| Name | Date started | Target end date |
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GCE A LEVEL — GRAVITATIONAL FIELDS QUESTION PACK

Legacy PH4 · New spec Unit 4 Topic 3 · A2 unit, 25% of A-level

REVISE

.wales

# PHYSICS — UNIT 4 · GRAVITATIONAL FIELDS

## *U4.3 Gravitational fields of force — Newton's law of gravitation, field strength & potential*

*Newton's law of gravitation $F = GMm/r^2$, gravitational field strength $g = GM/r^2$, gravitational potential $V_g = -GM/r$, potential energy, conservation of energy in launches off planetary surfaces, and escape velocity.*

NEW 2015 SPEC · UNIT 4 TOPIC 3

### Estimated time for entire question pack: ~1 h 10 min

*Derived from the legacy PH4 paper's pace of ~1.3 min/mark (80 marks in 1¾ hours).*

*You are advised to **not** attempt to complete all of this in one sitting.*

### ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every gravitational fields question from the legacy WJEC PH4 papers (2008 modular spec) that maps onto new-spec Unit 4 Topic 3.

Questions are ordered chronologically.

### INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

*The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.*



*For Examiner's use only*

| Q | Source | Max | Mark |
| --- | --- | --- | --- |
| 1 | Jun 14 Q5 | 10 | |
| 2 | Jan 14 Q5 | 11 | |
| 3 | Jun 16 Q5 | 11 | |

| Q | Source | Max | Mark |
| --- | --- | --- | --- |
| 4 | Jan 10 Q5 | 11 | |
| 5 | Jun 10 Q6 | 11 | |
| | | | |
| **Total** | | **54** | |

# Gravitational Fields — what the new spec asks

WJEC GCE A Level Physics (from 2015) · Unit 4: Fields & Options · Topic 4.3.

### Newton's law of gravitation A

- Force between two point masses: $F = GMm/r^2$ (always attractive).
- $G = 6.67 \times 10^{-11}$ N m² kg⁻².
- Same inverse-square structure as Coulomb's law.

### Gravitational field strength A

- $g = F/m$ — force per unit mass; vector field, points towards source.
- Point/spherical mass: $g = GM/r^2$ (radially inward).
- At Earth's surface $g \approx 9.81$ m $s^{-2}$; varies with altitude.

### Gravitational potential A

- $V_g = W/m$ — work done per unit mass bringing mass from infinity.
- Point/spherical mass: $V_g = -GM/r$ (always negative).
- $V_g \to 0$ at infinity; work done moving mass: $W = m\Delta V_g$.

### Gravitational PE & conservation A

- $U = mV_g = -GMm/r$ — energy required to separate masses to infinity.
- Total energy in orbit: $E = \frac{1}{2}mv^2 - GMm/r$.
- Conservation of energy in vertical launches off planetary surfaces.

### Escape velocity A

- $v_{esc} = \sqrt{2GM/R}$ at the surface of a body of mass M, radius R.
- Independent of the mass of the escaping object.
- Earth: $v_{esc} \approx 11.2$ km $s^{-1}$.

### Equipotentials & field lines A

- Field lines radially inward to source mass.
- Equipotentials are surfaces of constant $V_g$ — concentric spheres.
- No work done moving along an equipotential.

# Gravitational Fields in one page

Quick-reference notes — revisit before each section.

### Newton's law

$F = GMm/r^2$ (attractive between two point masses).

$G = 6.67 \times 10^{-11}$ N m² kg⁻².

Spherical bodies act as if mass concentrated at centre.

### g field

$g = F/m$ (m $s^{-2}$ or N $kg^{-1}$), vector inward to source.

Point/spherical mass: $g = GM/r^2$.

At Earth's surface: $g \approx 9.81$ m $s^{-2}$.

### Gravitational potential Vg

$V_g = -GM/r$ (always negative).

Work done bringing mass m from infinity: $W = mV_g$.

Between two points: $W = m(V_{g,B} - V_{g,A})$.

### Gravitational PE

$U = -GMm/r$ (negative because bound).

Total energy in orbit: $E = \frac{1}{2}mv^2 - GMm/r$.

For circular orbit: KE = −E, PE = 2E.

### Escape velocity

$\frac{1}{2}mv_{esc}^2 = GMm/R \rightarrow v_{esc} = \sqrt{2GM/R}$.

Independent of escaping mass.

Earth: ~11.2 km $s^{-1}$; Moon: ~2.4 km $s^{-1}$.

### Strategy

1. Identify spherical symmetry — point-mass formulae apply.
2. Use $g = GM/r^2$ for force, $V_g = -GM/r$ for energy.
3. Conservation: $KE_{initial} + PE_{initial} = KE_{final} + PE_{final}$.
4. Watch sign of Vg always.

# Section index

All questions in this pack — chronological order by source paper.

Examiner only

**5.** *(a)* Define:

(i) the gravitational field strength at a point; [1]

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(ii) the gravitational potential at a point. [1]

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*(b)* Charon is the moon of Pluto; it has a mass of $1.5 \times 10^{21}$ kg and its radius is 600 km.

(i) Calculate the gravitational force exerted by Charon on an object of mass 82 kg on its surface. [2]

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(ii) Calculate the gravitational potential energy of the 82 kg mass on Charon's surface (you may ignore Pluto). [2]

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Examiner only

*(c)* Pluto has a mass of $1.3 \times 10^{22}$ kg and radius of 1150 km. Calculate the potential energy of the 82 kg mass if it were on the surface of Pluto (you may ignore Charon). [2]

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*(d)* The 82 kg mass is fired from Charon's surface to Pluto. Neglecting any losses due to resistive forces, calculate the change in kinetic energy of the 82 kg mass from the instant it was fired to the instant just before it collides with Pluto. [2]

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Examiner only

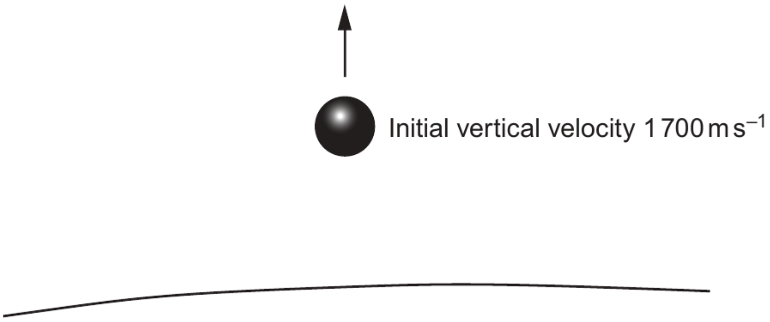
**5.** *(a)* The mass of the planet Mercury is $3.30 \times 10^{23}$ kg and its radius is 2440 km.

(i) Calculate the gravitational field strength on the surface of Mercury. [2]

(ii) Calculate the gravitational potential on the surface of Mercury. [2]

(iii) Explain briefly why the potential is negative. [1]

*(b)* A projectile of mass 0.454 kg is fired upwards from Mercury's surface with an initial vertical velocity of 1 700 m $s^{-1}$.




(i) Calculate the total energy of the projectile as it is being launched. [3]

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(ii) Use the principle of conservation of energy to calculate the maximum height that the projectile reaches (Mercury has no atmosphere so that air resistance is negligible). [3]

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Examiner only

**5.** The mass of the Moon is $7.34 \times 10^{22}$ kg and its mean radius is $1.74 \times 10^{6}$ m.

*(a)* Calculate the gravitational field strength at the surface of the Moon. [2]

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*(b)* A mass, $m$, is fired vertically from the surface of the Moon at a speed of $400\,\mathrm{m\,s^{-1}}$. Show that the greatest height above the surface reached by the mass is 51 km. (Hint: use the conservation of energy and $V_g = \frac{-GM}{r}$) [4]

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*(c)* In many applications an approximate value for the height reached by an object is obtained by neglecting the variation in the gravitational field strength with height. Determine the value for the height reached by the object in part *(b)* assuming a gravitational field strength equal to that at the surface of the Moon. [2]

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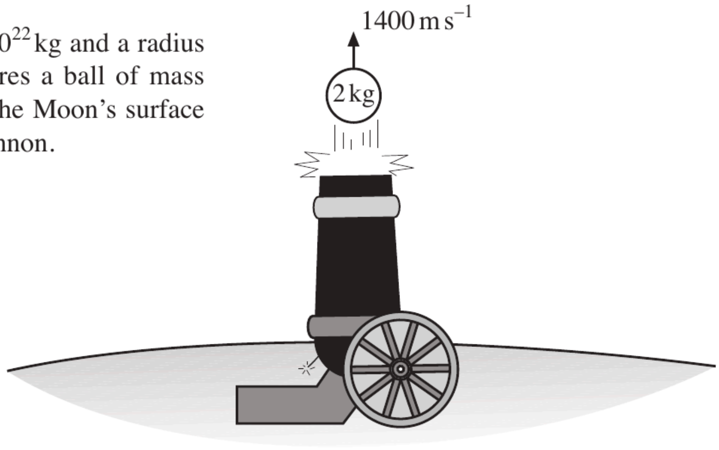
*(d)* Hence determine the difference in the heights obtained in parts *(b)* and *(c)* as a percentage of the height given in part *(b)*. [2]

*(e)* Discuss whether the use of the approximation in part *(c)* is appropriate in this case. [1]

**5.** The moon has a mass of $7{\cdot}35 \times 10^{22}$ kg and a radius of $1{\cdot}74 \times 10^{6}$ m. An astronaut fires a ball of mass 2·00 kg vertically upwards from the Moon's surface at a speed of $1400\,\mathrm{m\,s^{-1}}$ from a cannon.




*(a)* (i) Calculate the gravitational field strength at the surface of the Moon. [2]

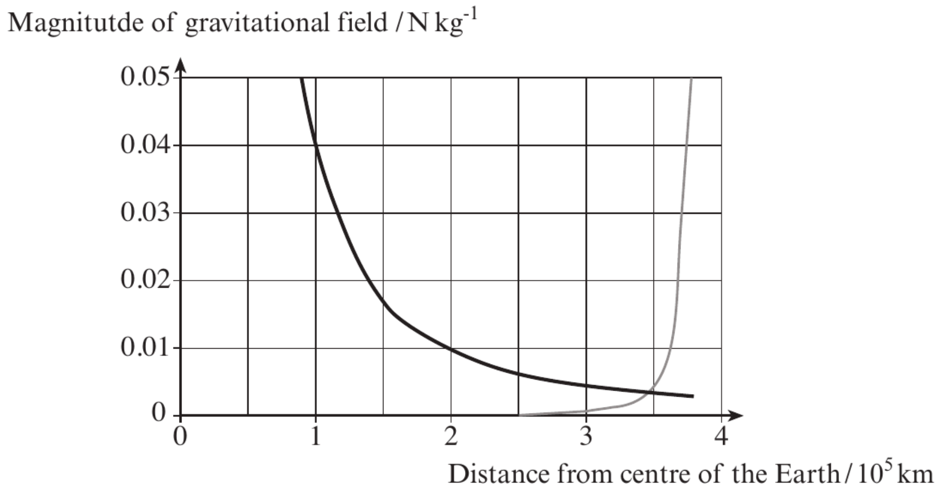
(ii) Calculate the weight of the cannon ball on the Moon's surface. [2]

*(b)* (i) Calculate the initial kinetic energy of the cannon ball. [1]

(ii) Show that the initial gravitational potential energy of the cannon ball is –5·6 MJ. [2]

(iii) Apply the principle of conservation of energy to the cannon ball and calculate the greatest height that the cannon ball reaches above the surface of the Moon. [4]

**6.** The graph below shows the **magnitudes** of the gravitational fields of the Earth (thick curve) and of the Moon (thin curve) along the line connecting the centre of the Earth to the centre of the Moon. Fields in excess of $0.05\ \text{N kg}^{-1}$ are beyond the scale of the graph and are not plotted.




*(a)* Show by calculation that the gravitational field due to the Earth at a distance $1.0 \times 10^5$ km agrees with the graph. (Mass of the Earth = $6.0 \times 10^{24}$ kg).

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[3]

*(b)* Explain why the Moon's gravitational field near the Earth is significantly less than the Earth's field near the Moon.

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[1]

*(c)* Estimate the distance of the point of intersection of the two curves from the centre of the Earth. Explain the significance of this point of intersection.

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[2]

*(d)* A spacecraft is launched directly **towards the Earth** from the equator of the Moon. Discuss the forces due to gravity that it experiences during its journey to Earth, mentioning their relative magnitudes.

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[3]

*(e)* A second spacecraft is launched on the far-side of the Moon so that it travels directly away from the Earth. Would it require more or less energy than the first spacecraft to escape from the Moon? Explain your answer.

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[2]

## END OF QUESTION PACK

5 questions · 54 marks · ~1 h 10 min

Source: WJEC PH4 (2008 modular spec)

Curated for WJEC Physics 2015 spec A2 Unit 4 — Topic 3