Force of Gravity

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Newton's 2nd Law → $F=ma$

At the Earth's surface acceleration due to gravity is $9.8\,m/s^2$. ← called g

At the surface of the Earth.

$F_g = mg$ $g = 9.8\,m/s^2$

Force of Gravity [or] Weight ↗ (F_g); mass ↑ (m)

Ex. What is the weight of a 30 kg dog?

$F_g = mg = 30\,kg \times 9.8\,m/s^2 = 294\,N$

Ex.
What is the mass of a 792N backpack?

$F_g = mg \rightarrow m = \frac{F_g}{g} = \frac{792\,N}{9.8\,m/s^2} = 81\,kg$

What about stuff not on the surface of the Earth?

Newton's Universal Law of Gravitation.

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

Mass of two objects (m_1, m_2)

Gravitational Constant (G)

Distance they are apart (r)

First Measured by Henry Cavendish

$G = 6.67 \times 10^{-11}\,N \cdot m^2/kg^2$

Ex. Quinn (78kg) and Callum (72kg) are in space.

What is the Force of gravity between them when they are 2.4 m apart?

$F_g = G\frac{M_1 m_2}{r^2}$

$M_1 = 78kg$

$m_2 = 72kg$

$r = 2.4m$

$G = 6.67\times10^{-11}\ N\cdot\frac{m^2}{kg^2}$

$$F_g = \frac{(6.67\times10^{-11})(78)(72)}{(2.4^2)} = 6.5\times10^{-8}N$$

The mass of the Earth is $M_E = 5.98\times10^{24}kg$

and the mass of the Sun is $M_S = 1.989\times10^{30}kg$

The Earth and the sun are $1.5\times10^{11}m$ apart.

How much Force is gravity exerting on the Earth and the Sun?

$$F_g = G\frac{M_E M_S}{r^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24})(1.989\times10^{30})}{(1.5\times10^{11})^2} = 3.53\times10^{22}N$$

On Planet Jim, Jerry weighs 25N on the surface. What would he weigh when he is placed one radius of the planet above the surface?

$$F_g = \frac{G M_p M_J}{r^2}$$

Jerry is on the surface

$$25N = \frac{G M_p M_J}{r^2}$$

r^2 ← Gravity pulls from the center of the planet

M_p = mass of planet

M_J = mass of Jerry

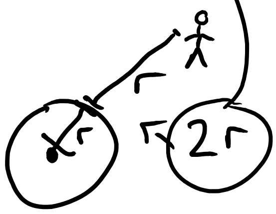
r = radius of the planet

Jerry is above the surface

How far is Jerry from the center of the planet?

$$F_g = \frac{G M_p M_J}{(2r)^2}$$

$$F_g = \frac{G M_p M_J}{4r^2}$$



$$25 = \frac{G M_p M_J}{r^2}$$

$$\frac{G M_p M_J}{4 r^2} = \frac{25}{4} = 6.25N$$

Proportionality

$F_g \propto$ mass

($\propto$ ↑ proportional to)

- mass doubles, F_g doubles
- mass halved, F_g halved

$F_g \propto \frac{1}{r^2}$ ← reciprocal squared

- distance is doubled, F_g $\frac{1}{4}\times$ ($x^2 \rightarrow (\frac{1}{2})^2 = \frac{1}{4}$)
- distance is halved, F_g $4\times$ ($\frac{1}{2} \rightarrow (\frac{2}{1})^2$)

Use the law of Universal gravitation to

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

$r_e = 6.38 \times 10^6$ m

$G = 6.67 \times 10^{-11}\ N \cdot \frac{m^2}{kg^2}$

Find the acceleration due to gravity at the surface of the Earth.

$$F_g = \frac{G M_E m}{r^2} \qquad F_g = mg$$

Inspection

$$F_g = \frac{G M_E}{r^2} \times m \qquad F_g = g \times m \qquad g = \frac{G M_E}{r^2}$$

Algebra

$$mg = \frac{G M_E m}{r^2} \qquad g = \frac{G M_E}{r^2}$$

Wks Package p #1, 2, 3