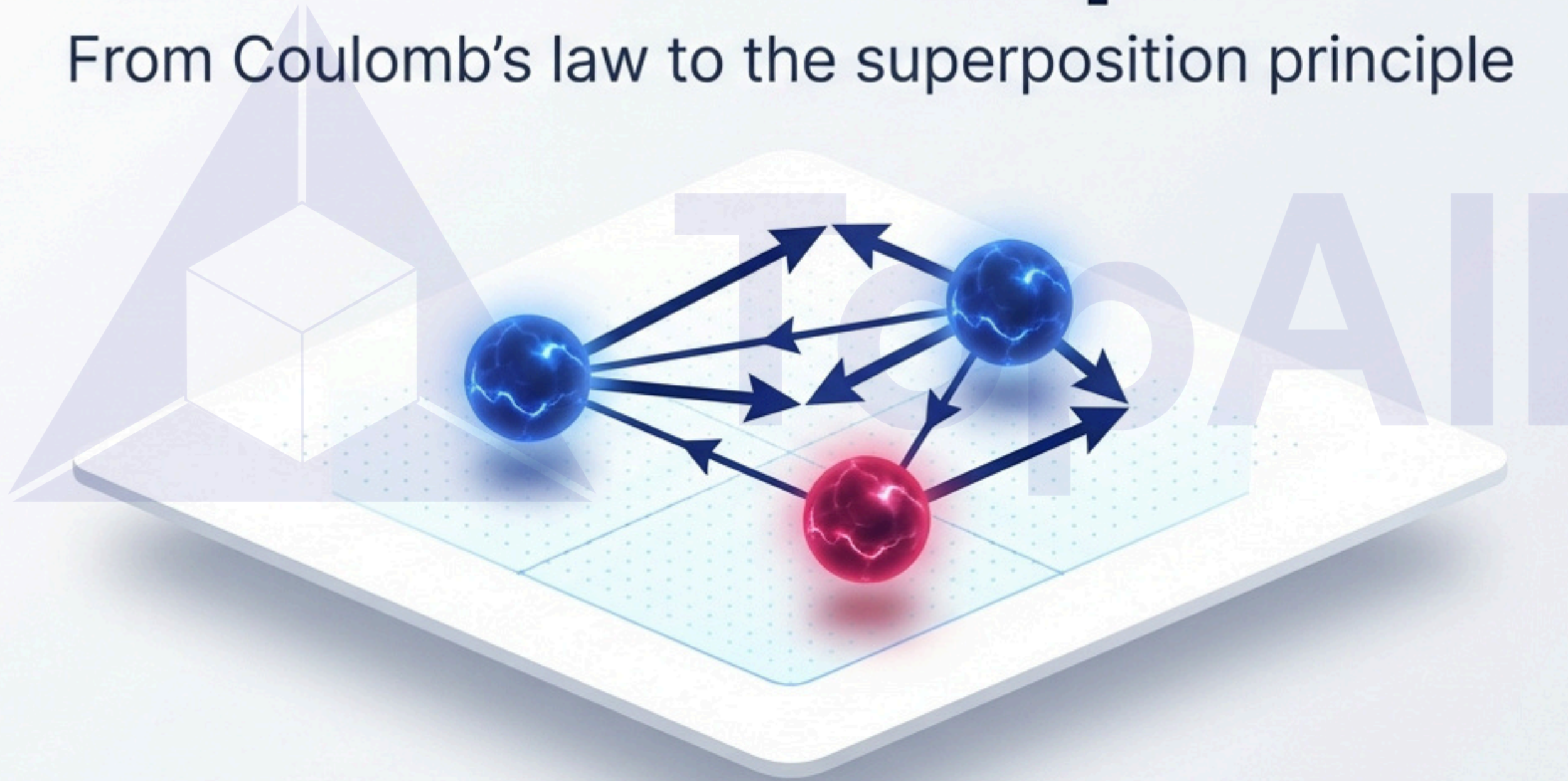


Forces Between Multiple Charges

From Coulomb's law to the superposition principle



Coulomb's Law: The Two-Charge Foundation

Scalar Magnitude

Product of charge magnitudes

Constant (9×10^9
 $\text{N m}^2 \text{C}^{-2}$ in vacuum)

$$F = k \frac{|q_1 q_2|}{r^2}$$

Inverse square of
separation distance

Attraction Simulation



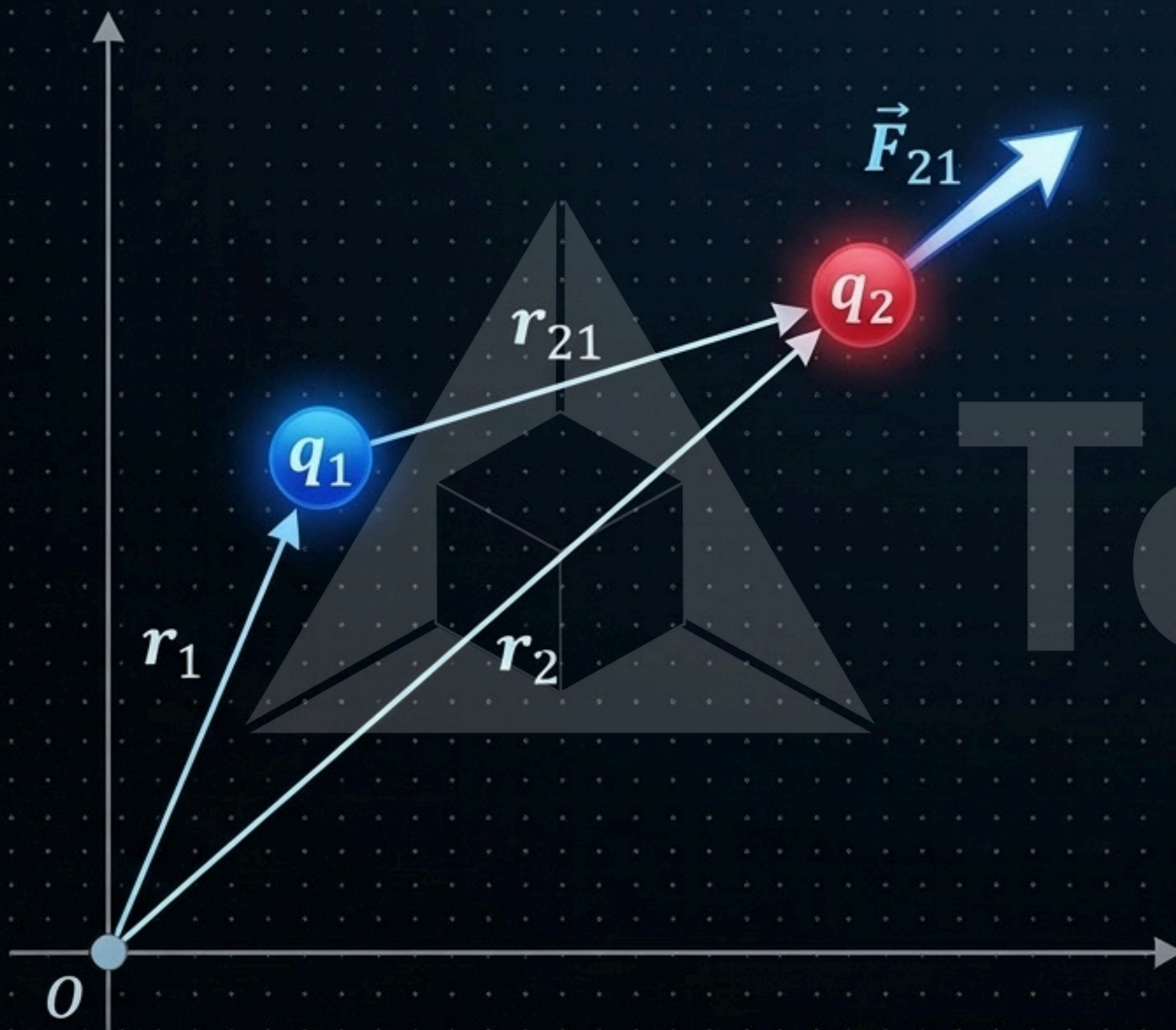
Unlike charges attract.

Repulsion Simulation



Like charges repel.

The Vector Nature of Electric Force



Math Breakdown

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21}$$

Unit vector $\hat{r}_{21}$ specifies direction. It is the compass pointing from q_1 to q_2 .

Success Chip



Newton's Third Law holds: $\vec{F}_{12} = -\vec{F}_{21}$.
The forces are equal and opposite.



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$$E=mc^2$$



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Scale of Strength: Electrostatics vs. Gravity

Comparison Block

Electric Force (F_e)

$$F_e = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2}$$

- Can be attractive or repulsive.

$$\text{Ratio } (F_e/F_g) \approx 2.4 \times 10^{39}$$

Gravitational Force (F_g)

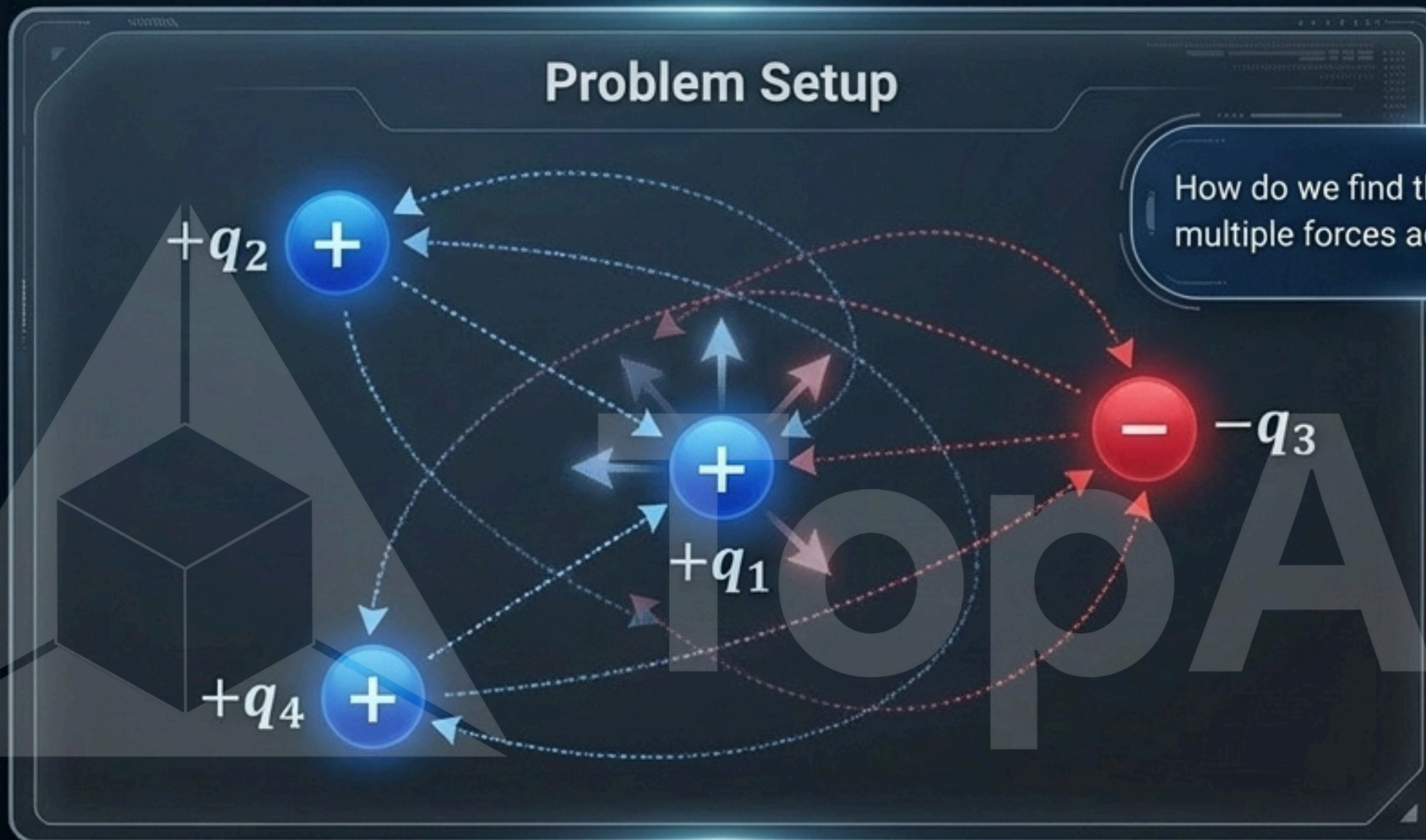
$$F_g = G \frac{m_e m_p}{r^2}$$

- Strictly attractive.

This 10^{39} difference is why gravity is completely ignored in subatomic particle mechanics.

The Multi-Charge Problem

Problem Setup



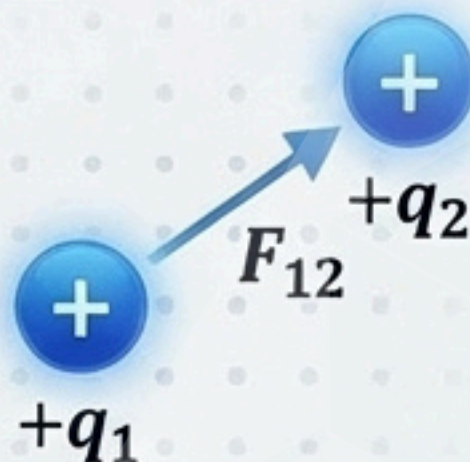
CAUTION: You cannot simply add the scalar magnitudes ($F_1 + F_2 + F_3$)! Forces are vectors; direction dictates the outcome.

To solve this, we need a new engine rule →

The Superposition Principle

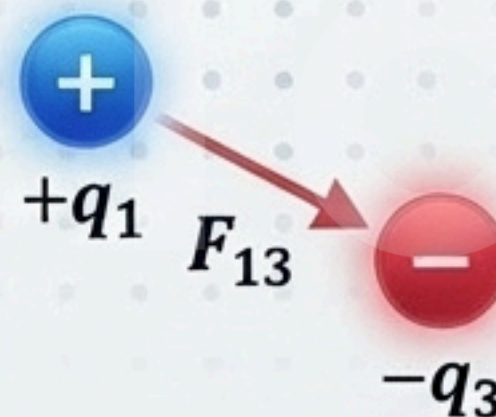
The Total Force is the Vector Sum of Individual Forces.

Step 1: Isolate



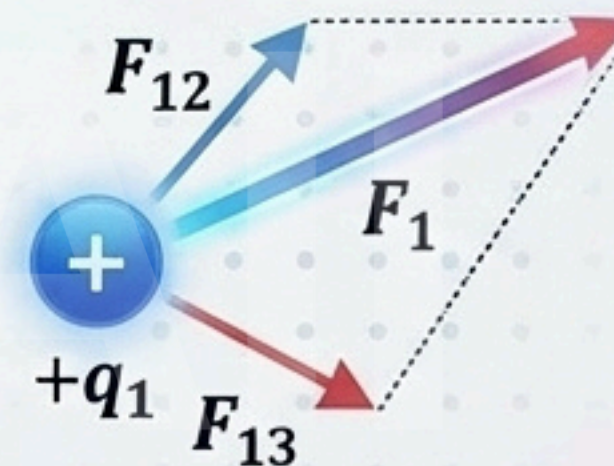
Calculate F_{12} as if q_3 does not.
(Principle of Independence)

Step 2: Repeat



Calculate F_{13} as if q_2
does not exist.

Step 3: Vector Add



Add vectors geometrically:
 $F_1 = F_{12} + F_{13} + \dots + F_{1n}$

Summary & Concept Check



Key Takeaway: Superposition = The vector addition of independent Coulomb forces. Individual interactions are unaffected by neighboring charges.

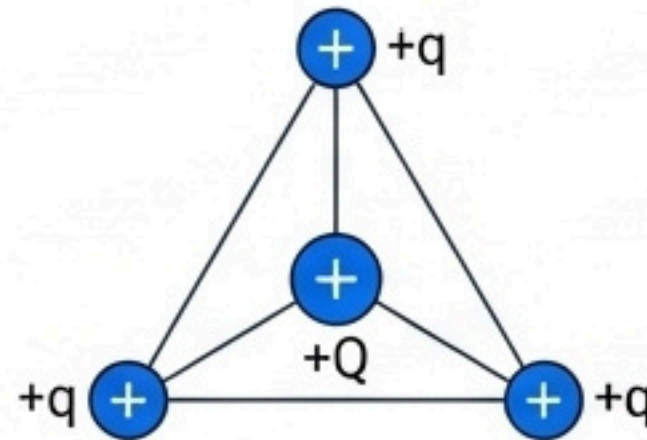


Exam Trap: Never add force magnitudes **algebraically** unless the vectors are perfectly parallel!

Check Your Understanding

Three identical charges (q) are placed at the vertices of an equilateral triangle.

What is the net force on a charge Q placed at the centroid?



Answer: Zero

By symmetry, the three equal force vectors cancel each other out.



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