

Gravitational force, potential and satellite orbits

Physics grades 11-12 (A Level · IB · Class 11-12) · Test answers (mark scheme)

The model answers give the method and the final answer in bold. Marks are awarded for the correct equation and substitution as well as the result, so show each step. Check units and that r is measured from the centre.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB D.1

Question 1 Field strength definition (2 marks)

Gravitational field strength is the gravitational force per unit mass acting on a small test mass at that point. It is directed towards the centre of the source mass.

Marking: 1 mark for force per unit mass; 1 mark for direction towards the source.

Question 2 Mars (3 marks)

a. $g = G M \div R^2 = 6.67 \times 10^{-11} \times 6.42 \times 10^{23} \div (3.39 \times 10^6)^2 = \mathbf{3.73 \text{ N/kg}}$.

b. $W = m g = 70 \times 3.73 = \mathbf{261 \text{ N}}$.

Marking: (a) 1 mark for the formula, 1 for the result; (b) 1 mark.

Question 3 Satellite orbit (3 marks)

a. $G M m \div r^2 = m v^2 \div r$, so $v = \sqrt{G M \div r} = \sqrt{3.98 \times 10^{14} \div 7.2 \times 10^6} = \mathbf{7.4 \text{ km/s}}$.

b. $T = 2\pi r \div v = 2\pi \times 7.2 \times 10^6 \div 7437 = 6083 \text{ s} = \mathbf{1.7 \text{ h}}$.

Marking: (a) 1 mark for equating forces, 1 for the result; (b) 1 mark.

Question 4 Kepler's third law (3 marks)

a. The square of the orbital period is proportional to the cube of the orbital radius.

b. $T^2 \propto r^3$, so $T_B = 200 \times 4^{(3/2)} = 200 \times 8 = \mathbf{1600 \text{ days}}$.

Marking: (a) 1 mark; (b) 1 mark for the ratio, 1 for the result.

Question 5 Potential graph (3 marks)

a. $V = -G M \div R = -3.98 \times 10^{14} \div 6.37 \times 10^6 = \mathbf{-62.5 \text{ MJ/kg}}$.

b. At $2R$, $V = -31.3 \text{ MJ/kg}$. Energy = $m \Delta V = 1.0 \times (-31.3 - (-62.5)) = \mathbf{31 \text{ MJ}}$.

Marking: (a) 1 mark; (b) 1 mark for reading V at $2R$, 1 mark for the difference.

Question 6 Escape speed of Venus (3 marks)

- a. $v = \sqrt{2 G M \div R} = \sqrt{2 \times 6.67 \times 10^{-11} \times 4.87 \times 10^{24} \div 6.05 \times 10^6} = \mathbf{10.4 \text{ km/s}}$.
- b. The kinetic energy $\frac{1}{2} m v^2$ and the potential energy $G M m \div R$ both contain m , so m cancels.

Marking: (a) 1 mark for the formula, 1 for the result; (b) 1 mark.

Question 7 Weightlessness (2 marks)

The astronauts and the spacecraft are in free fall with the same acceleration, so there is **no contact force** between them. They feel weightless because weight is sensed through contact forces.

Marking: 1 mark for gravity acts and both fall together; 1 mark for no contact force.

Question 8 Negative potential (1 mark)

It is defined as zero at infinity and gravity is attractive, so work must be done to move a mass out to infinity, which means the potential is **below zero**.

Marking: 1 mark for zero at infinity with attraction.