Gravitation — Assignment 1 (Topic-wise)

Class 11 Physics · NCERT Chapter 7

Narayan Gurukul Academy (ClassApna)

Instructions

- Answer all questions.
- Show full working for numericals; marks are awarded for steps.
- Use $G = 6.67 \times 10^{-11}\ \text{N m}^2\text{kg}^{-2}$, $M_e = 6 \times 10^{24}\ \text{kg}$, $R_e = 6.4 \times 10^{6}\ \text{m}$ unless stated otherwise.
- Time: 90 minutes.

Topic 1 — The Universal Law of Gravitation

1. (MCQ) The gravitational force between two bodies does not depend on —

- (a) the product of their masses
- (b) the distance between them
- (c) the medium between them
- (d) the universal gravitational constant

2. (MCQ) The dimensional formula of the gravitational constant G is —

- (a) $[M^{-1}L^{3}T^{-2}]$
- (b) $[ML^{3}T^{-2}]$
- (c) $[M^{-1}L^{-3}T^{2}]$
- (d) $[ML^{-3}T^{-2}]$

3. State Newton's universal law of gravitation. Express it in vector form for two particles of masses m_1 and m_2 at positions $\vec{r}_1$ and $\vec{r}_2$.

4. Two bodies of masses $5\ \text{kg}$ and $10\ \text{kg}$ are kept at a distance of $2\ \text{m}$. Calculate the gravitational force between them. Compare this with the force of gravity on each body at the Earth's surface.

Topic 2 — Acceleration due to Gravity

5. (MCQ) The value of g at the centre of the Earth is —

- (a) zero
- (b) $9.8\ \text{m s}^{-2}$
- (c) maximum
- (d) twice its surface value

6. (MCQ) At a height $h = R$ above the Earth's surface (where R is the Earth's radius), the value of g becomes —

- (a) $g/4$
- (b) $g/2$
- (c) $g/9$
- (d) $2g$

7. Derive the variation of g with depth d below the Earth's surface and show that g is maximum at the surface.

8. A planet has the same density as the Earth but twice its radius. Find the value of g on this planet in terms of the Earth's g.

Topic 3 — Gravitational Field and Intensity

9. (MCQ) The gravitational field inside a uniform thin spherical shell is —

- (a) zero
- (b) $\frac{GM}{r^2}$
- (c) $\frac{GMr}{a^3}$
- (d) constant and non-zero

10. State Newton's shell theorem and use it to find the gravitational field (a) outside a uniform solid sphere, (b) inside a uniform solid sphere at distance r from the centre.

11. Two point masses of $2\ \text{kg}$ and $8\ \text{kg}$ are placed $1\ \text{m}$ apart. Find the position of the point where the net gravitational field is zero.

Topic 4 — Gravitational Potential and Potential Energy

12. (MCQ) The gravitational potential at a point at distance r from a point mass M is proportional to —

- (a) $\frac{1}{r}$
- (b) $\frac{1}{r^2}$
- (c) r
- (d) r^2

13. Define gravitational potential. Derive an expression for it at a distance r from a point mass M.

14. Show that near the Earth's surface the gravitational potential energy $U = -\frac{GMm}{r}$ reduces to $U = mgh$.

15. Compute the gravitational potential energy of the Earth–Moon system. ($M_e = 6 \times 10^{24}$ kg, $M_m = 7.4 \times 10^{22}$ kg, mean distance $= 3.84 \times 10^{8}$ m)

Topic 5 — Binding Energy

16. (MCQ) The binding energy of a body of mass m on the Earth's surface is —

- (a) $\frac{GMm}{R}$
- (b) $\frac{GMm}{R^2}$
- (c) $\frac{GMm}{2R}$
- (d) $\frac{GMm}{\sqrt{R}}$

17. Define the binding energy of a gravitational system. Show that the binding energy of a body on the Earth's surface equals mgR.

18. A body of mass m is raised from the Earth's surface to a height $h = R$. Find the change in its binding energy.

Topic 6 — Escape Velocity

19. (MCQ) The ratio of the escape velocity to the orbital velocity of a satellite just above the Earth's surface is —

- (a) $\sqrt{2} : 1$
- (b) $1 : \sqrt{2}$
- (c) $2 : 1$
- (d) $1 : 2$

20. Derive the expression for the escape velocity from the surface of a planet and show that $v_e = \sqrt{2gR}$.

21. The Moon has a mass of 7.4×10^{22} kg and radius 1.74×10^{6} m. Calculate the escape velocity from the Moon's surface.

Topic 7 — Kepler's Laws and Satellite Motion

22. (MCQ) The time period of a satellite orbiting close to the Earth's surface is approximately —

- (a) 84 minutes
- (b) 24 hours

- (c) 365 days
- (d) 12 hours

23. State Kepler's three laws of planetary motion.

24. Derive the expression for the orbital velocity of a satellite in a circular orbit of radius r around the Earth and show that its time period $T = 2\pi\sqrt{\frac{r^3}{GM}}$.

25. A geostationary satellite is placed at a height h above the equator. Using $T = 24\ \text{h}$, show that $r = \left(\frac{GMT^2}{4\pi^2}\right)^{1/3}$ and calculate h.

Answer Key — Assignment 1

- **Q1** — (c) medium between them
- **Q2** — (a) $[M^{-1}L^3T^{-2}]$
- **Q3** — $\vec{F} = -\frac{Gm_1m_2}{r^2}\hat{r}$, attractive, along the line joining the particles
- **Q4** — $F = 8.3 \times 10^{-10}\ \text{N}$
- **Q5** — (a) zero
- **Q6** — (a) $g/4$
- **Q7** — $g_d = g(1 - d/R)$; zero at centre
- **Q8** — $g = 2g_e$ (since $M \propto R^3$, $g \propto R$)
- **Q9** — (a) zero (shell theorem)
- **Q10** — Outside: $E = GM/r^2$; inside $E = GMr/a^3$
- **Q11** — The field is zero at distance $\frac{2}{3}\ \text{m}$ from the 2 kg mass. Solve $2/x^2 = 8/(1-x)^2$
- **Q12** — (a) $1/r$
- **Q13** — $V = -GM/r$
- **Q14** — Expand $-\frac{GMm}{R+h}$ for $h \ll R$
- **Q15** — $U = -7.7 \times 10^{28}\ \text{J}$
- **Q16** — (a) GMm/R
- **Q17** — $BE = GMm/R = mgR$
- **Q18** — BE decreases by $\frac{GMm}{2R}$
- **Q19** — (a) $\sqrt{2} : 1$
- **Q20** — $v_e = \sqrt{2GM/R} = \sqrt{2gR}$
- **Q21** — $v_e = 2.38 \times 10^3\ \text{m s}^{-1}$
- **Q22** — (a) 84 minutes
- **Q23** — Law of orbits, law of areas, law of periods
- **Q24** — $v_o = \sqrt{GM/r}$, $T = 2\pi\sqrt{r^3/GM}$

- **Q25** — $h \approx 3.58 \times 10^{7}\ \text{m} \approx 35{,}800\ \text{km}$