A LEVEL PHYSICS

WORKED SOLUTIONS

7.2. Gravitational Fields MCQ

1. The distance between the Sun and the Earth is 1.5×10^{11} m

What is the gravitational force exerted on the Sun by the Earth?

- **A** 3.5×10^{22} N ☒
- **B** 1.7×10^{26} N ☐
- **C** 5.3×10^{33} N ☐
- **D** 8.9×10^{50} N ☐

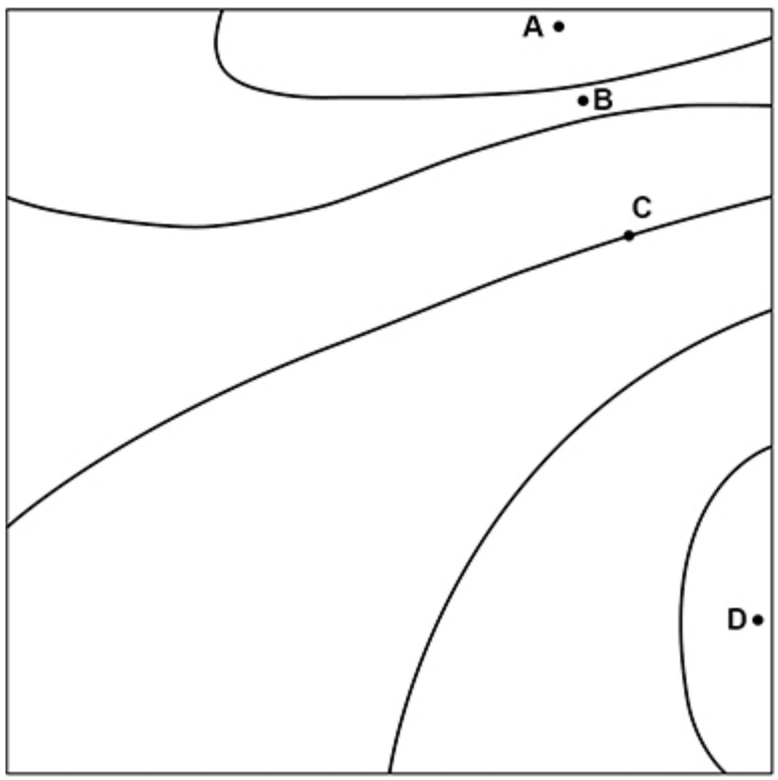
$$F = \frac{G m_1 m_2}{r^2}$$

$$F = \frac{6.67\times10^{-11} \times 5.97\times10^{24} \times 1.99\times10^{30}}{(1.5\times10^{11})^2}$$

$$F = 3.52\times10^{22}$$

(Total 1 mark)

2. The diagram shows gravitational equipotentials. Adjacent equipotentials are separated by an equal gravitational potential difference V.



Which point has the greatest gravitational field strength?

A ○

B ● — Field lines are closest together

C ○

D ○

(Total 1 mark)

3. A planet has radius R and density ρ. The gravitational field strength at the surface is g.

What is the gravitational field strength at the surface of a planet of radius $2R$ and density 2ρ?

A $2g$ ○

B $4g$ ●

C $8g$ ○

D $16g$ ○

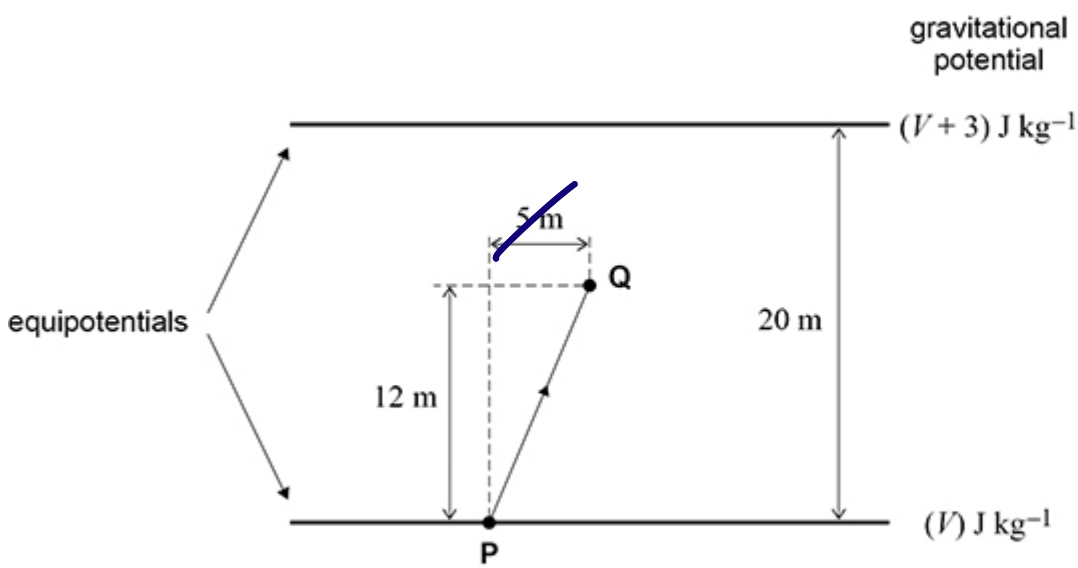
$\rho = \frac{m}{V}$ $m = \rho V$ $m \propto \rho R^3$

$g = \frac{Gm}{r^2}$ $g \propto \frac{\rho R^3}{R^2}$ $g \propto \rho R$

$g_2 = g_1 \frac{\rho_2 R_2}{\rho_1 R_1} = g \frac{2\rho\, 2R}{\rho R} = 4g$

(Total 1 mark)

4. The diagram shows equipotential lines for a uniform gravitational field. The lines are separated by 20 m.



An object of mass 4 kg is moved from **P** to **Q**.

Only vertical distance ∴ 12 m

What is the work done against gravity to move the object?

A 7.2 J

B 7.8 J

C 10.2 J

D 36 J

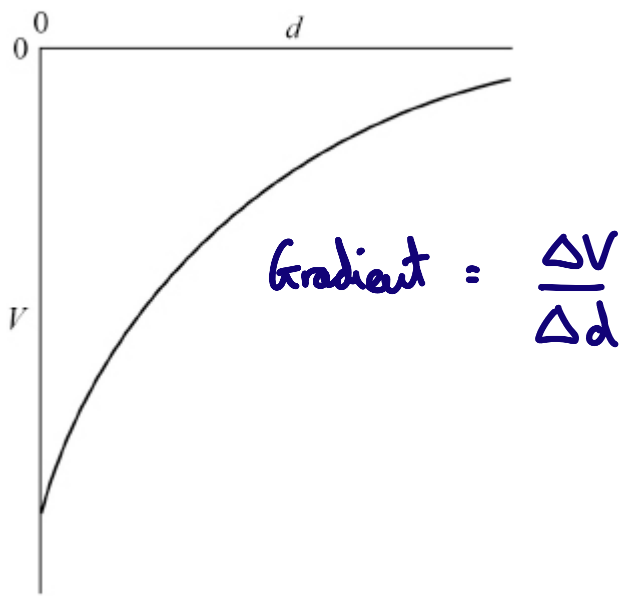
W: 3 J at 20 m per kg

W: 3 × 4 = 12 J at 20 m

W_{12}: $12 \times \left(\frac{12}{20}\right) = 7.2$ J at 12 m

(Total 1 mark)

5. The graph shows how the gravitational potential V varies with the vertical distance d from the surface of the Earth.



What does the gradient of the graph represent at the surface of the Earth?

A potential energy

B mass of the Earth

C magnitude of the gravitational constant

D magnitude of the gravitational field strength

(Total 1 mark)

$g = -\frac{\Delta V}{\Delta r}$ (from data book)

6. What is the angular speed of a satellite in a geostationary orbit around the Earth?

A 1.2×10^{-5} rad s^{-1}

B 7.3×10^{-5} rad s^{-1} ●

C 4.4×10^{-3} rad s^{-1}

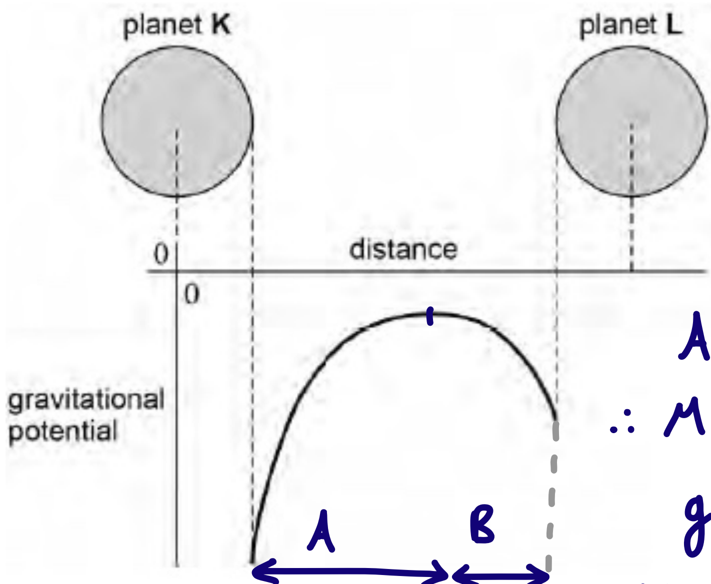
D 2.6×10^{-1} rad s^{-1}

$\omega = \frac{\theta}{t} = \frac{2\pi}{T} = \frac{2\pi}{24 \times 60 \times 60}$

$\omega = 7.27 \times 10^{-5}$ rad s^{-1}

(Total 1 mark)

7. The graph shows how the gravitational potential varies with distance between two planets, **K** and **L**, that have the same radius.



A > B

$\therefore M_K > M_L$

$g_K > g_L$

$V_{esc\,K} > V_{esc\,L}$

Which statement is correct?

A The mass of **L** is greater than the mass of **K**. ✗

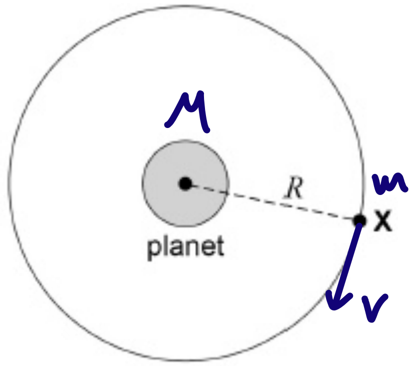
B The gravitational field strength at the surface of **L** is greater than that at the surface of **K**. ✗

C The escape velocity from planet **L** is greater than that from planet **K**. ✗

D More work must be done to move a mass of 1 kg from the surface of **K** to a distant point, than 1 kg from the surface of **L**. ●

(Total 1 mark)

8. A satellite **X** of mass m is in a concentric circular orbit of radius R about a planet of mass M.



What is the kinetic energy of **X**?

A $\frac{GMm}{2R}$ ●

B $\frac{GMm}{R}$

C $\frac{2GMm}{R}$

D $\frac{4GMm}{R}$

$E_k = \frac{1}{2} mv^2$

$E_k = \frac{1}{2} m\left(\sqrt{\frac{GM}{R}}\right)^2$

$E_k = \frac{mGM}{2R}$

(Total 1 mark)

9. The distance between the Sun and Mars varies from 2.1 × 10^{11} m to 2.5 × 10^{11} m.
When Mars is closest to the Sun, the force of gravitational attraction between them is F.

What is the force of gravitational attraction between them when they are furthest apart?

A $0.71F$ ●

B $0.84F$

C $1.2F$

D $1.4F$

$F \propto \frac{1}{r^2}$

$F_1 r_1^2 = F_2 r_2^2$

$F_2 = F_1 \cdot \frac{r_1^2}{r_2^2}$

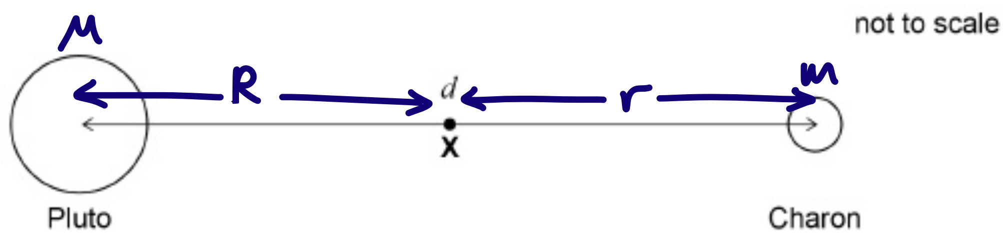
$F_2 = F \cdot \frac{2.1^2}{2.5^2} = 0.7056\,F$

(Total 1 mark)

10. Charon is a moon of Pluto that has a mass equal to $\frac{1}{9}$ that of Pluto.

The distance between the centre of Pluto and the centre of Charon is *d*.

X is the point at which the resultant gravitational field due to Pluto and Charon is zero.



What is the distance of **X** from the centre of Pluto?

A $\frac{2}{9}d$ ☐

B $\frac{2}{3}d$ ☐

C $\frac{3}{4}d$ ☒

D $\frac{8}{9}d$ ☐

(Total 1 mark)

$$g = \frac{GM}{R^2} - \frac{Gm}{r^2} = 0$$

$$Mr^2 = mR^2$$

$$Mr^2 = \frac{M}{9}R^2$$

$$r^2 = \frac{R^2}{9}$$

$$r = \frac{R}{3}$$

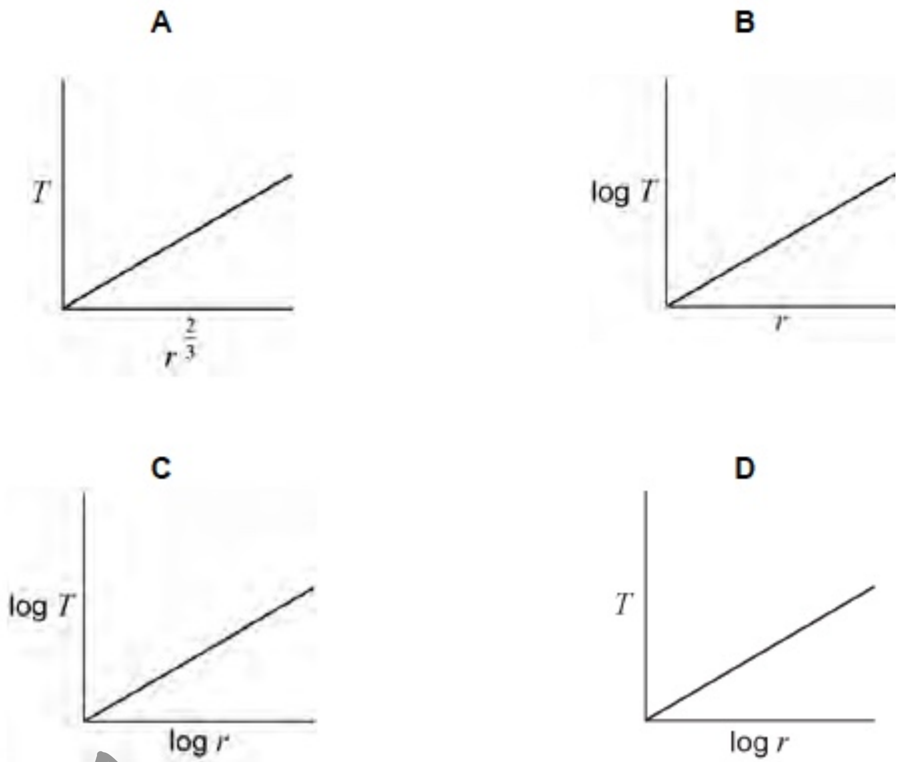
$$d = r + R$$

$$d = \frac{R}{3} + R = \frac{4R}{3} \leftarrow R = X$$

$$d = \frac{4X}{3}$$

$$X = \frac{3d}{4}$$

11. Which graph shows the relationship between the time period T and the orbital radius r of a planet in orbit around the Sun?



A ☐

B ☐

C ■

D ☐

$T^2 \propto r^3$

$\log T^2 \propto \log r^3$

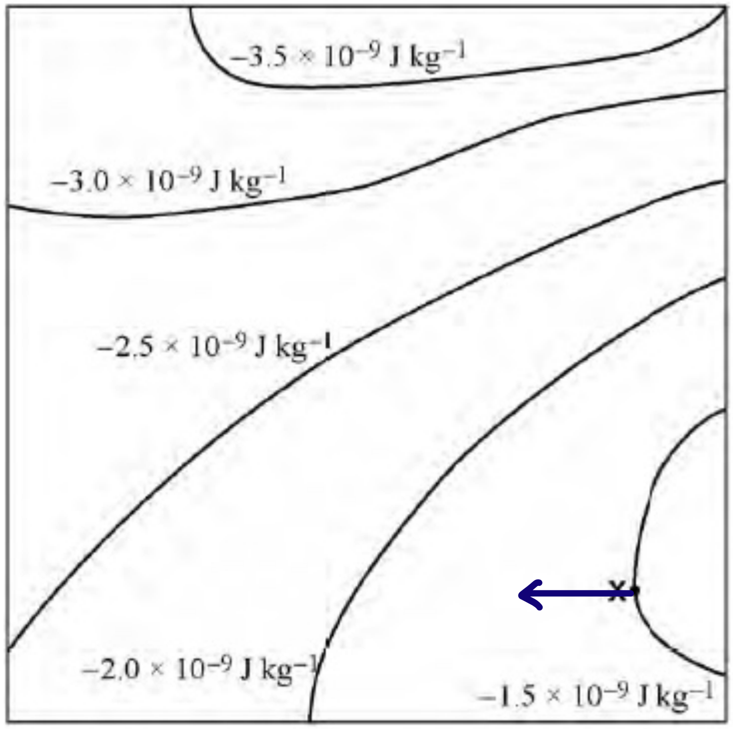
$2 \log T \propto 3 \log r$

$\log T \propto \log r$

$\therefore$ straight line

(Total 1 mark)

12. The diagram shows equipotential lines near a group of asteroids.



Which arrow shows the direction of the gravitational field at **X**?

A ↑

B ↓

C ←

D →

Perpendicular to field line, in direction where potential gets more negative

(Total 1 mark)

13. Planet **N** has a gravitational potential $-V$ at its surface. Planet **M** has double the density and double the radius of planet **N**. Both planets are spherical and have uniform density.

What is the gravitational potential at the surface of planet **M**?

A $-16V$

B $-8V$

C $-4V$

D $-0.2V$

$m = \rho V \quad m \propto \rho r^3$

$V = -\frac{GM}{r} \qquad \frac{V_1 r_1}{M_1} = \frac{V_2 r_2}{M_2}$

$V_2 = V_1 \cdot \frac{r_1}{r_2} \cdot \frac{M_2}{M_1} = -V \cdot \frac{1}{2} \cdot \frac{2 \times 2^3}{1 \times 1^3} = -V \cdot \frac{16}{2}$

(Total

14. Satellites **N** and **F** have the same mass and are in circular orbits about the same planet. The orbital radius of **F** is greater than that of **N**.

Which is greater for **F** than for **N**?

A gravitational force on the satellite

B angular speed

C kinetic energy

D orbital period

All smaller (A, B, C)

(Total 1 mark)

15. A planet of mass M and radius R rotates so quickly that material at its equator only just remains on its surface.

What is the period of rotation of the planet?

A $2\pi\sqrt{\frac{R}{GM}}$

B $2\pi\sqrt{\frac{GM}{R}}$

C $2\pi\sqrt{\frac{R^3}{GM}}$

D $2\pi\sqrt{\frac{GM}{R^3}}$

$F = \frac{mv^2}{R}$ $F = \frac{GmM}{R^2}$

$\frac{mv^2}{R} = \frac{GmM}{R^2}$ $v^2 = \frac{GM}{R}$ $v = \sqrt{\frac{GM}{R}}$

$T = \frac{s}{v} = \frac{2\pi R}{\sqrt{\frac{GM}{R}}} = 2\pi R\sqrt{\frac{R}{GM}}$

$= 2\pi\sqrt{\frac{R^3}{GM}}$

(Total 1 mark)

16. What is the angular speed of a satellite in a geostationary orbit around the Earth?

A 1.2×10^{-5} rad s^{-1}

B 7.3×10^{-5} rad s^{-1}

C 4.2×10^{-3} rad s^{-1}

D 2.6×10^{-1} rad s^{-1}

(Same as Q6)

(Total 1 mark)

17. Which row shows two scalar quantities?

A	gravitational potential	gravitational ~~field~~ strength	○
B	mass	gravitational potential	●
C	gravitational ~~field~~ strength	~~weight~~	○
D	~~weight~~	gravitational potential	○

(Total 1 mark)

18. An object moves freely at 90° to the direction of a gravitational field.

The acceleration of the object is

- **A** zero. ○
- **B** opposite to the direction of the gravitational field. ○
- **C** in the direction of the gravitational field. Always ●
- **D** at 90° to the direction of the gravitational field. ○

(Total 1 mark)

19. A spacecraft of mass 1.0×10^6 kg is in orbit around the Sun at a radius of 1.1×10^{11} m

The spacecraft moves into a new orbit of radius 2.5×10^{11} m around the Sun.

What is the total change in gravitational potential energy of the spacecraft?

- **A** -6.76×10^{14} J ○
- **B** -3.38×10^{14} J ○
- **C** 3.38×10^{14} J ○
- **D** 6.76×10^{14} J ●

$E_p = -\frac{GmM}{r}$

$\Delta E_p = \Delta\left(\frac{GmM}{r}\right)$

$\Delta E_p = -GmM\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

(Total 1 mark)

$\Delta E_p = 6.67\times10^{-11} \times 1.0\times10^{6} \times 1.99\times10^{30}\left(\frac{1}{1.1\times10^{11}} - \frac{1}{2.5\times10^{11}}\right)$

$\Delta E_p = 6.757\times10^{14}$ J