PHYS 2010 LECTURE 19

Next reminder: Exam 2 is Tuesday, $7^{00}-9^{00}$ pm.

Yesterday defined work done by a force as $W_F \equiv F_{\parallel} \cdot \Delta s$
$= |F|\,|\Delta s| \cos\theta$, with units of $J = \frac{kg \cdot m^2}{s^2}$.

Now, define $\boxed{\text{kinetic energy}}$ (usually KE, sometimes K) of an <u>object</u> (not a force):

$$KE = \frac{1}{2} m v^2$$

- $KE \geq 0$ always.
- Bigger KE if object is more massive <u>or</u> moving faster.

Units: $\frac{1}{2} m v^2$: $(\text{mass})\left(\frac{\text{length}}{\text{time}}\right)^2$: $kg \cdot \left(\frac{m}{s}\right)^2 = \frac{kg \cdot m^2}{s^2}$ = Joules.

Next, define $\boxed{\underline{\text{gravitational}}\ \text{potential energy}}$ (usu. PE, sometimes U)
This is a type of stored energy associated with a configuration of masses. For a mass m at a height y near the surface of earth, $PE_{grav} = mgy$.

Units: $(\text{mass})\left(\frac{\text{length}}{\text{time}^2}\right)(\text{length}) \Rightarrow kg \cdot \frac{m}{s^2} \cdot m = \frac{kg\,m^2}{s^2}$ = Joules (again).

(Note – defn of PE_{grav} can be derived from a more fundamental def'n of energy → but for now, call it a definition.)

Example of how to use PE, KE: Take an object of mass 1 kg, at a height of $y = 1\,m$. $PE = mgy = (1\,kg)(10\,\frac{m}{s^2})(1\,m) = 10\,J$.

Now, drop the ball. What are KE, PE before & after?

Before, $KE_i = 0$ $(v=0)$, $PE_i = 10\,J$.

After: Accel $= -g$, $y_0 = 1\,m$, $y_f = 0$. $\Rightarrow PE_f = 0$.

Actually just before hitting table.

$V_f = ?$ Use const. accel formula:

$$V_f^2 = \cancel{V_0^2}^{\,0} + 2a(\cancel{y_f}^{\,0} - y_0) = -2ay_0 = +2gy_0 = 20\,\frac{m^2}{s^2}$$

$$\text{So } KE_f = \frac{1}{2}mV_f^2 = \frac{1}{2}(1\,kg)\left(20\,\frac{m^2}{s^2}\right) = 10\,kg\frac{m^2}{s^2} = 10\,J.$$

... which $= PE_i$. Interesting coincidence!

But look more generally:

$$V_f^2 = -2ay_0$$

$$mV_f^2 = +2mgy_0$$

$$\frac{1}{2}mV_f^2 = mgy_0 \Leftarrow KE_f + \cancel{PE_f}^{\,0} = \cancel{KE_i}^{\,0} + PE_i$$

So energy in the total system is <u>conserved</u> no matter m, y, (or even g).

$\rightarrow$ Total mechanical energy $= E_{mech} = KE + PE$.

Now, I said the ball was at a height of 1 m above the table. But it's also 1700 m above sea level. So $y = 1701\,m$.

$$\rightarrow PE = mgy = 17{,}010\,J.$$

So now, if I drop it onto the table, it will make a crater! But all we changed was definition of $y \rightarrow$ only <u>changes</u> in PE are physically meaningful!

So dropping the ball 1 m means $\Delta PE = -\Delta KE$

$$= (mgy_f) - (mgy_o) = (17{,}000 - 17{,}010)\text{J} = -10\text{J}$$

so ΔKE is still 10 J.

Final definition: dissipation: conversion of mechanical energy into (sound, heat) energy. Usually happens through friction.

Now, use these newly-defined concepts to state the rules of conservation of energy: (A result of Newton's Laws.)

1. If a system is isolated from outside forces and there's no dissipation, $E_{mech} = KE + PE$ remains constant.

2. If the system is not isolated, then the energy of the system changes by the work done by all external forces on the system.

$$W_{ext} = \Delta(KE + PE)$$