Unit 6.2 — Fields

Electric Fields · Gravitational Fields · Field Drawing · Triboelectric Series

Hardest Practice Set · 14 problems · Full answer key begins after Problem 14

Constants: $k = 8.99\times10^{9}$ N·m^2/C^2 | $G = 6.674\times10^{-11}$ N·m^2/kg^2

$E = kQ/r^2$ (points away from +, toward −) $g = GM/r^2$ (points toward the mass) $F = qE$ net field = vector sum

Field-line rules: start on +, end on − · never cross · density shows strength · line count ∝ charge · meet conductors at 90°

SECTION A — Field of a Single Source: Magnitude and Direction

1. Find the electric field 0.15 m from a −8.0 μC charge. Give magnitude and direction.

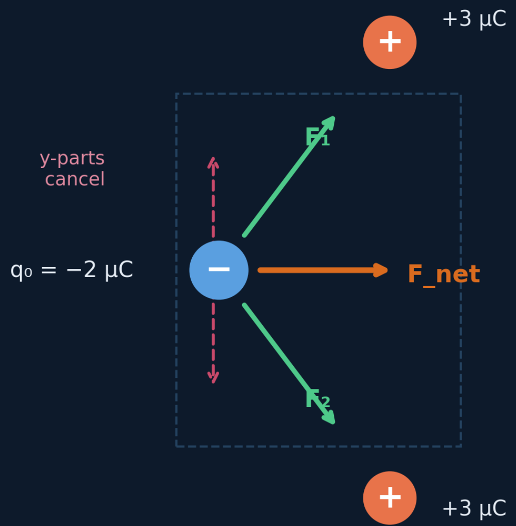
2. How far from a +6.0 μC charge is the electric field equal to 4.0×10^{6} N/C?

3. The field 0.50 m from a charge points radially inward with magnitude 3.6×10^{4} N/C. Find the charge, including its sign.

SECTION B — Vector Superposition: Net Field and Net Force

4. A −2.0 μC charge sits at the centre of the box. Two +3.0 μC charges sit 0.50 m away, one up-and-right and one down-and-right (0.30 m across, 0.40 m up in each case). Find the net electrostatic force on the centre charge. Use the symmetry: resolve each force into components and see what cancels.

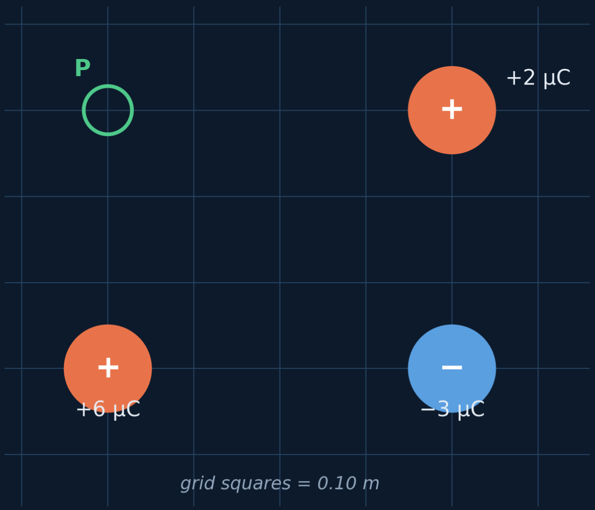
This is the vector-measurement move: break each force into x and y, cancel the parts that oppose, add the parts that agree.



each charge 0.50 m from centre (0.30 m across, 0.40 m up)

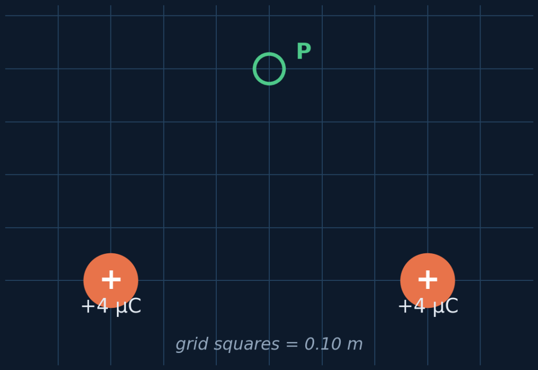
5. Three charges sit on the grid as shown: +6.0 μC at the origin, −3.0 μC at (0.40, 0), and +2.0 μC at (0.40, 0.30). Find the net electric field at point P = (0, 0.30). Give magnitude and direction.

Find each field vector separately (away from +, toward −), resolve into components on the grid, then add.



6. Two +4.0 μC charges sit at (−0.30, 0) and (+0.30, 0). Find the net electric field at point P = (0, 0.40) directly above the midpoint. Then state the direction a +1.0 μC test charge placed at P would accelerate.

By symmetry, one component of the two fields cancels. Which one?



SECTION C — Predicting Force in a Field

7. At point P in Problem 5 the net field was found. A −5.0 μC charge is now placed at P. Find the magnitude and direction of the force it feels. (Use $F = qE$.)

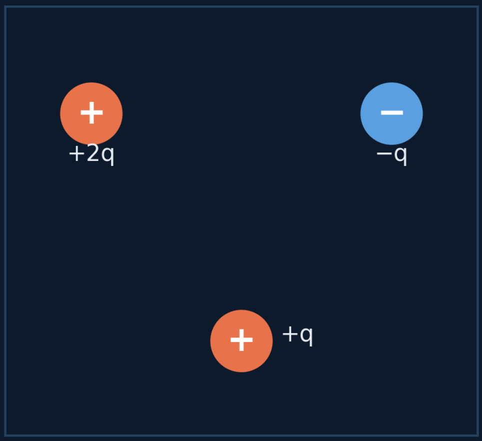
A negative charge feels a force opposite to the field direction.

8. A test charge released at a certain point in a two-charge field accelerates directly toward the +8 μC charge and away from the −2 μC charge nearby. What is the sign of the test charge, and what does that tell you about the net field direction at that point?

SECTION D — Drawing Fields for Multiple Sources (Exceeding Level)

9. Draw the complete electric field for the three charges shown: +2q, −q, and +q. Follow every field-line rule. Show roughly twice as many lines on the +2q, mark where lines terminate, and identify any point where the field is zero.

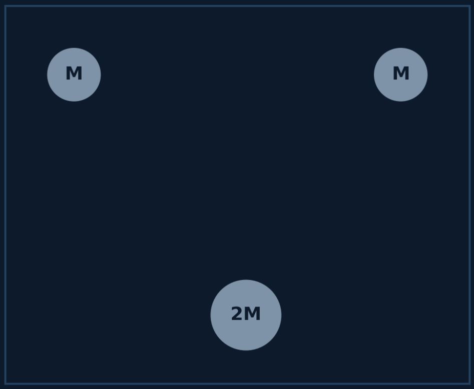
Lines leave +, enter −. The +2q owns twice the lines of the −q, so half of its lines must escape to infinity.



draw the electric field lines for all three charges

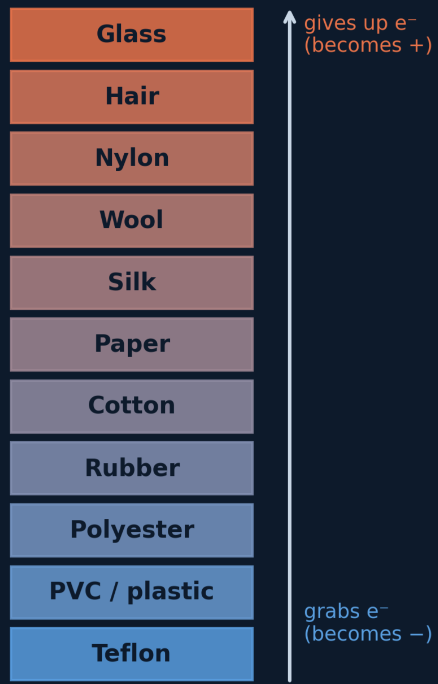
10. Draw the gravitational field for the three masses shown (M, M, and 2M). Every arrow points inward toward mass. Mark the approximate location of any null point where the field cancels.

Gravity has no repulsion. Every field line points into a mass — there are no sources, only sinks.



draw the gravitational field for all three masses

SECTION E — Triboelectric Series and Qualitative Charge



Use this triboelectric series for the problems below. Higher = gives up electrons (becomes +); lower = grabs electrons (becomes −).

11. A glass rod is rubbed with silk, then a separate rubber rod is rubbed with wool. The charged glass rod and the charged rubber rod are brought near each other. Do they attract or repel? Justify each charge using the series.

12. A wool cloth is rubbed with Teflon. Which object ends up negative, and by roughly how much charge compared to the other object? Explain what actually moved.

13. A student claims rubbing two identical glass rods together will charge them oppositely. Use the triboelectric series to explain why this fails.

14. A neutral metal sphere is brought near — but not touching — the negatively charged rubber rod from Problem 11. Explain using field and induction why the sphere is attracted, and state the sign of charge on the near and far sides of the sphere.

Answer Key

Unit 6.2 — Fields · Full worked solutions

1. Field of a single charge

$E = kQ/r^2 = (8.99\times10^9)(8.0\times10^{-6})/(0.15)^2$

$E = 71920/0.0225$

→ $E = 3.20\times10^6$ N/C, directed toward the charge (it is negative)

Common error: Forgetting that a negative source pulls the field inward. Magnitude uses |Q|; the sign sets direction.

2. Solve for distance

$E = kQ/r^2 \rightarrow r = \sqrt{(kQ/E)}$

$r = \sqrt{[(8.99\times10^9)(6.0\times10^{-6})/(4.0\times10^6)]}$

$r = \sqrt{(0.013485)}$

→ r = 0.116 m

Common error: Forgetting the square root, or dividing before taking it.

3. Solve for charge and sign

$Q = Er^2/k = (3.6\times10^4)(0.50)^2/(8.99\times10^9)$

field points INWARD → the charge is negative

→ $Q = -1.0\times10^{-6}$ C (−1.0 μC)

Common error: Reporting a positive charge. Inward field means a negative source.

4. Net force by symmetry

Each charge is 0.50 m away; components of the separation are 0.30 (x) and 0.40 (y).

$F_{each} = k(2.0\times10^{-6})(3.0\times10^{-6})/(0.50)^2 = 0.2158$ N (attractive, toward each +)

x-parts: both point +x → $F_x = 2(0.2158)(0.30/0.50) = 2(0.1295) = 0.259$ N

y-parts: one +y, one −y → cancel to zero

→ F_net = 0.259 N, directed along +x (toward the two charges)

Common error: Adding the full magnitudes (0.43 N). Only the x-components survive; the y-components cancel.

5. Net field from three charges

From +6 μC at r = 0.30: $E = 5.99\times10^5$ N/C, straight up (+y)

From −3 μC at r = 0.50: $E = 1.079\times10^5$ N/C, toward it → (−0.80, +0.60) → $(-8.6\times10^4, +6.5\times10^4)$

From +2 μC at r = 0.40: $E = 1.124\times10^5$ N/C, away → (−1.0, 0) → $(-1.124\times10^5, 0)$

$\Sigma E_x = -2.6\times10^4$; $\Sigma E_y = 5.99\times10^5 + 6.5\times10^4 = 5.35\times10^5$

$|E| = \sqrt{(2.6\times10^4)^2 + (5.35\times10^5)^2}$

→ $E = 5.35\times10^5$ N/C, about 3° left of straight up (92.8° from +x)

Common error: Using r = 0.40 for the −3 μC charge. Distances to P must come from the grid coordinates, not read off one axis.

6. Symmetric two-charge field

Each charge is $r = \sqrt{(0.30^2 + 0.40^2)} = 0.50$ m from P

$E_{each} = k(4.0\times10^{-6})/(0.50)^2 = 1.438\times10^5$ N/C, pointing away from each +

x-parts cancel (mirror image); y-parts add:

$\Sigma E_y = 2(1.438\times10^5)(0.40/0.50) = 2(1.151\times10^5)$

→ $E = 2.30\times10^5$ N/C straight up; a +1.0 μC test charge accelerates straight up (+y)

Common error: Letting the y-parts cancel instead of the x-parts. Two like charges below a point push the net field away, straight up.

7. Force from a known field

$F = qE = (5.0\times10^{-6})(5.35\times10^5)$

→ F = 2.68 N, directed OPPOSITE the field (about 3° right of straight down), since the charge is negative

Common error: Keeping the force along E. A negative charge is pushed against the field.

8. Reading force direction back to sign

The test charge is pulled toward + and pushed from − — that is how a POSITIVE charge behaves.

Force on a positive charge is along the field, so the net field at that point points toward the +8 μC side.

→ The test charge is positive; the net field points toward the +8 μC charge

Common error: Assuming attraction to a + means the test charge is negative. Positive charges move along the field.

9. Drawing three-charge electric field

Rules: lines leave +, enter −, never cross, density = strength.

+2q emits twice as many lines as −q absorbs, so half of the +2q lines curve away to infinity.

Lines from +q either terminate on −q or escape.

A null point sits on the far side of the −q from the two positives, where the fields cancel.

→ Correct diagram: 2:1 line ratio on +2q vs −q, no crossings, one null point beyond the −q

Common error: Drawing equal line counts on +2q and −q. Line count must scale with charge magnitude.

10. Drawing three-mass gravitational field

Every arrow points inward toward a mass — gravity is purely attractive.

Lines crowd near each mass (stronger field) and thin out between them.

A null point lies between masses where the pulls balance; nearer the smaller mass, and pulled toward the 2M side.

→ Correct diagram: all arrows inward, no outward lines, one null point shifted toward the lighter side

Common error: Drawing any outward arrow. Mass has no repulsion — gravitational field lines only ever point in.

11. Triboelectric attract/repel

Glass is high on the series → loses electrons → glass rod becomes +.

Rubber is low on the series → gains electrons → rubber rod becomes −.

Opposite signs.

→ They attract (glass +, rubber −)

Common error: Assuming both rods gain the same sign. Position on the series decides who gives and who takes.

12. What moves in charging

Wool sits high, Teflon sits at the very bottom (grabs electrons hardest).

Electrons move FROM wool TO Teflon.

Teflon becomes negative; wool becomes positive by the same amount.

→ Teflon becomes negative, with an equal and opposite charge to the wool — only electrons moved

Common error: Saying protons transferred. Only electrons move; charge is conserved and equal-and-opposite.

13. Identical materials cannot charge each other

Charging by friction depends on a DIFFERENCE in electron affinity (different series positions).

Two identical glass rods sit at the same position — neither pulls electrons harder.

No net transfer occurs.

→ They stay neutral — identical materials have no affinity difference to drive a transfer

Common error: Thinking friction alone creates charge. It only redistributes it, and only between unlike materials.

14. Induction on a neutral sphere

The rubber rod is negative, so its field repels electrons in the metal sphere.

Electrons pile up on the FAR side (becomes −); the near side is left positive.

The near + side is closer to the rod than the far − side, so attraction beats repulsion.

→ The sphere is attracted; near side +, far side − (net neutral, but polarised)

Common error: Expecting no force because the sphere is neutral overall. Induction separates charge and the closer side wins.