

# Notes:

## PHYSICS 12

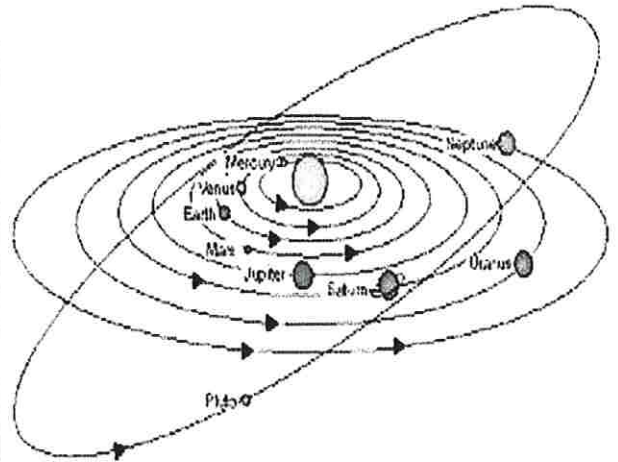
## ORBITS

The object is specifically stated to be in orbit or it is located in space.

To find force, Newton's Law of Universal Gravitation must be used:

$$F_g = G \frac{m_1 m_2}{r^2}$$

$$G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2 \cdot \text{kg}^{-2}$$



$$F_g = F_c$$

- Be careful not to substitute object's altitude = surface-to-surface distance but always center-to-center

**Example:** Find the speed of Apollo 13 when it is in orbit about the Moon at an altitude of 3000km.

○  $m_M = 7.35 \times 10^{22} \text{ kg}$   
 $r_M = 1.74 \times 10^6 \text{ m}$

! altitude = 3000 km  $\rightarrow 3.0 \times 10^6 \text{ m}$

∇ orbiting radius =  $r_M + \text{altitude}$

(=) neglecting the size of Apollo 13,

$$v = \sqrt{\frac{(6.67 \times 10^{-11})(7.35 \times 10^{22})}{[1.74 \times 10^6 + 3.0 \times 10^6]}}$$

$$v = 1016.99 \dots \text{ m/s}$$

$$F_c = F_g$$

$$\cancel{m_A} \frac{v^2}{r} = \frac{G m_M \cancel{m_A}}{r^2}$$

$$v^2 = \frac{G m_M}{r}$$

$$v = \sqrt{\frac{G m_M}{r}}$$

∴ Apollo's speed is  $1.02 \times 10^3 \text{ m/s}$ .

1. a) Find the altitude of a satellite orbiting the Earth at 5000 m/s. Mass of the Earth is  $5.98 \times 10^{24}$  kg.

$$v = 5000 \text{ m/s}$$

$$m_E = 5.98 \times 10^{24} \text{ kg}$$

$$r_E = 6.38 \times 10^6 \text{ m}$$

$$\text{altitude} = r - r_E$$

$$v = \sqrt{\frac{G m_E}{r}}$$

$$v^2 = \frac{G m_E}{r}$$

$$r = \frac{G m_E}{v^2}$$

$$r = \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{(5.0 \times 10^3)^2}$$

$$r = 15954640 \text{ m}$$

$$\begin{aligned} \text{altitude} &= 15954640 - 6.38 \times 10^6 \\ &= \underline{9.6 \times 10^6 \text{ m}} \end{aligned}$$

$\therefore$  Satellite's altitude is  $9.6 \times 10^6 \text{ m}$ .

b) Find the period of the probe.

Period =  $T$  = time to complete 1 revolution

$$t = \frac{d}{v}$$

$$= \frac{2\pi r}{v}$$

$$= \frac{2\pi (15954640)}{5000}$$

$$= \underline{20049 \text{ s}}$$

$$\hookrightarrow = \underline{5.6 \text{ hrs}}$$

$\therefore$  The probe completes one revolution around the Earth in 5.6 hours (or  $2.0 \times 10^4 \text{ s}$ ).

## POTENTIAL ENERGY ASSOCIATED WITH GRAVITY

(for objects high above the Earth's surface)

GPE = gravitational potential energy

- This energy is found by evaluating work required to move an object from Earth's surface to infinity. This work is done by applied force that counters gravity.

$$GPE = \frac{-G m M}{r}$$

- GPE = 0 in infinity as objects separated by infinitely large radius do not interact.

Recall: Total energy of an object is given by the sum of the potential and kinetic energy of the object.

- For an object to escape Earth, the total energy has to be zero.
- Total energy of an orbiting satellite is always negative as the satellite is not free to move away.

$$E_{TOT} = KE + GPE$$

Derive the formula for escape velocity:  $\Rightarrow E_{TOT} = 0 \text{ J}$

$$KE + GPE = 0$$

$$KE = -GPE$$

$$\frac{1}{2} m v^2 = \frac{G m_E m}{r}$$

$$v^2 = \frac{2 G m_E}{r}$$

$$v = \sqrt{\frac{2 G m_E}{r}}$$

Escape Velocity

$$v = \sqrt{\frac{2 G m_E}{r}}$$

2. Read textbook p. 144-145 Chapter 5.5

3. a) What is the speed a satellite needs to maintain an orbit with a fixed radius?

$$F_g = F_c$$
$$\frac{G m_E m_2}{r^2} = m_2 \frac{v^2}{r}$$
$$\frac{G m_E}{r} = v^2$$
$$v = \sqrt{\frac{G m_E}{r}}$$

b) How does the magnitude of this speed depend on the mass of the satellite?

- $v_{orb}$  is mass independent.
- $v_{orb}$  is dependent on the mass of the object that creates the gravitational field and the orbiting radius.

4. What is a geosynchronous satellite?

A satellite whose period is the same time needed for Earth to complete one revolution about its axis of rotation. This type of a satellite is always above the same spot on Earth.

5. How is time needed for one revolution about the orbit related to the speed of a satellite?

$$v = \frac{d}{t} = \frac{2\pi r}{T} \Rightarrow \text{as } T \uparrow \quad v \downarrow$$

∴ Speed and period are inversely proportional.

6. Calculate the magnitude of escape velocity of the Earth.

$$m = 5.98 \times 10^{24} \text{ kg}$$

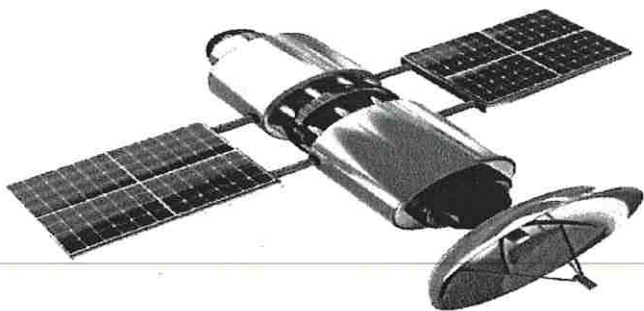
$$v_{\text{esc}} = \sqrt{\frac{2 G m_E}{r}}$$

$$= \sqrt{\frac{2(6.67 \times 10^{-11})(5.98 \times 10^{24})}{6.38 \times 10^6}}$$

$$= 1.1 \times 10^4 \text{ m/s}$$

7. If you wanted to calculate escape speed from another planet, what variables would change in the formula?

- the mass of the planet and its radius.



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