NARAYAN GURUKUL ACADEMY

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Gravitation — Topic-wise Assignment

Class 11 Physics · CBSE topic-wise · 6 topics + 2 case studies · answer key included

General Instructions

1. This assignment is split into 6 topic panels. Within each topic, questions are grouped by type — MCQ (1), VSA (1), SA-I (2), SA-II (3), LA (5) — marks per question as marked. Two Case-Based Questions (4 each) follow the topic panels.
2. All questions are compulsory. No overall choice is given; internal choice, where allowed, is clearly marked.
3. For MCQ questions choose the single correct option; for VSA answers write a single line. In case-based questions, attempt all parts.
4. All symbols carry their usual meaning. Use of a calculator is not permitted. Where needed, take $R = 6400$ km, $g = 9.8\ \mathrm{m\ s^{-2}}$ and $G = 6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$.

Topic 1: Kepler's Laws of Planetary Motion

A. MCQ — 1 mark each

1. All planets move in elliptical orbits with the Sun situated at

(A) the centre of the ellipse
(B) one of the two foci of the ellipse
(C) any point inside the ellipse
(D) the edge of the ellipse

2. Kepler's third law (law of periods) states that

(A) $T \propto a^2$
(B) $T^2 \propto a$
(C) $T^2 \propto a^3$
(D) $T \propto a^3$

B. Very Short Answer (VSA) — 1 mark each

3. State Kepler's law of orbits.

C. Short Answer I (SA-I) — 2 marks each

4. The areal velocity of a planet is constant. Show what this implies about the angular momentum of the planet.

D. Short Answer II (SA-II) — 3 marks each

5. The planet Neptune revolves around the Sun with a period of 165 years. Show that the radius of its orbit is approximately thirty times that of the Earth's orbit, taking both orbits as circular.

E. Long Answer (LA) — 5 marks each

6. Assuming the orbit of a planet to be circular, derive Kepler's third law from Newton's law of gravitation. State the law you derive.

Topic 2: Newton's Universal Law of Gravitation

A. MCQ — 1 mark each

7. The value of the universal gravitational constant G (in SI units) is

(A) 6.67×10^{-11} N m^2 kg^{-2}
(B) 6.67×10^{11} N m^2 kg^{-2}
(C) 6.67×10^{-11} N kg^2 m^{-2}
(D) 6.67×10^{-9} N m^2 kg^{-2}

8. The gravitational force is ________ in nature; the work done by it depends only on the end points and not on the path.

(A) non-conservative
(B) conservative
(C) dissipative
(D) frictional

B. Very Short Answer (VSA) — 1 mark each

9. Define the universal gravitational constant G.

C. Short Answer I (SA-I) — 2 marks each

10. Two particles of masses 1.0 kg and 2.0 kg are placed at a separation of 0.50 m. Assuming only their mutual gravitation acts, find the magnitude of the gravitational force between them and the initial acceleration of each particle.

11. Write the dimensional formula of the universal gravitational constant G.

D. Short Answer II (SA-II) — 3 marks each

12. Two spheres of the same material and the same radius r are placed touching each other. Show that the gravitational force between them is directly proportional to r^4.

E. Long Answer (LA) — 5 marks each

13. State Newton's universal law of gravitation. Define the universal gravitational constant G, giving its value and dimensions, and derive the relation between g and G.

Topic 3: Acceleration due to Gravity and its Variation

A. MCQ — 1 mark each

14. The value of acceleration due to gravity is maximum at

(A) the equator
(B) the poles
(C) every point of the surface
(D) a height $h = R$ above the surface

15. At a depth $d = \frac{R}{2}$ below the Earth's surface, the value of g becomes

(A) g
(B) $\frac{g}{4}$
(C) $\frac{g}{2}$
(D) zero

B. Very Short Answer (VSA) — 1 mark each

16. Why is the value of g minimum at the equator and maximum at the poles?

C. Short Answer I (SA-I) — 2 marks each

17. Show that at a height h very much smaller than the Earth's radius R ($h \ll R$), the acceleration due to gravity is approximately $g' \approx g\left(1 - \frac{2h}{R}\right)$.

18. At what height above the Earth's surface is the value of acceleration due to gravity reduced to one-fourth of its value on the surface? (Take $R = 6400$ km.)

D. Short Answer II (SA-II) — 3 marks each

19. Suppose the Earth increases its speed of rotation. At what new time period will the weight of a body on the equator become zero? Take $g = 10\,\text{m s}^{-2}$ and $R = 6400$ km.

E. Long Answer (LA) — 5 marks each

20. Discuss how the value of acceleration due to gravity varies (a) with altitude, (b) with depth, and (c) with the shape and rotation of the Earth.

Topic 4: Gravitational Potential and Gravitational Potential Energy

A. MCQ — 1 mark each

21. The gravitational potential due to a point mass M at a distance r is

(A) $-\frac{GM}{r}$
(B) $+\frac{GM}{r}$

(C) $-\frac{GM}{r^2}$
(D) $+\frac{GM}{r^2}$

22. The gravitational potential energy of a system of two masses m_1 and m_2 separated by a distance r (with $U(\infty) = 0$) is

(A) $+\frac{Gm_1m_2}{r}$
(B) $-\frac{Gm_1m_2}{r}$
(C) $-\frac{Gm_1m_2}{r^2}$
(D) $+\frac{Gm_1m_2}{r^2}$

B. Very Short Answer (VSA) — 1 mark each

23. Define gravitational potential at a point.

C. Short Answer I (SA-I) — 2 marks each

24. A particle of mass 1 kg is kept on the surface of a uniform sphere of mass 20 kg and radius 1.0 m. Find the work to be done against the gravitational force to take the particle away (to infinity) from the sphere.

D. Short Answer II (SA-II) — 3 marks each

25. A particle of mass m_2 is moved in the field of a fixed particle of mass m_1 so that their separation changes from r_1 to r_2. Derive the change in the gravitational potential energy of the system.

E. Long Answer (LA) — 5 marks each

26. Taking the gravitational potential energy of a two-particle system to be zero when the particles are infinitely far apart, derive an expression for the gravitational potential energy of the system when the separation is r.

Topic 5: Escape Speed

A. MCQ — 1 mark each

27. The escape velocity from the surface of the Earth is

(A) 7.9 km s^{-1}
(B) 11.2 km s^{-1}
(C) 9.8 km s^{-1}
(D) 13.4 km s^{-1}

28. The escape velocity of a body from the Earth is independent of

(A) the angle of projection
(B) the radius of the Earth
(C) the mass of the Earth
(D) the acceleration due to gravity

B. Very Short Answer (VSA) — 1 mark each

29. Define escape velocity and give its value for the Earth.

C. Short Answer I (SA-I) — 2 marks each

30. The mass of the Moon is 7.4×10^{22} kg and its radius is 1.74×10^{6} m. Calculate the escape velocity from the surface of the Moon. ($G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})

D. Short Answer II (SA-II) — 3 marks each

31. A particle is fired vertically upward from the surface of the Earth with a speed of 9.8 km s^{-1}. Find the maximum height it attains. Take $R = 6400$ km and $g =$ 9.8 m s^{-2} (only the Earth's gravitation acts).

E. Long Answer (LA) — 5 marks each

32. Derive an expression for the escape velocity of a body from the Earth in terms of g and R, and show that it is independent of the mass and the angle of projection. Compute its value for the Earth.

Topic 6: Orbital Velocity, Energy of a Satellite and Geostationary Satellites

A. MCQ — 1 mark each

33. The orbital speed of a satellite revolving close to the Earth's surface ($r \approx R$) is

(A) 11.2 km s^{-1}
(B) 7.9 km s^{-1}
(C) 3.1 km s^{-1}
(D) 24.0 km s^{-1}

34. A geostationary satellite revolves around the Earth

(A) from east to west with time period 12 h
(B) from west to east with time period 24 h, staying above one fixed point on the equator
(C) in any plane with time period 24 h
(D) in a polar orbit with time period 24 h

B. Very Short Answer (VSA) — 1 mark each

35. What is a geostationary (geo-synchronous) satellite?

C. Short Answer I (SA-I) — 2 marks each

36. Show that the orbital speed of a satellite moving in a circular orbit close to the Earth's surface is $v_o = \sqrt{gR}$, and obtain its value given $g = 9.8$ m s^{-2} and $R =$ 6400 km.

D. Short Answer II (SA-II) — 3 marks each

37. An artificial satellite is moving in a circular orbit around the Earth with a speed equal to one-fourth of the escape velocity from the Earth. Determine the height of the satellite above the Earth's surface in terms of R (the Earth's radius).

E. Long Answer (LA) — 5 marks each

38. A satellite is so placed that it appears stationary to an observer on Earth and serves as a fixed relay station. Given $R = 6400$ km and $g = 9.8\ \mathrm{m\,s^{-2}}$, find the height of the satellite above the Earth's surface, the radius of its orbit and its orbital speed.

Case-Based Questions

Case Study 1: A satellite in a circular orbit

A satellite of mass m is launched into a circular orbit of radius twice the Earth's radius ($r = 2R$). Take $R = 6400$ km and $g = 9.8\ \mathrm{m\,s^{-2}}$.

(a) What provides the centripetal force needed for the satellite's circular motion?
(b) Calculate the orbital speed of the satellite.
(c) Find the time period of the satellite.
(d) If the satellite's speed is suddenly increased to $\sqrt{2}$ times the value in (b), what happens to it?

Case Study 2: Kepler's laws of planetary motion

Kepler used Tycho Brahe's precise observations to describe planetary motion around the Sun: a planet moves in an elliptical orbit with the Sun at one focus, and its radius vector sweeps out equal areas in equal intervals of time.

(a) State Kepler's third law (law of periods).
(b) At which point of its orbit is the planet's speed greatest, and why?
(c) If a planet's orbital radius (mean distance from the Sun) is doubled, by what factor does its time period increase?
(d) A planet orbits the Sun at a mean distance four times that of the Earth. Find its time period in years.

Answer Key (Marking Scheme)

Q no.	Topic	Type	Marks	Answer (with short working hint)
Q1	Kepler's laws	MCQ	1	(B) one of the two foci
Q2	Kepler's laws	MCQ	1	(C) $T^2 \propto a^3$
Q3	Kepler's laws	VSA	1	Elliptical orbits; Sun at one focus
Q4	Kepler's laws	SA-I	2	Constant areal velocity ⇒ constant $L = mR^2\omega$
Q5	Kepler's laws	SA-II	3	$(165)^{2/3} \approx 30 \times$
Q6	Kepler's laws	LA	5	Centripetal = gravitation ⇒ $T^2 = 4\pi^2 r^3/GM$
Q7	Universal law	MCQ	1	(A) 6.67×10^{-11} N m^2 kg^{-2}
Q8	Universal law	MCQ	1	(B) conservative
Q9	Universal law	VSA	1	Force between unit masses at unit distance
Q10	Universal law	SA-I	2	$F = 5.3 \times 10^{-10}$ N; $a_1 = 5.3 \times 10^{-10}$, $a_2 = 2.65 \times 10^{-10}$ m s^{-2}
Q11	Universal law	SA-I	2	$[M^{-1}L^3T^{-2}]$
Q12	Universal law	SA-II	3	$m \propto r^3$, $F \propto m^2/r^2 \Rightarrow F \propto r^6/r^2 = r^4$
Q13	Universal law	LA	5	$g = GM/R^2$ derived; $G = 6.67 \times 10^{-11}$
Q14	Variation of g	MCQ	1	(B) poles
Q15	Variation of g	MCQ	1	(C) $g/2$ ($g_d = g(1 - d/R)$)
Q16	Variation of g	VSA	1	$g \propto 1/R^2$; $R_{\text{eq}} > R_{\text{pole}}$
Q17	Variation of g	SA-I	2	$g' = g(1 + h/R)^{-2} \approx g(1 - 2h/R)$ (binomial, $h \ll R$)
Q18	Variation of g	SA-I	2	$h = R = 6400$ km
Q19	Variation of g	SA-II	3	$T = 2\pi\sqrt{R/g} \approx 1.4$ h
Q20	Variation of g	LA	5	Decreases with height & depth; pole-max, shape/rotation adjust
Q21	Potential & PE	MCQ	1	(A) $V = -GM/r$
Q22	Potential & PE	MCQ	1	(B) $U = -Gm_1m_2/r$
Q23	Potential & PE	VSA	1	Work per unit mass from infinity; $V = -GM/r$

Q no.	Topic	Type	Marks	Answer (with short working hint)
Q24	Potential & PE	SA-I	2	$V = -1.334 \times 10^{-9}$ J kg^{-1}; $W = 1.334 \times 10^{-9}$ J
Q25	Potential & PE	SA-II	3	$\Delta U = Gm_1m_2(1/r_1 - 1/r_2)$
Q26	Potential & PE	LA	5	$U(r) = -Gm_1m_2/r$, negative ⇒ bound system
Q27	Escape speed	MCQ	1	(B) 11.2 km s^{-1} ($v_e = \sqrt{2gR}$)
Q28	Escape speed	MCQ	1	(A) the angle of projection
Q29	Escape speed	VSA	1	Minimum speed to leave Earth's field; 11.2 km s^{-1}
Q30	Escape speed	SA-I	2	$v_e = \sqrt{2GM/R} = 2.4$ km s^{-1}
Q31	Escape speed	SA-II	3	$H \approx 2.09 \times 10^4$ km
Q32	Escape speed	LA	5	$v_e = \sqrt{2GM/R} = \sqrt{2gR} = 11.2$ km s^{-1}
Q33	Satellites	MCQ	1	(B) 7.9 km s^{-1} ($v_o = \sqrt{gR}$)
Q34	Satellites	MCQ	1	(B) west-to-east, $T = 24$ h over the equator
Q35	Satellites	VSA	1	$T = 24$ h, equatorial, west-to-east, fixed point
Q36	Satellites	SA-I	2	$v_o = \sqrt{gR} = 7.9$ km s^{-1}
Q37	Satellites	SA-II	3	$v = v_e/4 \Rightarrow r = 8R \Rightarrow h = 7R$
Q38	Satellites	LA	5	$r \approx 4.23 \times 10^4$ km, $h \approx 3.6 \times 10^4$ km, $v_o \approx 3.1$ km s^{-1}
CS1	Satellites	Case-based	4	(a) Earth's gravity; (b) $v_o = \sqrt{gR/2} = 5.6$ km s^{-1}; (c) $T \approx$ 4 h; (d) $\sqrt{2}v_o = v_e$ — escapes
CS2	Kepler's laws	Case-based	4	(a) $T^2 \propto a^3$; (b) perihelion (equal areas); (c) $2^{3/2} \approx 2.83\times$; (d) $4^{3/2} = 8$ yr