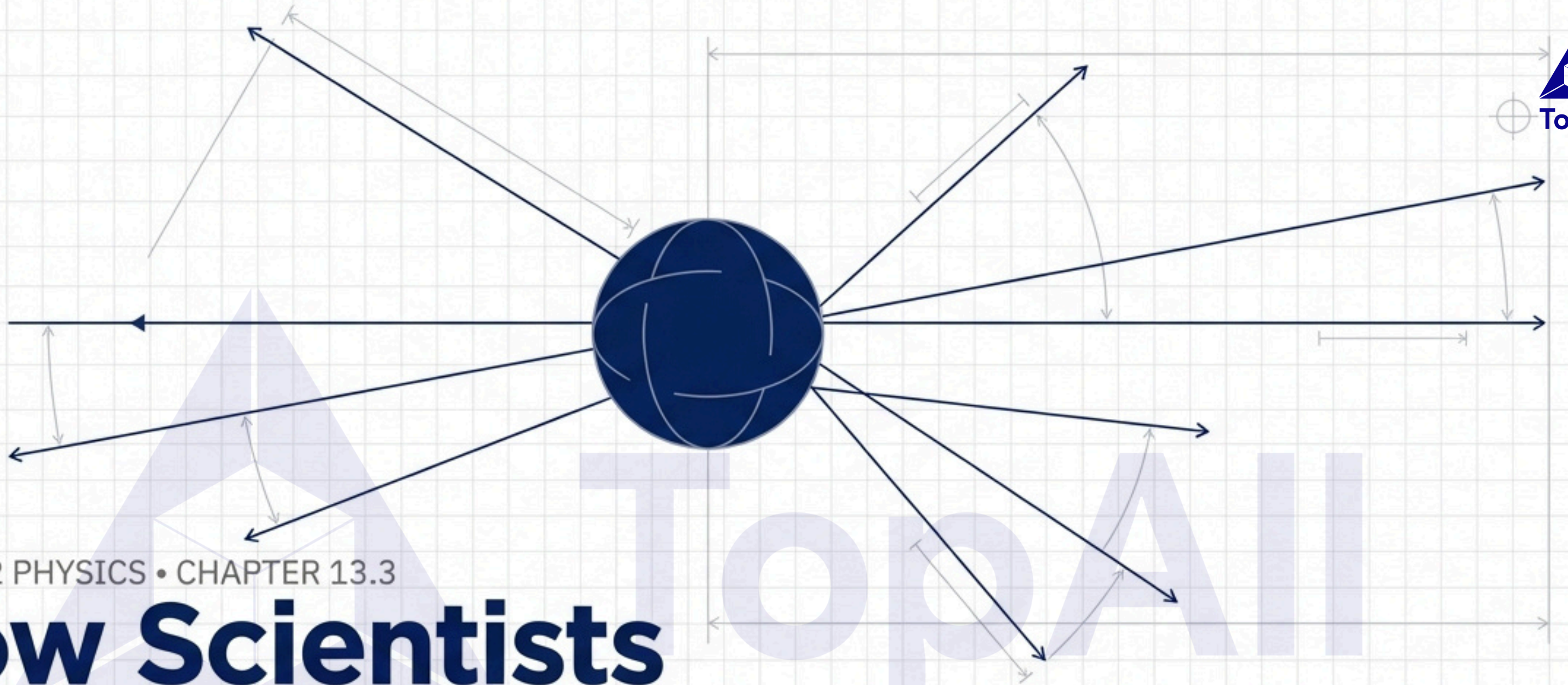




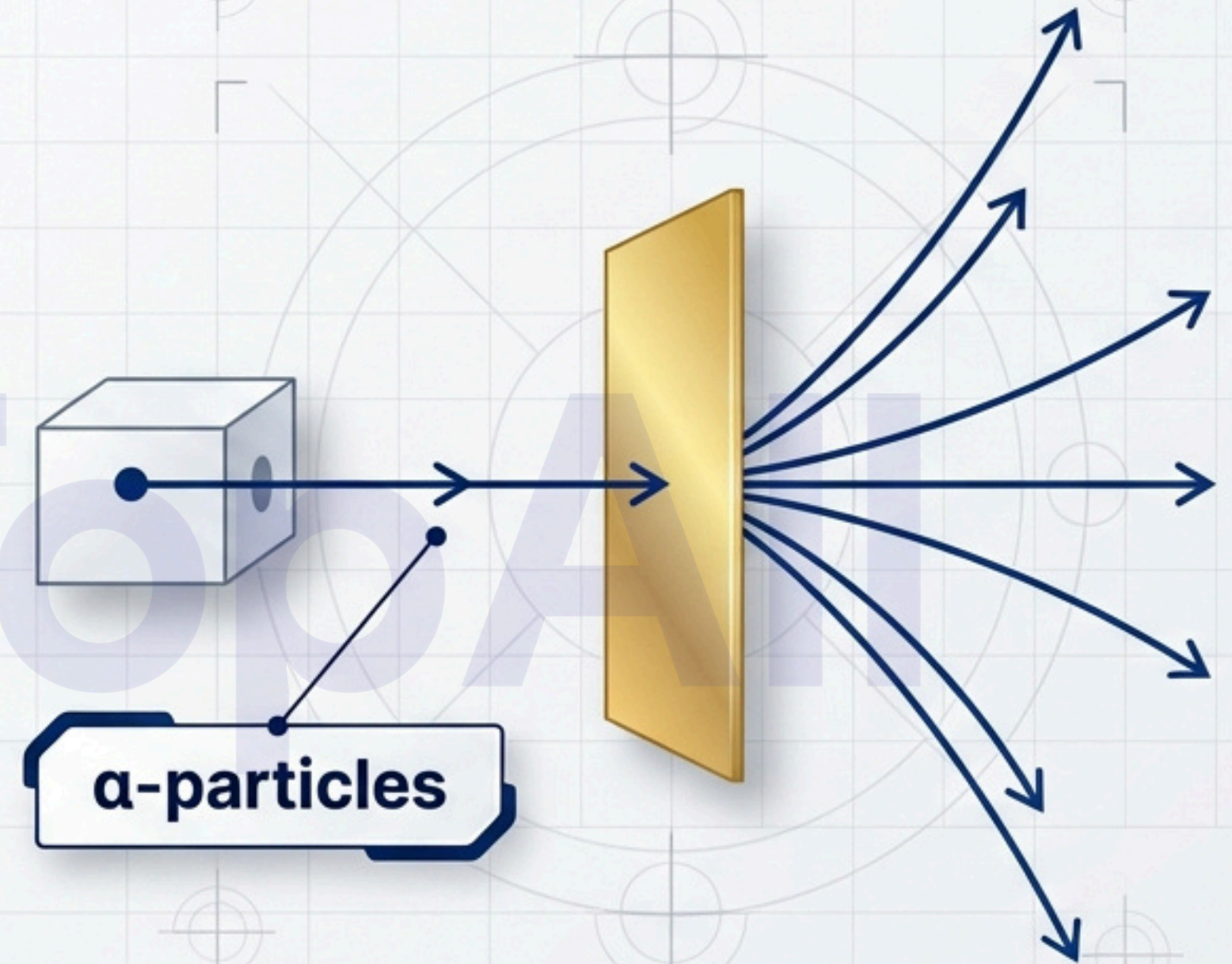
CLASS 12 PHYSICS • CHAPTER 13.3

How Scientists Measured the Nucleus

From Rutherford's gold foil to the discovery of constant nuclear density.

Rutherford's Gold Foil Experiment

Rutherford pioneered the concept of the atomic nucleus. To test his hypotheses, he suggested that Geiger and Marsden bombard thin gold foils with positively charged projectiles.



Finding the Upper Limit

Kinetic Energy: 5.5 MeV



Rutherford assumed Coulomb repulsion was solely responsible for scattering. Because the α -particle bounces back, the actual nucleus size must be smaller than this closest approach distance. If faster projectiles get closer, short-range nuclear forces interfere with the pure Coulomb calculation.



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$$E=mc^2$$



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Achieving Accurate Measurements



Probe Comparison



α -Particle Probes

Ideal for establishing upper boundaries. However, exact measurements fail at extreme close range because α -particles interact via the strong nuclear force, distorting pure scattering trajectories.



Fast Electron Probes

The refined tool. Fast electrons accurately measure nuclear size because they are not affected by the strong nuclear force in the same way, providing a clean map of the target's dimensions.

The Universal Nuclear Radius Formula

Cube root relationship
(Volume proportional to A)

$$R = R_0 A^{1/3}$$

Radius of the nucleus

Empirical constant = $1.2 \times 10^{-15} \text{ m}$ (1.2 fm)

Mass number
(total nucleons)

Electron scattering experiments revealed that the volume of a nucleus is directly proportional to its mass number.

Nuclei are Like Drops of Liquid

Radius: $R \propto A^{1/3}$



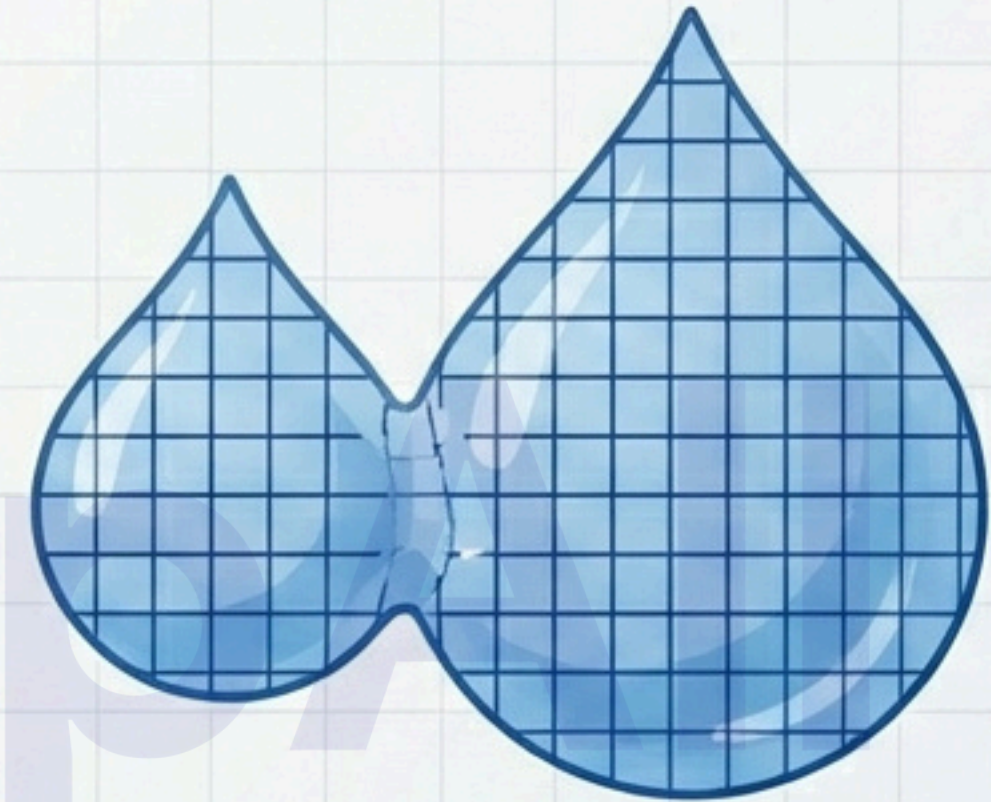
Volume: $V \propto R^3 \rightarrow V \propto A$



Mass: $M \propto A$



**Density = M/V = Constant
(Independent of A)**



Nuclear Density $\approx 2.3 \times 10^{17} \text{ kg m}^{-3}$

Water Density = 10^3 kg m^{-3}

Shows that most of the atom is empty space!

Key Takeaways

- ✓ • Rutherford's α -scattering proved the nucleus exists.
- ✓ • 5.5 MeV α -particles give a closest approach upper limit of $\approx 4.0 \times 10^{-14}$ m.
- ✓ • Electron scattering provides accurate sizing, bypassing strong force interference.
- ✓ • Radius follows Eq. (13.5): $R = R_0 A^{1/3}$ ($R_0 = 1.2 \times 10^{-15}$ m).
- ✓ • Nuclear density is an enormous constant: $\approx 2.3 \times 10^{17}$ kg m⁻³.

Test Yourself

1. Why do alpha particles with energy > 5.5 MeV deviate from Rutherford's pure Coulomb calculations?
2. Prove mathematically why nuclear density is independent of mass number A .



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