KINETIC ENERGY (K)

* Kinetic energy is the energy of motion. It is the most fundamental type of energy.
* In order to change an object’s kinetic energy you must change either its mass or its speed. We shall assume constant mass, for now.
* In order to speed an object up, you need a net force in the direction of motion.
* In order to slow an object down, you need a net force opposite the direction of motion.
* Either way you need a net force with a *component parallel to velocity/displcement*.
* To change kinetic energy the force must cause an acceleration.

So what exactly is kinetic energy? Let’s derive the formula.

RECALL:

$$W=\rightharpoonaccent{F}\_{||}\rightharpoonaccent{d}$$

 and remember a little formula that we all know and love?

$\sum\_{}^{}\rightharpoonaccent{F}$= m$\rightharpoonaccent{a}$

 Now let’s substitute. If we consider all forces together, $\sum\_{}^{}\rightharpoonaccent{F}$, we will find the TOTAL work, $\sum\_{}^{}W$

$\sum\_{}^{}W$= $\sum\_{}^{}\rightharpoonaccent{F}\_{||}\rightharpoonaccent{d}$= m$\rightharpoonaccent{a}\rightharpoonaccent{d}$

 From kinematics: $\rightharpoonaccent{v}^{2}=\rightharpoonaccent{v}\_{0}^{2}+2\rightharpoonaccent{a}\rightharpoonaccent{d} \rightarrow \rightharpoonaccent{a}\rightharpoonaccent{d}=\frac{1}{2}(\rightharpoonaccent{v}^{2}-\rightharpoonaccent{v}\_{0}^{2}) $

$\sum\_{}^{}W$= m$\frac{1}{2}(v^{2}-v\_{0}^{2}) $

$\sum\_{}^{}W$= $\frac{1}{2}mv^{2}-\frac{1}{2}mv\_{0}^{2} $

So is a net force acts on an object in a direction parallel to the displacement it will cause a change in the quantity ½mv2. This quantity must therefore be a type of energy. It is called KINETIC ENERGY.

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

The units are $\frac{kg m^{2}}{s^{2}}≡Joule (J)$

Gravitational potential energy (Ug) (TAKE 1)

* We have been discussing the relationship between **WORK** and **ENERGY** and have so far established that if work is done to an object there will be a change in energy.
* What if you lift an object straight up into the air at *constant speed* within a gravitational field?
* You are doing positive work (You apply an upward force and the object is displaced upward). If you do positive work the energy must increase. But there is no change in the kinetic energy (constant speed).
* What kind of energy is gained in this case? Let’s look at the situation a little more closely.

 **F**

 **F** h

 **d**

 ho (not necessarily the ground)

W = $\rightharpoonaccent{F}$|| $\rightharpoonaccent{d}$

W= (mg) d

W= (mg) (h-ho)

W= mgh – mgho

So here we have work is equal to the change in the quantity *m g h* , we know work is a change in energy, therefore *m g h must be a form of energy.***This form of energy is named GRAVITATIONAL POTENTIAL ENERGY (Epg)**. At this new position relative to the ground the object can fall back to ho, gaining kinetic energy.

Ug=mgh

m: mass in kg g: gravitational field strength in N/kg h: height in m

 **(magnitude only!)** (from some chosenzero point)

Notice that if there were no gravitational field, there would be no potential energy. The potential energy here does not belong to the mass alone. It is shared by the Earth/mass system!

Work, Energy and the Work Energy Theorem:

Part 1:

Among the most well known (although not necessarily understood) scientific principles is the ***law of conservation of energy***. Most commonly it is stated as

*Energy can neither be created nor destroyed, it may only change form.*

This is a nice, tidy little statement but what does it mean? In this form it does little to tell us what energy IS. It also fails to mention what FORMS the energy may take, not to mention that the term **work** does not show up in the theorem in this form.

The above statement of the Law of Conservation of Energy is only one of many. Below are two others:

* *“Besides the 54 known chemical elements there is in the physical world one agent only, and this is called Kraft [energy or work]. It may appear, according to circumstances, as motion, chemical affinity, cohesion, electricity, light and magnetism; and from any one of these forms it can be transformed into any of the others.”*

*1837, Karl Friedrich Mohr*

* *The energy of an isolated system is fixed. The energy of any system can change from one value to another only as the result of work done to the system by an external agent (force), or by heat into or out of the system.*

We can summarize these with the following:

*Initial Energy + Work1 + Heat2= Final Energy*

1: Work here is work done to the object/system by EXTERNAL forces.

2: Heat is the transfer of thermal energy from/to the surroundings. Thermal energy transferred INTO an object is positive heat, thermal energy transferred OUT OF an object is negative heat

As we move through this unit, we will develop other versions of the theorem.

A few other details:

* The SI unit for energy (in any form), as well as for work or heat is the **Joule (J)**. In MKS units a Joule is one kilogram-metre squared per second squared.

1J$≡$1$\frac{kg∙m^{2}}{s^{2}}$

* Other common units are calories (cal), British thermal units (Btu), ergs (erg), kilowatt-hours (kWh) and electron-volts (eV)
* Three main types of energy are *KINETIC ENERGY*, *POTENTIAL ENERGY and THERMAL ENERGY*.
* The *TOTAL MECHANICAL ENERGY* of an object or system is the sum of the kinetic energy and potential energies. It does not include internal energies like nuclear, chemical or thermal or energies like light and sound as these quantities are generally insignificant in mechanical processes.
* Energy is a SCALAR QUANTITY. Energy DOES NOT HAVE DIRECTION.
* Work is *change in energy*. (W=∆E)
* Work can be negative! If you do ***negative work*** to an object you will ***decrease its energy***. If you do ***positive work*** to an object you will ***increase its energy***.
* Work is done if a force causes an object to be displaced. W=$\rightharpoonaccent{F}\rightharpoonaccent{d}$
* In order to do work to an object a force must have a component parallel to the motion of the object.

Conservative AND NON-CONSERVATIVE forces:

* All forces can be categorized as either CONSERVATIVE or NON-CONSERVATIVE based upon how they affect the energy of an object or system.

conservative forces

* Conserve the total energy of an object.
* *ACTION AT A DISTANCE FORCES*
* Examples include: Fg , Fs , Fe , FB
* Are associated with potential energies.

non-conservative forces

* Can change the total energy of an object (through heat and sound).
* *CONTACT FORCES*
* Examples include: FN , Ff , FT , Fa

Because EVERY force is either conservative or non-conservative $\sum\_{}^{}F$ = $\sum\_{}^{}F\_{c}+ \sum\_{}^{}F\_{nc}$

Therefore $\sum\_{}^{}W$ = $\sum\_{}^{}W\_{c}+ \sum\_{}^{}W\_{nc}$

The more common notation used in the work energy theorem will simply be:

$\sum\_{}^{}W$ *= Wc + Wnc*

Work done by a conservative force:

Because we are most familiar with gravitation, we will use Fg as our example of a conservative force.

Recall the recent example we used to derive Epg = mgh. We are going to use a similar example, but this time look at the work done by gravity:

 h

 **Fg**

 **d**

 ho

 Fg

Wg = $\rightharpoonaccent{F}$||g $\rightharpoonaccent{d}$

Wg = -(mg) d (Fg is down, d is up)

Wg = -(mg) (h-ho)

Wg = - (mgh – mgho)

Wg = - ∆Ug

Okee-dokee! From this we are going to make a generalization:

Wc = - ∆U

This is true of any conservative force.

Kinetic Energy, Potential Energy and the Work Energy Theorem

$\sum\_{}^{}W$ *= ΔK*

$\sum\_{}^{}W$ *= Wc + Wnc= ΔK*

*-ΔU + Wnc= ΔK*

*Wnc= ΔK + ΔU*

At this point it is an arbitrary matter of preference whether we use one form or the other. If you prefer to consider gravitation as an external force performing work on an object, or if you prefer to consider gravitation as part of the system and thus as a form of potential energy.

However you must choose.

Consider the example below solved in 3 ways:

We have discussed what energy is and a few of its forms.

There are two main forms of energy:

* 1. Kinetic energy, the energy of motion.

K =½mv2

 m: mass in kg v: SPEED of the object in m/s

Energy is a scalar quantity (we will discuss why later), this means it has no direction!

The units for energy are

* 2. Potential energy, the energy of position. An object has *potential energy* if its position relative to some other object gives the potential to move, or to gain kinetic energy.

The simplest example is to think of a massive object held above the surface of the Earth. If I simply drop that object it will fall toward Earth, gaining kinetic energy. Because of its position above Earth it has some energy “stored up” that can be released and become kinetic energy.

 This particular kind of potential energy is called GRAVITATIONAL POTENTIAL ENERGY:

Ug=mgh

m: mass in kg g: gravitational field strength in N/kg h: height in m (from some chosen

 **magnitude only!** zero point)

The units are:

**Using Ug in Calculations (Conservation of Mechanical Energy).**

Now we will see how the idea of gravitational potential energy can be used in calculations. We will explore this by using an example.

**EX1:** A 1.40kg ball is dropped from rest 11.0m

 above the ground. Find the speed of the ball

when it is 1.00m above the ground, using

 kinematics.

11.00m

1.00m

 **v**2= (0m/s)2 + 2(9.80m/s2)(10.0m)

**vo**=0m/s **v**2= 196m2/s2

**a**=9.80m/s2

**d**=10.0m **v**2=**v**o2 + 2**ad v**=14.0m/s

**v**= ?

\*Note : I made down the (+) direction.

Okay, now some follow up questions for you. Use the results of the above calculations to solve.

(DO THESE ON A SEPARATE PAGE)

 1. Find the initial kinetic energy (Ko) of the mass.

 2. Find the final kinetic energy (K) of the mass (at 1.00m).

 3. Find the initial gravitational potential energy (Ugo) of the mass.

 4. Find the final gravitational potential energy (Ug) of the mass (at 1.00m).

 5. Find the total initial mechanical energy (Ko + Ugo) of the mass.

 6. Find the total final mechanical energy (K + Ug) of the mass.

 **7. Compare your answers to 5 & 6.**

 8. Find the change in kinetic energy (ΔK) of the mass.

 9. Find the change in gravitational potential energy (ΔUg) of the mass.

 **10. Compare your answers to 8 & 9.**

 Hopefully we have noticed something. When the mass is dropped it falls down and gains kinetic energy while losing gravitational potential energy. The amount of lost potential energy is equal to the gained kinetic energy. The other thing to notice is that the total mechanical energy is the same at the beginning and the end.

Consider the next example:

**EX2:** A 680g mass is thrown straight upward at 16.0m/s. Answer parts a. through d. using kinematics:

 a. Find the speed of the mass after it has risen 6.00m

 b. Find the speed after it has risen 8.00m.

 c. Find the speed after is has risen 10.0m.

 d. Find the maximum height reached by the mass.

Use the answers from a. through d. to solve the following.

e. Find the initial kinetic energy of the mass.

 f. Find the kinetic energy at 6.00m, 8.00m, 10.0m and at maximum height.

 g. Find the initial gravitational potential energy.

 h. Find the gravitational potential energy at 6.00m, 8.00m, 10.0m and maximum height.

 i. Find the total mechanical energy at 0.00m. 6.00m, 8.00m, 10.0m and at maximum height.

 j. Find the change in gravitational potential energy from 6.00m to 10.0m.

 k. Find the change in kinetic energy from 6.00m to 10.0m.

Use the space below to answer:

Hopefully we have noticed something again. As the mass rises and slows down it loses kinetic energy and gains gravitational potential energy. The amount of lost kinetic energy is equal to the gained gravitational potential energy. So in both of the examples we should see that the energy simply changes from on from to another. The total mechanical energy (E, the sum of the K and U ) is the same at the beginning and the end, and at all points in between.

This is true if the only forces present are CONSERVATIVE FORCES (gravity, electrostatic, magnetic, spring). If there are NON-CONSERVATIVE FORCES (friction, normal, tension…)the total energy of the object may change as we will see.