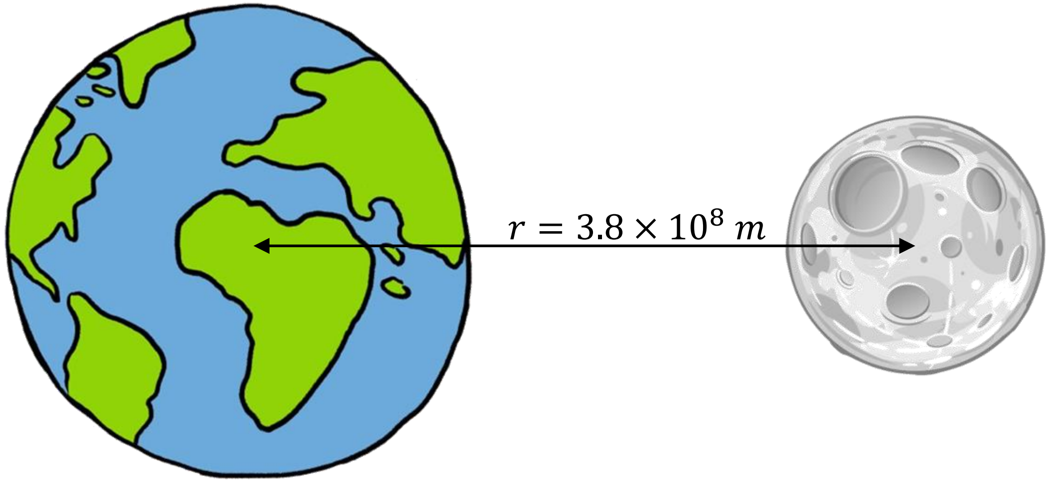
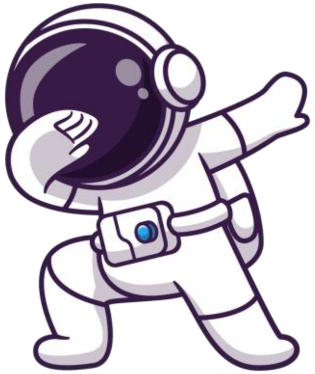
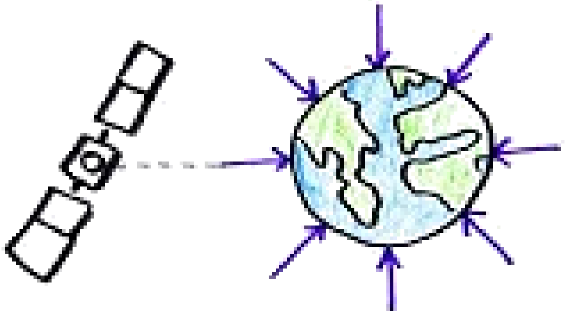




Gravitational Fields



ATARs Plus

Formulas: Gravitational Fields

Constants:

$$G = 6.67 \times 10^{-11} \ \frac{Nm^2}{kg^2}$$

$$M_E = 5.98 \times 10^{24} \ kg^2$$

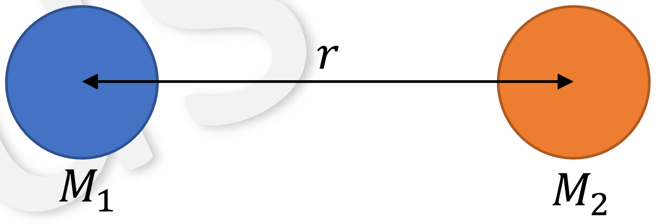
$$R_E = 6.37 \times 10^6 \ m$$

Units:

r: radius in meters
T: orbit time in seconds
M: mass in kg
G: Gravitational constant in Nm^2/kg^2

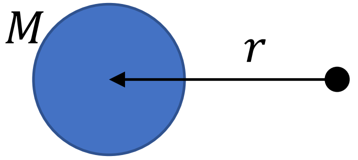
Netwon's law of universal gravitation:

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



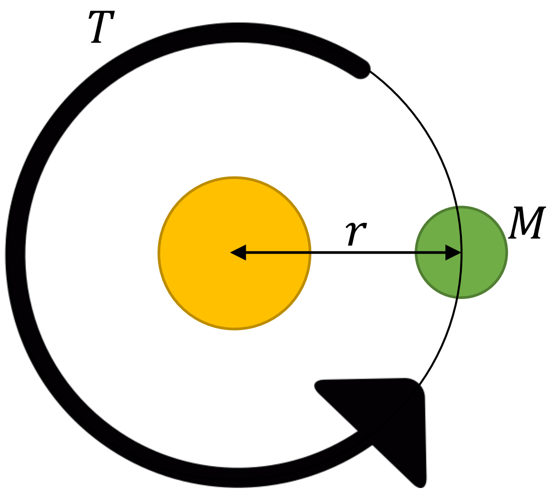
Gravitational field:

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



Kepler's law:

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$



Zero Net Gravitational Field

There is a point between the Earth and the Moon where the total gravitational field is zero. The significance of this is that returning lunar missions are able to return to Earth under the influence of the Earth's gravitational field once they pass this point. Given that the mass of Earth is 6.0×10^{24} kg, the mass of the Moon is 7.3×10^{22} kg and the radius of the Moon's orbit is 3.8×10^{8} m, calculate the distance of this point from the centre of the Earth:

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The question states that the total gravitation field is zero:

$$g_{Net} = g_{Earth} - g_{Moon} = 0$$

$$\therefore g_{Earth} - g_{Moon}$$

$$G\frac{M_{Earth}}{x^2} = G\frac{M_{Moon}}{y^2}$$

Gravitational Constant cancels out from both sides, sub in masses:

$$\frac{6.0 \times 10^{24}}{x^2} = \frac{7.3 \times 10^{22}}{y^2}$$

$$\frac{y^2}{x^2} = \frac{7.3 \times 10^{22}}{6.0 \times 10^{24}}$$

Take the square root of both sides:

$$\frac{y}{x} = 0.1103$$

$$\therefore y = 0.1103x$$

Sub the above into:

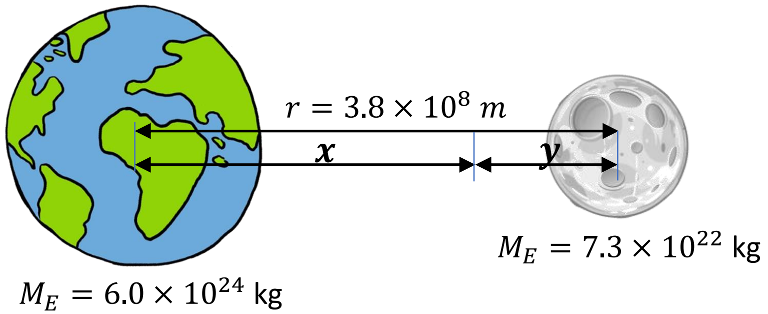
$$x + y = 3.8 \times 10^{8}\ m$$

Then solve for x:

$$x + 0.1103x = 3.8 \times 10^{8}$$

$$x = \frac{3.8 \times 10^{8}}{1.1103}$$

$$\boldsymbol{\therefore x = 3.4 \times 10^{8}\ m}$$



Fractional gravitational force and distance away

An astronaut travels away from Earth to a region in space where the gravitational force due to Earth is only 1.0% of that at Earth's surface. What distance, in Earth radii, is the astronaut from the centre of the earth:

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We know gravity at the earth's surface is approximately equal to 9.8m/s/s. Let's first validate this:

$$g_{Earth} = G\frac{M_{Earth}}{r_{surface}^2}$$

$$g_{Earth} = 6.67 \times 10^{-11}\,\frac{5.98 \times 10^{24}}{(6.37 \times 10^6)^2}$$

$$g = 9.83\ m/s^2$$

At the astronaut, the gravitational force due to earth is only 1.0%:

$$g_{astronaut} = 0.01 \times g_{Earth}$$

$$g_{astronaut} = 0.01 \times 9.83$$

$$g_{astronaut} = 0.0983\ m/s^2$$

Using the same gravitational field formula:

$$g_{astronaut} = G\frac{M_{Earth}}{r^2}$$

$$0.0983 = 6.67 \times 10^{-11}\,\frac{5.98 \times 10^{24}}{r^2}$$

$$r^2 = 6.67 \times 10^{-11}\,\frac{5.98 \times 10^{24}}{0.0983}$$

$$r^2 = 4.057 \times 10\text{^}15$$

$$r = 63699607$$

$$\boldsymbol{\therefore r = 6.4 \times 10^7\ m}$$