energy is transformed into heat, $\text{work}_{\text{input}} = \text{work}_{\text{output}}$ and $(Fd)_{\text{input}} = (Fd)_{\text{output}}$.
- **Power** The time rate of work:

$$\text{Power} = \frac{\text{work done}}{\text{time interval}}$$