¶ 1.1

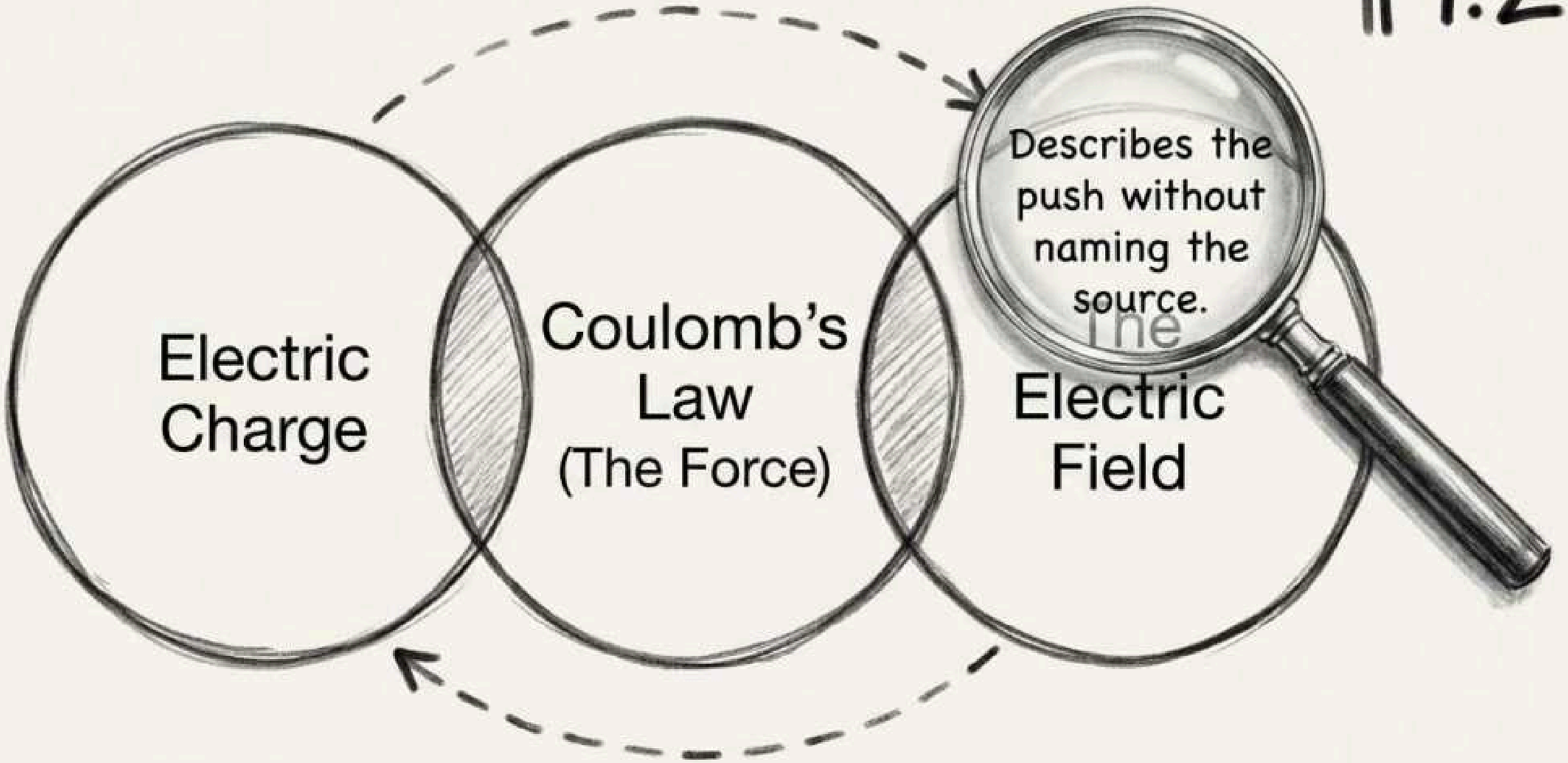
PHYS 102 B: Lecture 1

Electric Charge, Coulomb's Law, and the Electric Field



Gemini Notebook

¶ 1.2



Everything else in the course grows from these ideas.

Gemini Notebook

¶ 1.3

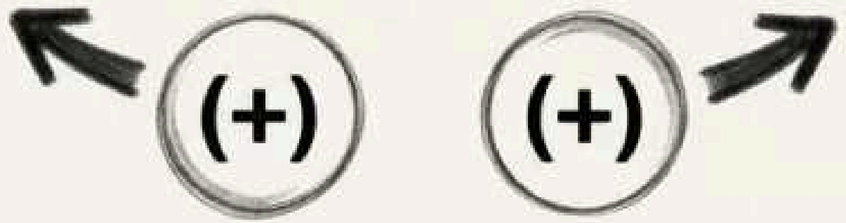


Observation:
Something real moves -> Electric Charge.

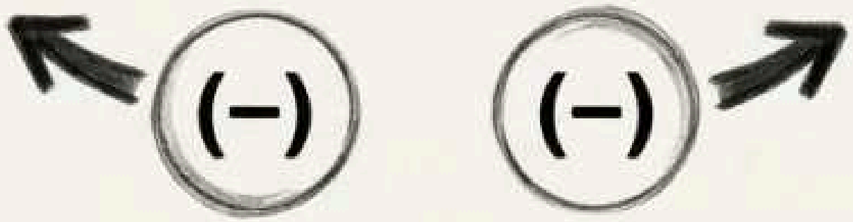


Gemini Notebook

¶ 1.4



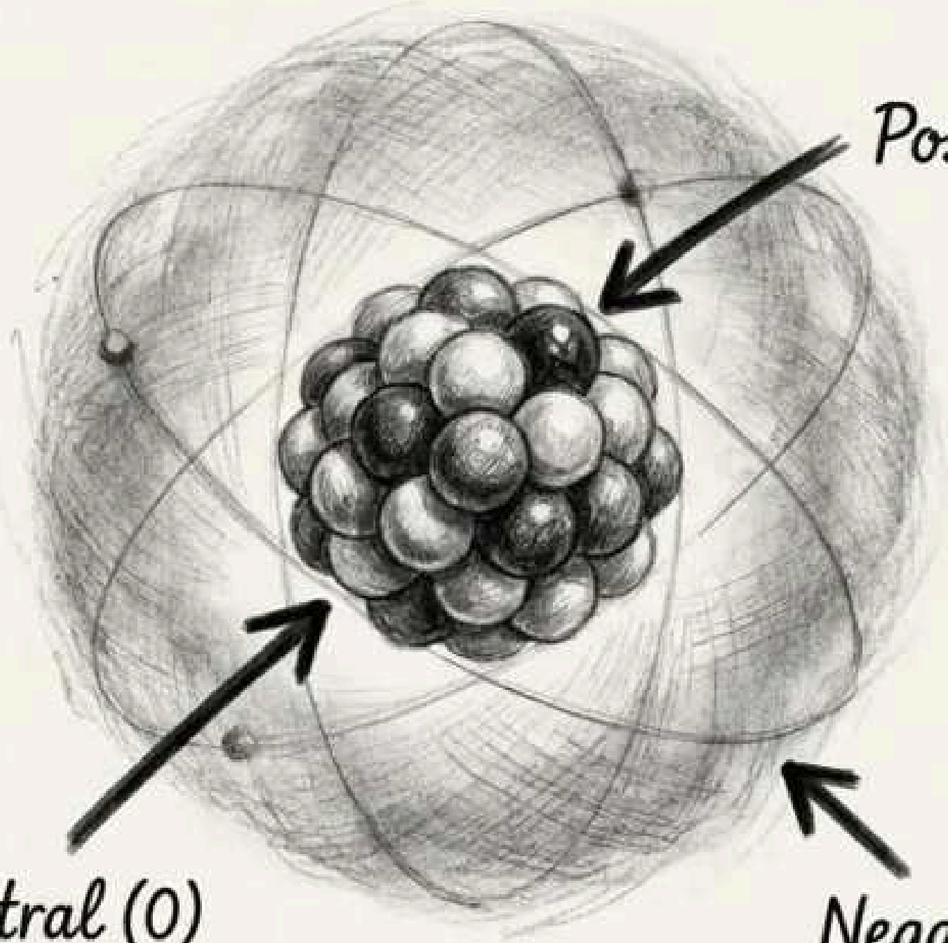
Repel



Repel



Attract



Positive/Negative convention chosen by Benjamin Franklin. Ordinary matter is neutral.

Gemini Notebook

$e \approx 1.602 \times 10^{-19}\ C$

¶ 1.5



Smallest free charge (proton/electron) = e

Charge is Quantized (Always whole numbers)

1 Coulomb = ~6,000,000,000,000,000,000 electrons

Gemini Notebook

Conservation of Charge:
Never created or destroyed, only moved.

¶ 1.6

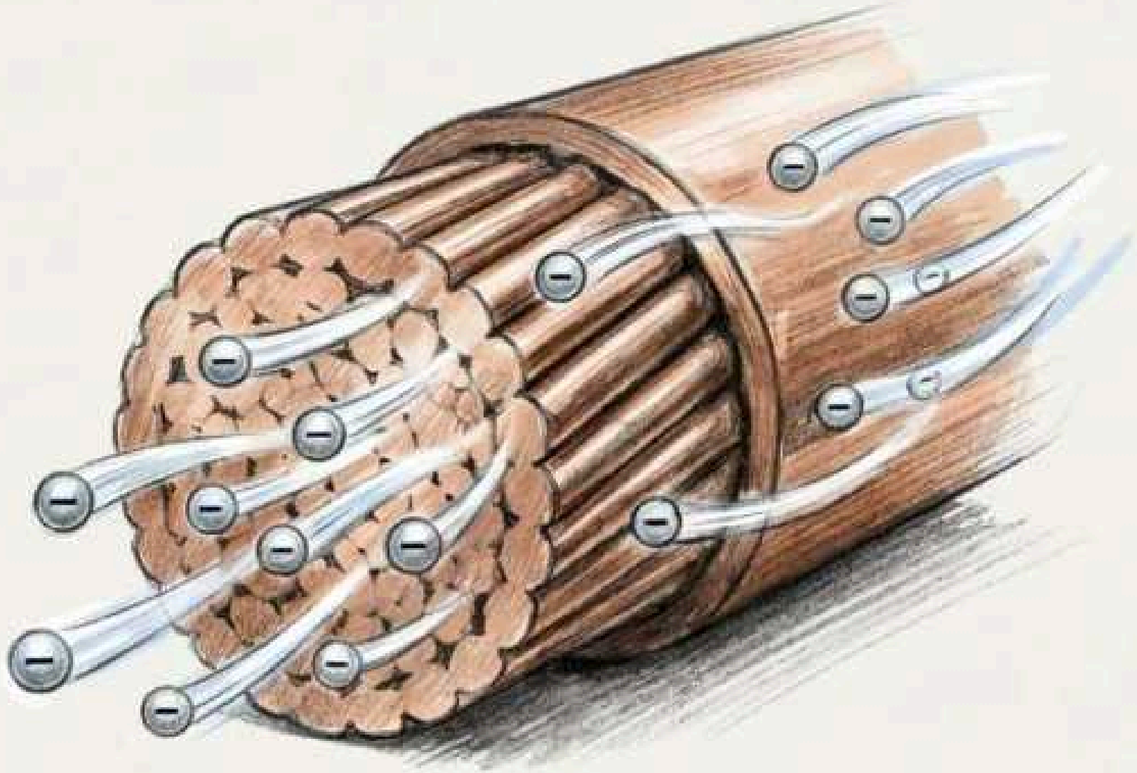
Before: Neutral (Net 0)

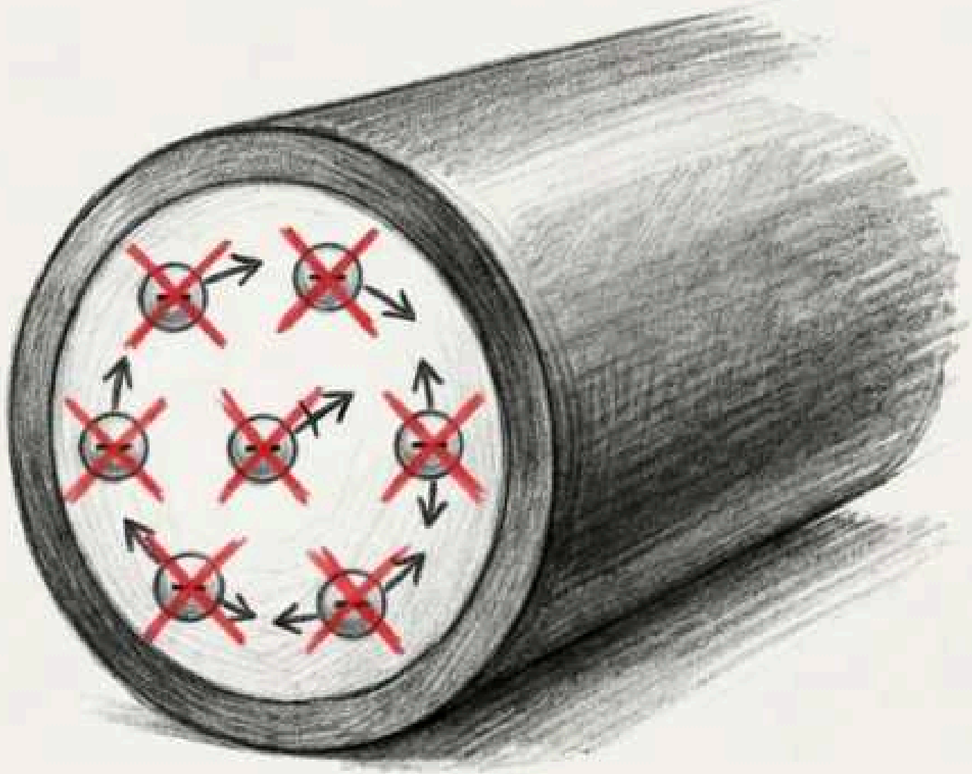
After: Balloon (-), Hair (+). Total Net = 0



Gemini Notebook

¶ 1.7





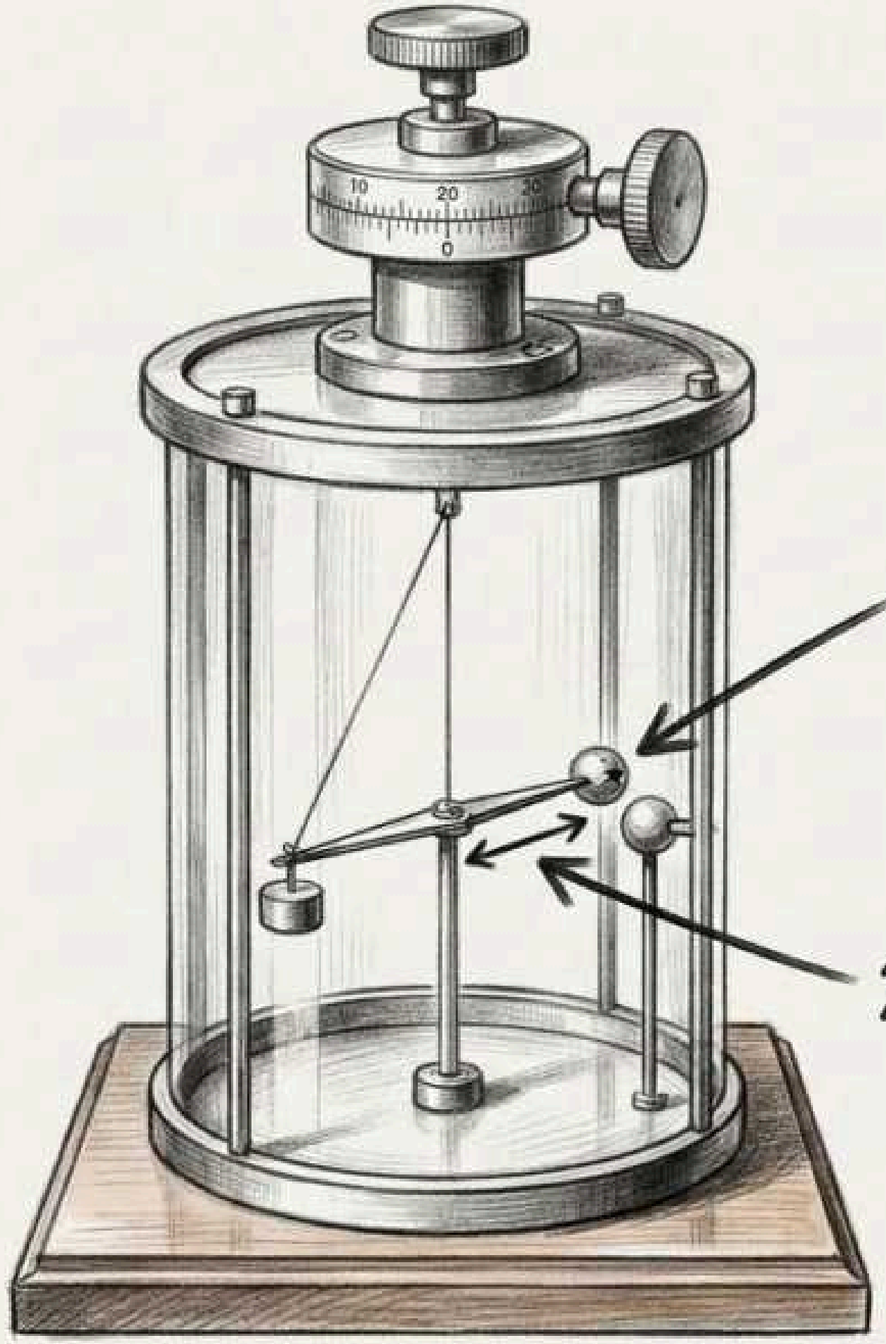
Conductors (e.g., Copper, Salt Water)
= Electrons travel freely.

Insulators (e.g., Rubber, Glass, Air)
= Electrons stay put.

Explains why wire carries current, but static stays trapped on a balloon.

Gemini Notebook

¶ 1.8



1. Proportional to product of charges

2. Inversely proportional to distance squared (r^2)

Gemini Notebook

¶ 1.9

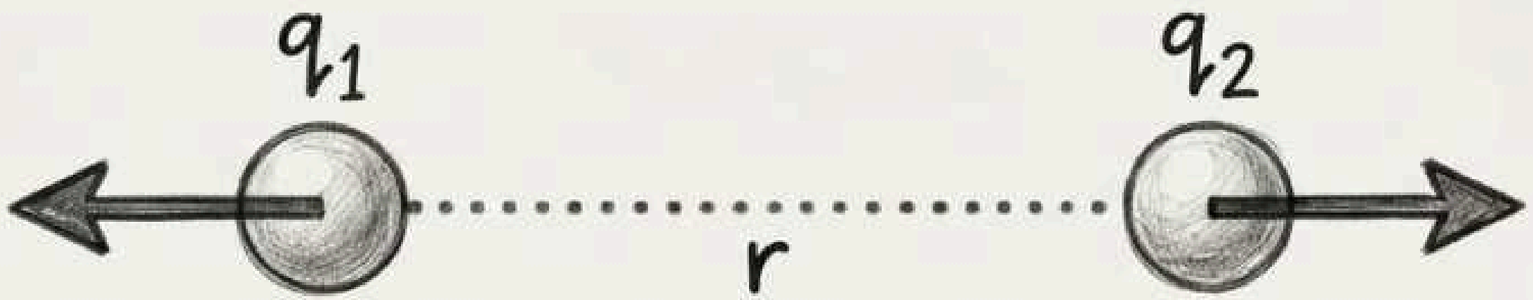
$$F = k\frac{(q_1 q_2)}{r^2}$$

q_1, q_2 = Charges

r^2 = Distance squared

F = Force
(Pushes apart if signs match, pulls together if they differ)

$k = 8.99 \times 10^9\ N\ m^2/C^2$

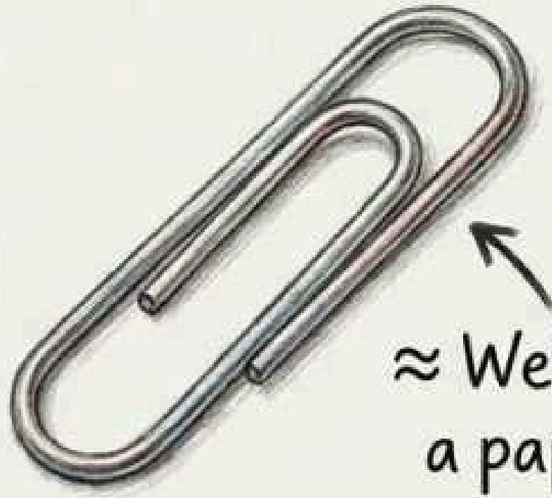


Gemini Notebook

¶ 1.10

Given: $q_1 = 1\ \mu C,\ q_2 = 1\ \mu C,\ r = 1\ m.$

$$F = \frac{(8.99 \times 10^9) \times (10^{-12})}{1^2} = \mathbf{0.009\ N}$$



≈ Weight of a paperclip

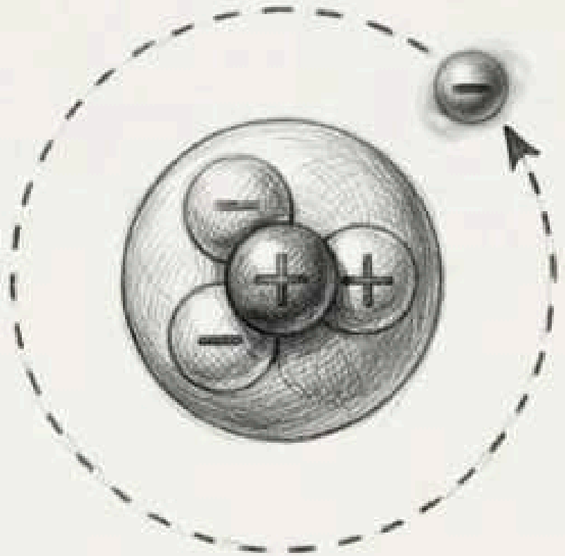
$$F = \frac{(8.99 \times 10^9) \times (10^{-12})}{\cancel{1^2}\ r^2}$$

$r = 0.1\ m\ (10cm)$

$$F = \mathbf{0.9\ N}$$

Move them 10x closer → Force grows by 100x.

Gemini Notebook



Electricity

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

Force in H-atom
$\approx 8.2 \times 10^{-8}$ N

Gravity

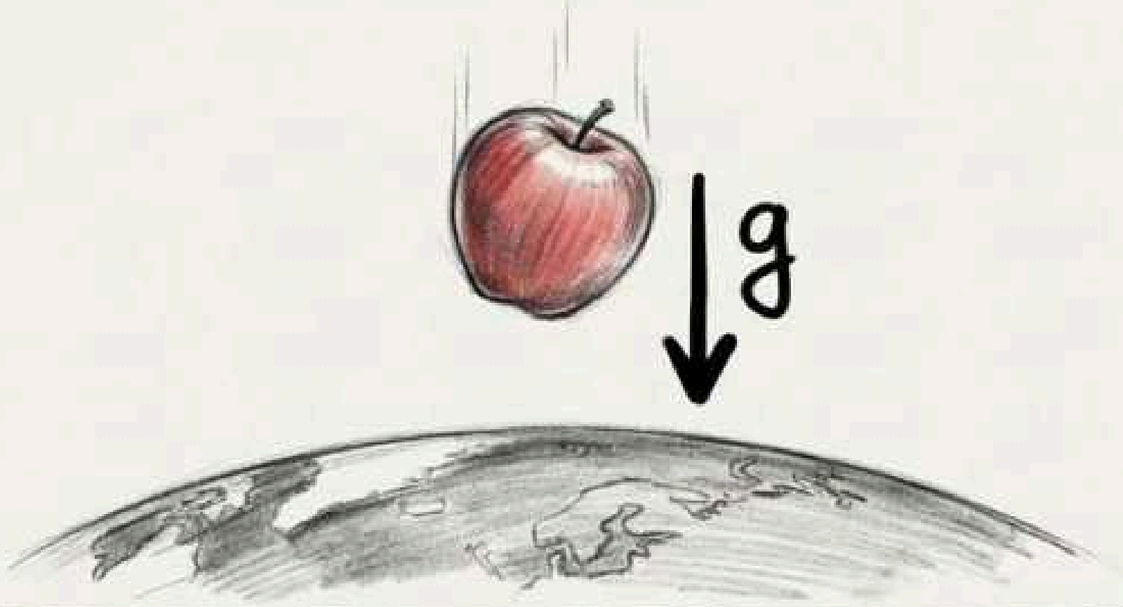
$$F_g = G\frac{m_1 m_2}{r^2}$$

Gravitational pull in H-atom
is 10^{39} times smaller.

Both fall off as $1/r^2$, but electricity is unfathomably stronger.

Gemini Notebook

¶ 1.12

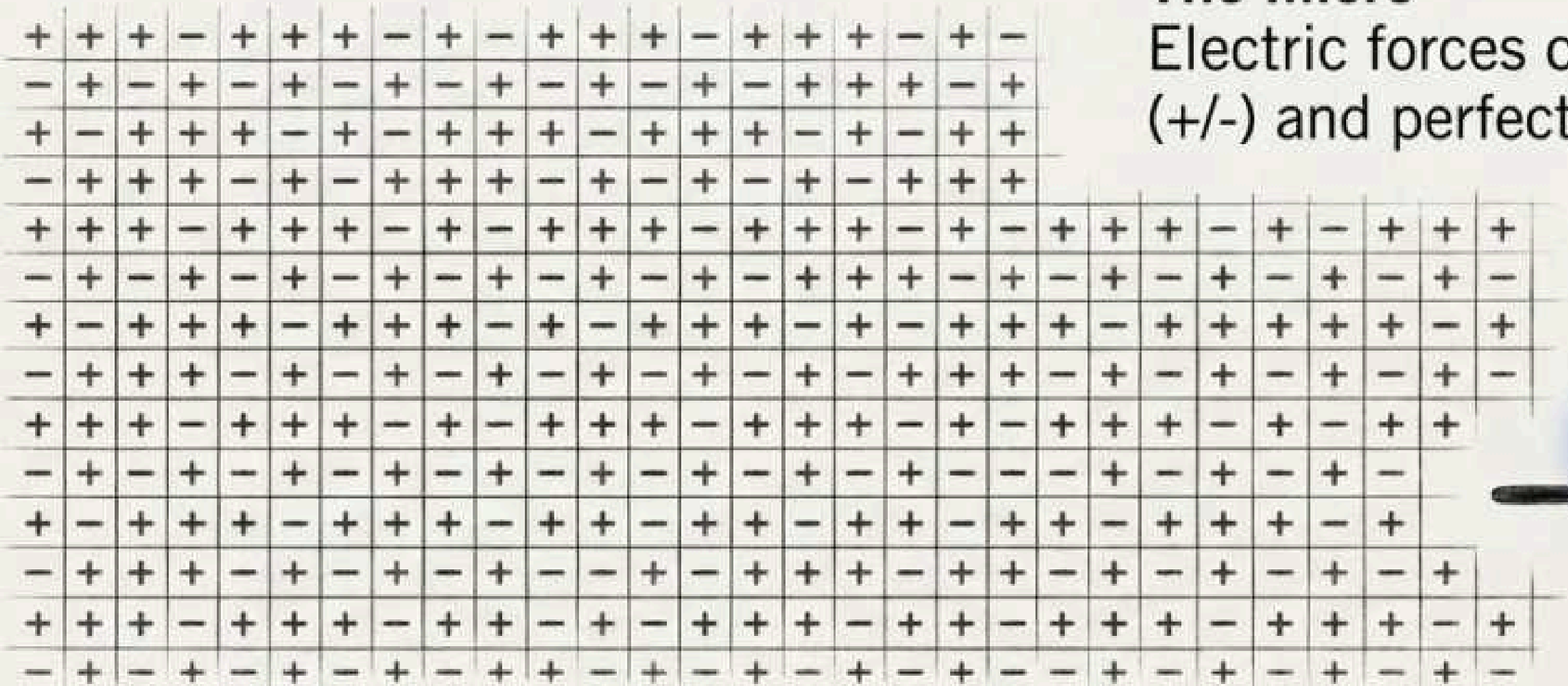


The Macro

Mass is always positive.
Gravity only adds up.

The Micro

Electric forces come in two signs (+/-) and perfectly cancel out.



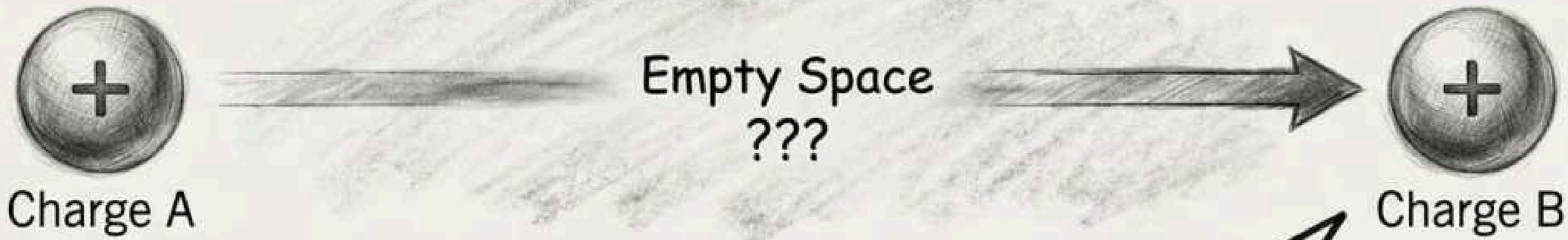


Only a tiny imbalance escapes cancellation—causing sparks and shocks.

Gemini Notebook

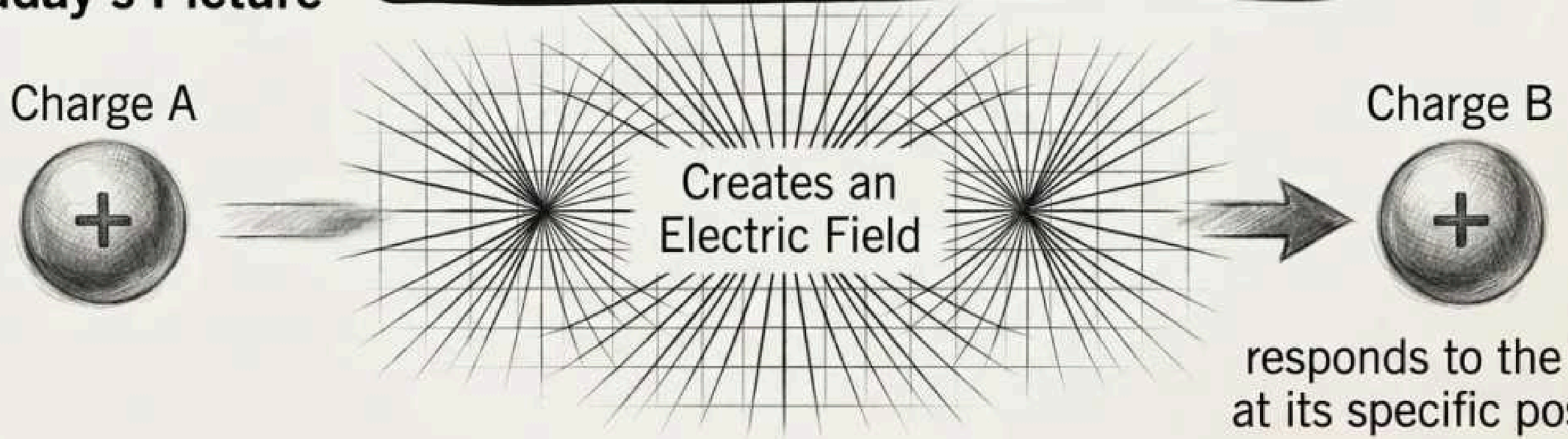
¶ 1.13

The Old Puzzle



Faraday's Picture

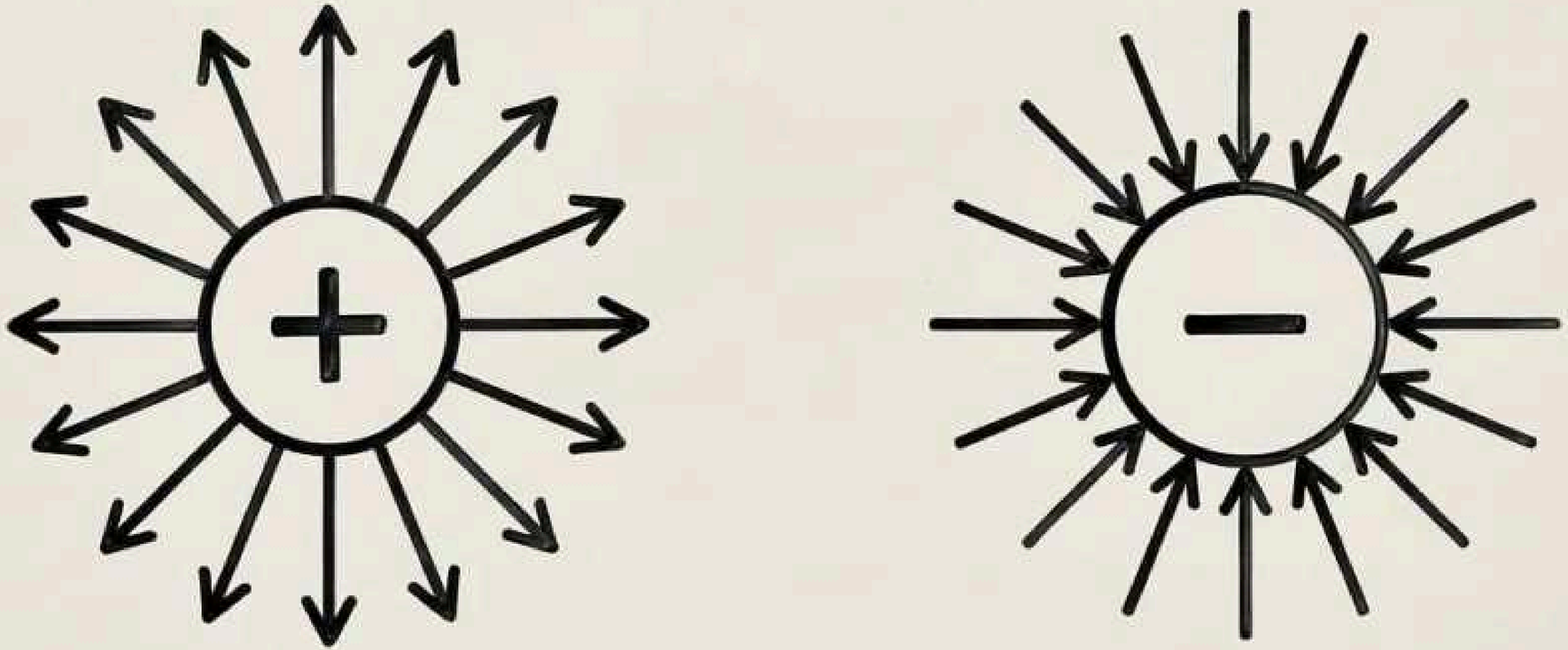
The field is the middle step.



Gemini Notebook

$E = \frac{F}{q}$ (Force per unit of test charge). Unit: N/C.

Point Charge Formula: $E = k\frac{q}{r^2}$

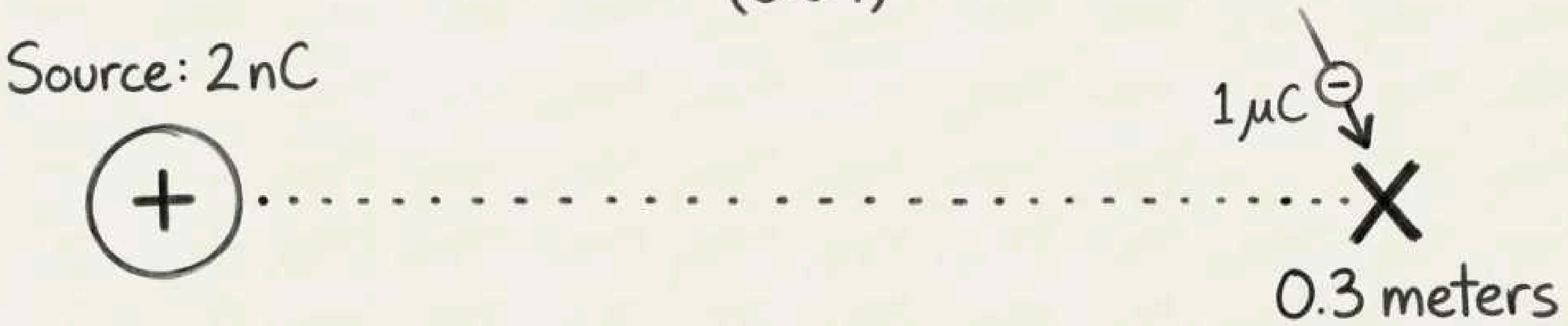


Field points away from positive, toward negative.

Gemini Notebook

¶ 1.15

$$E = \frac{8.99 \times 10^{9} \times 2 \times 10^{-9}}{(0.09)} \approx 200\,\text{N/C}$$



$$F = qE = (1\,\mu\text{C}) \times (200\,\text{N/C}) = 200\,\mu\text{N}$$

Gemini Notebook

¶ 1.16

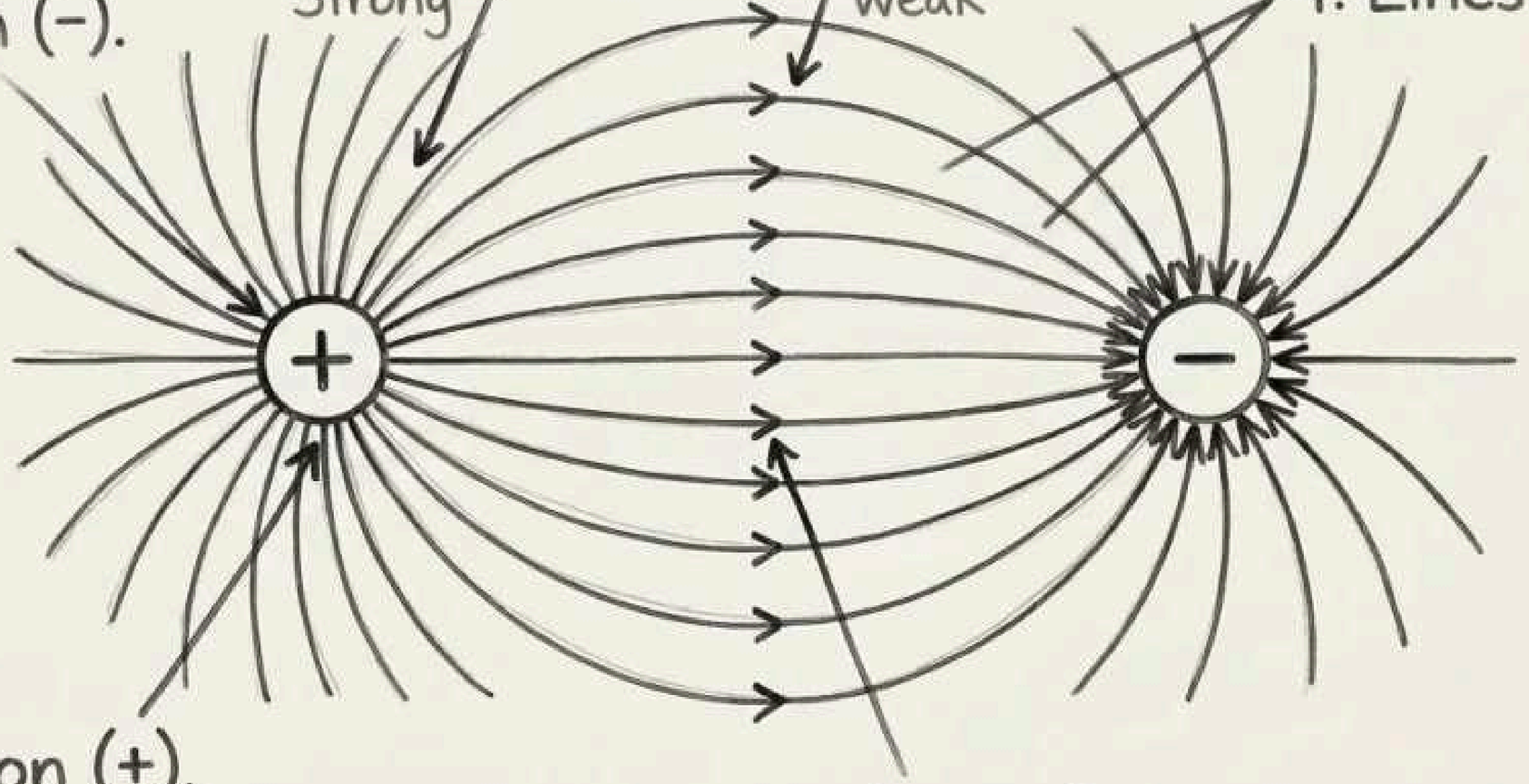
1. Start on (+),
   End on (−).

3. Density = Strength.

Strong

Weak

4. Lines never cross.



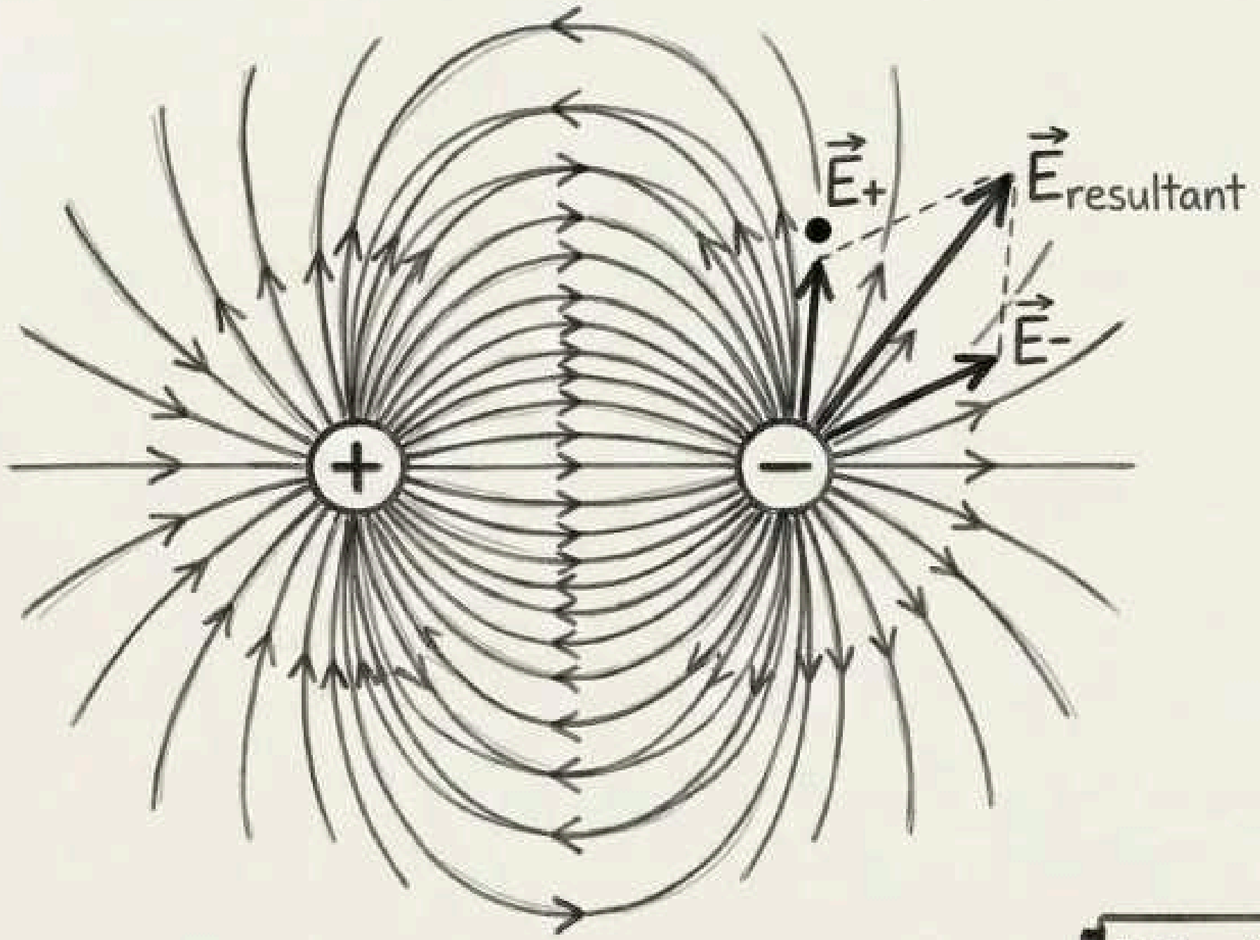
1. Start on (+),
   End on (−).

2. Arrows indicate force direction
   on a positive charge.

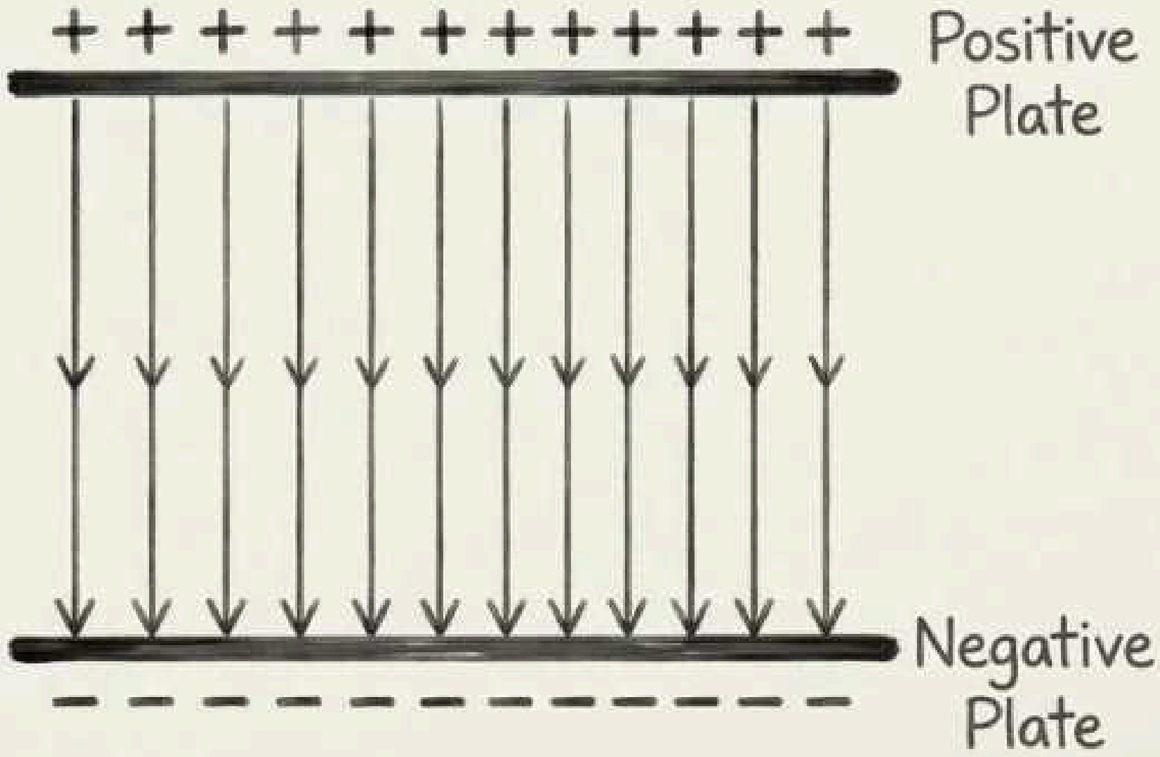
Gemini Notebook

¶ 1.17

Superposition (The Dipole)



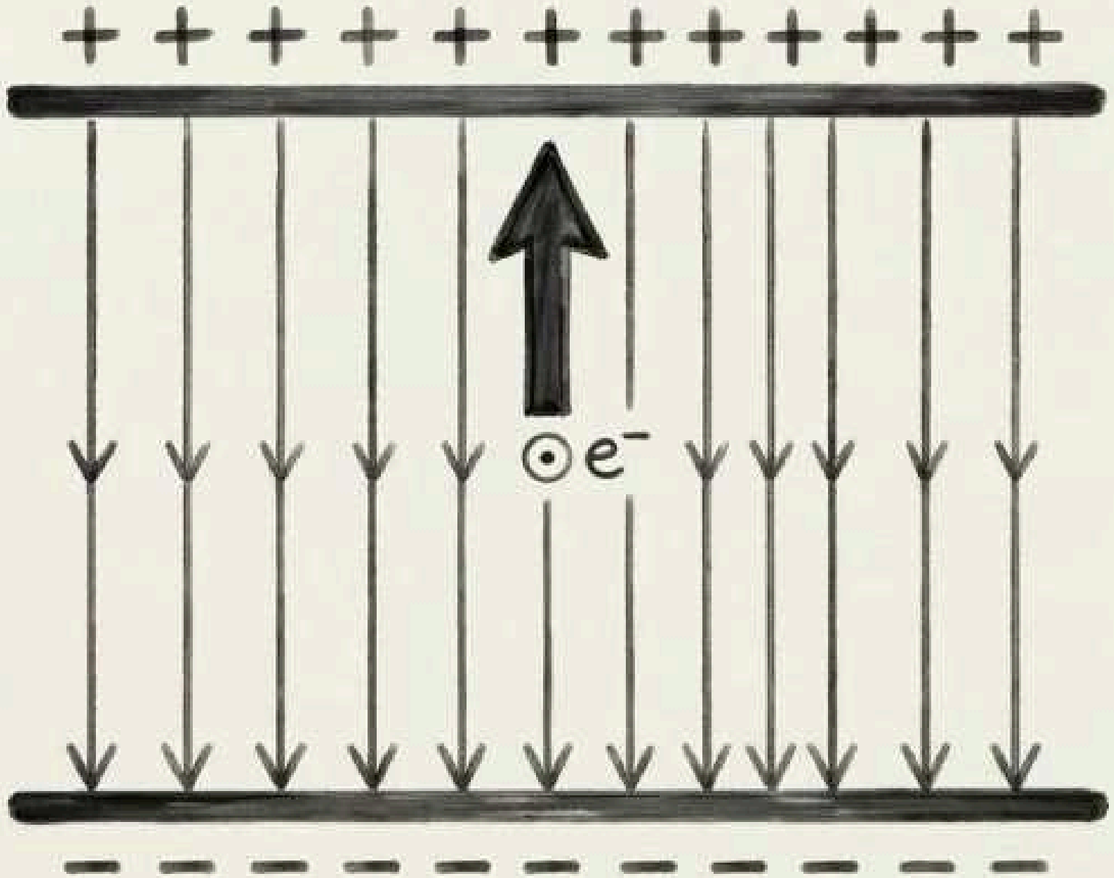
Parallel Plates



Uniform Field — Critical for Lecture 2.

Gemini Notebook

¶ 1.18



Uniform Field: $\vec{E} = 1000\ N/C$

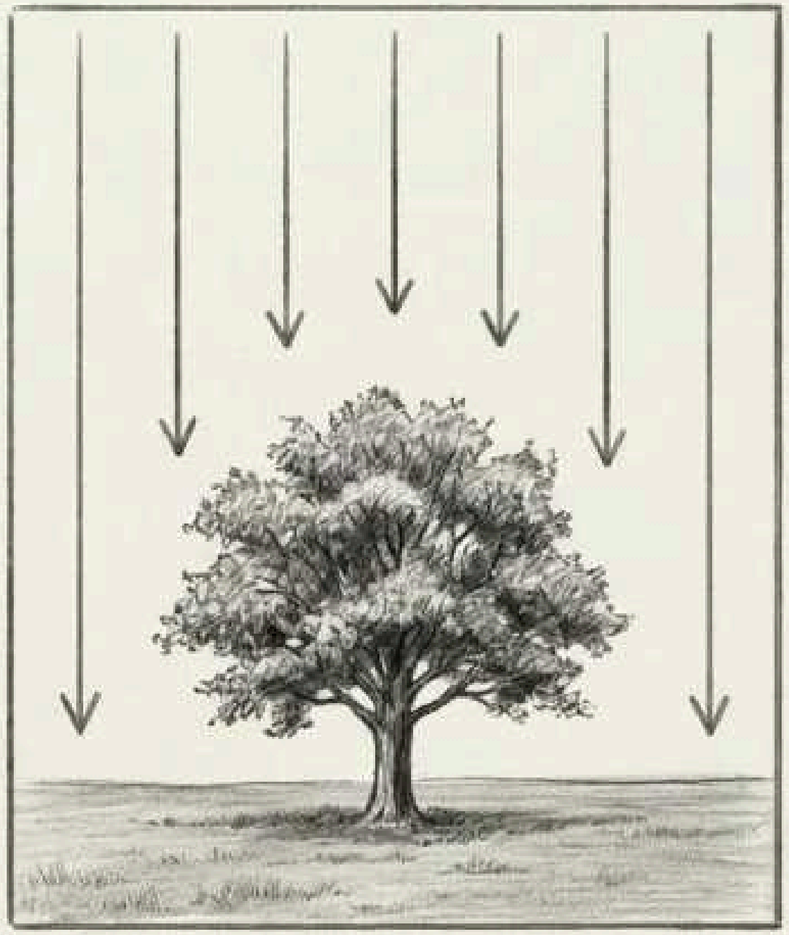
Force: $\vec{F} = q\vec{E} = 1.6 \times 10^{-16}\ N$

Acceleration: $a = \frac{F}{m} = 1.8 \times 10^{14}\ m/s^2$

Far more acceleration than gravity.

Gemini Notebook

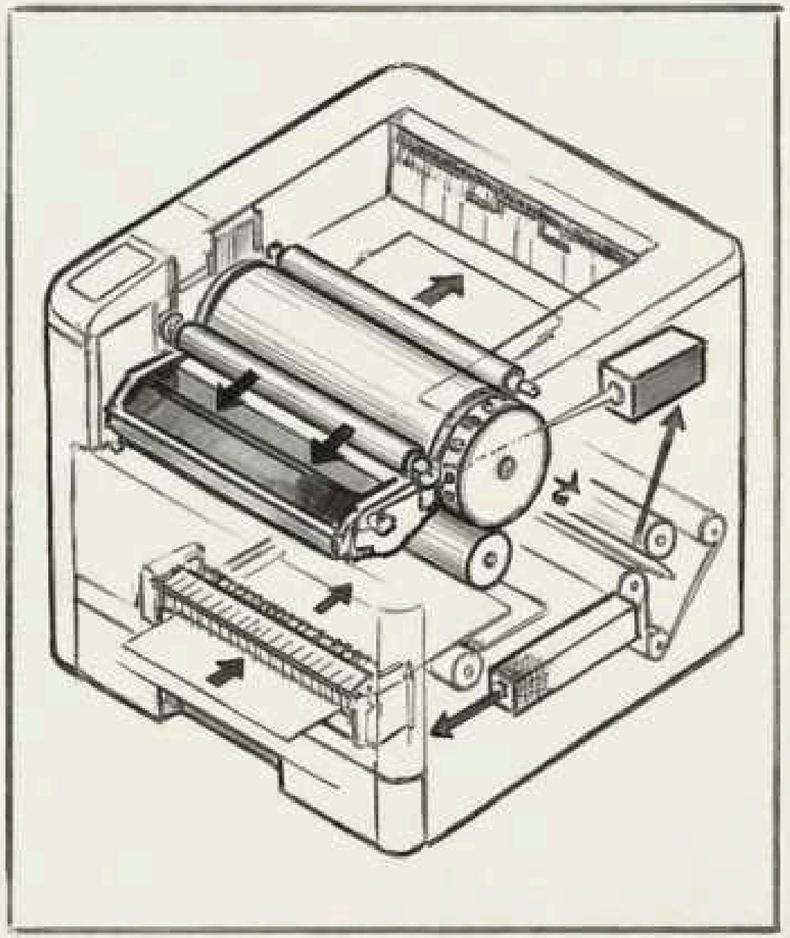
¶ 1.19



Clear Day: ↓ 100 N/C



Air Breakdown (Lightning): 3,000,000 N/C



Photocopiers: Using fields to place toner.

Gemini Notebook

¶ 1.20

Where did the charge come from?



Why did it jump?

Why stronger in dry winter air vs. humid air?

Gemini Notebook

¶ 1.21

Next: How much energy does a charge have in a field?

- Electric Potential
- Voltage
- The Capacitor

Gemini Notebook