U3A Maths

24-Feb-2026 Term 1 / Week 5

Effects of Gravity

Homework (Calculator Precision)

Time dilation due to Earth's Gravity as per Einstein's General Relativity

$$\Delta t_r = \Delta t_0 \sqrt{1 - \frac{2GM}{rc^2}}$$

Given $\Delta t_0 = 24$ hrs (8.6400×10^4 s)

$G = 6.67408 \times 10^{-11}$

$M = 5.972 \times 10^{24}$ kg

$c = 2.998 \times 10^8$ m/s

(dist. to surface / centre) $r_e = 6.371 \times 10^6$ m

(dist to Satellite) $r_s = 26.371 \times 10^6$ m

-3-

Δt_{re} (Time elapsed at dist 'r_e')

$$= 8.64 \times 10^4 \sqrt{1 - \frac{2 \times 6.67408 \times 10^{-11} \times 5.972 \times 10^{24}}{6.371 \times 10^6 \times (2.998)^2 \times 10^{16}}}$$

$$= 8.64 \times 10^4 \sqrt{1 - \frac{79.715211520 \times 10^{13}}{57.262,573,484 \times 10^{22}}}$$

$$= 8.64 \times 10^4 \sqrt{1 - 1.392,099,703 \times 10^{-9}}$$

$$= 8.64 \times 10^4 \sqrt{0.999,999,998,608}$$

$$= 86,399.999,939,866,\ldots$$

Similarly,

$\Delta t_{rs} = 86,399.999,985,471,\ldots$

(Time elapsed at a distance 'r_s' from the centre of earth)

-4-

- The calculator needs to have at least 10 to 12 digit precision
- Std. IEEE 754 Single Precision (1 + 8 + 23 bits) (sign, exponent, mantissa) corresponds to ≈7 decimal digit precision
- IEEE 754 Double Precision (1 + 11 + 52 bits) corresponds to ≈16 decimal digit precision

Gravitational Force

- The Equation for gravitational force was developed by Newton.
- Newton's Law

The force of attraction between two bodies with mass m_1 & m_2 at distance 'r' is:

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

For International System of units (SI units)

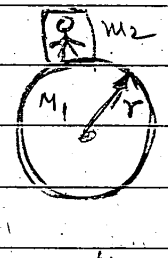
m_1 & m_2 ⇒ kg (kilograms)

r ⇒ m (meters)

G ⇒ Gravitational Constant $= 6.67408 \times 10^{-11}$ N m²/kg²

Ex. 1

- Let us now analyse the effect of gravity on a person standing on earth



As per Newton's law:

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

Also, we have that force acting on the person is the weight of the person!

Say $F_g = m_2 g$ $\quad (F = m a)$ — Force (F), Mass (m), Accln (a)

where g – Accln due to gravity

For a person Standing on Earth.

$$F_g = F_G$$

$$\cancel{m_2}\, g = G \cdot \frac{M_1 \cancel{m_2}}{r^2}$$

$\therefore$ Accln due to Gravity $(g) = \dfrac{G M_1}{r^2}$

where $G = 6.67408 \times 10^{-11}$ N. m²/kg²

$M_1 = 5.972 \times 10^{24}$ kg (Mass of Earth)

$r = 6{,}371$ km $(6.371 \times 10^{6}$ m$)$

$$\therefore g = \frac{6.67408 \times 10^{-11} \times 5.972 \times 10^{24}}{(6.371 \times 10^{6})^2}$$

$$= 9.81 \text{ m/s}^2$$

$\therefore$ Force exerted by a person of 75 kg is

$$F_g = m \times g$$

$$= 75 \times 9.81 \simeq 735 \text{ N}$$

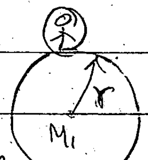
— x —

Ex.2

Calculate the Accelaration due to gravity on the moon.

We can use the same eqn as above with parameters of the moon.

Note: 'G' is a universal constant, so, it remains the same.



Mass of Moon $(M_1) = 7.35 \times 10^{22}$ kg

Radius of Moon $(r) = 1{,}737$ km $(1.737 \times 10^{6}$ m$)$

$$\therefore g_m = \frac{G M_1}{r^2} = \frac{6.67408 \times 10^{-11} \times 7.35 \times 10^{22}}{(1.737 \times 10^{6})^2}$$

$$= \frac{6.67408 \times 7.35}{(1.737)^2} \times \frac{10^{-11} \times 10^{22}}{10^{12}}$$

$$= 16.258 \times 10^{-1}$$

$$= 1.6258 \text{ m/s}^2$$

Ex.3 Calculate the weight or force exerted by a person with a mass of 75 kg on the moon.

$$F_{g_m} = m \times g_m$$

$$= 75 \times 1.6258 \simeq 122 \text{ N}$$

The same person with a mass of 75 kg will be about 6 times lighter on the moon!

Ex.4

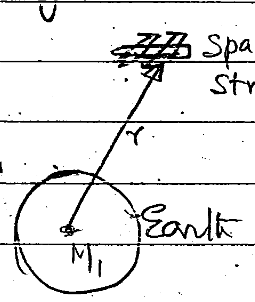
Calculate the acclaration due to earth's gravity on the Space Station for the given parameters.

(Earth) $M_1 = 5.972 \times 10^{24}$ kg

dist. to Spacestn. $r = (6371 + 559)$ km

$= 6.93 \times 10^{6}$ m.

$G = 6.67408 \times 10^{-11}$



We can use the same Eqn as above

$$g_s = \frac{G M_1}{r^2} = \frac{6.67408\times10^{-11}\times5.972\times10^{24}}{(6.93\times10^{6})^2}$$

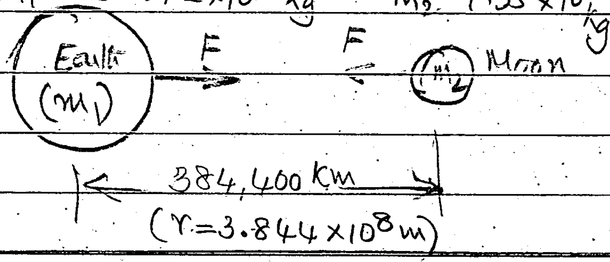
$$= \underline{8.299 \ m/s^2}$$

[Substantial gravity! weightlessness is due to free fall of space stn.!]

Ex.5

Calculate the force of attraction between the Earth and the moon

$m_1 = 5.972\times10^{24}$ kg $m_2 = 7.35\times10^{22}$ kg



Using Newton's law

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

$$= \frac{6.67408\times10^{-11}\times5.972\times10^{24}\times7.35\times10^{22}}{(3.844\times10^{8})^2}$$

$$= 19.856 \times \frac{10^{-11}\times10^{24}\times10^{22}}{10^{16}}$$

$$= 19.856\times10^{19}$$

$$= \underline{1.9856\times10^{20} \ N}$$

Home work

The mass of Jupiter is 1.9×10^{27} kg and its radius is 71,000 km.

(a) Calculate the accelaration due to gravity on the surface of the Jupiter

(b) What will be the weight of the person with a mass of 65 kg.

Ans

(a) 25.14 m/s^2

(b) 1,634 N