

Exercise walk-through

6.6

Motion of Orbiting Satellites

AP Physics 1

Orbiting satellites

Gravity supplies the centripetal force. Set them equal:

Orbital speed

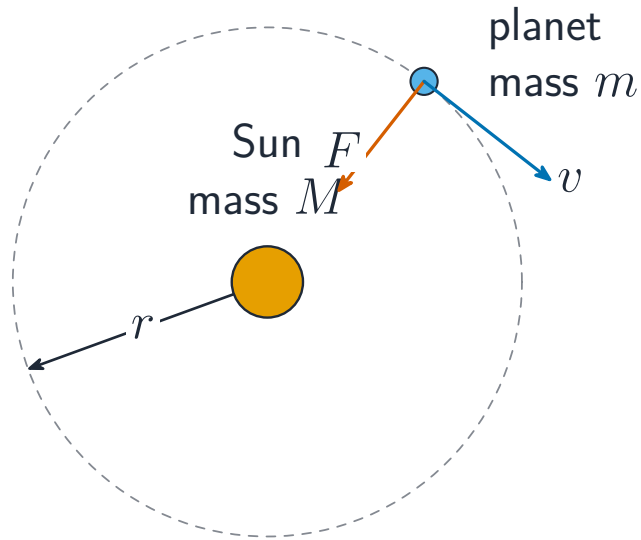
$$\frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{GM}{r}}$$

- speed is independent of the satellite's mass
- a **bigger** orbit means a **slower** speed



Satellites are continuous free-fall around Earth

Motion of Orbiting Satellites



Gravity provides the centripetal force that keeps a satellite in orbit

Escape velocity

the definition

the launch speed that just lets an object **leave for good**

the condition

its total mechanical energy is exactly **zero** – it arrives at infinity with no speed left

so

$$\frac{1}{2}mv^2 - \frac{GMm}{r} = 0, \text{ giving } v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$$

the relation

$v_{\text{esc}} = \sqrt{2} \times$ the circular orbital speed at the same radius

no mass in it

the escaping object's own mass cancels, so it is the same for a pebble and a rocket

Escape speed is set by **where you start**, not by what you are. Launching from a higher orbit needs less of it, which is why staged launches work.

Exam tips

- Conserve **angular momentum** $L = I\omega$ when no external torque acts: a smaller I (arms pulled in) gives a larger ω .
- A rolling object splits its energy between $\frac{1}{2}mv^2$ and $\frac{1}{2}I\omega^2$, linked by $v = r\omega$ – so it accelerates down a ramp **more slowly** than a sliding one.
- For a circular orbit set gravity equal to the centripetal requirement: $v = \sqrt{GM/r}$, so a larger orbit is **slower** and the satellite's mass cancels.
- Pulling in raises the spin **and** the kinetic energy – the extra energy comes from the work done pulling inward; L is unchanged.
- Watch which rotational quantity is conserved: L (no torque) versus energy (no friction) are different conditions.

Exercises 2.1-2.3

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]

Exercises 2.1-2.3

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

2.1

- the gravitational pull of the planet on the satellite
-

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

2.2

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

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

2.3

- $\frac{GMm}{r^2} = \frac{mv^2}{r}$

Exercises 3.1-3.2

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

Exercises 3.1-3.2

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- A its engine
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3.1 B

- gravity.

3.2 As the orbital radius increases, the orbital speed

[1]

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

3.2 B

- decreases.

Exercise 3.3 (a)

3.3 A satellite orbits Earth ($M = 6.0 \times 10^{24}$ kg, $G = 6.67 \times 10^{-11}$ N m² kg⁻²) at radius $r = 7.0 \times 10^6$ m.

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

[1]

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(a)

- $$v = \sqrt{\frac{GM}{r}}$$

Exercise 3.3 (b)

3.3 A satellite orbits Earth ($M = 6.0 \times 10^{24}$ kg, $G = 6.67 \times 10^{-11}$ N m² kg⁻²) at radius $r = 7.0 \times 10^6$ m.

(b) Find the orbital speed.

[3]

Exercise 3.3 (b)

3.3 A satellite orbits Earth ($M = 6.0 \times 10^{24}$ kg, $G = 6.67 \times 10^{-11}$ N m² kg⁻²) at radius $r = 7.0 \times 10^6$ m.

(b) Find the orbital speed.

[3]

(b)

$$\bullet \quad v = \sqrt{\frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{7.0 \times 10^6}} = \sqrt{5.7 \times 10^7} = 7.6 \times 10^3 \text{ m s}^{-1}$$