Gravitation — Test 2 (CBSE Pattern)

Class 11 Physics · NCERT Chapter 7

Time: 90 minutes · Maximum Marks: 40

Narayan Gurukul Academy (ClassApna)

General Instructions

1. All questions are compulsory.
2. Section A: Question 1–10 are MCQs/Very Short Answer type, each of **1 mark**.
3. Section B: Question 11–14 are of **2 marks** each.
4. Section C: Question 15–18 are of **3 marks** each.
5. Section D: Question 19–20 are of **5 marks** each.
6. Internal choice is provided in one question of 3 marks and one of 5 marks.
7. Use $G = 6.67 \times 10^{-11}\ \mathrm{N\ m^2 kg^{-2}}$, $M_e = 6 \times 10^{24}\ \mathrm{kg}$, $R_e = 6.4 \times 10^6\ \mathrm{m}$, $g = 9.8\ \mathrm{m\ s^{-2}}$.

Section A — MCQ / VSA (10 × 1 = 10 marks)

1. The value of the universal gravitational constant G is approximately —

- (a) $6.67 \times 10^{-11}\ \mathrm{N\ m^2 kg^{-2}}$
- (b) $6.67 \times 10^{-11}\ \mathrm{N\ m^2 kg^{2}}$
- (c) $6.67 \times 10^{11}\ \mathrm{N\ m^2 kg^{-2}}$
- (d) $9.8 \times 10^{-11}\ \mathrm{N\ m^2 kg^{-2}}$

2. The ratio of the acceleration due to gravity inside a deep mine (at depth d) to that on the surface is —

- (a) $1 - \frac{d}{R}$
- (b) $1 + \frac{d}{R}$
- (c) $\left(1 - \frac{d}{R}\right)^{-1}$
- (d) 1

3. Two spheres, each of mass M and radius R, touch each other. The gravitational force between them is proportional to —

- (a) M^2
- (b) R^2

- (c) MR
- (d) independent of M and R

4. A body is projected vertically upward with a speed equal to the orbital velocity of a near-surface satellite. It will —

- (a) not escape; it returns to the surface like a projectile
- (b) escape to infinity
- (c) fall into the centre of the Earth
- (d) continue in a circular orbit near the surface

5. State the condition for a satellite to be geostationary in two properties. (VSA)

6. The gravitational potential at a point inside a uniform thin spherical shell is —

- (a) constant and equal to $-\frac{GM}{a}$
- (b) zero
- (c) proportional to r
- (d) proportional to $\frac{1}{r}$

7. The escape velocity from the Moon's surface is about 2.4 km s^{-1}. A body of double the mass, projected at the same speed, will have an escape velocity that is —

- (a) independent of its mass; still about 2.4 km s^{-1}
- (b) $\approx 3.4 \text{ km s}^{-1}$
- (c) $\approx 1.2 \text{ km s}^{-1}$
- (d) $\approx 4.8 \text{ km s}^{-1}$

8. The speed of a planet is **maximum** when it is at the ________ of its orbit. (Complete the sentence.)

9. The total energy of a satellite of mass m in a circular orbit of radius r is —

- (a) $-\frac{GMm}{2r}$
- (b) $+\frac{GMm}{2r}$
- (c) $-\frac{GMm}{r}$
- (d) $+\frac{GMm}{r}$

10. Who first experimentally measured the value of the gravitational constant G? (VSA — name the scientist.)

Section B — Short Answer I (4 × 2 = 8 marks)

11. Derive the expression $g = \frac{GM}{R^2}$ for the acceleration due to gravity at the Earth's surface.

12. Show that the orbital velocity of a satellite is independent of its mass.

13. Define binding energy of a body on the Earth's surface and write its expression.

14. If the Earth's radius shrinks to half keeping its mass constant, what happens to (a) the value of g and (b) the escape velocity? Justify.

Section C — Short Answer II (4 × 3 = 12 marks)

15. Derive the expression relating gravitational field intensity $\vec{E}$ to potential V, and comment on why potential is often easier to compute.

OR

Two small bodies of masses 1 kg and 4 kg are kept 9 m apart. Find the point on the line joining them where the resultant gravitational field is zero.

16. Derive the expression for the time period of a satellite in a circular orbit and show that it decreases as the orbit radius decreases. Find the period of a satellite orbiting at a height equal to the Earth's radius.

17. A stone of mass 1 kg is dropped from a height equal to the Earth's radius. Calculate its speed just before touching the ground (neglect air resistance).

18. Derive the relation between the escape velocity and the orbital velocity for a body close to the Earth's surface, and hence show $v_e = \sqrt{2}\,gR$ near the surface.

Section D — Long Answer (2 × 5 = 10 marks)

19. (a) Using the shell theorem, derive the gravitational field at a point (i) outside, (ii) on the surface, and (iii) inside a uniform solid sphere of mass M and radius R.
(b) Plot the variation of the field with distance from the centre of the sphere.
(c) If a tunnel is bored along a diameter through the Earth, show that the motion of a particle released in the tunnel is simple harmonic. Find its time period.

20. (a) Derive the total energy of a satellite and show that the binding energy of a satellite in orbit is equal to half the magnitude of its potential energy.
(b) Calculate the binding energy of a satellite of mass 200 kg orbiting at a height of 600 km.
(c) A body is projected from the Earth's surface with a speed $v = \sqrt{\frac{2}{5}}\,v_e$ ($\approx 0.63\,v_e$). Show that it rises to a height $h = \frac{2R}{3}$ above the surface.

OR

(a) Derive $v_e = \sqrt{\frac{2GM}{R}}$ from energy conservation.
(b) Two identical spheres of radius R and mass M are placed touching each other. Show that the force between them is $F = \frac{GM^2}{4R^2}$.

(c) A satellite moves in an orbit just above the Earth's surface. What fraction of the escape velocity from that altitude is its orbital velocity?

Answer Key — Test 2

- **Q1** — (a)
- **Q2** — (a) $g_d/g = 1 - d/R$
- **Q3** — (a) $F \propto M^2$ (constant density → $M \propto R^3$)
- **Q4** — (a) not escape; returned projectile
- **Q5** — Period 24 h; orbits in equatorial plane, west to east
- **Q6** — (a) constant $-\frac{GM}{a}$
- **Q7** — (a) independent of mass
- **Q8** — perihelion (perigee)
- **Q9** — (a) $-\frac{GMm}{2r}$
- **Q10** — Henry Cavendish
- **Q11** — Equate $mg = GMm/R^2$
- **Q12** — $v_o = \sqrt{GM/r}$; no m in the expression
- **Q13** — $BE = GMm/R = mgR$
- **Q14** — (a) g becomes $4g$ (b) v_e becomes $\sqrt{2}\,v_e$
- **Q15** — $\vec{E} = -\nabla V$; zero-field point at distance 3 m from the 1 kg mass
- **Q16** — $T = 2\pi\sqrt{r^3/GM}$; at $r = 2R_e, T = 2\pi\sqrt{8R_e^3/GM} \approx 3.99$ h
- **Q17** — $v = \sqrt{gR} \approx 7.92 \times 10^3 \text{ m s}^{-1}$
- **Q18** — $v_e = \sqrt{2}\,v_o = \sqrt{2gR}$
- **Q19** — (b) field rises linearly inside $\propto r$, then falls as $1/r^2$ outside (c) $T = 2\pi\sqrt{R/g} \approx 84$ min (SHM via $F \propto -r$)
- **Q20** — (b) $BE = GMm/2r \approx 5.7 \times 10^9$ J (c) Put $v^2 = \frac{4GM}{5R}$ and solve $\frac{1}{2}v^2 - \frac{GM}{R} = -\frac{GM}{R+h} \rightarrow h = \frac{2R}{3}$