Newton's Law of Universal Gravitation

Newton proposed....

...two objects of mass attract each other.

....the bigger the masses, the stronger the attraction.

... the larger the separation distance, the weaker the attraction.

$$\boxed{F_G = \frac{G\, M_1 M_2}{r^2}}$$

$\left[\frac{N m^2}{kg^2}\right]$ $[kg^2]$ $[m^2]$ $[N]$

$m_1 \xrightarrow{F_G}$ $\xleftarrow{F_G} m_2$ $\vec{F}_{12} = -\vec{F}_{21}$

F_G mutual gravitational force experienced by both masses and is always a pull towards each other

M_1 mass of object 1

M_2 mass of object 2

r distance of separation between centres of mass for objects 1 and 2

G universal gravitational constant

p. 955 value $6.673 \times 10^{-11} \frac{N.m^2}{kg^2}$

important page

p. 578 value $6.67 \times 10^{-11} \frac{N.m^2}{kg^2}$

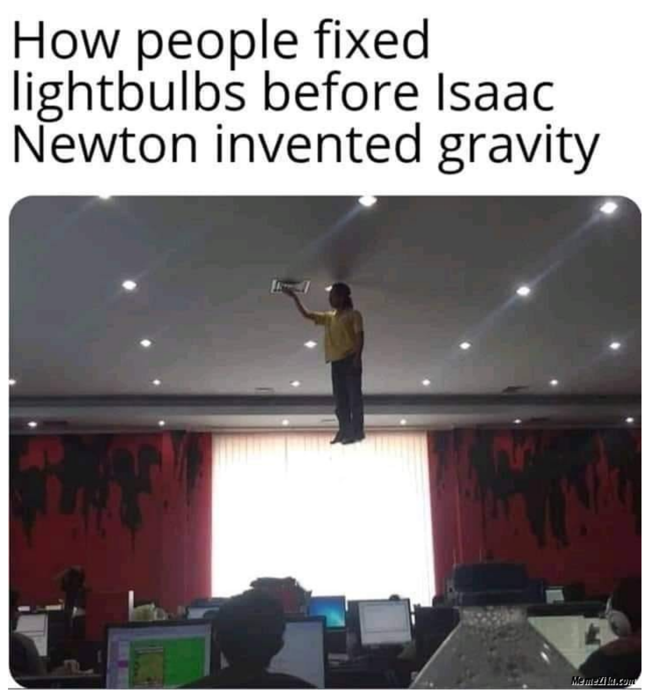
Newtons Universal Gravity Examples

Ex 1: What is the force of gravity that a 70.0 kg basketball player exerts on another 65.0 kg basketball player when they are separated by 2.5 m?

Ex 2: What is the force of gravity between Earth and the Sun? What is the mean orbital speed of Earth?

Ex 3: The Internation Space Station orbits around 420 km above the surface of the Earth and is around 441 Mg. What is the force of gravity between Earth and the ISS? What is the mean orbital speed of the ISS?

Do Practice Problems 2-8 on page 580
Try #7 without calculating any numerical values for force. #8 challenging as it could require the use of the quadratic formula.



Ex 1)

$M_1 = 65.0\ kg$

$M_2 = 70.0\ kg$

$r = 2.5\ m$

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

$$= \frac{\left(6.673\times10^{-11}\ \frac{Nm^2}{kg^2}\right)(65.0\ kg)(70.0\ kg)}{(2.5\ m)^2}$$

$$= 4.858\times10^{-8}\ N$$

$$= \boxed{49\ nN}$$

Ex 2

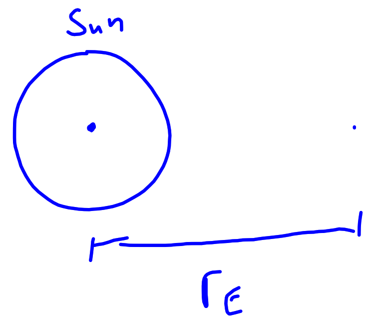
What is Mean orbital distance?

$M_E = 5.98 \times 10^{24}$ kg

$M_s = 1.99 \times 10^{30}$ kg

$r_E = 1.4957 \times 10^{11}$ m

$T_E = 3.16 \times 10^{7}$ s



$$F_G = \frac{G M_s M_E}{r_E^2} =$$

$$= \frac{\left(6.673 \times 10^{-11} \frac{Nm^2}{Kg^2}\right)\left(1.99 \times 10^{30}\ Kg\right)\left(5.98 \times 10^{24}\ Kg\right)}{\left(1.4957 \times 10^{11}\ m\right)^2}$$

$$= 3.549 \times 10^{22}\ N$$

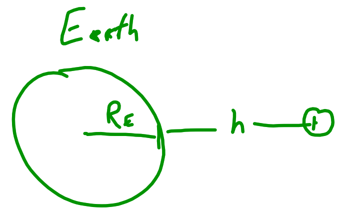
$$= \boxed{3.55 \times 10^{22}\ N}$$

$$V = \frac{2\pi r_E}{T_E} = \frac{2\pi(1.4957 \times 10^{11}\ m)}{(3.16 \times 10^{7}\ s)}$$

$$= 29739.7\ m/s$$

$$= \boxed{297\ Km/s}$$

Ex 3



$M_{ISS} = 441\ Mg$

$h = 420\ Km$

$M_E = 5.98 \times 10^{24}\ kg$

$R_E = 6.38 \times 10^6\ m$

$$F_G = \frac{G M_{ISS} M_E}{(R_E + h)^2}$$

$T_{ISS} = 92.68\ min$

$$F_G = \frac{\left(6.673 \times 10^{-11} \frac{Nm^2}{kg^2}\right)\left(441 \times 10^3\ kg\right)\left(5.98 \times 10^{24}\ kg\right)}{\left(6.38 \times 10^6\ m + 420 \times 10^3\ m\right)^2}$$

$= 3.8058 \times 10^6\ N$

$= \boxed{3.81 \times 10^6\ N}$

$$V = \frac{2\pi(R_E + h)}{T_{ISS}}$$

$92.68\ min \times \frac{60\ s}{1\ min} = 5560.8\ s$

$$V = \frac{2\pi(6.38 \times 10^6\ m + 420 \times 10^3\ m)}{5560.8\ s}$$

$= 7683.4\ m/s$

$= \boxed{7.\cancel{88}\ km/s}$

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