**Newton’s 1st law of motion:**

A body continues in its state of rest, or in uniform motion in a straight line, unless compelled to change that state by forces impressed upon it.

**Newton’s 2nd law of motion:**

The time rate of change of an object’s momentum equals the applied force. $F=\Delta p/\Delta t=ma$ if $\Delta m=0$.

**Newton’s 3rd law of motion:**

When body A exerts a force on body B, body B will exert an equal, but opposite, force on body A.

**Newton’s law of universal gravitation:**

The force of gravity between two bodies is directly proportional to the product of the two masses and inversely proportional to the square of the distance between them.

$F=Gm_1m_2/R^2$

Universal gravitational constant $G = 6{,}67\cdot10^{-11}Nm^2/kg^2$

$m_1 = M_E= M= 6\cdot10^{24}$ kg

Earth’s gravitational parameter $\mu = M\cdot G= 4\cdot10^5\ km^3/s^2$

$R_E = 6400$ km

**Kepler’s 1st law:**

The orbits of the planets are ellipses with the sun at one focus.

**Kepler’s 2nd law:**

The line joining a planet to the sun sweeps out equal areas in equal times.

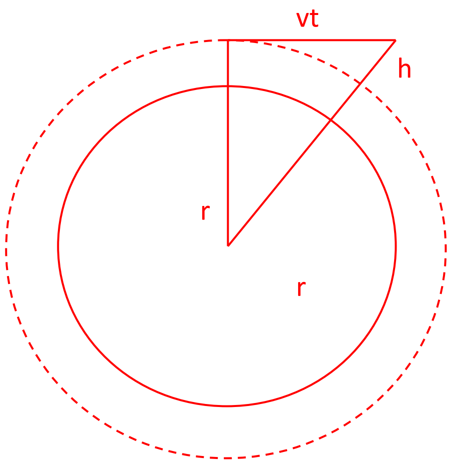
**Kepler’s 3rd law:**

The square of the orbital period is directly proportional to the cube of the average distance between the planet and the sun.

$T^2 = 4\pi^2a^3/\mu$

Show that $mv^2/r = \mu m/r^2$, i.e. the centripetal force equals the gravitational force for a satellite in earth orbit.

A geometrical approach to find the centripetal force (Tipler):




$(r+h)^2=(vt)^2+r^2$

$r^2 + 2rh + h^2 = v^2t^2 + r^2$

$h(2r + h) = v^2t^2$

and $h << r$

$2rh = v^2t^2$

$h= \frac{1}{2} (v^2/r)\, t^2$

Comparing this with the constant acceleration expression $h = \frac{1}{2} at^2$, gives $a=v^2/r$.

With $F = ma = mv^2/r$.

Newton's law of universal gravitation gives $F = \mu m/r^2$. For an object in orbit around the earth, the centripetal force is equal but opposite to the gravitational force, hence $mv^2/r = \mu m/r^2$

Show Kepler's third law, i.e. that $r^3$ is proportional to $T^2$. Show that the centripetal force can be expressed as $m\omega^2 r$.

$mv^2/r = \mu m/r^2$

$v^2 = \mu/r$

$(2\pi r/T)^2 = \mu/r$

$4\pi^2 r^3 = \mu T^2$, hence $r^3$ is proportional to $T^2$

$mv^2/r = (m/r)(2\pi r/T)^2 = m\omega^2 r$ as $\omega = 2\pi f = 2\pi/T$