

16.1 Gravitational fields and orbital motion

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS gravitational field • centripetal force

Objective

Gravitational fields and orbital motion. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

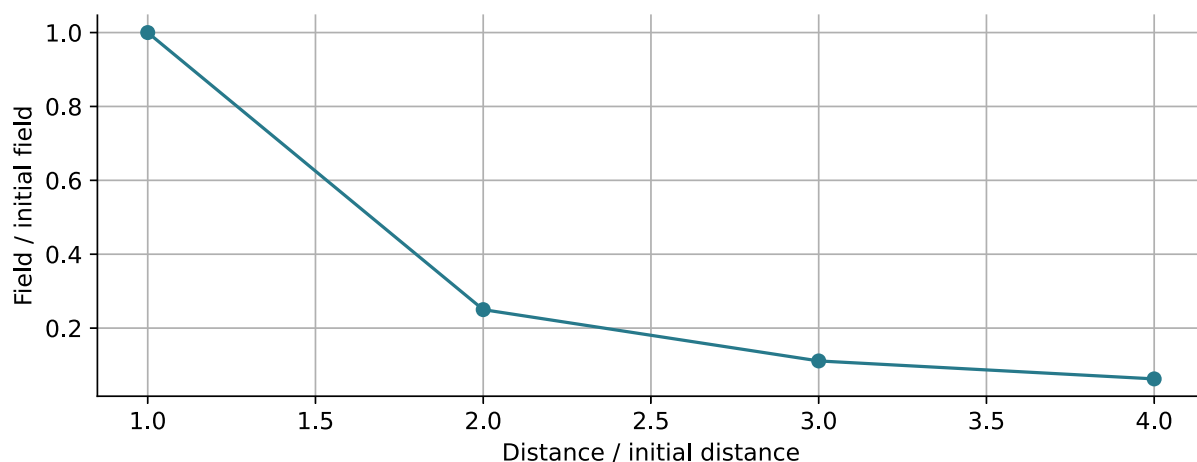
1 Key knowledge and worked examples

■ What would explain this observation?

- An orbiting satellite is continuously falling while moving sideways. Being in orbit does not require gravity to vanish.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ 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.



■ **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.
- 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**

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

Field strength is 18 units at r . Find it at $3r$ for an inverse-square field. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ **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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Gravity is zero everywhere a spacecraft experiences apparent weightlessness. This claim is false: Weightlessness in an orbiting spacecraft means apparent weight is small in free fall, not that there is no gravitational field.

Key:

Gravitational fields and orbital motion: 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.

2 Practice

2.1 What direction is the net force in uniform circular motion? Choose one answer.

- **A** Toward the centre
- **B** Along the velocity
- **C** Always outward

[1]

2.2 Field strength is 18 units at r . Find it at $3r$ for an inverse-square field. Show the relation, substitution and units.

[2]

2.3 Decide whether this claim is true and justify: Gravity is zero everywhere a spacecraft experiences apparent weightlessness.

[2]

2.4 A description of gravitational force per unit mass: write the technical term.

[1]

3 Exam-style questions

3.1 A spherical source produces field 12 units at r . At $2r$ the test mass is doubled. Compare field and force with the original case. [4]

Solutions

2.1 A 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.

2.2 Inverse-square field at $3r=18/3^2=2$ units.

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

2.4 gravitational field. gravitational field means A description of gravitational force per unit mass.

3.1 Field becomes 3 units, one quarter; force becomes one half because test mass doubles. Field is independent of test mass; the inverse-square model applies outside the spherical source.