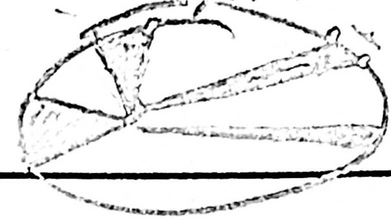
Newton's Law of Universal Gravitation:

$F_{gravity} = G\left(\frac{m_1 m_2}{r^2}\right)$ --or-- $G\left(\frac{Mm}{r^2}\right)$, where **G** is the gravitational constant (an empirically measured quantity), m_1 and m_2 are two different masses, and **r** is the distance between their centers of mass. When one mass orbits the other, **r** is also referred to as the "orbital radius." *[Often, M is used for a planetary mass, and m is used for its satellite.]*

$G = 6.67x10^{-11}\frac{Nm^2}{kg^2}$



4. Calculate the force of gravity between a 100kg student and a 60kg student whose centers of mass are 1.7m apart.

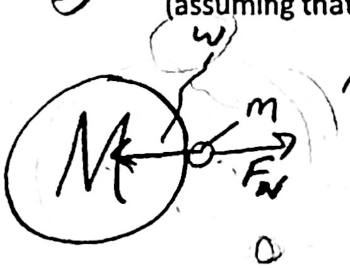
$$F_g = 6.67\times10^{-11}\frac{N\cdot m^2}{kg^2}\left(\frac{(100kg)(60kg)}{(1.7m)^2}\right) = 1.38\times10^{-7}N$$

Combining Circular Motion and The Law of Gravitation:

5. Find the value of **g** at Earth's surface. Earth's mass is ($5.972x10^{24}$kg) and its average radius ($6.371x10^6$m).

$$g = 6.67\times10^{-11}\frac{Nm^2}{kg^2}\left(\frac{5.972\times10^{24}kg}{(6.371\times10^6 m)^2}\right) = 9.81 m/s^2$$

6. Derive a general formula for the value of **g** at a distance **r** from the center of a planet with mass **M** (assuming that this location is at or above the planet's surface).



$$F_g = W = mg$$

$$F_g = G\frac{Mm}{r^2}$$

$$\cancel{m}g = G\frac{M\cancel{m}}{r^2}$$

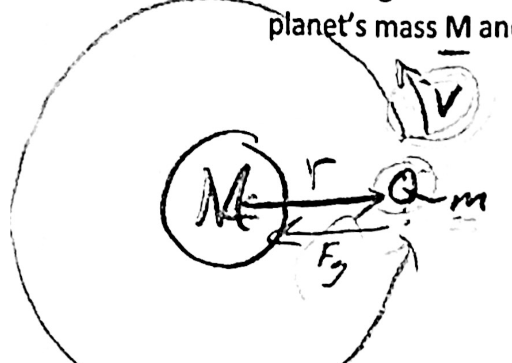
$$g = \frac{GM}{r^2}$$

8. What is the velocity of a space station that is orbiting ~~the Earth with~~ an orbital radius of 30,000km?

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\times10^{-11}\frac{Nm^2}{kg^2}(5.972\times10^{24}kg)}{30,000,000m}}$$

$$V = 3644 m/s$$

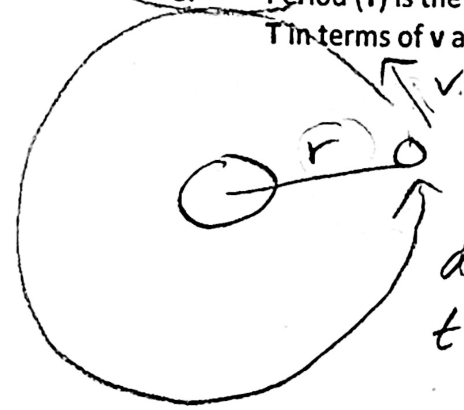
7. Derive a general formula for the speed **v** of a satellite in a circular orbit – in terms of the orbited planet's mass **M** and the satellite's orbital radius **r.**



$\Sigma F = \frac{mv^2}{r}$ $\qquad \frac{mv^2}{r} = G\frac{Mm}{r}$

$\Sigma F = F_g = G\frac{Mm}{r^2}$ $\qquad v = \sqrt{\frac{GM}{r}}$

8. Period (**T**) is the amount of time it takes for a satellite to complete a full orbit. Write equations for: **T** in terms of **v** and **r**; and **v** in terms of **T** and **r**.



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

$d = rt$

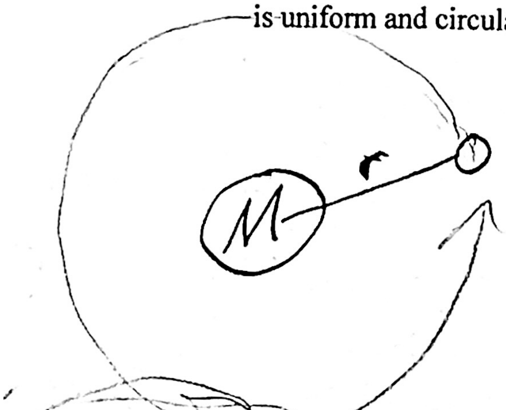
$t = \frac{dist}{rate}$

9. Find the necessary orbital radius for a geostationary satellite (a satellite that is always over the same point on the equator. You'll need the Earth's mass -- 5.972×10^{24}kg.

$$T = 2\pi\sqrt{\frac{r^3}{GM}} \Rightarrow 86{,}400s = 2\pi\sqrt{\frac{r^3}{(6.67\times10^{-11}\frac{Nm^2}{kg^2})(5.972\times10^{24}kg)}}$$

$$r = 4.22\times10^7 m$$

10. Derive a formula for **T** in terms of **r**, **G**, and the mass of the orbited body (**M**). Assume that the orbit is uniform and circular. *[This is the general form of Kepler's 3rd Law.]*



$v = \sqrt{\frac{GM}{r}}$ $\qquad \sqrt{\frac{GM}{r}} = \frac{2\pi r}{T}$

$v = \frac{2\pi r}{T}$ $\qquad T = \frac{2\pi r}{\sqrt{\frac{GM}{r}}}$

$T = 2\pi\sqrt{\frac{r^3}{GM}} \Leftarrow T^2 = \frac{4\pi^2 r^3}{GM} \Leftarrow T^2 = \frac{4\pi^2 r^2}{\left(\frac{GM}{r}\right)}$