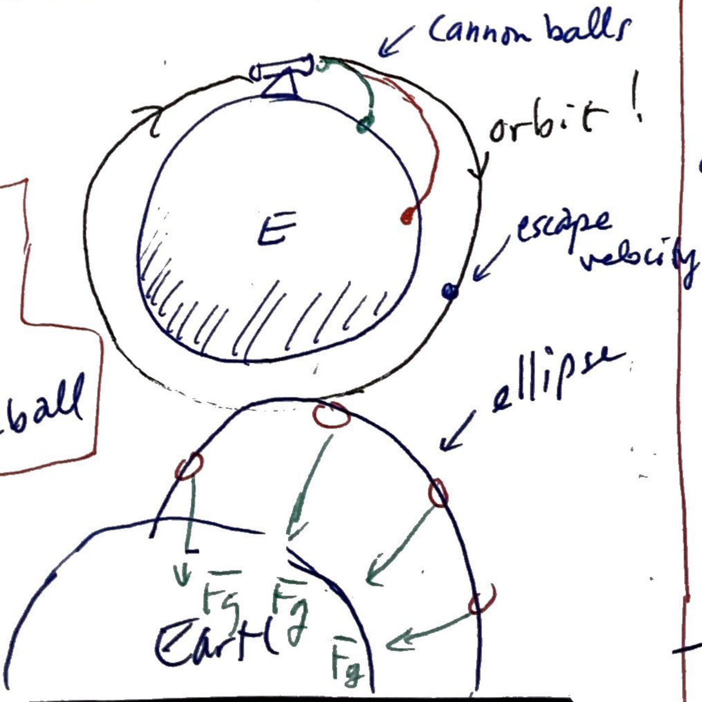
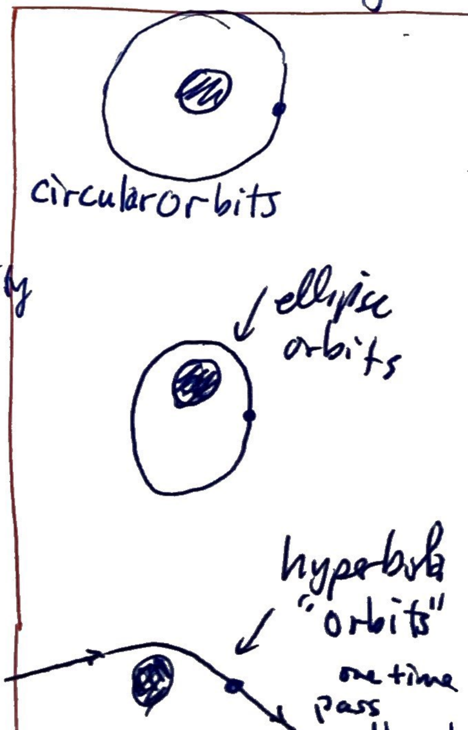
5B Gravitational Force.

- Newton surmised his First Law the one that says "if you are traveling at a constant speed in a straight line, you will continue in a straight line at a const. s unless you are under the influence of a force".

- But the earth does not travel in a straight line so there must be a force. Likewise, when the apple falls off the tree it acc'lts, it is speeding up, so there must be a force.

- Are these two different forces? Newton observed the moon's orbit and concluded that the force on the apple and on the moon are the same. He called this Force "Gravity"

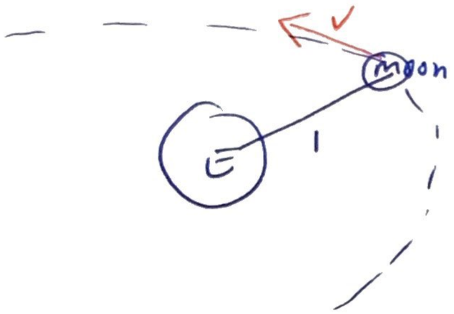




⊛ Newton's 4th LAW: Two masses attract each other - modelled by:

$$\boxed{F_G = G\,\frac{M_S\, m_e}{R_{S.E.}^2}}$$

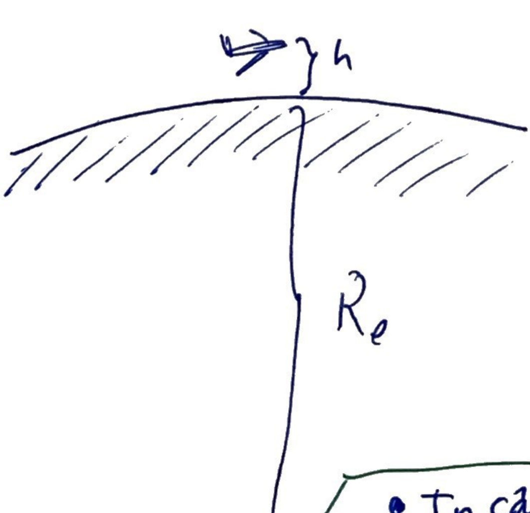
mass of object 1
mass of object 2
distance between objects
constant of proportionality



$$F_G = G\,\frac{M_E\, m_{moon}}{R_{E.m}^2}$$

$$F_G = G\,\frac{M_{astroid}\, m_{rock}}{R_{A.R.}^2}$$

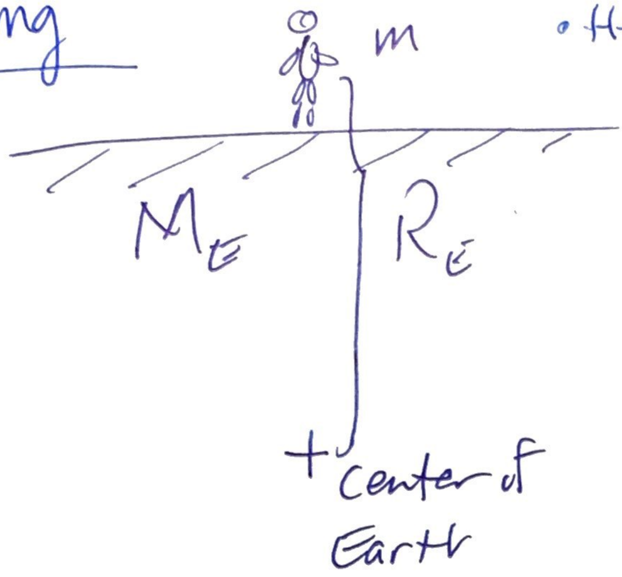
- Near the surface, the force is calculated using the distance from the center of the Earth.



$$F_G = G\,\frac{M_E\, m_{airplane}}{(R_e + h)^2}$$

- In calc. based physics we learn that the net effect of the planes forces of gravity caused by all masses in the Earth has a net effect as an attraction of all mass compressed to the center.

* F=mg



• Here we derive "g"

$$F_g = \left(G\frac{M_E}{R_E^2}\right) m$$

Compare to

$$F_g = (g) m$$

So $$g = G\frac{M_E}{R_E^2}$$

$$\boxed{G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}}$$ Gravitational Constant.

$$\boxed{M_E = 5.98 \times 10^{24} kg}$$ mass of earth

$$\boxed{R_E = 6.38 \times 10^{6} m}$$ radius of earth

$$\frac{N}{kg} = \frac{\cancel{kg}\, m/s^2}{\cancel{kg}}$$

• Now

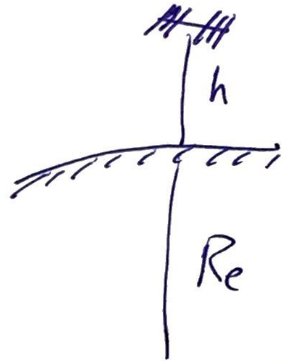
$$g = \frac{\left(6.67 \times 10^{-11} \frac{N \cancel{m^2}}{kg \cancel{^2}}\right)\left(5.98 \times 10^{24} \cancel{kg}\right)}{\left(6.38 \times 10^{6} \cancel{m}\right)^2}$$

or $g = 9.799\ m/s^2$ or just $\boxed{9.8\ m/s^2}$

acceleration due to gravitational attraction

Ex The ISS is at 240 km above the Earth. What is "g" up there?

$$g_{ISS} = G \cdot \frac{M_e}{(R_e + 240\,km)^2}$$

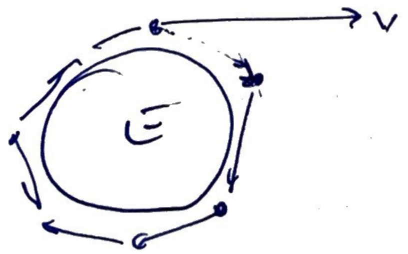


$$= \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{(6.38 \times 10^6 + 2.4 \times 10^5\,m)^2}$$

$$= \boxed{9.10\,m/s^2}$$

But wait ... the astronauts floats! so is not $g = 0$?

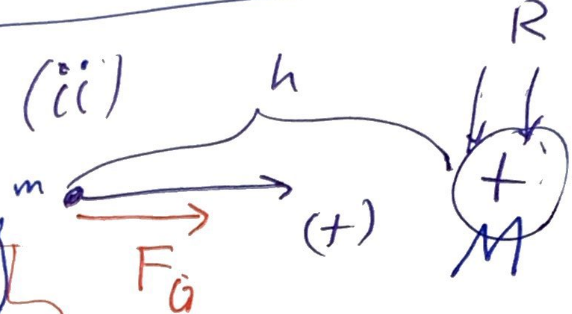
Ans: No the astronaughts are falling all the time but the space station is moving so fast that their fall misses the Earth constantly.



⊛ The Further away we get from the Earth the slower the orbital speed. Find V at diff't orbits...

(i) Diagram

(ii)



Newton's 2nd $F_G = ma_r$

$G\frac{Mm}{R^2}$ Newton's 4th

(iii)

$$\boxed{G\frac{M_E m}{(R_E+h)^2} = m\left(\frac{V^2}{(R_E+h)}\right)}$$

(iv) Solve the velocity needed to maintain orbit for (R_E+h).

$$G\frac{M_E \cancel{m}\,\cancel{(R_E+h)}}{\cancel{m}\,(R_E+h)^{\cancel{2}}} = V^2$$

$$\boxed{V = \sqrt{G M_E / R_E+h}}$$

EX How fast is the ISS moving?

$$V = \sqrt{(6.67\times10^{-11})(5.98\times10^{24}) / \{6.38\times10^{6} + 240{,}000\,m\}}$$

$$V = 7762\,m/s\left(\frac{1\,km}{1000\,m}\right)\left(\frac{3600\,s}{1\,hr}\right) = \underline{\underline{27{,}943.9\,km/hr.}}$$

$$= \boxed{17{,}363.6\ miles/hr}$$

⑥

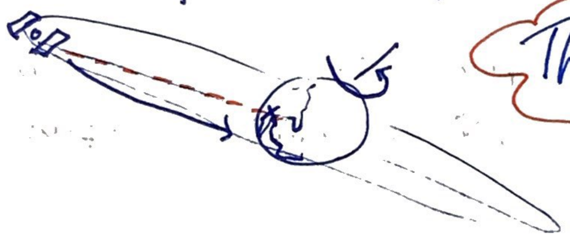
* geo synchronous orbit

As we orbit further and further from the Earth, the speed decreases:

$$\boxed{V = \sqrt{GM_E/(R_E+h)} \quad \text{as } h\uparrow,\ V\downarrow}$$

There is an orbital distance where the period of orbit matches the period of the Earth. This is called geo synchronous orbit

- Perfect place to park a satellite -



The satellite is above the same spot always. DishTV

- Newton's Laws:

$$F_G = m\frac{V^2}{R+h}$$

$$G\frac{M_e \cancel{m}}{(R+h)^{\cancel{2}}} = \cancel{m}\frac{V^2}{\cancel{R+h}}$$

$$\frac{GM_e}{V^2} = R+h$$

but

$$\boxed{V = \frac{\text{Circumference}}{\text{Period} \leftarrow T} = \frac{2\pi(R+h)}{24hr}}$$

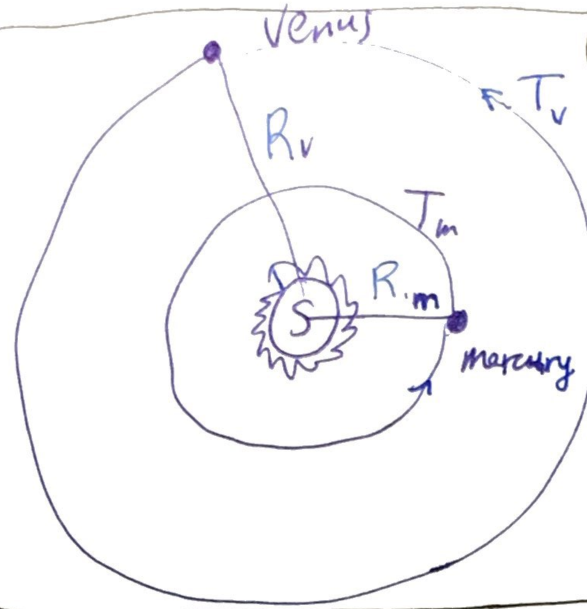
$$\frac{GM}{\left[\frac{2\pi(R+h)}{T}\right]^2} = R+h$$

$$\boxed{\left(\frac{GM}{4\pi^2}\right)T^2 = (R+h)^3}$$

period squared = Radius Cubed

"Kepler's Law"

Applied To Planets



$h_m^3 \propto T_m^2$

$h_v^3 \propto T_v^2$

$$\boxed{\left(\frac{h_m}{h_v}\right)^3 = \left(\frac{T_m}{T_v}\right)^2}$$

$\therefore$ $\boxed{T \propto h^{3/2}}$

EX NOW...

- Solve for "R + h" that keeps a satellite above Calif:
  - Kepler's Law

$$R + h = \sqrt[3]{G\frac{MT^2}{4\pi^2}}$$

24hr.

earth ↑ R, ↑ h we want

$$\boxed{\sqrt[3]{a} = a^{1/3}}$$

- Populate

$$R + h = \left(\frac{6.67\times10^{-11}\,(5.98\times10^{24})\left(24\text{hr}\cdot3600\frac{s}{hr}\right)^2}{4\pi^2}\right)^{1/3}$$

$$= \left(7.54\times10^{22}\,m^3\right)^{1/3}$$

$$= \boxed{4.23\times10^7\,m} = R + h$$

↑ center of earth to geo. satellite

$$= 4.23\times10^4\,\text{km} = \boxed{42{,}300\text{ km}}$$

from center of the Earth

(*) Gravity is one of the 4 forces in Nature.

the others are

- ElectroMagnetic - pos & neg charges attract {static electricity}, North and South Poles on magnets attract.
- Weak force - force between sub-atomic particles
- Strong force - force between protons and neutrons. Keeps atoms together.