CHARGES DAY 1: CHARGE & COULOMB'S LAW

COURSE PREVIEW

Mechanics asked how forces move things. E&M asks where a whole family of forces COMES from: a single property of matter called **charge**. Everything this semester — fields, potential, circuits, magnetism, induction — grows out of the one law on page 2.

Your calculus toolkit transfers whole: the dm strips of Unit 4 become **dq strips**, accumulations become field integrals, and the exponential-approach equations from drag return as circuits.

WARMUP Static Inventory (3 min)

A rubbed balloon sticks to a wall. List: **(a)** what moved when the balloon was rubbed, **(b)** why the wall attracts it even though the wall is neutral, **(c)** one everyday observation that shows there are TWO kinds of charge.

CHARGE: CONSERVED AND QUANTIZED

Charge comes in a smallest piece: **$e = 1.6 \times 10^{-19}$ C** (the proton's charge; the electron carries −e). Every object's charge is a whole-number multiple, **$q = ne$** — and in every process ever observed, total charge is conserved: it moves, it never appears or vanishes.

Working units: a coulomb is enormous. Real electrostatics lives in microcoulombs (1 μC = 10^{-6} C) and nanocoulombs — get fluent in the conversions now.

WE DO Exercise 1: Count the Electrons

A rubbed rod carries $q = -4.8$ μC. **(a)** Which way did electrons move — onto or off the rod? **(b)** How many excess electrons is that? ($n = |q|/e$.) **(c)** The rod has ~10^{23} atoms — what fraction gained an electron? What does that say about how gentle "charging" is?

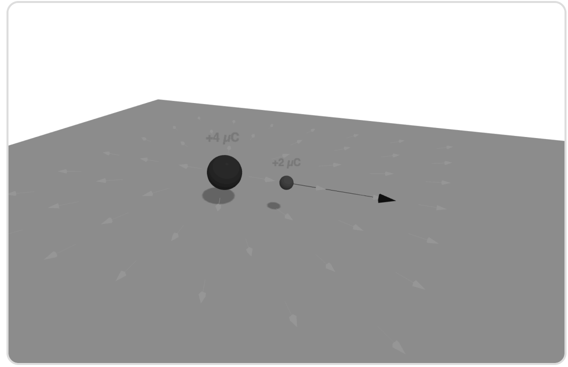
COULOMB'S LAW

THE LAW EVERYTHING GROWS FROM

$$F = k \cdot q_1 q_2 / r^2$$

$k = 9.0 \times 10^9$ N·m²/C² (exam table value — we use it everywhere). Like charges repel, opposites attract, and the force acts along the line between them — always as a Newton's-third-law pair.

The friendly regime: $k \times (\mu C)^2 = 9\times10^9 \times 10^{-12} = 9\times10^{-3}$ — so microcoulomb pairs at meter distances produce millinewtons to newtons.



A +4 µC charge, its field arrows, and a +2 µC probe feeling the push.

WE DO **Exercise 2: One Clean Computation**

Charges of +4.0 µC and +2.0 µC sit 1.0 m apart. Find the force on each — fill in the chain:

$F = k \cdot q_1 q_2 / r^2 = (9.0\times10^9)(\_\_\_\_\_\_\_\_)(\_\_\_\_\_\_\_\_)/(\_\_\_\_\_\_\_\_)^2 = \_\_\_\_\_\_\_\_$ N

Direction on the 2 µC charge: ________   Direction on the 4 µC charge: ________

YOU DO **Exercise 3: Your Turn**

Charges of +3.0 µC and −6.0 µC sit 3.0 m apart. **(a)** Find the magnitude of the force between them. **(b)** Attract or repel? **(c)** If the distance is cut to 1.0 m, what is the new force — by scaling, not recomputing?

SUPERPOSITION: FORCES JUST ADD

Why superposition matters. With three or more charges, each PAIR interacts by Coulomb's law independently — the net force on any charge is the vector sum of the individual pulls. No interference, no correction terms. This is what will let us chop rods into dq pieces on Day 3 and simply add.

WE DO **Exercise 4: Three on a Line**

Charges sit on a line: $q_1 = +4.0\ \mu C$ at $x = 0$, $q_2 = +1.0\ \mu C$ at $x = 1.0$ m, $q_3 = -2.0\ \mu C$ at $x = 2.0$ m. Find the NET force on q_2 (magnitude and direction).

Setup: force from q_1 pushes q_2 ________ (fill in); force from q_3 pulls q_2 ________. Compute each, assign signs, add.

YOU DO **Exercise 5: Scaling Discipline**

Two charges exert 0.036 N on each other. Without knowing q or r, find the new force if: **(a)** one charge is tripled; **(b)** the distance is doubled; **(c)** BOTH charges are doubled AND the distance is halved.

CALC **Exercise 6: Where Does It Balance?**

Charges $+4.0\ \mu C$ and $+1.0\ \mu C$ sit 3.0 m apart. Somewhere between them a third charge would feel zero net force. **(a)** Set $k\cdot 4/x^2 = k\cdot 1/(3-x)^2$ and solve for x (measured from the 4 μC charge). **(b)** Why must the balance point sit closer to the SMALLER charge?

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Electron Bookkeeping

A sphere carries +3.2 μC. **(a)** Did it gain or lose electrons? **(b)** How many?

P2 Straight Coulomb

Find the force between charges of 5.0 μC and 2.0 μC separated by 2.0 m, and state whether your answer changes if both are negative.

P3 Three in a Row

$q_1 = +2.0$ μC at $x = 0$, $q_2 = -3.0$ μC at $x = 1.0$ m, $q_3 = +2.0$ μC at $x = 2.0$ m. Find the net force on q_2 — think before you compute: what do the two pulls do?

P4 Touch and Separate

Two identical conducting spheres carry +6.0 μC and −2.0 μC. They touch (charge splits equally between identical spheres — conservation!) and are moved 2.0 m apart. **(a)** Each sphere's charge after contact. **(b)** The force between them now. **(c)** Attract or repel — and why did that change?