Gravitational Fields Questions – OCR A Level Physics

Praneel Physics

1. State Newton's law of universal gravitation. **(P)**

Working and Answer:

The force between two masses is proportional to the product of the masses and inversely proportional to the square of the distance between them.

2. Define gravitational field strength. **(P)**

Working and Answer:

Gravitational force per unit mass at a point.

3. Write the formula for gravitational potential energy between two point masses. **(P)**

Working and Answer:

$$E = -\frac{GMm}{r}$$

4. What is the unit of gravitational potential? **(P)**

Working and Answer:
Joules per kilogram (J/kg).

5. State whether gravitational field is a scalar or vector quantity. **(P)**

Working and Answer:
It is a vector quantity; it has both magnitude and direction.

6. Explain why gravitational potential is always negative. **(PP)**

Working and Answer:

It is defined as zero at infinity, so work must be done against gravity to move a mass to infinity; thus, values closer in are negative.

7. Sketch the variation of gravitational field strength with distance from the centre of a planet. **(PP)**

Working and Answer:

(Graph showing inverse square decrease beyond surface, linear inside uniform planet.)

8. Explain the significance of the minus sign in gravitational potential energy. **(PP)**

Working and Answer:

It indicates that energy is required to separate the masses (i.e., the system is bound).

9. Describe the difference between gravitational field strength and gravitational potential. **(PP)**

Working and Answer:

Field strength is force per mass; potential is energy per mass. Field strength is a vector, potential is scalar.

10. A satellite of mass 500 kg is in orbit 7000 km from Earth's centre. Calculate the gravitational potential energy. Take $M = 5.97 \times 10^{24}\,\text{kg}$ and $G = 6.67 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$. **(PPP)**

Working and Answer:

$$E = -\frac{GMm}{r} = -\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 500}{7.0 \times 10^{6}} \approx -2.85 \times 10^{10}\,\text{J}$$

11. Calculate the escape velocity from Earth's surface. Radius = 6.37×10^6 m. **(PPP)**

Working and Answer:

$$v = \sqrt{\frac{2GM}{r}} \approx \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{6.37 \times 10^6}} \approx 11180\,\mathrm{ms^{-1}}$$

12. Calculate the gravitational field strength at a point 10 000 km from the centre of the Earth. **(PPP)**

Working and Answer:

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{(1 \times 10^7)^2} \approx 3.99\,\mathrm{N/kg}$$

13. Determine the orbital period of a satellite at a radius of 4.2×10^7 m from Earth's centre. **(PPP)**

Working and Answer:

$$T = 2\pi\sqrt{\frac{r^3}{GM}} \approx 2\pi\sqrt{\frac{(4.2 \times 10^7)^3}{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}} \approx 8.64 \times 10^4 \text{ s}$$

(about 24 hours)

14. Derive the equation for orbital speed of a satellite in circular orbit. **(PPPP)**

Working and Answer:

Equating centripetal force and gravitational force:

$$\frac{mv^2}{r} = \frac{GMm}{r^2} \Rightarrow v = \sqrt{\frac{GM}{r}}$$

15. Explain how gravitational potential varies with distance from a mass. **(PPPP)**

Working and Answer:

It increases (becomes less negative) as distance increases, approaching zero at infinity.

16. Describe how a geostationary orbit is achieved. **(PPPP)**

Working and Answer:

Satellite must be in equatorial orbit, same direction as Earth's rotation, with a 24-hour period and at specific altitude (42,000 km from Earth's centre).

17. Discuss energy changes when a rocket escapes Earth's gravitational field. **(PPPP)**

Working and Answer:

Kinetic energy is converted into gravitational potential energy; work is done against gravity to reach zero potential at infinity.

18. A 1000 kg satellite is in circular orbit at altitude 300 km. Determine its speed and kinetic energy. Earth radius = 6.37×10^6 m. **(PPPPP)**

Working and Answer:

$$r = 6.37 \times 10^6 + 3 \times 10^5 = 6.67 \times 10^6 \, \text{m}$$
$$v = \sqrt{\frac{GM}{r}} \approx \sqrt{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{6.67 \times 10^6}} \approx 7750 \, \text{ms}^{-1}$$
$$E_k = \frac{1}{2}mv^2 = 0.5 \times 1000 \times 7750^2 \approx 3.00 \times 10^{10} \, \text{J}$$

19. A 1500 kg space probe moves from Earth's surface to 1000 km altitude. Calculate change in gravitational potential energy. **(PPPPP)**

Working and Answer:

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

$$r_1 = 6.37 \times 10^6, \quad r_2 = 7.37 \times 10^6$$

$$\Delta E = 6.67\times10^{-11}\times5.97\times10^{24}\times1500\left(\frac{1}{6.37\times10^6} - \frac{1}{7.37\times10^6}\right) \approx 2.34\times10^{10}\ \text{J}$$

20. Compare gravitational and electric fields in terms of direction, source, and governing law. **(PPPPP)**

Working and Answer:

Gravitational fields are always attractive, produced by mass, follow inverse-square law. Electric fields can attract or repel, produced by charge, also follow inverse-square law.

21. Sketch gravitational potential versus distance from centre of Earth, and explain shape. **(PPPPP)**

Working and Answer:

The curve becomes less negative with distance and asymptotically approaches zero at infinity. The inverse relationship with r gives the curve a hyperbolic shape.