CH-7: GRAVITATION

Part–1: Universal Law of Gravitation • Gravitational Field • Potential

1. Universal Law of Gravitation

Gravitational force between two masses m_1 and m_2

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

Where

- G = Universal Gravitational Constant
- r = distance between centres of two masses

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2. Universal Gravitational Constant

$$G = 6.67\times10^{-11} Nm^2kg^{-2}$$

SI Unit: Nm^2/kg^2
Dimensions:

$$[M^{-1}L^3T^{-2}]$$

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3. Newton's Law (Vector Form)

The direction of force at a mass is towards other mass along the line joining the centre of these two masses.

$$\vec{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$$

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4. Acceleration Due to Gravity

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

Where

- M = Mass of earth
- R = Radius of earth

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5. Weight

$$W = mg$$

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6. Gravitational Field Intensity

$$E = \frac{F}{m}$$

Or

$$E = \frac{GM}{r^2}$$

SI Unit: N/kg

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7. Relation Between g and Gravitational Field

$$g = E$$

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8. Gravitational Potential

$$V = -\frac{GM}{r}$$

SI Unit: J/kg

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9. Gravitational Potential Energy

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

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10. Relation Between Potential and Potential Energy

$$U = mV$$

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11. Escape Condition

Total mechanical energy to free a body from gravitation

$$E = 0$$

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12. Variation of g with Height

$$g_h = \frac{g}{\left(1+\frac{h}{R}\right)^2}$$

If $h \ll R$

$$g_h = g\left(1-\frac{2h}{R}\right)$$

Exam Tips

- Gravitaiona force is always **Attractive**
- Gravitational Potential and Potential Energy both are **Negative**.
- g and Gravitational Field Intensity has same Numerical value.

Part–2: Escape Velocity • Satellites • Kepler's Laws

13. Escape Velocity

Escape Velocity is the minimum velocity required to leave the gravitational field of Earth permanently.

$$v_e = \sqrt{\frac{2GM}{R}}$$

Using

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

$$v_e = \sqrt{2gR}$$

For Earth

$$v_e = 11.2 km/s$$

14. Orbital Velocity

Velocity of a satellite near Earth's surface

$$v_o = \sqrt{\frac{GM}{R}}$$

Or

$$v_o = \sqrt{gR}$$

For Earth

$$v_o = 7.9 km/s$$

15. Relation between Escape Velocity and Orbital Velocity

$$v_e = \sqrt{2}\, v_o$$

16. Time Period of Satellite

Using orbital velocity

$$T = \frac{2\pi r}{v}$$

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

17. Geostationary Satellite

Conditions

- Time Period = 24 hours
- Circular Orbit
- Equatorial Plane
- Same Direction as Earth's Rotation

Height above Earth

$$h = 3.6\times10^7 m$$

Approx.

$$35800km$$

18. Variation of g with Depth

At depth d

$$g_d = g\left(1-\frac{d}{R}\right)$$

19. Variation of g with Height

$$g_h = g\left(1-\frac{2h}{R}\right)$$

For h << R

20. Kepler's First Law

Every planet moves in an elliptical orbit with the Sun at one focus.

21. Kepler's Second Law

The line joining the planet and the Sun sweeps equal areas in equal intervals of time.

22. Kepler's Third Law

$$T^2 \propto r^3$$

or

$$\frac{T^2}{r^3} = Constant$$

23. Total Energy of Satellite

$$E = -\frac{GMm}{2r}$$

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24. Kinetic Energy of Satellite

$$KE = \frac{GMm}{2r}$$

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25. Potential Energy of Satellite

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

Exam Tips

 Remember

- Escape Velocity = **11.2 km/s**
- Orbital Velocity = **7.9 km/s**
- PE=−2KE
- E=−KE

In Satellite Questions
