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NEET PHYSICS ESSENTIALS

GRAVITATION

NEET PHYSICS ESSENTIALS

CONCEPT SUMMARY

KEY CONCEPTS | FORMULAS | RECOGNITION CUES
MISCONCEPTIONS | EXAM TRAPS | QUICK CHECKS

UNDERSTAND THE PHYSICS

RECOGNIZE THE PATTERN

SOLVE WITH CONFIDENCE



SAME PHYSICS.
A HIGHER SCORE.

1. Chapter Introduction

Gravitation describes the attractive interaction between masses. It connects force and field with potential energy, falling bodies, escape, and satellite motion.

2. Chapter in One View

Central idea: Mass creates a gravitational field. That field determines the force on another mass; the potential describes gravitational energy per unit mass; energy conservation helps predict motion.

- Identify the source body and geometry.
- Find the field or potential at the point of interest.
- Choose the correct region: inside, surface, or outside.
- Select the relation for force, energy, escape, or orbit.
- Check distance definitions, assumptions, signs, and units.

3. Must-Know Concepts

- Universal attraction: every mass attracts every other mass; force acts along the line joining their centres.
- Inverse-square law: for point masses, force varies as $1/r^2$.
- Gravitational field: force per unit test mass; a vector directed towards the source.
- Superposition: forces and fields add as vectors; potential adds as a scalar.
- Null point: net gravitational field is zero because field vectors cancel; potential need not be zero.

- Spherical shell: field is zero inside; outside it acts like a point mass at the centre.
- Uniform solid sphere: inside, g ∝ r; outside, $g \propto \frac{1}{r^2}$.
- Potential: scalar potential energy per unit mass, conventionally zero at infinity.
- Potential energy: for two masses; $U = -\frac{GMm}{r}$ work by gravity equals −ΔU.
- Variation of g: decreases with altitude; for a uniform-density Earth model, decreases linearly with depth.
- Escape: minimum speed to reach infinity with zero final speed in the ideal model.
- Satellite orbit: gravity provides centripetal acceleration; circular-orbit relations link radius, speed, period, and energy.
- Kepler: $T^2 \propto a^3$ for an ideal two-body orbit.

4. Formula + Meaning

Newton's law of gravitation

$$F = \frac{Gm_1m_2}{r^2}$$

- Meaning: magnitude of the attractive force between two point masses.
- Use when: two point masses interact, or a spherically symmetric body is observed from outside.
- Condition: r is centre-to-centre separation; for an external point, use the total mass at the centre.

- Do not use blindly when: the point lies inside an extended body or the mass distribution is non-spherical.
- Exam Trap: doubling r makes F one-fourth.

Gravitational field

$g = \frac{F}{m}$ for a point source, $g = \frac{GM}{r^2}$ directed towards M.

- Meaning: force per unit test mass.
- Use when: asked for field, acceleration due to gravity, or force on a mass ($\vec{F}$ = m $\vec{g}$).
- Condition: point source or external point of a spherical body for $\frac{GM}{r^2}$
- Trap: the source field does not depend on the test mass.

Gravitational potential

$V = -\frac{GM}{r}$ with V = 0 at infinity.

- Meaning: gravitational potential energy per unit mass.
- Use when: asked for potential or when comparing energy per unit mass at different positions.
- Condition: point mass or external point of a spherical body; for multiple sources, add potentials algebraically.
- Do not confuse: V is not the same as potential energy U; U = mV.

Variation of gravitational acceleration

Situation	Relation	Condition / Trap
Surface	$g_0 = \frac{GM}{R^2}$	Spherical body assumption.
Altitude h	$g_h = g_0\left(\frac{R}{R+h}\right)^2$	Point at height $h$above surface; use $R + h$as centre distance.
Small altitude	$g_h \approx g_0\left(1 - \frac{2h}{R}\right)$	Valid only for $h \ll R$.
Depth d	$g_d = g_0\left(1 - \frac{d}{R}\right)$	Uniform-density spherical Earth model.
Earth rotation at equator	$g_{\text{eff}} \approx g - \omega^2 R$	Simple surface relation; rotational correction depends on latitude.

RECOGNITION CUE First locate the point: outside, above the surface, or below the surface. The geometry decides which g relation applies

5. Formula Selection Guide

See this situation	Think this model	Use this relation
Two masses and separation	Mutual gravitational force	$F = \frac{Gm_1m_2}{r^2}$
Asked for force on a mass in a known field	Field-to-force relation	$\vec{F} = m\vec{g}$
Several sources; net field	Vector superposition	$\vec{g}_{\text{net}} = \sum \vec{g}_i$
Several sources; potential	Scalar superposition	$V = \sum \left(-\frac{GM_i}{r_i}\right)$
Inside a thin shell	Shell interior	$g = 0;\ V = -\frac{GM}{R}$
Inside a uniform solid sphere	Enclosed mass changes with r	$g = \frac{GMr}{R^3}$
At altitude h	Centre distance $R + h$	$g_h = g_0\left(\frac{R}{R+h}\right)^2$
At depth d	Uniform-density model	$g_d = g_0\left(1 - \frac{d}{R}\right)$

See this situation	Think this model	Use this relation
Escape / maximum height	Energy conservation	$v_e = \sqrt{\frac{2GM}{r}}$
Circular orbit	Gravity supplies centripetal force	$v_o = \sqrt{\frac{GM}{r}}$
Orbital period	Kepler / circular orbit	$T = 2\pi\sqrt{\frac{r^3}{GM}}$
Circular satellite binding energy	Energy needed to unbind orbit	$E_{\text{bind}} = \frac{GMm}{2r}$
Potential versus r graph	Negative radial slope	$g_r = -\frac{dV}{dr}$

6. When to Use / When Not to Use

Field versus potential

- Use field when the question asks for force, acceleration, or a null point.
- Use potential when the question asks for energy per unit mass or potential difference.
- Do not add field magnitudes without directions; do not add potential as a vector.

Shell versus solid sphere

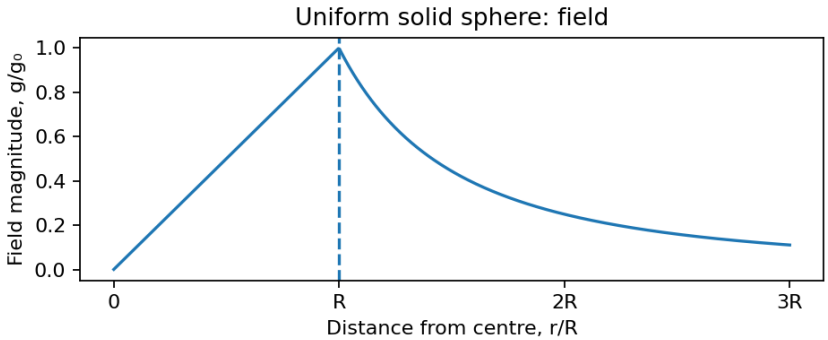
- Use g = 0 inside an ideal uniform thin shell.
- Use $g = \frac{GMr}{R^3}$ inside a uniform solid sphere.
- Do not apply the exterior $\frac{GM}{r^2}$ formula indiscriminately inside a body.

Escape versus circular orbit

- Use escape speed when the target is infinity with zero final speed.
- Use circular-orbit speed when gravity supplies the required centripetal acceleration.
- At the same radius, $v_e = \sqrt{2}v_0$.

7. Key Diagrams / Graphs

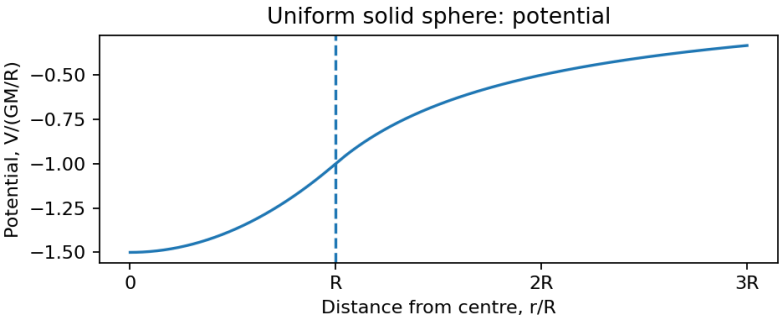
Uniform solid sphere — gravitational field



Notice: Inside, field magnitude rises linearly from zero; outside, it decreases as $1/r^2$.

Exam Use: Choose the inside or outside formula after checking r relative to R.

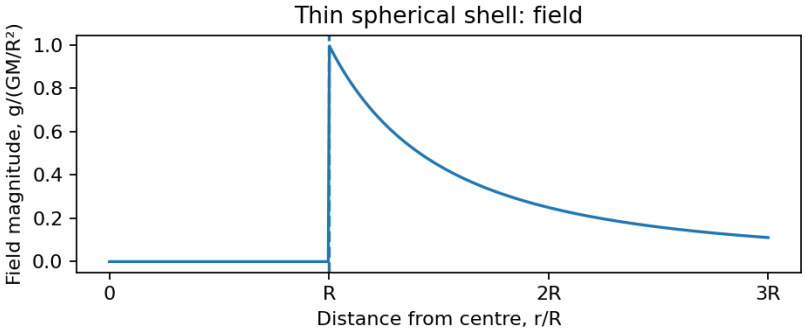
Uniform solid sphere — gravitational potential



Notice: Potential is most negative at the centre, reaches −GM/R at the surface, then approaches zero from below.

Exam Use: Use the correct inside or outside potential expression.

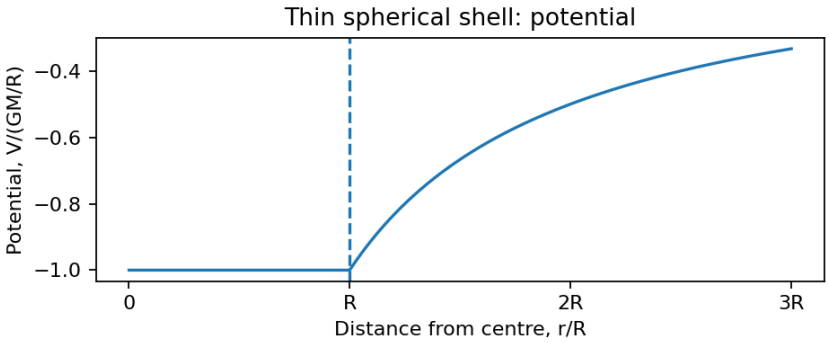
Thin spherical shell — gravitational field



Notice: Field is zero inside and follows the inverse-square relation outside.

Exam Use: Inside the shell, use g = 0 rather than GM/r^2.

Thin spherical shell — gravitational potential



Notice: Potential is constant inside the shell and varies as $-\frac{GM}{r}$ outside.

Exam Use: Zero field inside does not imply zero potential.

8. Must-Know Satellite Formulas

Quantity	Formula	Use / Condition
Circular orbital speed	$v_o = \sqrt{\frac{GM}{r}}$	Circular orbit; $r$measured from centre.
Escape speed	$v_e = \sqrt{\frac{2GM}{r}}$	Ideal escape to infinity; neglect atmosphere and other bodies.
Orbital period	$T = 2\pi\sqrt{\frac{r^3}{GM}}$	Circular orbit; central mass M, radius $r$from centre.
Kepler's third	$T^2 = \frac{4\pi^2 a^3}{GM}$	Ideal two-body orbit; a=

Quantity	Formula	Use / Condition
law		semi-major axis.
Kinetic energy	$K = \frac{GMm}{2r}$	Circular orbit.
Potential energy	$U = -\frac{GMm}{r}$	Satellite; zero at infinity.
Total energy	$E = -\frac{GMm}{2r}$	Bound circular orbit.
Binding energy	$E_{\text{bind}} = \lvert E \rvert = \frac{GMm}{2r}$	Energy required to unbind a circular-orbit satellite.
Elliptical-orbit energy	$E = -\frac{GMm}{2a}$	**Ideal bound two-body orbit; a= semi-major axis.**

BINDING-ENERGY TRAP Binding energy is the positive energy required to unbind a system. Total energy of a bound orbit is negative. Do not use $\frac{GMm}{2r}$ for a general pair of stationary masses; their potential-energy magnitude is GMm/r

Geostationary satellite: circular, equatorial, prograde orbit with period equal to one sidereal day; it appears fixed above one longitude.

Polar satellite: orbit passes near the poles and can cover different latitudes as Earth rotates.

Apparent weightlessness: satellite and contents are in continuous free fall; gravity has not vanished.

9. Common Misconceptions

- Wrong: zero field means zero potential. → Correct: field is a vector; potential is a scalar. → Why: contributions cancel differently.
- Wrong: equal interaction forces mean equal accelerations. → Correct: acceleration depends on net force and mass. → Why: Newton's third-law pairs act on different bodies.
- Wrong: a satellite has no gravity. → Correct: gravity supplies centripetal acceleration. → Why: apparent weightlessness is shared free fall.
- Wrong: orbital radius is altitude. → Correct: r = R+h. → Why: orbital formulas use centre-to-centre distance.

10. Exam Traps

- Using $\frac{GM}{r^2}$ inside a sphere without checking the model.
- Using altitude h instead of centre distance R+h.
- Confusing field g, potential V, and potential energy U.
- Adding vector fields as scalars or potential as a vector.
- Using circular-orbit energy formulas for a non-circular orbit without replacing r by the semi-major axis a where required.

- Confusing total orbital energy (negative) with binding energy (positive).

11. Quick Checks

Q: If separation doubles, what happens to force? → It becomes one-fourth.

Q: What is the field inside a thin uniform spherical shell? → Zero.

Q: Is potential inside a shell zero? → No; it is constant at $-\frac{GM}{R}$

Q: How does g vary inside a uniform solid sphere? → Linearly with distance from the centre.

Q: What radius is used for a satellite at altitude h? → r = R+h.

Q: How are escape speed and circular orbital speed related? → $v_e = \sqrt{2}v_0$ at the same radius.

Q: What does the slope of a V–r graph give? → The radial field with a minus sign.

Q: What is the binding energy of a circular orbit? → $\frac{GMm}{2r}$

Q: When is $g_h = g_0\left(1 - \frac{2h}{R}\right)$ valid? → When h ≪ R.

Q: What condition is needed for $g_d = g_0\left(1 - \frac{d}{R}\right)$?→ Uniform-density spherical-body model.

12. Mini Exam Reasoning

Clue: A satellite moves in a circular orbit at altitude h.

→ Physics situation: circular motion under gravity.

→ Model: r = R+h; gravity supplies centripetal force.

→ Relation: $\frac{GMm}{r^2} = \frac{mv^2}{r}, so\ v = \sqrt{\frac{GM}{r}}$

→ Check: satellite mass cancels; use centre-to-centre radius.

Clue: A point lies inside a uniform thin spherical shell.

→ Physics situation: shell interior.

→ Model: spherical symmetry.

→ Relation: g = 0, $V = -\frac{GM}{R}$

→ Check: zero field, non-zero constant potential.

13. One-Minute Recall

- Force: $F = Gm_1m_2/r^2$; attractive and inverse-square.
- Field: vector; force per unit mass; directed towards the source.
- Potential: scalar; energy per unit mass; zero at infinity by convention.
- Outside a spherical body: use total mass at the centre.
- Inside a shell: g = 0 but $V = -\frac{GM}{R}$
- Inside a uniform solid sphere: $g \propto r$.
- Altitude: use R+h; depth formula assumes uniform density.
- Escape speed: $\sqrt{(2GM/r)}$; circular speed: $\sqrt{\frac{GM}{r}}$
- Circular period: $T = 2\pi\sqrt{\frac{r^3}{GM}}$
- Circular-orbit total energy = $-\frac{GMm}{2r}$; binding energy = $+\frac{GMm}{2r}$.

- Before applying a formula, check geometry, region, distance, and assumptions.

14. Complete Formula List — Application Conditions

Reference symbols: M= attracting/source mass; m= test/satellite mass; R= body radius; r= centre-to-centre distance; h= altitude; d= depth; a= semi-major axis; G= universal gravitational constant. Potentials/energies use zero at infinity unless stated.

Quantity	Formula	Conditions of Application
Force	$F = \frac{Gm_1m_2}{r^2}$	Point masses or external point of spherical body; magnitude; $r$is centre separation.
Net force	$\vec{F}_{\text{net}} = \sum \vec{F}_i$	Several sources; vector sum.
Field definition	$\vec{g} = \frac{\vec{F}}{m};\ \vec{F} = m\vec{g}$	Force per unit test mass; keep vector direction.
Point/exterior field	$g = \frac{GM}{r^2}$	Point mass or outside spherical body.
Net field	$\vec{g}_{\text{net}} = \sum \vec{g}_i$	Several sources; vector sum; null point means net field zero.

Quantity	Formula	Conditions of Application
Thin shell, outside	$g = \frac{GM}{r^2}$	$r \geq R$.
Thin shell, inside	$g = 0$	$r < R$; ideal uniform shell.
Uniform solid sphere, outside	$g = \frac{GM}{r^2}$	$r \geq R$.
Uniform solid sphere, inside	$g = \frac{GMr}{R^3}$	$r < R$; uniform density.
Surface gravity	$g_0 = \frac{GM}{R^2}$	Spherical body at its surface.
Altitude	$g_h = \frac{GM}{(R+h)^2} = g_0\left(\frac{R}{R+h}\right)^2$	$h$above surface; external point.
Small altitude	$g_h \approx g_0\left(1 - \frac{2h}{R}\right)$	Only $h \ll R$.
Depth	$g_d = g_0\left(1 - \frac{d}{R}\right)$	Uniform-density spherical-body model.
Effective gravity at equator	$g_{\text{eff}} \approx g - \omega^2 R$	Simple surface relation; rotation included.

Quantity	Formula	Conditions of Application
Point/exterior potential	$V = -\frac{GM}{r}$	Zero potential at infinity.
Shell potential, outside	$V = -\frac{GM}{r}$	$r \geq R$.
Potential, inside	$V = -\frac{GM}{R}$	$r < R$; constant.
Uniform solid sphere potential, outside	$V = -\frac{GM}{r}$	$r \geq R$.
Uniform solid sphere potential, inside	$V = -\frac{GM(3R^2 - r^2)}{2R^3}$	$r < R$; uniform density.
Potential superposition	$V = \sum \left(-\frac{GM_i}{r_i}\right)$	Scalar algebraic sum.
Field–potential relation	$g_r = -\frac{dV}{dr}$	Radial coordinate and consistent sign convention.
Two-mass potential energy	$U = -\frac{GMm}{r}$	Two point masses; zero at infinite separation.
Potential-energy	$\Delta U = m\Delta V$	Test mass $m$in a

Quantity	Formula	Conditions of Application
change		gravitational potential.
Near-surface energy change	$\Delta U \approx mg\Delta h$	Small height range where $g$is nearly constant.
Work by gravity	$W_g = -\Delta U$	Conservative gravitational force.
Circular orbital speed	$v_o = \sqrt{\frac{GM}{r}}$	Circular orbit; gravity provides centripetal force.
Escape speed	$v_e = \sqrt{\frac{2GM}{r}}$	Ideal escape to infinity with zero final speed; neglect atmosphere/other bodies.
Surface escape speed	$v_e = \sqrt{2g_0R}$	From surface.
Speed relation	$v_e = \sqrt{2}\, v_o$	Same radius.
Circular orbital period	$T = 2\pi\sqrt{\frac{r^3}{GM}}$	Circular orbit; $r$from centre.
Kepler's third law	$T^2 = \frac{4\pi^2 a^3}{GM}$	Ideal two-body orbit; $a$semi-major axis.

Quantity	Formula	Conditions of Application
Circular orbit kinetic energy	$K = \frac{GMm}{2r}$	Circular bound orbit.
Circular orbit potential energy	$U = -\frac{GMm}{r}$	Circular orbit; zero at infinity.
total energy	$E = -\frac{GMm}{2r}$	Circular bound orbit.
Circular orbit binding energy	$E_{\text{bind}} = \frac{GMm}{2r} = \lvert E \rvert$	Energy needed to unbind circular orbit.
Elliptical orbit total energy	$E = -\frac{GMm}{2a}$	Ideal bound two-body orbit; $a$semi-major axis.
Energy to separate stationary pair	$E_{\text{required}} = \frac{GMm}{r}$	Initial kinetic energy zero; separate to infinity.
Radial launch maximum distance	$\frac{1}{r_{\max}} = \frac{1}{R} - \frac{u^2}{2GM}$	Radial launch from surface at speed $u$below escape speed.
Circular satellite acceleration	$a = \frac{GM}{r^2} = \frac{v^2}{r}$	Circular orbit.
Geostationary	$T =$one sidereal	Appears fixed over one

Quantity	Formula	Conditions of Application
orbit	day; equatorial, prograde, circular	longitude.
Newton's third law	Interaction forces equal and opposite	Force pair acts on different bodies; accelerations need not match.

15. Formula-Selection Boundary Check

Check	Question to Ask
Geometry	Point mass, shell, uniform solid sphere, or another body?
Region	Inside, surface, or outside?
Distance	Is $r$measured from the centre? Is $h$altitude and $d$depth?
Quantity	Force, field, potential, potential energy, speed, period, or binding energy?
Vector / Scalar	Do I need direction (vector sum) or signed scalar addition?

Check	Question to Ask
Reference	Is zero potential/energy taken at infinity?
Assumptions	Uniform density, circular orbit, small altitude, ideal escape?
Final check	Are units, sign, direction, and limiting behaviour sensible?

Go Deeper with the Complete NEET Physics Essentials Books

This summary supports rapid recall and formula selection. The complete Concept Book provides fuller concept development, step-by-step derivations, detailed diagrams, microquestions, solved examples and integrated problem-solving. The MCQ Practice Book provides extended NEET-level practice.

COMPLETE CONCEPT BOOK

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