6.6 Motion of Orbiting Satellites

Name: ____________ Class: ________ Date: __________ **Total: 13 marks**

Objective

Build the skills to answer exam questions on **the motion of orbiting satellites**.

You must be able to:

- explain that **gravity** 引力 provides the centripetal force for a circular orbit
- derive the orbital speed: $v = \sqrt{\dfrac{GM}{r}}$
- use **Kepler's third law** 开普勒第三定律: $T^2 \propto r^3$
- state that a satellite's own mass cancels out

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

Gravity is the centripetal force

For a circular orbit,

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

Lower orbits are faster; higher orbits are slower.

Kepler's third law

The period and radius are linked by

$$T^2 = \frac{4\pi^2}{GM} r^3,$$

so $T^2 \propto r^3$ – a bigger orbit takes much longer.

The mass cancels

The satellite's mass m cancels, so orbital speed and period do not depend on it.

2 Practice

Now apply the methods above.

2.1 What provides the centripetal force that holds a satellite in orbit? [1]

2.2 A satellite moves to a lower orbit. State whether its speed increases or decreases. [1]

2.3 Compute the orbital speed where $GM/r = 4.0 \times 10^7\ \text{m}^2\ \text{s}^{-2}$. [2]

2.4 State whether a heavier satellite at the same radius orbits faster, slower, or the same. [1]

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3 Exam-style questions

3.1 The orbital speed of a satellite depends on [1]

- **A** its own mass
- **B** the central mass and the orbital radius
- **C** its colour
- **D** the launch angle

3.2 According to Kepler's third law, a larger orbit has a [1]

- **A** shorter period
- **B** longer period
- **C** the same period
- **D** zero period

3.3 Satellite B orbits at twice the radius of satellite A (same planet).

(a) State how B's orbital speed compares with A's (qualitatively). [1]

(b) Using $T^2 \propto r^3$, state how B's period compares with A's. [2]

3.4 A satellite orbits where $GM/r = 2.5 \times 10^7\ \text{m}^2\ \text{s}^{-2}$.

(a) Find its orbital speed. [2]

(b) State whether doubling the satellite's mass changes this speed. [1]

4 Go further

You are ready for more on this subtopic:

- work through the interactive **6.6 Motion of Orbiting Satellites** lesson on the **Learn** page;
- read the **Energy and Momentum of Rotating Systems** section of the AP Physics C: Mechanics handout on the **Know** page for the full explanation and worked diagrams.

Solutions

2.1 Gravity.

2.2 It increases (lower orbits are faster).

2.3 $v = \sqrt{4.0 \times 10^7} \approx 6300 \text{ m s}^{-1}$.

2.4 The same (mass cancels).

3.1 B —the central mass and the orbital radius.

3.2 B —a larger orbit has a longer period.

3.3 (a) B is slower (larger r gives smaller v). (b) $T^2 \propto r^3$, so $T_B/T_A = 2^{3/2} \approx 2.8$ times longer.

3.4 (a) $v = \sqrt{2.5 \times 10^7} \approx 5000 \text{ m s}^{-1}$. (b) No —mass cancels, so the speed is unchanged.