

CHARGES DAY 2: THE ELECTRIC FIELD

WARMUP Day 1 Bridge

Yesterday's last move: the force on a $+2.0\ \mu\text{C}$ probe $1.0\ \text{m}$ from a $+4.0\ \mu\text{C}$ charge was $0.072\ \text{N}$. Divide out the probe: $F/q_{\text{probe}} = \rule{1cm}{0.4pt}\ \text{N/C}$. Now divide out a different probe — if the probe had been $+1.0\ \mu\text{C}$, F would be $0.036\ \text{N}$, and $F/q_{\text{probe}} = \rule{1cm}{0.4pt}\ \text{N/C}$. 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**:

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

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: $\mathbf{F} = q\mathbf{E}$ (negative charges feel it backwards).

μC arithmetic: $k \times (\mu\text{C}) = 9 \times 10^3$, so a few μC at meter range means tens of thousands of N/C .

WE DO Exercise 1: Field First, Force Second

A $+6.0\ \mu\text{C}$ charge sits alone. **(a)** Find E at a point $2.0\ \text{m}$ away: $E = kq/r^2 = \rule{1cm}{0.4pt}\ \text{N/C}$, pointing _____. **(b)** A $-2.0\ \mu\text{C}$ charge is now placed at that point. $F = qE = \rule{1cm}{0.4pt}\ \text{N}$, pointing _____. **(c)** Why did we NOT have to redo Coulomb's law for part (b)?

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 $-4.0 \mu\text{C}$ 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 $x = 0$, $-4.0 \mu\text{C}$ 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 ($q = +1.6 \times 10^{-19}$ C) placed in it. **(b)** On an electron. **(c)** The electron's force is tiny — why does it still accelerate violently? ($m_e = 9.1 \times 10^{-31}$ kg; estimate the order of magnitude of a .)

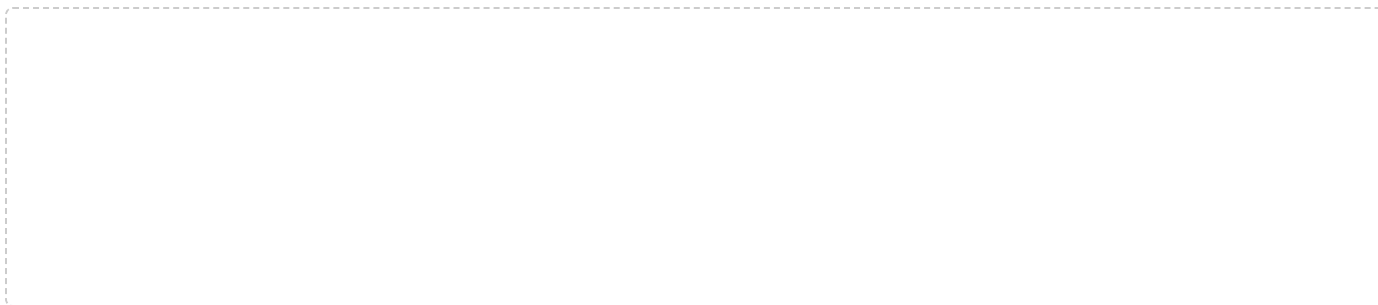
READING FIELD MAPS

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).

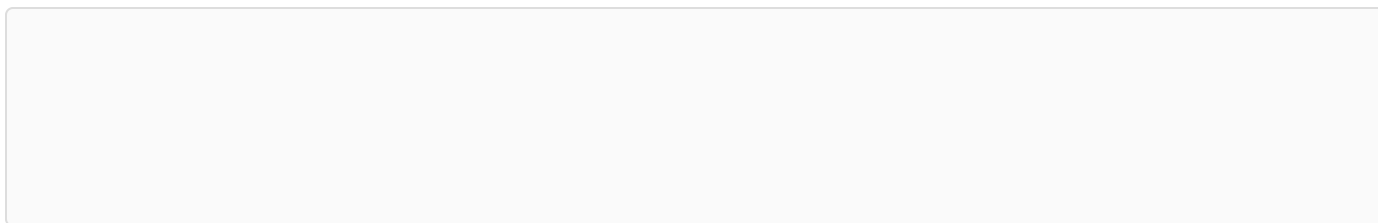
WE DO Exercise 5: Sketch the Dipole

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?

$+9.0 \mu\text{C}$ at $x = 0$ and $+1.0 \mu\text{C}$ at $x = 4.0 \text{ m}$. 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 $+2.0\ \mu\text{C}$ charge, with direction.

P2 Field $\rightarrow$ Force

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

P3 Midpoint, Like Charges

Two $+5.0\ \mu\text{C}$ 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 $1.8 \times 10^4\ \text{N/C}$ pointing TOWARD the charge. **(a)** What is the charge's sign? **(b)** Its magnitude? **(c)** At what distance would the field be $7.2 \times 10^4\ \text{N/C}$?