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Gravitation — B McMULLEN

The force of gravity is thought of as the force that pulls everything towards the ground.

The gravitational field strength g on Earth is $9.8 NKg^{-1}$! This figure differs on different planets.

The downward force caused by an object due to gravity is called the weight of the object.

Remember that Weight and Mass are different !!

Definitions.

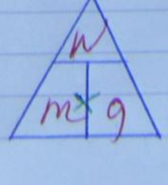
- **mass** — This is a measure of the matter contained in an object and is measured in Kg. (Kilograms)
- **Weight** — This is the force due to gravity acting on an object and is measured in N. (Newtons)

Weight = mass x gravitational field strength

- Weight → Newtons
- mass → Kilograms
- gravitational field strength → Newtons per Kilogram.

$W = mg$

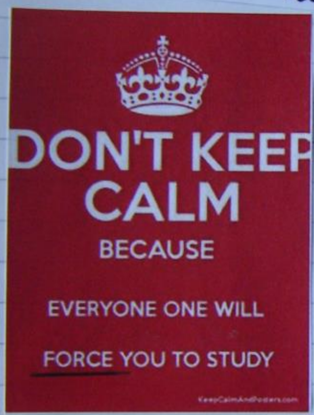
- W → N
- m → Kg
- g → NKg^{-1}



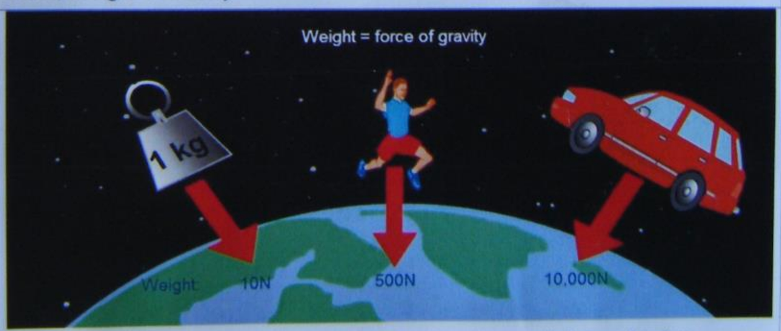
1/ $W = mg$

2/ $g = \frac{W}{m}$

3/ $m = \frac{W}{g}$



Mass, Weight & Gravity



The weight of an object is a measure of how heavy that object is and is caused by the force of gravity on that object. The weight of an object will depend on the strength of gravity acting on the object.

This diagram uses $g = 10 N kg^{-1}$ on Earth.
In Physics classes we use $g = 9.8 N kg^{-1}$!

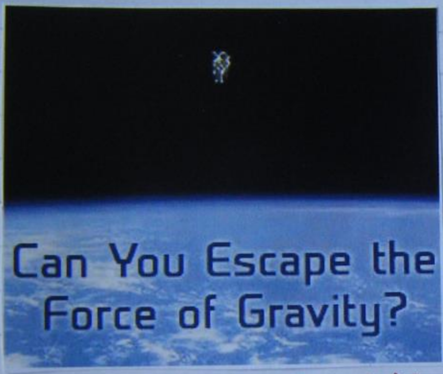
Newton's Universal law of gravitation

The Force of Gravity

- *Gravitation:* every piece of matter in the universe, no matter how large or small, pulls on every other piece of matter
- *Gravity:* force that pulls us and everything around us toward the center of the Earth
  - "Gravitation" on Earth

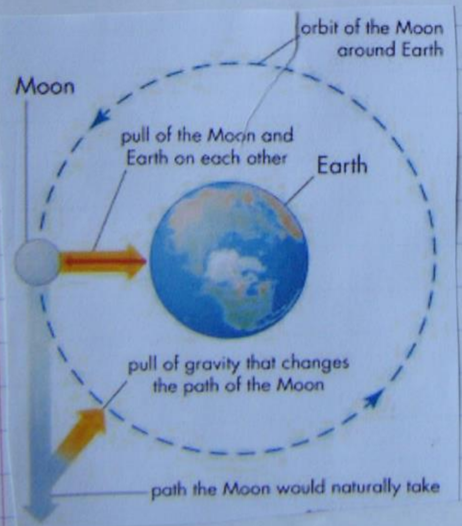
Center → American Spelling

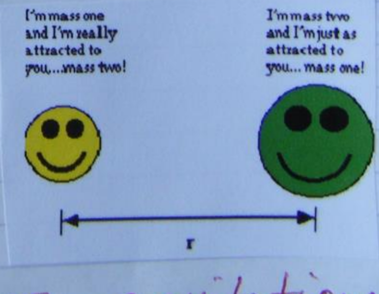
Centre → British Spelling



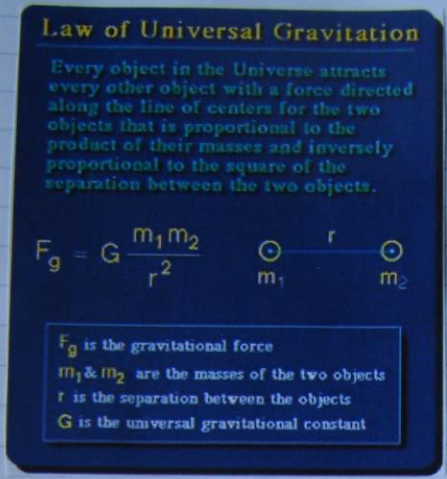
In a word 'No'!!

Party time!!!





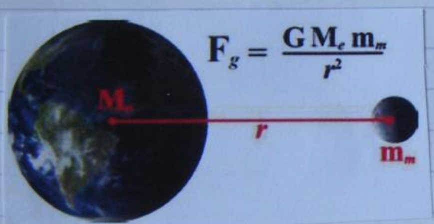
The gravitational force of attraction between any objects.

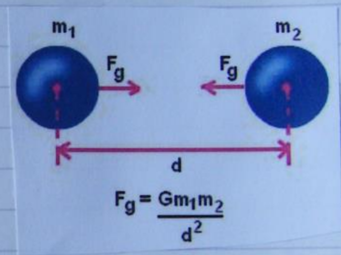


G, the Universal constant of gravitation.
$= 6{\cdot}67 \times 10^{-11} m^3 Kg^{-1} s^{-2}$

Show that the units for G can also be stated as $Nm^2 Kg^{-2}$.

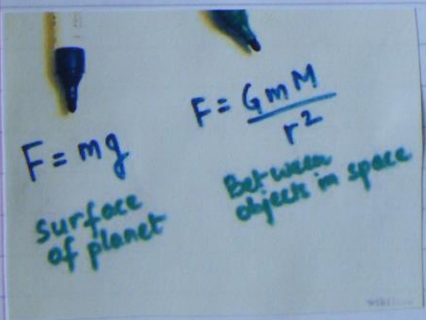
(HINT!! Use dimensional analysis)

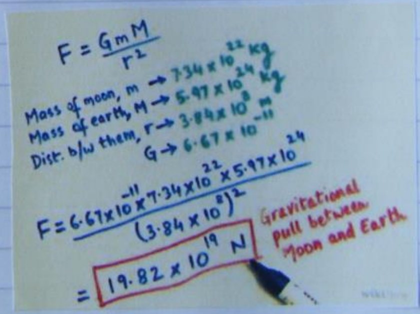




Earth (Me) Moon (Mm)

distance is measured between the centre of the two objects



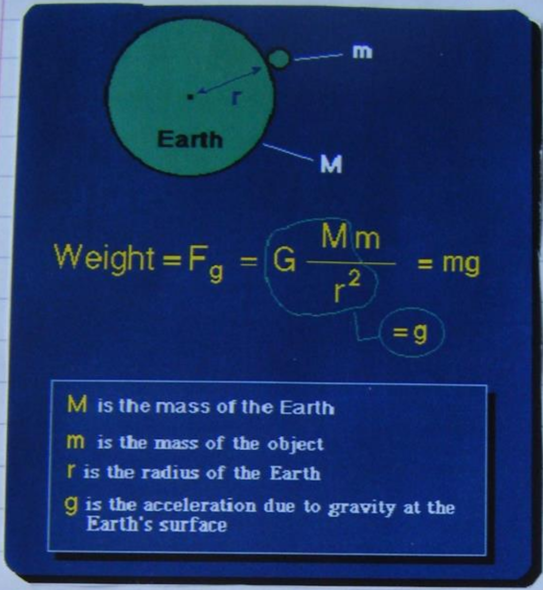


The gravitational force of attraction between the Earth and the Moon is responsible for high tide and low tide that we experience every day.

The sun also has an influence on the tides

Findingthe gravitational field strength

1) At the Surface of a planet



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

g is dependant on the following two factors:

- Mass of the planet
- radius of the planet

g is also discussed in terms of the gravitational field strength.

2) At a distance h above the surface of a planet.

$$g = \frac{GM}{(r+h)^2}$$

r = radius of the planet
h = height of the object above the planets surface

ALL measurements are taken from the centre of a planet.

• g will be smaller if you were up in a hot air balloon than it would be if you were standing on the ground below.

Ex1

Q// The gravitational field strength g on the surface of Mars is $3 \cdot 7\ N\,kg^{-1}$.
The mass of Mars is $6 \cdot 4 \times 10^{23}$ kg.
Show that the radius of Mars is $3 \cdot 4 \times 10^{6}$ m.

A// $F_g = F_g$

$$\Rightarrow mg = \frac{GMm}{r^2} \Rightarrow g = \frac{GM}{r^2}$$

$$\Rightarrow r^2 = \frac{GM}{g} = \frac{6 \cdot 67 \times 10^{-11} \times 6 \cdot 4 \times 10^{23}}{3 \cdot 7}$$

$$\Rightarrow r^2 = 1 \cdot 15 \times 10^{13} \Rightarrow r = 3 \cdot 4 \times 10^{6} m$$

Ex2

Q// Pallas is an asteroid or minor planet which orbits the Sun between Mars and Jupiter.

Details of Pallas are given below.

Diameter of Pallas	= 522 km
Distance from the Sun	= $4 \cdot 14 \times 10^{11}$ m
Mass of Pallas	= $2 \cdot 18 \times 10^{20}$ kg
Time to orbit the Sun	= 4·61 Earth years

Calculate the gravitational field strength "g" at the surface of Pallas.

A// $F_g = F_g$

$$\Rightarrow mg = \frac{GMm}{r^2} \Rightarrow g = \frac{GM}{r^2}$$

$$\Rightarrow g = \frac{6 \cdot 67 \times 10^{-11} \times 2 \cdot 18 \times 10^{20}}{(261 \times 10^{3})^2} = 0 \cdot 213\ N\,kg^{-1}$$

* The radius = $\frac{1}{2} \times$ diameter * { 261 km = 261×10^{3} m

Ex3

Q

(a) (i) State what is meant by *gravitational field strength*.

(ii) The gravitational field strength at the surface of Mars is $3 \cdot 7\,\mathrm{N\,kg^{-1}}$.

The radius of Mars is $3 \cdot 4 \times 10^3$ km.

(A) Use Newton's universal law of gravitation to show that the mass of Mars is given by the equation

$$M = \frac{gr^2}{G}$$

where the symbols have their usual meaning.

(B) Calculate the mass of Mars.

(b) A spacecraft of mass 100 kg is in circular orbit 300 km above the surface of Mars.

Show that the force exerted by Mars on the spacecraft is $3 \cdot 1 \times 10^2$ N.

A

a) i) Gravitational field strength is the force exerted on a 1 kg mass placed in the field.

ii)(A) $F_g = F_g \Rightarrow mg = \frac{GMm}{r^2}$

$\Rightarrow g = \frac{GM}{r^2} \Rightarrow M = \frac{gr^2}{G}$

remember to change km into m !!

(B) $M = \frac{3 \cdot 7 \times (3 \cdot 4 \times 10^6)^2}{6 \cdot 67 \times 10^{-11}} = 6 \cdot 4 \times 10^{23}$ kg

b) $F = \frac{GMm}{r^2}$ $\quad r = r_M + h = 3 \cdot 4 \times 10^6 + 300 \times 10^3$

$r = 3 \cdot 7 \times 10^6$ m

$\Rightarrow F = \frac{6 \cdot 67 \times 10^{-11} \times 6 \cdot 4 \times 10^{23} \times 100}{(3 \cdot 7 \times 10^6)^2} = 310$ N

$= 3 \cdot 1 \times 10^2$ N

$\therefore$ QED