CHARGES DAY 2: THE ELECTRIC FIELD

WARMUP **Day 1 Bridge**

Yesterday's last move: the force on a +2.0 μC probe 1.0 m from a +4.0 μC charge was 0.072 N. Divide out the probe: F/q_probe = _____ N/C. Now divide out a different probe — if the probe had been +1.0 μC, F would be 0.036 N, and F/q_probe = _____ N/C. What do you notice?

THE FIELD: INFLUENCE WAITING IN SPACE

That probe-independent number belongs to the SOURCE charge and the location alone. We name it the **electric field**:

$$\mathbf{E = F/q} \quad \rightarrow \quad \text{for a point charge: } \mathbf{E = kq/r^2}$$

Units: N/C. Direction: the way a POSITIVE test charge would be pushed — radially away from +, radially toward −. Once you know E somewhere, the force on ANY charge there is one multiplication: **F = qE** (negative charges feel it backwards).

μC arithmetic: $k\times(\mu C) = 9\times10^3$, so a few μC at meter range means tens of thousands of N/C.

WE DO **Exercise 1: Field First, Force Second**

A +6.0 μC charge sits alone. **(a)** Find E at a point 2.0 m away: E = kq/r^2 = _____ N/C, pointing _____. **(b)** A −2.0 μC charge is now placed at that point. F = qE = _____ N, pointing _____. **(c)** Why did we NOT have to redo Coulomb's law for part (b)?

FIELDS ADD LIKE FORCES DO

Same superposition principle, new object. Each source charge contributes its own kq/r^2 field at every point; the total field is the VECTOR sum. Yesterday's tug-of-war problems are today's field maps.

WE DO Exercise 2: Midpoint Between Opposites

+4.0 μC at x = 0 and −4.0 μC at x = 2.0 m. At the midpoint (1.0 m from each): **(a)** Which way does the + charge's field point there? The − charge's field? **(b)** Compute each magnitude and the total. **(c)** Compare: what would the total be at the midpoint if BOTH charges were +4.0 μC — and why, in one sentence?

YOU DO Exercise 3: Off to One Side

Same pair (+4.0 μC at x = 0, −4.0 μC at x = 2.0 m). Find the net field at x = 3.0 m (1.0 m past the negative charge): compute both contributions with directions, then combine.

CALC Exercise 4: Fields on a Particle

A uniform field of 5.0×10^{4} N/C points +x. **(a)** Find the force on a proton ($q = +1.6\times10^{-19}$ C) placed in it. **(b)** On an electron. **(c)** The electron's force is tiny — why does it still accelerate violently? ($m_e = 9.1\times10^{-31}$ kg; estimate the order of magnitude of a.)

READING FIELD MAPS

FIELD-LINE RULES

- Lines leave + charges and enter − charges; the COUNT leaving/entering is proportional to |q|.
- The field points along the line's tangent; **density of lines = strength of field**.
- Lines never cross — the field has ONE direction at each point.
- Close to any point charge, the map looks like that charge alone (its $1/r^2$ term dominates).

WE DO Exercise 5: Sketch the Dipole

Sketch the field of +q and −q separated by a small distance: **(a)** draw 8 lines leaving the +, curving to enter the −; **(b)** mark the point on the bisector where the field is strongest; **(c)** draw the E direction AT the midpoint.

YOU DO Exercise 6: Where Is the Field Zero?

+9.0 µC at x = 0 and +1.0 µC at x = 4.0 m. The net field is zero somewhere between them. **(a)** Set $k(9)/x^2 = k(1)/(4-x)^2$ and solve. **(b)** One sentence: why is there NO zero point outside the pair for like charges, but there IS one outside for a +/− pair?

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Point-Charge Field

Find E at 3.0 m from a +2.0 μC charge, with direction.

P2 Field → Force

The field at some point is 4.5×10^{4} N/C pointing east. Find the force (magnitude AND direction) on: **(a)** a +3.0 μC charge there; **(b)** a −3.0 μC charge there.

P3 Midpoint, Like Charges

Two +5.0 μC charges sit 4.0 m apart. Find the net field at their midpoint, then the net field 1.0 m from the LEFT charge (still on the line between them).

P4 Work Backwards

At 2.0 m from an unknown point charge, the field is 1.8×10^{4} N/C pointing TOWARD the charge. **(a)** What is the charge's sign? **(b)** Its magnitude? **(c)** At what distance would the field be 7.2×10^{4} N/C?