

Gravitational fields

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

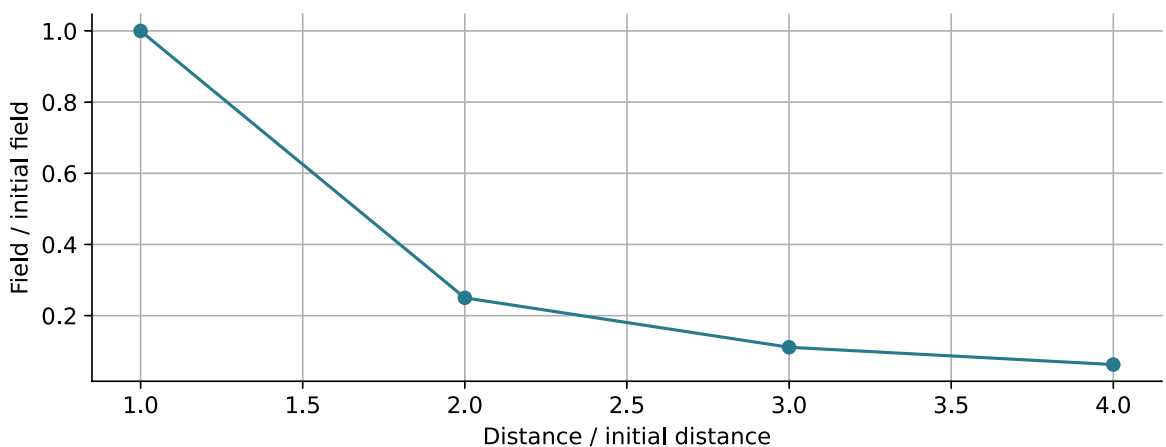
Gravitational fields and orbital motion

■ What would explain this observation?

- An orbiting satellite is continuously falling while moving sideways. Being in orbit does not require gravity to vanish.
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■ Build the model

- **Gravitational field** strength is force per unit mass.
- A gravitational force can provide the **centripetal force** for a circular orbit.
- Field and potential describe different quantities.
- gravitational field: A description of gravitational force per unit mass.
- centripetal force: Net force toward the centre of a curved path.



Inverse square: double the distance and the field falls to a quarter

■ Choose evidence that can test it

- For a point mass or outside a spherical mass, field strength follows an inverse-square distance dependence.
- Use distance from the centre, not height above the surface alone.

In the lab: State the circular-orbit approximation and ignore atmospheric drag only when justified. Draw the force toward the central body and velocity tangential to the orbit. Do not add an outward force merely because the path is circular.

■ Work from known quantities

- Known: field strength is 8 units at distance r from a spherical source.
- At $2r$, $g_2/g_1 = (r/2r)^2 = 1/4$. $g_2 = 8/4 = 2$ units.
- The gravitational force on a fixed test mass decreases in the same ratio.

Your turn: Field strength is 18 units at r . Find it at $3r$ for an inverse-square field.

■ Check the conclusion and its limits

- Weightlessness in an orbiting spacecraft means apparent weight is small in free fall, not that there is no gravitational field.

Not true: Gravity is zero everywhere a spacecraft experiences apparent weightlessness. An orbiting spacecraft is in free fall: gravity is nearly as strong there as on the ground and supplies the centripetal force. Crew and craft fall together, so nothing presses them down - that is apparent weightlessness, not zero gravity.

Key:

- Gravitational field strength is force per unit mass.
- For a point mass or outside a spherical mass, field strength follows an inverse-square distance dependence.
- Watch for: weightlessness in an orbiting spacecraft means apparent weight is small in free fall, not that there is no gravitational field.

■ Write from a field strength of 8 units

- An inverse-square field has strength 72 units at distance r .
- Find the strength at $3r$. Apparent weightlessness in orbit is not zero gravity.

■ Write from a tripling

- The field strength is 12 units at distance r from a spherical source.
- At $3r$: $g = 12 \div 9 \approx 1.3$ units – inverse-SQUARE, so a tripled distance divides by nine, not three.

■ **Write from a faster inner orbit**

- Two circular orbits, one at half the radius of the other.
- $v^2 = GM/r$, so the inner satellite moves FASTER – gravity must supply more centripetal force closer in.

■ **Write from a weight on Mars**

- Surface gravity on Mars is about 3.7 N kg^{-1} ; an astronaut has mass 60 kg.
- Weight there = $60 \times 3.7 = 222 \text{ N}$, against $60 \times 9.8 \approx 588 \text{ N}$ on Earth – MASS is constant, weight is local.