A-LEVEL PHYSICS • EXERCISE SHEET

13.3 Gravitational field of a point mass

Name: ____________ Class: ________ Date: __________ **Total: 14 marks**

Objective

Build the skills to answer exam questions on the **gravitational field of a point mass** —the equation $g = GM/r^2$.

You must be able to:

- derive and use $g = \dfrac{GM}{r^2}$
- describe how g varies with distance
- explain why g is nearly constant near the Earth's surface

1 Worked examples

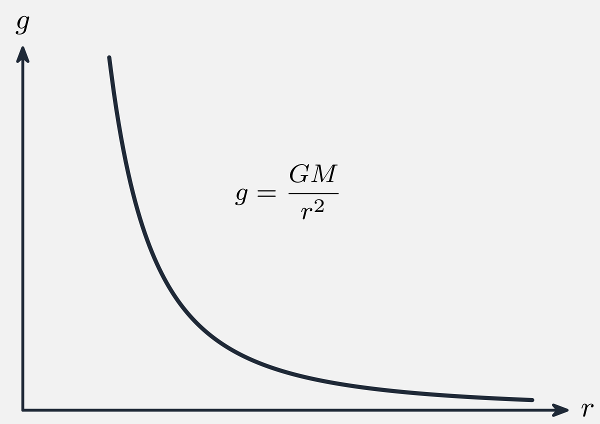
Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

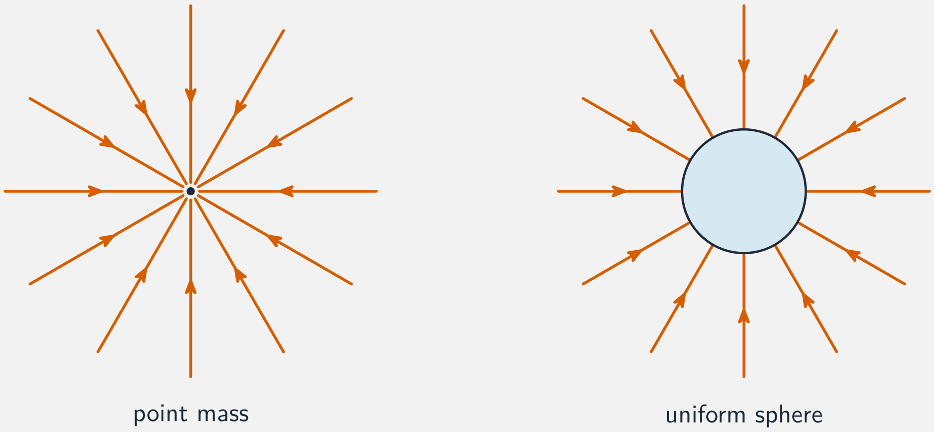
■ **Field of a point mass**

Put $F = \dfrac{GMm}{r^2}$ into $g = F/m$:

$$g = \frac{GM}{r^2}.$$

So g falls off as an **inverse square** of distance:





Field lines around a point mass

■ **Nearly constant near the surface**

Rising a height $h \ll R$ changes r from R to $R+h$, but $(R+h)/R \approx 1$, so g barely changes —it is effectively constant in a lab.

2 Practice

Now apply the methods above.

2.1 Write the equation for the gravitational field strength g due to a point mass. [1]

2.2 State how g varies with distance r from a point mass. [1]

2.3 At the Earth's surface $g = 9.8\ \text{N kg}^{-1}$. Find g at a distance of $2R$ from the centre (a height R above the surface). [2]

2.4 Explain why g is **nearly constant** near the Earth's surface. [1]

3 Exam-style questions

3.1 At **twice** the distance from a point mass, g becomes: [1]

- **A** twice as large
- **B** half as large
- **C** one quarter as large
- **D** four times as large

3.2 The Moon has mass 7.3×10^{22} kg and radius 1.7×10^{6} m. Calculate g at its surface. ($G = 6.67 \times 10^{-11}$.) [3]

3.3 Derive $g = \dfrac{GM}{r^2}$ from Newton's law of gravitation and $g = F/m$. [2]

3.4 A planet has the same mass as Earth but **twice** the radius. State its surface g as a fraction of Earth's. [1]

3.5 On the axes, **sketch** how the gravitational field strength g of a planet varies with distance r from its centre, for r from the surface ($r = R$) out to $r = 4R$. Mark the surface value g_0. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **13.3 Gravitational field of a point mass** past-paper sheet in the Library, or try these in **Practice**

mode:

- 9702/41 N25 —Q3 ($g = GM/r^2$, derivation)
- 9702/43 N25 —Q3 (field strength)
- 9702/43 J25 —Q1 (g and field lines)
- 9702/44 J25 —Q1 (gravitational field, structured)

Solutions

2.1 $g = \dfrac{GM}{r^2}$.

2.2 $g \propto \dfrac{1}{r^2}$ (inverse-square).

2.3 At $2R$, g is $\dfrac{1}{2^2} = \dfrac{1}{4}$ of the surface value: $g = 9.8/4 = 2.45\ \mathrm{N\ kg^{-1}}$.

2.4 A small height change is **tiny compared with the Earth's radius**, so r (and hence $g \propto 1/r^2$) barely changes.

3.1 **C** —one quarter.

3.2 $g = \dfrac{GM}{R^2} = \dfrac{(6.67 \times 10^{-11})(7.3 \times 10^{22})}{(1.7 \times 10^6)^2} = 1.7\ \mathrm{N\ kg^{-1}}$.

3.3 Force on a test mass m: $F = \dfrac{GMm}{r^2}$; field strength $g = \dfrac{F}{m} = \dfrac{GM}{r^2}$.

3.4 $\dfrac{1}{4}$ of Earth's (since $g \propto 1/R^2$).

3.5 A curve **starting at** g_0 at $r = R$ and **falling** as an inverse square —to $g_0/4$ at $2R$, $g_0/9$ at $3R$, $g_0/16$ at $4R$ —approaching (but never reaching) zero.