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Class 12
Physics

Chapter 15

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FEDERAL BOARD OF INTERMEDIATE & SECONDARY EDUCATION
CLASS XII — PHYSICS

CHAPTER: GRAVITATION (Domain B Mechanics)

MCQs & Short Questions with Answer Key

SLOs Covered: P-12-B-01 to P-12-B-09 | Total Questions: 50 (30 MCQs + 20 Short Qs)

SECTION A: MULTIPLE CHOICE QUESTIONS (MCQs)

1. The gravitational force between two masses is given by:

A) $F = mv^2/r$
B) $F = GMm/r^2$
C) $F = GMm/r$
D) $F = mg$
✓ **Answer: B**

2. If the distance between two masses is doubled, the gravitational force becomes:

A) 4 times
B) 2 times
C) 1/2 times
D) 1/4 times
✓ **Answer: D**

3. The value of the universal gravitational constant G is approximately:

A) 6.67×10^{-11} N m² kg^{-2}
B) 9.8 m s^{-2}
C) 6.02×10^{23} N m²
D) $6.67 \times 10^{--}$ N m²
✓ **Answer: A**

4. Newton's law of gravitation states that the force is:

A) Directly proportional to the square of distance
B) Inversely proportional to the product of masses
C) Directly proportional to the product of masses
D) Independent of distance
✓ **Answer: C**

5. Which of the following correctly shows the unit of G?

A) N m² kg^{-2}
B) N kg^{-1}
C) kg m s^{-2}
D) N m kg^{-1}
✓ **Answer: A**

6. Gravitational field lines around a uniform sphere:

A) Are parallel lines
B) Point radially outward from the centre
C) Point radially inward toward the centre
D) Form closed loops
✓ **Answer: C**

7. For a point outside a uniform sphere, the sphere's mass may be considered to be concentrated at:

A) The surface
B) The centre
C) Any point inside
D) Infinity
✓ **Answer: B**

8. Gravitational field strength g is defined as:

A) Force per unit mass
B) Force per unit charge
C) Mass per unit force
D) Force × mass
✓ **Answer: A**

9. The gravitational field inside a hollow uniform sphere is:

A) Maximum
B) Equal to g at surface
C) Zero
D) Proportional to r
✓ **Answer: C**

10. The unit of gravitational field strength is:

A) N kg
B) N kg■¹
C) kg N■¹
D) J kg■¹
✓ **Answer: B**

11. Two identical masses of 10 kg each are placed 1 m apart. The gravitational force between them is approximately:

A) 6.67 × 10■■ N
B) 6.67 × 10■¹¹ N
C) 9.8 N
D) 6.67 × 10■■ N
✓ **Answer: A**

12. Newton's law of gravitation is applicable to:

A) Only large masses
B) Only point masses
C) Any two masses
D) Only masses on Earth
✓ **Answer: C**

13. If the mass of one object is tripled while the distance remains constant, the gravitational force:

A) Triples
B) Becomes nine times
C) Remains the same
D) Becomes 1/3
✓ **Answer: A**

14. The gravitational force is a:

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A) Contact force
B) Non-contact force
C) Frictional force
D) Magnetic force
✓ **Answer: B**

15. For a satellite in a circular orbit, the gravitational force provides the:
A) Tangential force
B) Centripetal force
C) Normal force
D) Net upward force
✓ **Answer: B**

16. The orbital speed of a satellite at radius r from Earth's centre is:
A) $v = GM/r$
B) $v = \sqrt{GMr}$
C) $v = \sqrt{GM/r}$
D) $v = GM/r^2$
✓ **Answer: C**

17. As the orbital radius of a satellite increases, its orbital speed:
A) Increases
B) Decreases
C) Remains constant
D) First increases then decreases
✓ **Answer: B**

18. The time period of a satellite in circular orbit is related to its orbital radius by:
A) $T \propto r$
B) $T^2 \propto r^3$
C) $T \propto r^2$
D) $T^2 \propto r^2$
✓ **Answer: B**

19. A geostationary satellite has an orbital period of:
A) 12 hours
B) 24 hours
C) 48 hours
D) 6 hours
✓ **Answer: B**

20. Geostationary satellites orbit directly above the:
A) North Pole
B) South Pole
C) Equator
D) Tropic of Cancer
✓ **Answer: C**

21. The direction of orbit of a geostationary satellite is:
A) East to West
B) West to East
C) North to South
D) South to North
✓ **Answer: B**

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22. The height of a geostationary orbit above Earth's surface is approximately:

A) 400 km
B) 2000 km
C) 36,000 km
D) 100,000 km
✓ **Answer: C**

23. The gravitational field strength at a distance r from a point mass M is:

A) $g = GM/r$
B) $g = GM/r^2$
C) $g = GMr$
D) $g = G/Mr^2$
✓ **Answer: B**

24. The equation $F = GMm/r^2$ gives the force between:

A) A charge and a field
B) Two point masses
C) A mass and Earth only
D) Two magnetic poles
✓ **Answer: B**

25. The gravitational field strength g at Earth's surface is approximately:

A) 6.67 N kg■¹
B) 9.8 N kg■¹
C) 3.7 N kg■¹
D) 11.2 N kg■¹
✓ **Answer: B**

26. Why is g approximately constant near Earth's surface?

A) Earth is a perfect sphere
B) The change in r is negligible compared to Earth's radius
C) G is variable
D) Earth's mass changes
✓ **Answer: B**

27. At a height h (where $h << R$) above Earth's surface, g approximately:

A) Increases
B) Remains exactly the same
C) Decreases slightly
D) Becomes zero
✓ **Answer: C**

28. The gravitational potential at a distance r from a point mass M is:

A) $\phi = GMr$
B) $\phi = -GM/r^2$
C) $\phi = -GM/r$
D) $\phi = GM/r$
✓ **Answer: C**

29. Gravitational potential is defined as work done per unit mass in bringing a test mass from:

A) Earth's centre to surface
B) Infinity to that point
C) That point to infinity
D) Surface to that point

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✓ **Answer: B**

30. The SI unit of gravitational potential is:

A) J kg

B) N kg■¹

C) J kg■¹

D) N m

✓ **Answer: C**

SECTION B: SHORT QUESTIONS WITH ANSWERS

Q1. State Newton's Law of Gravitation.

Answer: Newton's Law of Gravitation states that every object in the universe attracts every other object with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. Mathematically: $F = GMm/r^2$, where $G = 6.67 \times 10$■^{11} N m² kg■^{2}.

Q2. Define gravitational field strength.

Answer: Gravitational field strength (g) at a point is defined as the gravitational force per unit mass acting on a small test mass placed at that point. It is a vector quantity pointing toward the source mass. Unit: N kg■^{1}.

Q3. How can gravitational fields be represented using field lines?

Answer: Gravitational field lines show the direction and relative strength of the gravitational field. They are drawn pointing toward the mass (attractive field). Closer field lines indicate stronger field. For a uniform sphere, field lines point radially inward toward its centre.

Q4. State the condition for a uniform sphere in gravitational problems.

Answer: For a point outside a uniform sphere, the entire mass of the sphere may be considered to be concentrated at its centre (a point mass). This simplifies gravitational calculations significantly.

Q5. Derive the expression for gravitational field strength $g = GM/r^2$.

Answer: From Newton's law, force on a test mass m at distance r from mass M: $F = GMm/r^2$. Since $g = F/m$, dividing both sides by m gives: $g = GM/r^2$. This is the gravitational field strength due to a point mass M at distance r.

Q6. What is a geostationary satellite? State its key properties.

Answer: A geostationary satellite orbits Earth at the same angular speed as Earth's rotation. Key properties: (i) Orbital period = 24 hours, (ii) Orbits directly above the Equator, (iii) Direction of orbit: West to East, (iv) Height above surface ≈ 36,000 km. It appears stationary relative to Earth's surface.

Q7. Relate gravitational force to centripetal acceleration for circular orbits.

Answer: For a satellite of mass m in circular orbit of radius r around Earth (mass M): Gravitational force = Centripetal force. $GMm/r^2 = mv^2/r$. Simplifying: $GM/r = v^2$. Therefore orbital speed $v = \sqrt{(GM/r)}$. This shows that orbital speed depends only on M and r, not on satellite's mass.

Q8. Why is g approximately constant near Earth's surface?

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Answer: g = GM/r². At Earth's surface, r = R ≈ 6400 km. For small heights h (where h << R), r changes negligibly: r ≈ R. Therefore g ≈ GM/R² ≈ constant ≈ 9.8 N kg■¹. The percentage change in g is approximately 2h/R, which is very small for everyday heights.

Q9. Define gravitational potential and write its formula.

Answer: Gravitational potential (ϕ) at a point is the work done per unit mass in bringing a small test mass from infinity to that point. Formula: ϕ = -GM/r. The negative sign indicates that work is done by the gravitational field (binding energy). Unit: J kg■¹.

Q10. Explain why gravitational potential is always negative.

Answer: Gravitational potential ϕ = -GM/r is always negative because gravity is an attractive force. Work is done by the gravitational field (not against it) when a mass is brought from infinity to any point. Taking infinity as reference (ϕ = 0), all other points have lower (negative) potential. This negative value represents the bound state of the mass.

Q11. Derive Kepler's Third Law from gravitational and centripetal force.

Answer: For circular orbit: GMm/r² = m(4π²r/T²). Simplifying: GM = 4π²r³/T². Therefore T² = (4π²/GM) × r³, i.e., T² ∝ r³. This is Kepler's Third Law: the square of the time period is proportional to the cube of the orbital radius.

Q12. What is gravitational potential energy of two point masses?

Answer: The gravitational potential energy (E_p) of a system of two point masses M and m separated by distance r is: E_p = -GMm/r. The negative sign indicates a bound system. Work must be done against gravity to separate the masses to infinity (where E_p = 0).

Q13. How does gravitational field strength vary with distance from Earth's centre?

Answer: Inside Earth (r < R): g increases from 0 at centre to maximum at surface, g ∝ r. At surface (r = R): g = GM/R² ≈ 9.8 N kg■¹ (maximum). Outside Earth (r > R): g = GM/r², decreases with increasing r. At r = 2R, g becomes one-quarter of its surface value.

Q14. What is the significance of the negative sign in ϕ = -GM/r?

Answer: The negative sign in ϕ = -GM/r signifies that: (i) Gravitational potential is always less than zero (attractive field), (ii) A mass at infinity (ϕ = 0) has more potential energy than at any finite distance, (iii) Energy must be supplied to a mass to move it from a finite distance to infinity (escape condition), (iv) It indicates a bound gravitational system.

Q15. Compare gravitational potential and gravitational potential energy.

Answer: Gravitational Potential (ϕ): Property of the field at a point; ϕ = -GM/r; unit: J kg■¹; scalar. Gravitational Potential Energy (E_p): Energy of a mass m in the field; E_p = mϕ = -GMm/r; unit: J; scalar. Relationship: E_p = mϕ. Both are negative, indicating bound systems, and both are zero at infinity.

Q16. What are field lines? State their properties for gravitational fields.

Answer: Field lines are imaginary lines used to represent a gravitational field. Properties: (i) They point in the direction of gravitational force on a test mass, (ii) Closer lines indicate stronger field, (iii) They never cross each other, (iv) For a sphere, lines point radially inward, (v) They originate from infinity and end at the mass, (vi) Field line density is proportional to field strength.

Q17. Define escape velocity and derive its expression.

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Answer: Escape velocity is the minimum speed needed for an object to escape Earth's gravitational field. Derivation: At surface, KE + PE = 0 (just escaping). ½mv² - GMm/R = 0. v² = 2GM/R. v_esc = sqrt(2GM/R) = sqrt(2gR). For Earth: v_esc ≈ sqrt(2 × 9.8 × 6.4×10■) ≈ 11.2 km s■¹.

Q18. How do geostationary satellites differ from other satellites?

Answer: Geostationary satellites: Period = 24 hours (same as Earth), orbit above Equator, appear stationary, used for communication/weather. Other satellites (e.g., LEO): Period < 24 hours (e.g., ISS ≈ 90 min), can orbit at any inclination, move across the sky, used for imaging/GPS. The key difference is the matching of orbital period with Earth's rotation period.

Q19. Why is gravitational force considered a fundamental force?

Answer: Gravitational force is fundamental because: (i) It acts between all masses universally, (ii) It cannot be shielded or neutralized, (iii) It has infinite range, (iv) It is always attractive, (v) It governs motion of planets, stars, and galaxies, (vi) It shaped the large-scale structure of the universe. It is the weakest fundamental force but dominant at astronomical scales due to large masses.

Q20. Calculate the gravitational field strength on the surface of a planet of mass M = 6×10²■ kg and radius R = 6.4×10■ m. (G = 6.67×10■¹¹ N m² kg■²)

Answer: Using g = GM/R²: g = (6.67×10■¹¹ × 6×10²■) / (6.4×10■)² g = (4.002×10¹■) / (4.096×10¹³) g = 9.77 ≈ 9.8 N kg■¹ This confirms the gravitational field strength at Earth's surface is approximately 9.8 N kg■¹.

■ *All questions are based on FBISE Class XII Physics SLOs — Domain B: Mechanics (Gravitation)*
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