Chapter 5 – Work and Energy

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How far did you push that 10 kg cement block in 5 seconds? How much **work** did you do?

Work is a function of the **force required** to **move a mass through a distance** in a **given amount of time** and can be expressed with the following equation:

$$W = Fd$$

F is force in Newton (N)
d is distance in meters (m)
W is work in **N-m** or **joules** (J)

One Joule of work is equal to using a **one Newton of force** to move an object through **1 meter**.

If you push on that 10 kg cement block, no matter how much force you apply to the block, if the block does not move, then no work was done on the block. The amount of blood, sweat, and tears (I wonder what has happened to that rock group?) that poured out of the person while pushing on that block doesn't matter, if you **didn't move it**, you **didn't do any work**.

Work is done only when **components of a force are parallel to a displacement**. Use the following equation to resolve the vectors of the force(s) applied to the object when the applied force is not parallel to the direction of movement of the object:

$$W = Fd(\cos\theta) \text{ or } W = Fd(\sin\theta)$$

If many forces are acting on an object, then the net force (think back to the force board) is used to determine the net work on the object. Think of this as Jim Carrey, Sylvester Stallone, and Arnold Schwarzenegger pulling a tree stump out of the ground.

$$W_{net} = F_{net}d(\cos\theta) \text{ or } W_{net} = F_{net}d(\sin\theta)$$

Work is a scalar quantity and can be positive of negative.
1. Work is positive when the direction of the force is in the same direction as the displacement.
2. Work is negative when the direction of the force is in the opposite direction of the displacement.

Negative Work???? The work may have only changed the forward speed (slowed) of the object. Jim Carrey might only slow down Sylvester Stallone in a game of tug-a-war.

Energy – the ability to do work

The release of energy to do work and doing work on an object adds energy to it. Work and energy are equivalent concepts and work and energy will have the same units, the joule. These equivalent concepts can be illustrated by the following:

$$W_{net} = F\Delta x = (ma)\Delta x \qquad \text{and more simply} \qquad E = W = Fd$$

Note: One joule has the ability to exert a force of one Newton over a distance of one meter.

Energy is the property that enables work to be performed. The more energy available, then the more work done. Energy therefore has two basic forms, **kinetic energy** and **potential energy**. The **total summation of kinetic energy and potential energy** is a system will be **equal to the mechanical energy** of the system.

Kinetic Energy – energy in motion (work is being done)

Kinetic energy (**KE**) is a scalar quantity that depends on **speed** and **mass**. The SI unit for energy is the joule (**J**), also the basic unit for work. Kinetic energy is expressed with the following formula:

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

Work-Kinetic Energy Theorem – When kinetic energy is present work is being done. If there is not kinetic energy, then the object is not moving and no work is being done. This theorem is expressed by:

$$W_{net} = \Delta KE$$

All forces on the object must be considered when calculating the work done. If an object's speed increases, then the final **KE** is greater than the initial **KE**. If an object's speed decreases, then the final **KE** is less than the initial **KE**.

Note: Have you every done work on an object and that object became warm? A certain amount of the energy in the system was converted into heat energy. Heat energy is also known as ___________ energy.

Potential Energy – Energy that is stored due to its position (not currently doing work)

Potential energy (**PE**) is present in an object that has the potential to move because it has position relative to another location. The **SI** unit for **PE** is the joule (**J**).

Potential energy depends on:

1. properties of the object (**mass**)
2. the object's interaction with its environment (**position** to other location – height)

Two types of Potential Energy:

1. Gravitational Potential Energy
2. Elastic Potential Energy

Gravitational Potential Energy (**PE_g**) – **PE_g** is dependent upon the objects height above a reference surface (zero level) that my not necessarily be the Earth's surface. Gravity provides the acceleration to the surface of the planet. The object accelerates downward due to free-fall acceleration. The gravitational potential energy is express with the following formula:

$$PE_g = mgh$$

As an object is in free-fall acceleration, the PEg is slowly being converted into KE. At the moment before impact, the object's PEg has become entirely KE.

$$\tfrac{1}{2} mv^2 = mgh$$

When solving **PE_g** problems, establish the zero level (reference point) on the vertical or y-axis. The velocity of an object on impact at its zero level can be calculated using the following equation:

$$V = \sqrt{2gh}$$

Elastic Potential Energy (**$PE_{elastic}$**) – **$PE_{elastic}$** is potential energy that is stored in a compressed spring or in a stretched elastic band (Think back to the water balloon lab.). When the spring or band releases the stored **PE**, it is at that moment converted into **KE**. If a force is not compressing the spring or stretching the elastic band, then they are at their **relaxed length**. The formula for **$PE_{elastic}$** is:

$$PE_{elastic} = \tfrac{1}{2} kx^2$$

k = spring constant (force constant);
x = distance (meters) stretched or compressed

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Energy … We cannot create it, nor can we destroy it, but we *Homo sapiens* have become masters at manipulating it.

Conserved Quantities – For practical purposes, the amount of material that is on Earth is constant (purest will argue about those items that have been tossed into the solar system and beyond so for practical purposes, lets negate that tiny amount of material). We have changed the form of the material, used some, discarded some into a landfill and recycled some, but the amount of material on Earth is unchanged. **Material (mass) is a conserved quantity**.

Energy can appear in many disguises. Heat energy, chemical energy, mechanical energy, light energy, and electrical energy are the major energy types. Each type can be converted into another type and the **energy with in a system is conserved**.

Lets apply energy conservation to a roller coaster. If V_i is the initial speed of the roller coaster, we can compute the speed at any point along its path just from knowing how far it descended. Let **h** be the distance descended and V_f is the final velocity.

Initial energy = $\frac{1}{2} mv_i^2 + mgh$
Final energy = $\frac{1}{2} mv_f^2$

The above equations are equal by conversation of energy.

$\frac{1}{2} mv_f^2 = \frac{1}{2} mv_i^2 + mgh$ then $V_f = \sqrt{V_i^2 + 2gh}$

Lets refer back to the water balloon lab. When the water balloon was at the apex of its path, the **KE** was minimum and **PE** was maximum. What happened to the energy when the water balloon went ***SPLAT*** on the ground?

1. Energy distorted the ground (though very minute).
2. Energy distorted the water balloon (it broke apart).
3. Some energy was converted into sound (**SPLAT!**).
4. As the molecules jiggled about energy is converted to heat.

Heat is the nothing but the kinetic energy of billions of molecules!!!!!!

As two objects in direct contact move past each other, the kinetic friction causes kinetic energy to be converted into another energy form. **Heat energy** is **lost energy** or the "**waste energy**" of a system. Heat is a form of energy that is difficult to account for but heat energy is still a part of the overall energy system.

Tim "the tool man" Taylor always wants more power!
Tool Time circa 1991 – 1999

Power – The rate at which energy is transferred

When do you do **more work**? Walking or running up the stairs?

When do you use **more power**? Walking or running up the stairs?

Work (**W**) that is done on an object in time interval Δt is the power applied to the object. The power can be expressed by this equation.

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

Power – watts
Work – joule
Time – seconds

One watt of power is **one joule of work** done in **one second of time**.

You will see watts on a light bulb, and on appliance labels to indicate power consumption. What is the power output of your stereo system?

Another type of power rating:

Horsepower (hp)- It is estimated through observations that a **strong horse** can move a **750 N** object through a distance of **1 meter** in **1 second**, therefore, **1hp** » **750 watts**

small electric motor	≈	1 hp
lawn mower engine	≈	2.5 - 4 hp
car engine	≈	95 - 400 hp
diesel train engine	≈	10,000 hp
nuclear power plant	≈	300,000 hp