Edexcel A2 Physics: Gravitational Fields – Calculation Practice

Praneel Physics

1. Calculate the gravitational force between two masses of 5 kg and 10 kg that are 2 meters apart. **(P)**

Working and Answer:
Using Newton's law of gravitation: $F = G\dfrac{m_1 m_2}{r^2}$ where
$G = 6.67 \times 10^{-11}\,\text{N m}^2/\text{kg}^2$, $m_1 = 5\,\text{kg}$, $m_2 = 10\,\text{kg}$, and $r = 2\,\text{m}$:
$F = 6.67 \times 10^{-11}\dfrac{5 \times 10}{2^2} = 6.67 \times 10^{-11}\dfrac{50}{4} = 8.34 \times 10^{-10}\,\text{N}$

2. What is the gravitational potential energy of a 2 kg mass at a height of 3 meters? **(P)**

Working and Answer:
Using the formula for gravitational potential energy: $U = mgh$ where $m = 2\,\text{kg}$, $g = 9.81\,\text{m/s}^2$, and $h = 3\,\text{m}$: $U = 2 \times 9.81 \times 3 = 58.86\,\text{J}$

3. If the gravitational field strength on the surface of a planet is $10\,\text{N/kg}$, what is the weight of a 15 kg object on that planet? **(P)**

Working and Answer:
Using the formula for weight: $W = mg$ where $m = 15\,\text{kg}$ and $g = 10\,\text{N/kg}$:
$W = 15 \times 10 = 150\,\text{N}$

4. Calculate the gravitational field strength at a distance of 4 meters from a mass of 20 kg. **(P)**

Working and Answer:
Using the formula for gravitational field strength: $g = G\frac{m}{r^2}$ where
$G = 6.67 \times 10^{-11}\,\text{N m}^2/\text{kg}^2$, $m = 20\,\text{kg}$, and $r = 4\,\text{m}$:
$g = 6.67 \times 10^{-11}\frac{20}{4^2} = 6.67 \times 10^{-11}\frac{20}{16} = 8.34 \times 10^{-10}\,\text{N/kg}$

5. A satellite orbits a planet at a height of 500 km above the surface. If the radius of the planet is 6000 km, calculate the gravitational field strength at the satellite's orbit. **(PP)**

Working and Answer:
First, find the distance from the center of the planet:
$r = 6000\,\text{km} + 500\,\text{km} = 6500\,\text{km} = 6.5 \times 10^6\,\text{m}$. Using the formula for gravitational field strength: $g = G\dfrac{M}{r^2}$. Assuming M (mass of the planet) is known, substitute $G = 6.67 \times 10^{-11}$ and calculate g.

6. Determine the gravitational potential at a distance of 10 m from a mass of 50 kg. **(PP)**

Working and Answer:
Using the formula for gravitational potential: $V = -G\frac{m}{r}$ where
$G = 6.67 \times 10^{-11}\,\text{N m}^2/\text{kg}^2$, $m = 50\,\text{kg}$, and $r = 10\,\text{m}$:
$V = -6.67 \times 10^{-11}\frac{50}{10} = -3.335 \times 10^{-10}\,\text{J/kg}$

7. A 10 kg mass is dropped from a height of 20 m. Calculate the gravitational potential energy at the top and the kinetic energy just before it hits the ground. **(PP)**

Working and Answer:
At the top: $U = mgh = 10 \times 9.81 \times 20 = 1962\,\text{J}$. Just before hitting the ground, all potential energy converts to kinetic energy: $KE = U = 1962\,\text{J}$

8. Calculate the radius of a planet if the gravitational field strength at its surface is 9.81 N/kg and its mass is 5.97×10^{24} kg. **(PP)**

Working and Answer:

Using the formula: $g = G\frac{M}{r^2}$. Rearranging gives:

$$r = \sqrt{G\frac{M}{g}} = \sqrt{6.67 \times 10^{-11}\frac{5.97 \times 10^{24}}{9.81}} \approx 6.37 \times 10^{6}\,\text{m}$$

9. A spacecraft is in a circular orbit 300 km above the Earth's surface. Calculate the orbital speed of the spacecraft. **(PPP)**

Working and Answer:
First, find the radius from the center of the Earth:
$r = 6371\,\text{km} + 300\,\text{km} = 6671\,\text{km} = 6.671 \times 10^6\,\text{m}$. Using the formula for orbital speed: $v = \sqrt{\dfrac{GM}{r}} = \sqrt{\dfrac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{6.671 \times 10^6}} \approx 7.73 \times 10^3\,\text{m/s}$

10. Calculate the gravitational force acting on a 1000 kg satellite in a low Earth orbit at an altitude of 200 km. **(PPP)**

Working and Answer:
First, find the radius from the center of the Earth:
$r = 6371\,\text{km} + 200\,\text{km} = 6571\,\text{km} = 6.571 \times 10^6\,\text{m}$. Using the formula for gravitational force:
$$F = G\frac{mM}{r^2} = 6.67 \times 10^{-11}\frac{1000 \times 5.97 \times 10^{24}}{(6.571 \times 10^6)^2} \approx 9.81 \times 10^3\,\text{N}$$

11. A mass of 80 kg is placed at a height of 10 m above the ground. Calculate the work done against gravity to lift the mass. **(PPP)**

Working and Answer:
Using the work done formula: $W = mgh = 80 \times 9.81 \times 10 = 7848\,\text{J}$

12. Determine the gravitational potential energy of a 5 kg mass at a height of 15 m above the ground. **(PPP)**

Working and Answer:
Using the formula for gravitational potential energy:
$U = mgh = 5 \times 9.81 \times 15 = 735.75\,\text{J}$

13. A planet has a mass of $7.35 \times 10^{22}\,\text{kg}$ and a radius of $3.2 \times 10^{6}\,\text{m}$. Calculate the gravitational field strength at its surface. **(PPPP)**

Working and Answer:
Using the formula: $g = G\dfrac{M}{r^2} = 6.67 \times 10^{-11}\dfrac{7.35 \times 10^{22}}{(3.2 \times 10^{6})^2} \approx 5.5\,\text{N/kg}$

14. Calculate the escape velocity from the surface of a planet with a mass of $4.0 \times 10^{24}\,\text{kg}$ and a radius of $6.0 \times 10^{6}\,\text{m}$. **(PPPP)**

Working and Answer:
Using the escape velocity formula:

$$v_e = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 4.0 \times 10^{24}}{6.0 \times 10^{6}}} \approx 11180\,\text{m/s}$$

15. A satellite is in a geostationary orbit. Calculate the height of the orbit above the Earth's surface. **(PPPP)**

Working and Answer:
Using the formula for the radius of a geostationary orbit:
$T = 24 \times 3600\,\text{s}$, $r = \left(\dfrac{GMT^2}{4\pi^2}\right)^{1/3}$. Substituting $G = 6.67 \times 10^{-11}\,\text{N m}^2/\text{kg}^2$ and $M = 5.97 \times 10^{24}\,\text{kg}$: $r \approx 4.224 \times 10^7\,\text{m}$. Height above the surface:
$h = r - R_E \approx 4.224 \times 10^7 - 6.371 \times 10^6 \approx 3.587 \times 10^7\,\text{m}$

16. Calculate the gravitational potential energy of a 10 kg mass at a distance of 1000 km from the center of a planet with mass 6×10^{24} kg. **(PPPP)**

Working and Answer:
Using the formula: $U = -G\dfrac{mM}{r}$ where $r = 1000\,\text{km} = 1 \times 10^6\,\text{m}$:
$U = -6.67 \times 10^{-11}\dfrac{10 \times 6 \times 10^{24}}{1 \times 10^6} \approx -4.002 \times 10^6\,\text{J}$

17. A 1500 kg car is parked on a hill that is 30 m high. Calculate the gravitational potential energy of the car. **(PPPP)**

Working and Answer:
Using the formula for gravitational potential energy:
$U = mgh = 1500 \times 9.81 \times 30 = 441450\,\text{J}$

18. Determine the gravitational force between two objects with masses 3 kg and 4 kg that are 0.5 m apart. **(PPPPP)**

Working and Answer:
Using Newton's law of gravitation:
$$F = G\frac{m_1 m_2}{r^2} = 6.67 \times 10^{-11}\frac{3 \times 4}{(0.5)^2} = 6.67 \times 10^{-11}\frac{12}{0.25} = 3.20 \times 10^{-9}\,\text{N}$$

19. Calculate the gravitational potential energy of a 12 kg object at a height of 25 m. **(PPPPP)**

Working and Answer:
Using the formula for gravitational potential energy:
$U = mgh = 12 \times 9.81 \times 25 = 2943\,\text{J}$

20. A planet has a mass of 8.0×10^{22} kg and a radius of 4.0×10^{6} m. Calculate the gravitational field strength at its surface. **(PPPPP)**

Working and Answer:

Using the formula: $g = G\dfrac{M}{r^2} = 6.67 \times 10^{-11} \dfrac{8.0 \times 10^{22}}{(4.0 \times 10^{6})^2} \approx 4.2\,\text{N/kg}$

21. Calculate the height above the Earth's surface where the gravitational field strength is 4.9 N/kg. **(PPPPP)**

Working and Answer:

Using the formula: $g = G\dfrac{M}{(R+h)^2}$. Rearranging gives: $h = \sqrt{\dfrac{GM}{g}} - R$.

Substituting $g = 4.9\,\text{N/kg}$, $R = 6.371 \times 10^6\,\text{m}$:

$$h \approx \sqrt{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{4.9}} - 6.371 \times 10^6 \approx 6.371 \times 10^6\,\text{m}$$