

Exercise walk-through

5.7

Gravitational fields and orbits (154–160)

Pearson Edexcel · International A-Level · Physics

CP15: attenuation is a thickness law

Action	Why it matters
Fix geometry and count time	Source contribution must be comparable across thicknesses.
Measure and subtract background	Background does not follow the absorber transmission law.
Repeat; plot log corrected rate versus lead thickness	Test exponential attenuation. Avoid near-background readings with large relative uncertainty.

Use the evidence

Three half-value thicknesses transmit $1/8$. Follow supervised source handling and shielding.

Evidence does not settle every cosmic prediction

Evidence

Expansion supports an earlier hotter, denser universe.

Gravitational effects unexplained by visible matter motivate dark matter.

Inference and uncertainty

Age and fate depend on expansion history and matter content; modern models include dark energy.

One value of H_0 does not by itself prove perpetual expansion or future collapse.

Use the documents in their learning order

Reference: learn the complete knowledge, methods and assumptions.



Skill sheet: supported practice → reduced support → exam-style demands.



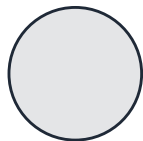
Authentic set: transfer to original wording; correct with reasons.



Return to the reference for a diagnosed gap; reattempt before using reserved assessment questions.

Exercise 2.1

2.1 A spherical planet has mass 8.0×10^{23} kg and radius 2.0×10^6 m. Find surface field strength using $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$. State its direction. [3]

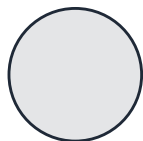


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$$R = 2.0 \times 10^6 \text{ m}$$

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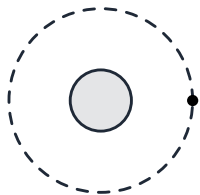
2.1 Divide Newtonian force by test mass.

$$g = \frac{GM}{R^2} = \frac{(6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2})(8.0 \times 10^{23} \text{ kg})}{(2.0 \times 10^6 \text{ m})^2} = 13.3 \text{ N kg}^{-1}$$

Value; radially inward.

Exercise 2.2

2.2 Gravitational potential at radius 3.0×10^7 m is -1.2×10^7 J kg⁻¹. Find the source mass and explain the negative sign. Use G from 2.1. [4]

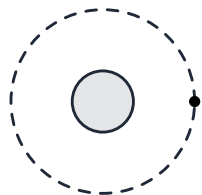


$$r = 3.0 \times 10^7 \text{ m}$$

$$V = -1.2 \times 10^7 \text{ J/kg}$$

Exercise 2.2

2.2 Gravitational potential at radius $3.0 \times 10^7 \text{ m}$ is $-1.2 \times 10^7 \text{ J kg}^{-1}$. Find the source mass and explain the negative sign. Use G from 2.1. [4]



$$r = 3.0 \times 10^7 \text{ m}$$

$$V = -1.2 \times 10^7 \text{ J/kg}$$

2.2 Potential uses zero at infinity.

$$M = -\frac{Vr}{G} = -\frac{(-1.2 \times 10^7 \text{ J kg}^{-1})(3.0 \times 10^7 \text{ m})}{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}} = 5.40 \times 10^{24} \text{ kg}$$

Mass. Positive work is needed to take a unit mass to infinity; its finite-radius potential is below the chosen zero.

Exercise 2.3

2.3 Compare gravitational and electric fields of isolated point sources: inverse-square dependence, source property, force directions and potential scalar/vector character. [4]

gravitational field

electric field

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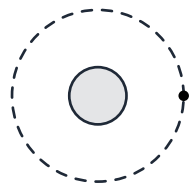
gravitational field

electric field

2.3 Both force magnitudes vary as inverse square outside a point/spherical source. Gravity acts on mass; electric interaction on charge. Gravity attracts, whereas charges may attract or repel and electric field direction is for a positive test charge. Both field strengths are vectors and both potentials scalars.

Exercise 3.1

3.1 A 500 kg probe moves from radius 6.0×10^6 to 1.8×10^7 m around a planet with $GM = 3.6 \times 10^{14} \text{ m}^3 \text{ s}^{-2}$. Find the signed change in potential energy. Explain why constant surface g is unsuitable and why your result alone is not total launch energy. [5]



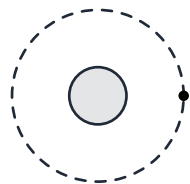
$$m = 500 \text{ kg}$$

$$r_1 = 6.0 \times 10^6 \text{ m}$$

$$r_2 = 1.8 \times 10^7 \text{ m}$$

Exercise 3.1

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$$\begin{aligned} m &= 500 \text{ kg} \\ r_1 &= 6.0 \times 10^6 \text{ m} \\ r_2 &= 1.8 \times 10^7 \text{ m} \end{aligned}$$

3.1 Use final minus initial radial potential energy.

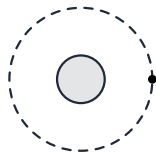
$$\Delta E = GMm \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

$$\Delta E = (3.6 \times 10^{14} \text{ m}^3 \text{ s}^{-2})(500 \text{ kg}) \left(\frac{1}{6.0 \times 10^6 \text{ m}} - \frac{1}{1.8 \times 10^7 \text{ m}} \right) = +2.00 \times 10^{10} \text{ J}$$

Magnitude, positive increase. Field varies substantially over this radial interval. Launch can also change kinetic energy and involve losses.

Exercise 3.2

3.2 Derive the circular-orbit period equation from Newton's law and centripetal force. A satellite has orbital radius 2.4×10^7 m and period 4.0×10^4 s. Calculate planet mass using G from 2.1. [5]

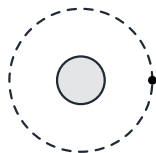


$$r = 2.4 \times 10^7 \text{ m}$$

$$T = 4.0 \times 10^4 \text{ s}$$

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$$r = 2.4 \times 10^7 \text{ m}$$

$$T = 4.0 \times 10^4 \text{ s}$$

3.2 Set gravity equal to inward resultant.

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \quad v = \frac{2\pi r}{T}$$

Eliminate v and cancel orbiting mass.

$$T^2 = \frac{4\pi^2 r^3}{GM} \quad M = \frac{4\pi^2 r^3}{GT^2}$$

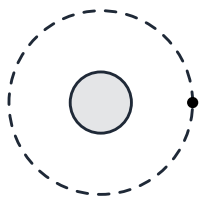
Derivation.

$$M = \frac{4\pi^2 r^3}{GT^2} = \frac{4\pi^2 (2.4 \times 10^7 \text{ m})^3}{(6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2})(4.0 \times 10^4 \text{ s})^2} = 5.11 \times 10^{24} \text{ kg}$$

Substitution and result.

Exercise 3.3

3.3 A planet rotates every 5.0×10^4 s and has $GM = 8.0 \times 10^{13} \text{ m}^3 \text{ s}^{-2}$, radius 3.0×10^6 m. Find the height of a stationary satellite. State all geometric/directional conditions and explain why an inclined orbit of the same period fails. [7]

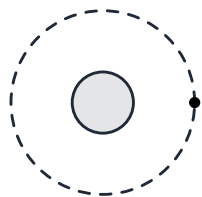


$$T = 5.0 \times 10^4 \text{ s}$$

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$$T = 5.0 \times 10^4 \text{ s}$$

$$R = 3.0 \times 10^6 \text{ m}$$

3.3 Match rotation period and solve the orbit equation.

$$r = \left(\frac{GMT^2}{4\pi^2} \right)^{1/3} = \left[\frac{(8.0 \times 10^{13} \text{ m}^3 \text{ s}^{-2})(5.0 \times 10^4 \text{ s})^2}{4\pi^2} \right]^{1/3} = 1.72 \times 10^7 \text{ m}$$

Radius.

$$h = r - R = (1.7175 \times 10^7 - 3.0 \times 10^6) \text{ m} = 1.42 \times 10^7 \text{ m}$$