Chapter 1 — Gravitation — Notes & Worked Examples

1. Key concepts & definitions

- **Gravitation**: Attractive force between any two masses in the universe. (Newton's Universal Law of Gravitation)

- **Acceleration due to gravity (g)** at the surface of a planet of mass M and radius R:

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

(Weight $W = mg$). Byju's

- **Gravitational potential energy (near a planet)**: For mass m at distance r from centre of planet of mass M,

$$U = -\frac{GMm}{r}$$

- **Escape velocity** from a planet of mass M and radius R:

$$v_{\text{esc}} = \sqrt{\frac{2GM}{R}}$$

(Minimum speed to escape gravitational field ignoring atmosphere).

- **Orbital (circular) velocity** at a height where radius from centre is r:

$$v = \sqrt{\frac{GM}{r}}$$

---

2. Important formula list (for quick revision)

- Newton's law: $F = \frac{Gm_1m_2}{r^2}$
- $g = \frac{GM}{R^2}$
- Weight: $W = mg$
- Gravitational potential energy: $U = -\frac{GMm}{r}$
- Escape velocity: $v_{\text{esc}} = \sqrt{\frac{2GM}{R}}$

(Use $G = 6.67 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$.)

3. Worked numerical

Q1. Two spheres of mass $10\ \text{kg}$ and $40\ \text{kg}$ are 200 m apart (centre to centre). Find the gravitational force between them. (Use $G = 6.67 \times 10^{-11}$.)

Solution (step-by-step):
Given $m_1 = 10\ \text{kg}$, $m_2 = 40\ \text{kg}$, $r = 200\ \text{m}$, $G = 6.67 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$.

Apply Newton's law:

$$F = \frac{Gm_1m_2}{r^2}$$

Q2. Gravitational force between a man (50 kg) and a car (1500 kg) separated by 10 m. (G as above.)

Solution:
$m_1 = 50$, $m_2 = 1500$, $r = 10\ \text{m}$.

$$F = \frac{6.67 \times 10^{-11} \times 50 \times 1500}{10^2}$$

Q3. Calculate g at Earth's surface using $M = 6.0 \times 10^{24}\ \text{kg}$ and $R = 6400$

Q4. Find the escape velocity from Earth using $M = 6.0 \times 10^{24}\ \text{kg}$, $R = 6.4 \times 10^{6}\ \text{m}$, $G = 6.67 \times 10^{-11}$.

Solution:

$$v_{\text{esc}} = \sqrt{\frac{2GM}{R}}.$$

Example 5 —

Q5. Find magnitude of gravitational force between Sun and Earth using $M_{\text{sun}} = 1.989 \times 10^{30}$ kg, $M_{\text{earth}} = 5.972 \times 10^{24}$ kg, and average distance $r = 1.496 \times 10^{11}$ m.

Solution (outline):

$$F = \frac{GM_{\text{sun}}M_{\text{earth}}}{r^2}.$$

4. Textbook-style 2, 3, 4 mark questions (with short model answers)

I include the typical categories below — use these as direct board-style answers. (These are directly aligned to the textbook exercises and official solution guides.) Byju's +1

2-mark (short answer) examples

1. **Define escape velocity.**
   Minimum speed required by a body at the surface of a planet to escape to infinity (neglecting atmosphere), $v_{\text{esc}} = \sqrt{2GM/R}$.

1. Introduction to Gravitation

Gravitation is the force of attraction between any two objects having mass.

It is a non-contact force and acts over long distances.

2. Universal Law of Gravitation

Every object in the universe attracts every other object with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.

Formula:

$F = G(m1\ m2) / r^2$

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

3. Effects of Gravitation

- Keeps planets in orbit

- Causes falling of objects

- Responsible for tides

- Holds atmosphere

4. Free Fall

When an object falls under the influence of gravity alone, it is called free fall.

5. Acceleration Due to Gravity

$g = 9.8\ m/s^2$

It is independent of mass.

6. Equations of Motion

$v = u + gt$

$s = ut + \frac{1}{2}gt^2$

$v^2 = u$

7. Mass

Mass is the quantity of matter in an object.

Unit: kg

8. Weight

Weight is the gravitational force acting on an object.

$W = mg$

Unit: Newton

9. Thrust and Pressure

Pressure = Thrust / Area

Unit: Pascal

10. Important Long Answers

- Universal Law of Gravitation
- Free fall and acceleration due to gravity
- Difference between mass and weight