PENANG SANGAM HIGH SCHOOL

WEEK 9 **LESSON NOTES**

PYHSICS – Y13

STRAND: GRAVITATION

SUB-STRAND: Total energy of a satellite.

CONTENT LEARNING OUTCOME: to be able to determine the total energy and relate it to Potential and Kinetic energies.

The ***Kinetic Energy*** (K_e) of a projectile at a distance ***r*** from earth;

Equate centripetal force ($\mathbf{f}_c$) equal to gravitational force ($\mathbf{f}_g$)

$$\mathbf{f}_c = \mathbf{f}_g$$

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$mv^2 = \frac{GMm}{r}$$

$$\frac{1}{2}mv^2 = \frac{GMm}{2r}$$

$$\boxed{K_e = \frac{GMm}{2r}}$$

Total energy of satellite in circular orbit at a distance "r" from the centre of the earth.

$$E_P = U = -\frac{GMm}{r} \quad , \quad E_K = \frac{GMm}{2r}$$

At the surface of the earth, the E_P is large and negative. (much less than points further away). The total mechanical energy of a satellite in a circular orbit at a distance "r" from the centre of the earth will be the **sum** of its **gravitational potential energy and its kinetic energy.**

$$\mathbf{E_{Total}} = \mathbf{U} + \mathbf{E_K}$$

$$= -\frac{GMm}{r} + \frac{GMm}{2r}$$

$$= \frac{GMm - 2GMm}{2r}$$

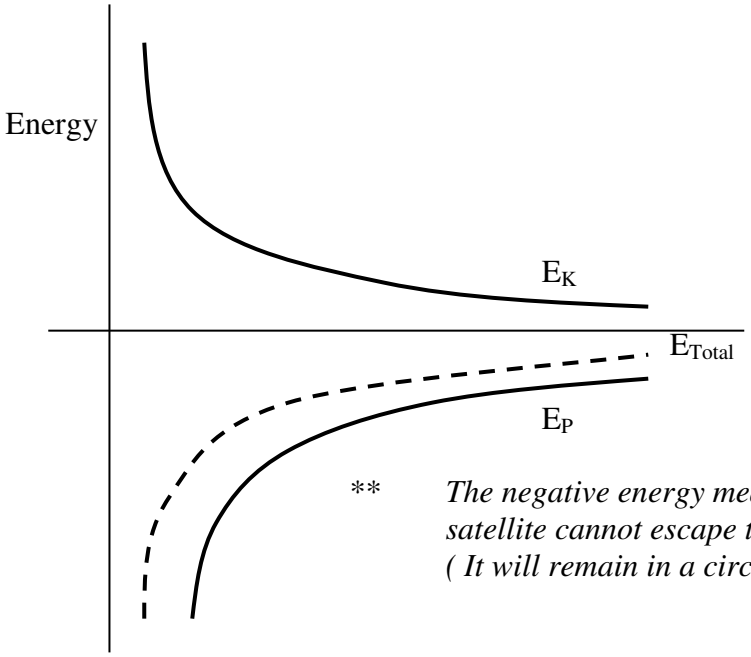
$$= -\frac{GMm}{2r}$$

$$\boxed{\mathbf{E_{Total}} = -\frac{GMm}{2r}}$$

So the total energy is the negative of the kinetic energy.

$$\boxed{-\frac{GMm}{2r} = -E_K} \qquad \boxed{E_T = -E_K}$$

Graph of Energy of satellite versus distance



** *The negative energy means that the projectile or satellite cannot escape the planet.*
(It will remain in a circular orbit.)

Binding Energy

Binding energy is the energy needed for a projectile or a satellite to escape the gravitational field.

$E_{Total} \geq 0$ for a projectile.

In order for the projectile to escape, its total energy should be positive.

If the satellite is to be in a circular orbit, the total energy is $E_{Total} = -\frac{GMm}{2r}$

Since in order for the satellite to escape, the total energy has to be ≥ 0 means that

$$E_T \geq \frac{GMm}{2r}$$

Therefore the ***binding energy*** for a projectile in circular orbit $= \boxed{\frac{GMm}{2r}}$, which is the KINETIC ENERGY

Exercise

(a) What is the gravitational potential energy of a 50 kg satellite in a circular orbit 500 km above the surface of the earth?
(b) Determine the kinetic energy of the satellite.
(c) Calculate the total energy of the satellite.
[Mass of earth $= 5.98 \times 10^{24}$ kg , Radius of earth $= 6.4 \times 10^{6}$ m]