CHAPTER 4
GRAVITATION
— Class 9 Science – Key Notes —

Remember!
Gravitation is very weak, but it is responsible for many important things in the universe!

What is Gravitation?

- Gravitation is a universal force of attraction between any two objects having mass.
- It acts even if the objects are very far apart.
- It is a very weak force, but becomes important when mass is large.
- Force of gravity decreases with altitude.
- The weight of a body is the force with which the Earth attracts it.
- Weight = m × g (product of mass and acceleration due to gravity)
- Weight may vary from place to place (because g changes).
- All objects experience a force of buoyancy when immersed in a fluid.

4.1.1 UNIVERSAL LAW OF GRAVITATION

Every object in the universe attracts every other object with a force which is:

- Directly proportional to the product of their masses.
- Inversely proportional to the square of the distance between them.
- The force acts along the line joining the centres of the two objects.

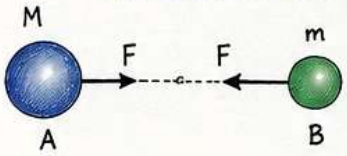


Fig. 1: The gravitational force between two objects acts along the line joining their centres.

Mathematical Form:

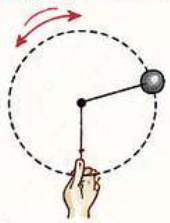
$$F = G\frac{Mm}{d^2}$$

Where,
F = gravitational force (newton)
M, m = masses of two objects (kg)
d = distance between their centres (m)
G = universal gravitation constant
$(6.67 \times 10^{-11}\ N\ m^2/kg^2)$

Activity 4.1: Motion in a Circular Path

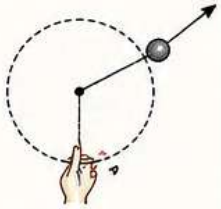
- Take a piece of thread.
- Tie a small stone at one end.
- Hold the other end of the thread and whirl it round.
- Note the motion of the stone.
- Release the thread.
- Again, note the direction of motion of the stone.

When thread is whirled



Stone moves in a circular path. The force acting towards the centre is called centripetal force.

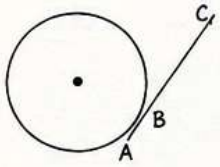
When thread is released



Stone flies off in a straight line which is tangent to the circle.

Tangent to a Circle

A straight line that meets a circle at one and only one point is called a tangent to the circle.



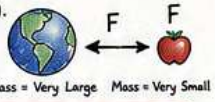
Line ABC is a tangent to the circle at point B.

Why Moon Doesn't Fall?

- The Moon moves around the Earth due to the centripetal force.
- This force is provided by the gravitational attraction of the Earth.
- If there were no such force, the Moon would move in a straight line away from Earth.
- Same way, planets move around the Sun because of Sun's gravity.

Does Apple Attract the Earth?

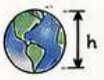
- According to Newton's Third Law, apple does attract Earth.
- But Earth does not move towards apple because Earth's mass is extremely large.
- For a given force, acceleration ∝ 1 / mass (Newton's Second Law).
- Apple's mass is very small compared to Earth, so Earth's acceleration towards apple is negligibly small (we cannot see it).



Same reason why Earth does not move towards the Moon or why Sun does not move towards planets.

ACCELERATION DUE TO GRAVITY (g)

- It is the acceleration produced in a body due to Earth's gravity.
- Symbol: g SI Unit: m/s^2
- Average value of g on Earth's surface: $g \approx 9.8\ m/s^2$
- Values of g at different places:
  Equator: $9.78\ m/s^2$
  Poles: $9.83\ m/s^2$
  At height h above surface:



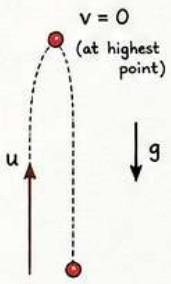
$$g_h = g\left(\frac{R}{R+h}\right)^2$$

Where R = radius of Earth ($\approx 6.4 \times 10^6$ m)

MOTION FORMULAS (Under gravity)

For vertical motion with acceleration due to gravity (g) (downward as positive)

1. $v = u + gt$
2. $s = ut + \frac{1}{2}gt^2$
3. $v^2 = u^2 + 2gs$



Where,
u = initial velocity (m/s)
v = final velocity (m/s)
t = time (s)
s = displacement (m)

MASS vs WEIGHT

Mass (m)	Weight (W)
• Amount of matter in a body.	• Force by which Earth attracts the body.
• Scalar quantity.	• Vector quantity.
• Unit: kilogram (kg)	• Unit: newton (N)
• Constant everywhere (does not change).	• Changes from place to place (depends on g).
• Measured by beam balance.	• Measured by spring balance.
• m = constant	• W = m × g

KEY TAKEAWAYS

- Gravitation is a universal attractive force.
- It acts between all objects having mass.
- Weight of a body = m × g
- Gravitational force ∝ M × m and ∝ $1/d^2$
- Direction of gravitational force is along the line joining centres.
- g ≈ 9.8 m/s^2 on Earth's surface.
- Mass remains same, weight may change.
- Many natural phenomena (fall of objects, motion of planets, tides) are due to gravitation.

IMPORTANT FORMULAS

1. Weight: W = m × g
2. Universal Law of Gravitation: $F = G\frac{Mm}{d^2}$
3. Acceleration due to gravity: $g = \frac{GM}{R^2}$ (at Earth's surface)
4. Motion equations (under g):
   $v = u + gt$
   $s = ut + \frac{1}{2}gt^2$
   $v^2 = u^2 + 2gs$

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

UNIT CHECK

- Force (F) → newton (N)
- Mass (M, m) → kilogram (kg)
- Distance (d) → metre (m)
- Acceleration (g) → m/s^2
- G → $N\ m^2/kg^2$

Isaac Newton (1642–1727)

- Born in Woolsthorpe, England.
- Great scientist, mathematician and philosopher.
- Discovered Universal Law of Gravitation.
- Formulated the Laws of Motion.
- Worked on light, colour, telescope and invented Calculus.