

Escape Speed

How fast must an object move to leave Earth forever?



The exact velocity needed to break the gravitational tether.



H2: Defining the Threshold

Escape speed is the minimum initial velocity required for an object to overcome a planet's gravitational pull and reach infinity.



Header: 'The 'Ideal Case' Rule

This assumes a single initial burst of speed. Once launched, there is absolutely no further propulsion (engines are off) and no atmospheric resistance.

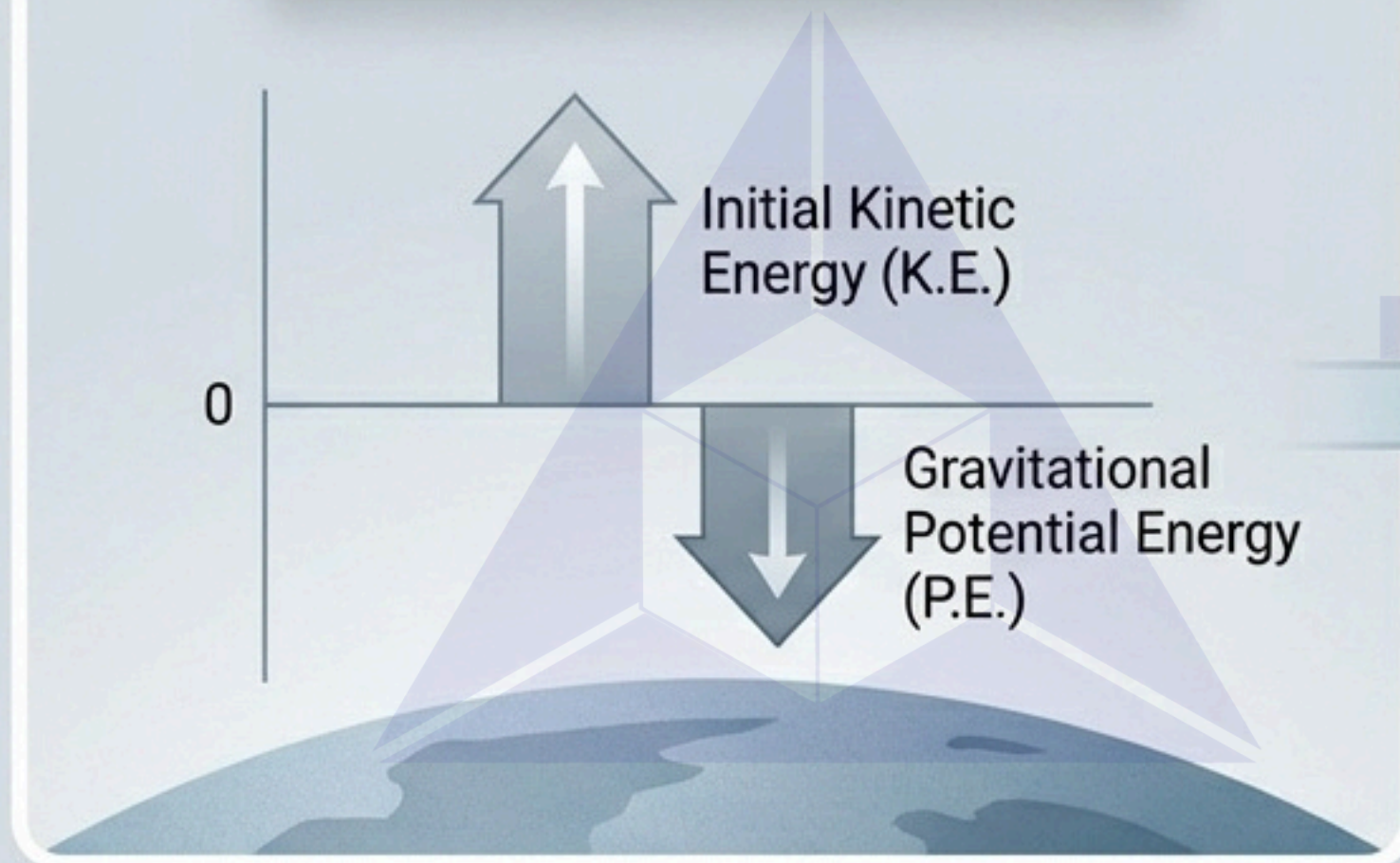


Think of throwing a stone, not flying a plane.

H2: The Energy Logic

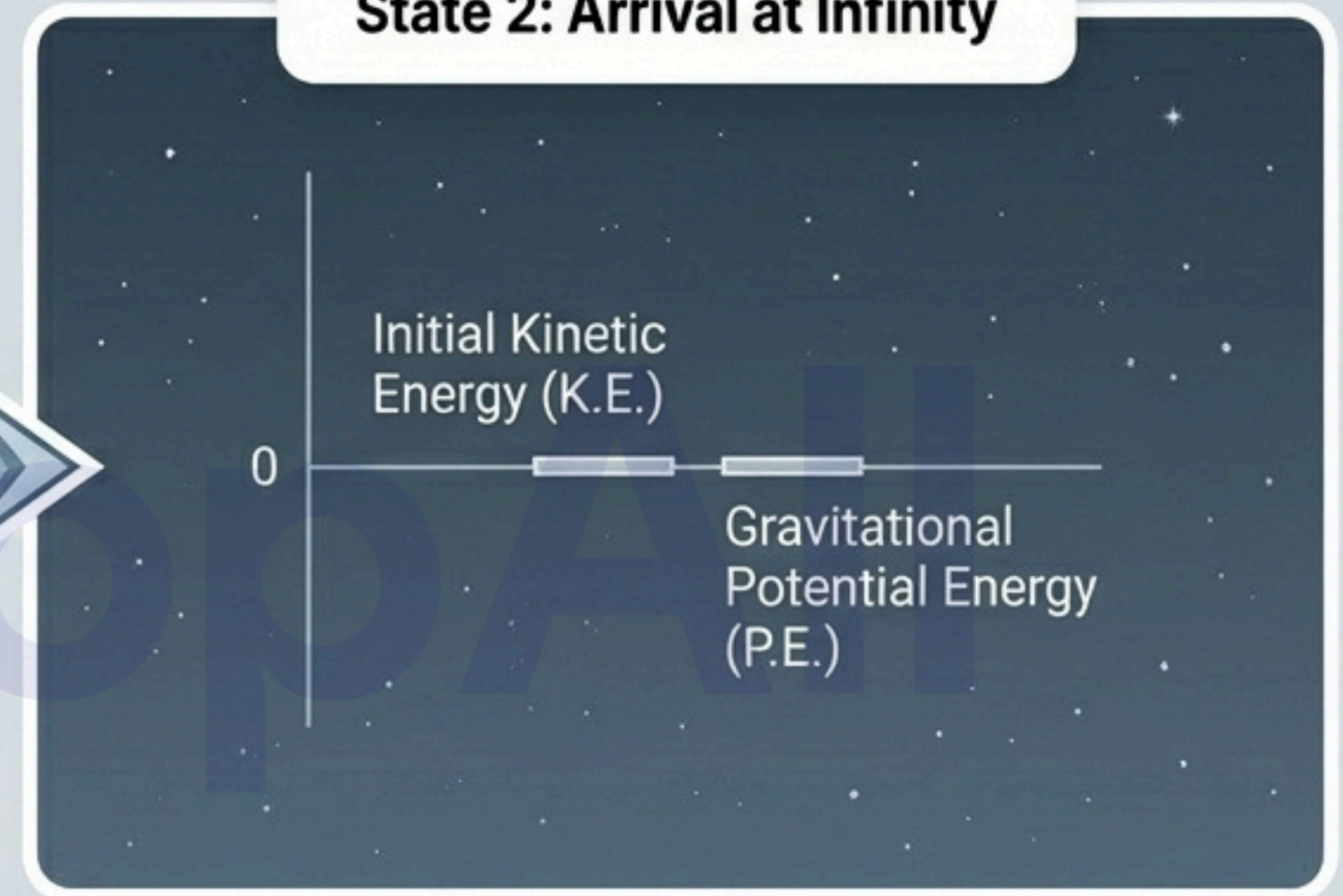
To just barely escape, the object's total mechanical energy at infinity must be exactly zero.

State 1: Launch from Surface



$$E_{\text{initial}} = \frac{1}{2}mv_i^2 + \left(-\frac{GM_E m}{R_E}\right)$$

State 2: Arrival at Infinity



$$E_{\text{final}} = 0 \text{ (Zero speed, zero gravitational pull)}$$

➤ If initial energy equals final energy, we can solve for our launch speed.



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$$E=mc^2$$



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H2: The Blueprint of the Formula

Equate the states:

$$\frac{1}{2}mv_i^2 - \frac{GM_E m}{R_E} = 0$$

The Aha! Moment:

$$\cancel{\frac{1}{2}mv_i^2} = \cancel{\frac{GM_E m}{R_E}}$$

Solve for v :

$$v_{\text{escape}} = \sqrt{\frac{2GM_E}{R_E}}$$

Substitute g (since $g = GM_E/R_E^2$):

$$v_e = \sqrt{2gR_E}$$

Notice how the mass (m) cancels out! A pebble and a spaceship require the exact same escape speed.

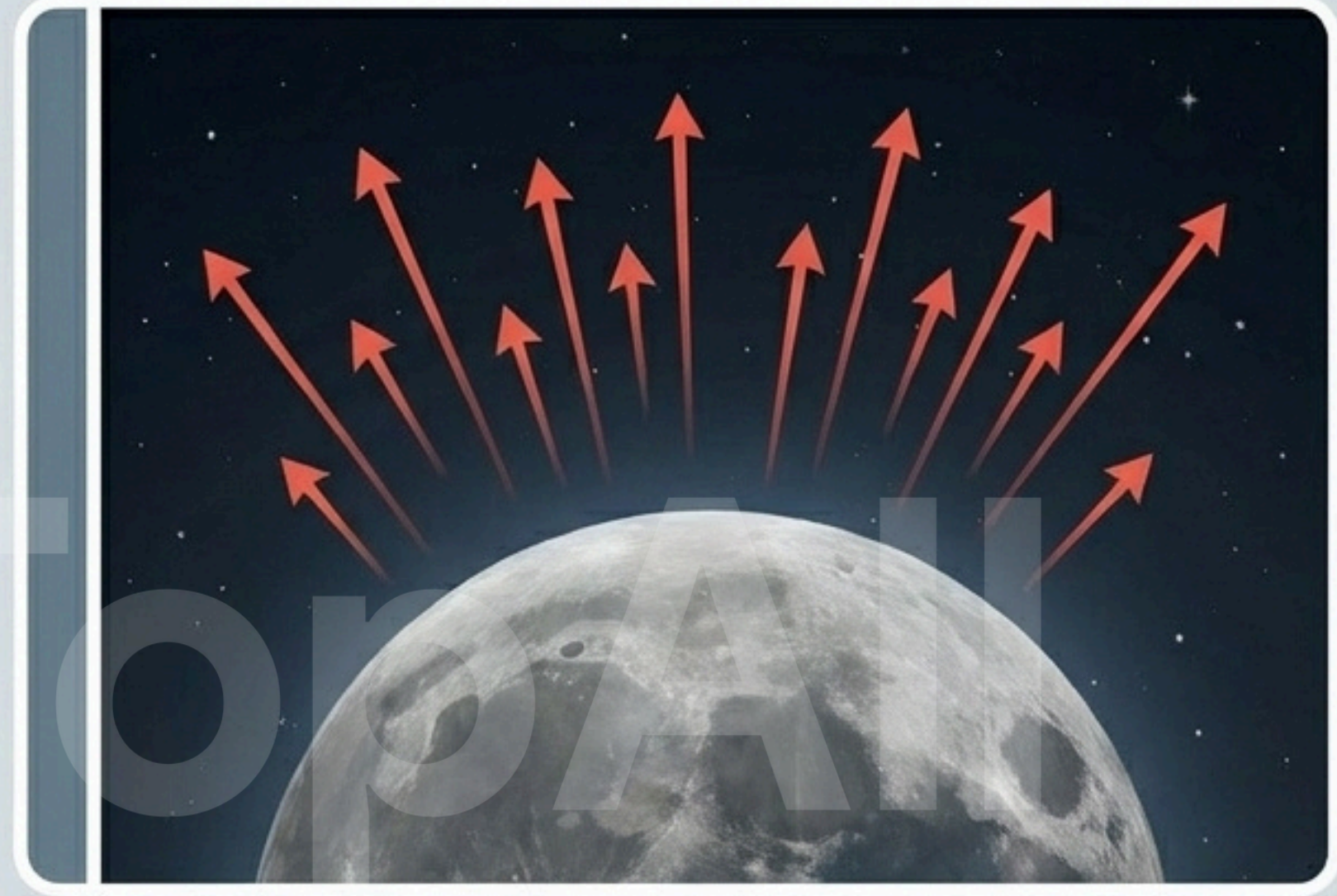
H2: Planetary Application: Earth vs. Moon



Earth

Escape Speed = 11.2 km/s

Result: Gas molecules move slower than 11.2 km/s, so gravity holds the atmosphere securely.



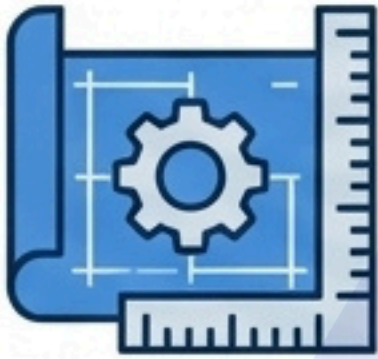
Moon

Escape Speed = 2.3 km/s

Result: Gas molecules move faster than 2.3 km/s. Thermal velocity exceeds the escape pull, causing gases to drift into space.

➤ A planet's ability to hold an atmosphere depends entirely on its escape speed.

H2: Key Takeaways for the Exam



The Dependencies

Escape speed depends only on the mass/radius of the planet (R) and acceleration due to gravity (g).



The Independence

It does not depend on the mass of the projectile being launched, nor the angle of projection.



The Magic Number

Earth's escape speed is approximately 11.2 km/s (ignoring atmospheric air resistance).

Master these three principles to navigate any escape speed problem.



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