std.10th SCIENCE

1.Gravitation: Comprehensive Study Guide

For Excellent Preparation

November 5, 2025

1. Core Concepts and Summary

1. **Gravitational Force:**
   - It is a universal attractive force acting between any two objects in the universe.
   - The phenomenon was discovered by Sir Isaac Newton.
   - Gravitation is the specific force by which the Earth attracts objects toward its center.
2. **Newton's Universal Law of Gravitation:**
   - The force of attraction between two objects is **directly proportional to the product of their masses** ($\propto M_1 M_2$).
   - The force is **inversely proportional to the square of the distance** between them ($\propto 1/r^2$).
   - **Formula:**
     $$F = G\frac{M_1 M_2}{r^2}$$
     where G is the Universal Gravitational Constant.
3. **Kepler's Laws:**
   - **Kepler's First Law (Law of Orbits):** The orbit of a planet is an ellipse with the Sun at one of the foci.
   - **Kepler's Second Law (Law of Equal Areas):** The line joining the planet and the Sun sweeps out equal areas in equal intervals of time.
   - **Kepler's Third Law (Law of Periods):** The square of the period of revolution (T^2) of a planet around the Sun is directly proportional to the cube of the mean distance (r^3) of the planet from the Sun.
     $$\frac{T^2}{r^3} = \text{Constant}(K)$$
4. **Acceleration due to Gravity 'g':**
   - The acceleration produced in an object due to the Earth's gravitational force.
   - Its average value on the Earth's surface is approximately **9.8** m/s^2.
   - **Formula:**
     $$g = G\frac{M}{R^2}$$
     where M is the mass of the Earth and R is the radius of the Earth.
   - The value of g changes with location, height, and depth.
5. **Free Fall:**

- When an object moves under the sole influence of the gravitational force, its motion is called free fall.
- In this condition, the acceleration of the object is $a = g$.

6. **Escape Velocity:**
   - The minimum initial velocity required for an object to escape from the Earth's gravitational field and not return.
   - **Formula:**
   $$v_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$
   - The escape velocity for the Earth is approximately **11.2** km/s.

2. Key Formulas

- **Gravitational Force:**
$$F = G\frac{M_1 M_2}{r^2}$$
- **Acceleration due to Gravity:**
$$g = G\frac{M}{R^2}$$
- **Kepler's Third Law:**
$$\frac{T^2}{r^3} = K$$
- **Escape Velocity:**
$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$$
- **Weight of an object:**
$$W = m \times g$$
- **Equations of Motion (for Free Fall, when 'g' is used):**
  - $v = u + gt$
  - $s = ut + \frac{1}{2}gt^2$
  - $v^2 = u^2 + 2gs$

3. Sample Multiple-Choice Questions (MCQs)

1. In Newton's Universal Law of Gravitation, what does the constant G represent?

   (a) Constant of Mass and Time
   (b) Gravitational Acceleration
   (c) Planetary Constant
   (d) Universal Gravitational Constant

   Solution: (4) Universal Gravitational Constant. The value of G is constant throughout the universe and does not depend on the masses or distance.

2. If an object is thrown vertically upward from the Earth's surface with a velocity of **11**.**2** km/s, what will happen to the object?

   (a) It will reach a height of **11**.**2** km and then fall back down.
   (b) It will be attracted toward the center of the Earth.
   (c) It will escape the Earth's gravitational field and will not return.
   (d) It will remain stationary at a certain height.

   Solution: (3) It will escape the Earth's gravitational field and will not return. **11**.**2** km/s is the Earth's escape velocity.

3. According to Kepler's laws, the square of the orbital period (T^2) of a planet around the Sun is directly proportional to what?

   (a) The square of the planet's mass (M^2)
   (b) The square of the mean distance from the Sun (r^2)
   (c) The cube of the mean distance from the Sun (r^3)
   (d) The planet's velocity (v)

   Solution: (3) The cube of the mean distance from the Sun (r^3). This is Kepler's Third Law: $\frac{T^2}{r^3} =$ Constant.

4. Practice Worksheet

Instructions: Answer the following questions. (2 Marks each)

Questions 1 to 15:

1. Who is credited with the discovery of the concept of 'Gravitation'?

2. State Newton's Universal Law of Gravitation (both in words and formula).

3. Explain the fundamental difference between the Gravitational Constant (G) and the Acceleration due to Gravity (g).

4. What does Kepler's Second Law relate to? Briefly explain it.

5. What is the approximate average value of the acceleration due to gravity (g) on the Earth's surface?

6. Does the value of g increase or decrease as one moves away from the Earth's center (i.e., higher altitude)? State the reason.

7. If the distance between two objects is doubled, how will the gravitational force between them be affected?

8. What is 'Free Fall'? What is the acceleration of an object during free fall?

9. The weight of an object on the Moon is how many times its weight on Earth? What happens to the object's mass?

10. Calculate the weight of an object with a mass of **5** kg on Earth. (Use $\mathbf{g} = \mathbf{9.8}$ m/s$^{\mathbf{2}}$)

11. How does Kepler's Third Law relate the 'force of attraction' and the 'period of revolution'?

12. What is the numerical value of the escape velocity for Earth?

13. If the mass of one of the two planets is doubled, how will the gravitational force change? (Assuming the distance remains constant)

14. What type of force is necessary for artificial satellites to orbit the Earth, and where does this force come from?

15. Gravitational force is always _____ in nature. (Attractive/Repulsive)

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5. Answer Key for Practice Worksheet

Q.1 Sir Isaac Newton.

Q.2 The force of attraction between any two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. **Formula:** $F = G\frac{M_1 M_2}{r^2}$.

Q.3 **Gravitational Constant (G):** It is a universal constant whose value is the same everywhere in the universe (6.674×10^{-11} N $\cdot$ m^2/kg^2). **Acceleration due to Gravity (g):** It is a variable quantity that depends on the mass and radius of the planet and the object's location, with an approximate value of 9.8 m/s^2 on Earth's surface.

Q.4 Kepler's Second Law relates to the **speed of a planet** in its elliptical orbit. It states that the line joining the planet and the Sun sweeps out equal areas in equal intervals of time, meaning the planet moves faster when closer to the Sun and slower when farther away.

Q.5 **9.8** m/s^2.

Q.6 It **decreases**. The acceleration due to gravity is inversely proportional to the square of the distance from the center of the Earth ($g \propto \frac{1}{R^2}$). As altitude increases, the distance (R) increases, causing g to decrease.

Q.7 The gravitational force will be **reduced by a factor of four** ($\frac{1}{4}$). Since $F \propto \frac{1}{r^2}$, doubling r to $2r$ changes F to $F' \propto \frac{1}{(2r)^2} = \frac{1}{4r^2}$.

Q.8 'Free Fall' is the motion of an object solely under the influence of the Earth's gravitational force. The acceleration of the object during free fall is $a = g$ (acceleration due to gravity).

Q.9 The weight of an object on the Moon is approximately $\frac{1}{6}$th of its weight on Earth. The object's mass **remains the same** everywhere in the universe.

Q.10 **Calculation:** Weight (W) is given by $W = m \times g$. $W = 5$ kg $\times\ 9.8$ m/s$^2 = 49$ N.

Q.11 Kepler's Third Law states that $T^2 \propto r^3$. The force of attraction is $F \propto \frac{1}{r^2}$. Thus, a shorter period (T) implies a smaller mean distance (r), which in turn implies a **greater force of attraction** (F).

Q.12 The escape velocity for Earth is **11.2** km/s.

Q.13 The gravitational force will **double**. Since $F \propto M_1 M_2$, doubling M_1 will double the force F.

Q.14 A **centripetal force** is necessary for circular motion (orbiting). This force is provided by the **Earth's gravitational force of attraction**.

Q.15 Gravitational force is always **attractive** in nature.

Best wishes for your preparation!