Newton's Law of Universal Gravitation 萬有引力定律

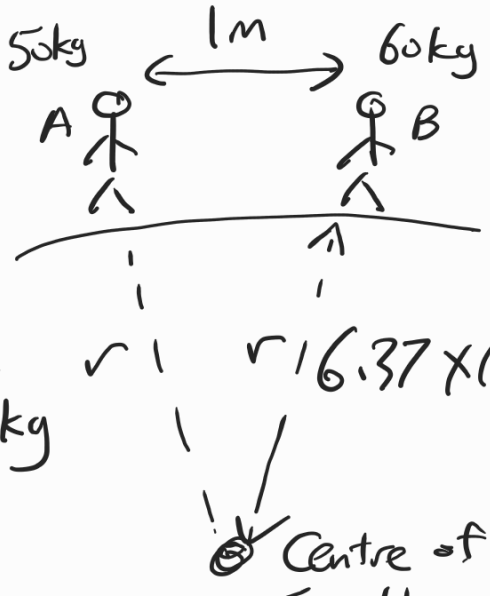
$$F = G\frac{M_1 M_2}{r^2}$$

G : gravitational constant
$6.67\times10^{-11} Nm^2kg^{-2}$
引力常數

mass of 2 objects
M_1 M_2

r : distance btw 2 objects.

Example



mass of earth = 5.97×10^{24} kg

a) Find the force btw A + B

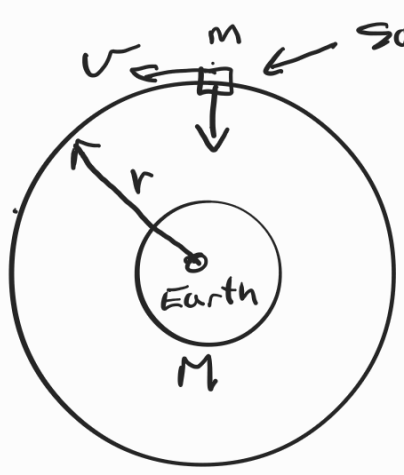
b) Find the force btw A and the earth

a) $F = \frac{M_1 M_2}{r^2} G = 6.67\times10^{-11} \times \frac{50\times60}{1^2} = 2\times10^{-7} N$ //

b) $F = G\frac{M_1 M_2}{r^2} = 6.67\times10^{-11} \times \frac{50(5.97\times10^{24})}{(6.37\times10^6)^2}$

$= 491 N$ // $\Rightarrow (mg)$

Circular motion between earth + satellite



gravitational force btw earth + satellite = Centrifugal force acting on satellite

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

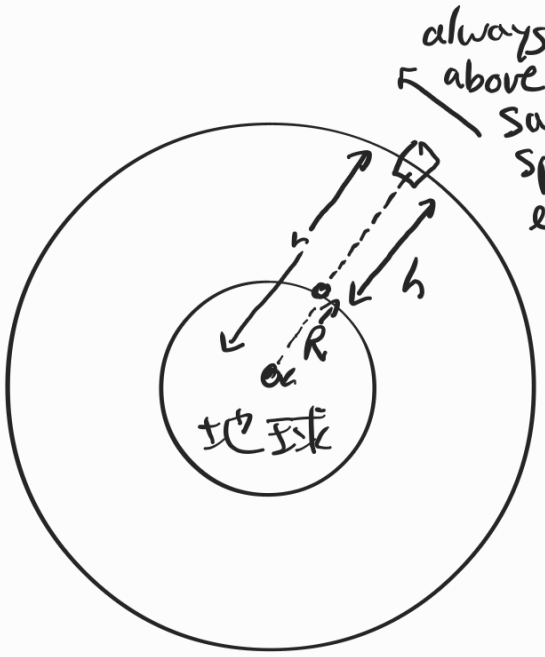
m : mass of satellite
M : mass of earth

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

$$v = \sqrt{\frac{GM}{r}}$$

對地靜止衛星

Example : A geo stationary satellite travels at the same ω as the earth



m mass of satellite
M mass of earth

$G : 6.67\times10^{-11}$

$M : 5.97\times10^{24}\ kg$

R radius of earth : $6.37\times10^{6}\ m$

a) Find the angular velocity
b) Find the height h

(a) Period $T = 1\text{ day} = 24 \times 60 \times 60 = 86400\text{ s}$

Angular speed $\omega = \frac{2\pi}{T} = \frac{2\pi}{86400} = 7.272 \times 10^{-5}$ rad s^{-1}

(b) Centripetal force = gravitational force

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

$$\Rightarrow r^3 = \frac{GM}{\omega^2} \qquad r^3 = \frac{(6.67 \times 10^{-11})(5.97 \times 10^{24})}{(7.272 \times 10^{-5})^2}$$

$$r = 4.223 \times 10^7 \text{ m}$$

$$h = r - R = 4.223 \times 10^7 - 6.37 \times 10^6$$

$$= 3.59 \times 10^7 \text{ m}$$ //

Gravitational Field Strength (g) 引力場

$g = \frac{F}{m}$ force per unit mass of earth's attraction $\qquad g = \frac{9.81\text{ N}}{1\text{ kg}} = 9.81$ N kg^{-1} (ms^{-2})

per unit mass

$$g = \frac{F}{m} = \left[G \frac{M m}{r^2}\right]\left[\frac{1}{m}\right] = G \frac{M}{r^2}$$

Force due to earth

G = gravitational constant
M = mass of earth
r = radius of earth

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