6.6 Motion of Orbiting Satellites

Name: ____________ Class: ________ Date: __________ **Total: 9 marks**

Objective

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

You must be able to:

- explain how **gravity** provides the centripetal force that keeps a satellite in orbit
- relate the **orbital speed** 轨道速度 to the radius with $\frac{GMm}{r^2} = \frac{mv^2}{r}$
- describe the energy of a satellite as kinetic plus gravitational potential energy

1 Worked examples

Study these first. Each one shows the method for a question type used later.

Gravity is the centripetal force

Setting the gravitational force equal to the required centripetal force:

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

Closer orbits are faster

Because $v \propto 1/\sqrt{r}$, a satellite in a **lower** orbit moves **faster**.

Energy

A satellite has kinetic energy $\frac{1}{2}mv^2$ and (negative) gravitational potential energy; the two together give its total orbital energy.

2 Practice

2.1 State what provides the centripetal force on an orbiting satellite. [1]

2.2 State how the orbital speed changes if the orbital radius increases. [1]

2.3 Write the equation obtained by setting the gravitational force equal to the centripetal force. [1]

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3 Exam-style questions

3.1 The centripetal force on a satellite in orbit is provided by [1]

- **A** its engine
- **B** gravity
- **C** air resistance
- **D** the normal force

3.2 As the orbital radius increases, the orbital speed [1]

- **A** increases
- **B** decreases
- **C** stays constant
- **D** becomes zero

3.3 A satellite orbits Earth ($M = 6.0 \times 10^{24}$ kg, $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}) at radius $r = 7.0 \times 10^6$ m.

(a) Write the expression $v = \sqrt{GM/r}$. [1]

(b) Find the orbital speed. [3]

4 Go further

- work through the **6.6 Motion of Orbiting Satellites** lesson on the **Learn** page;
- read the **Energy and Momentum of Rotating Systems** section of the AP Physics 1 handout on the **Know** page.

Solutions

2.1 the gravitational pull of the planet on the satellite.

2.2 it decreases ($v \propto 1/\sqrt{r}$).

2.3 $\dfrac{GMm}{r^2} = \dfrac{mv^2}{r}$.

3.1 **B**.

3.2 **B**.

3.3 (a) $v = \sqrt{\dfrac{GM}{r}}$. (b) $v = \sqrt{\dfrac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{7.0 \times 10^{6}}} = \sqrt{5.7 \times 10^{7}} = 7.6 \times 10^{3}$ m s^{-1}.