

Field maps, voltage and energy per unit charge

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train electric field, potential and energy at AP Physics 2 level, in the style of unit 10. They cover field lines, uniform fields, point charges, equipotentials and the link between work, potential difference and kinetic energy, moving from single steps to multi-part free-response reasoning. Use $k = 8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$ and $e = 1.60 \times 10^{-19} \text{ C}$, and show units.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 10

Problem 1 Field from a force (easy)

A test charge of $+2.0 \text{ nC}$ feels a force of $6.0 \times 10^{-6} \text{ N}$ to the east at a point in a room in Accra.

1. Calculate the electric field at the point.
2. State the direction of the field.
3. State the force on a -2.0 nC charge placed at the same point.

Problem 2 Field of a point charge (easy)

A charge of -3.0 nC is fixed in place.

1. Calculate the field strength at 0.15 m from it.
2. State the direction of the field there.

Problem 3 Reading field lines (easy)

Field lines are drawn around two isolated charges. Near charge A the lines are close together; near charge B they are far apart.

1. State which charge produces the stronger field nearby.
2. State what the arrowheads on a field line show.
3. Explain why two field lines can never cross.

Problem 4 Field between plates (easy)

Two parallel plates 1.5 cm apart have a potential difference of 300 V .

1. Calculate the electric field between them.
2. Calculate the force on a 4.0 nC charge between the plates.

Problem 5 Energy from a voltage (easy)

A $2.0 \text{ }\mu\text{C}$ charge is moved through a potential difference of 12 V .

1. Calculate the change in its potential energy.
2. State what the volt measures in terms of joules and coulombs.

Problem 6 Electron-volts (easy)

Wanjiru studies an electron accelerated through 250 V.

1. State the energy gained in eV.
2. Convert it to joules.
3. Convert $3.2 \times 10^{-17} \text{ J}$ to eV.

Problem 7 Electron between plates (medium)

An electron starts from rest at the negative plate of a pair of plates 3.0 cm apart with a potential difference of 150 V. Use $e = 1.60 \times 10^{-19} \text{ C}$ and $m = 9.11 \times 10^{-31} \text{ kg}$.

1. Calculate the field strength.
2. Calculate the electric force and acceleration.
3. Calculate the speed on reaching the positive plate.

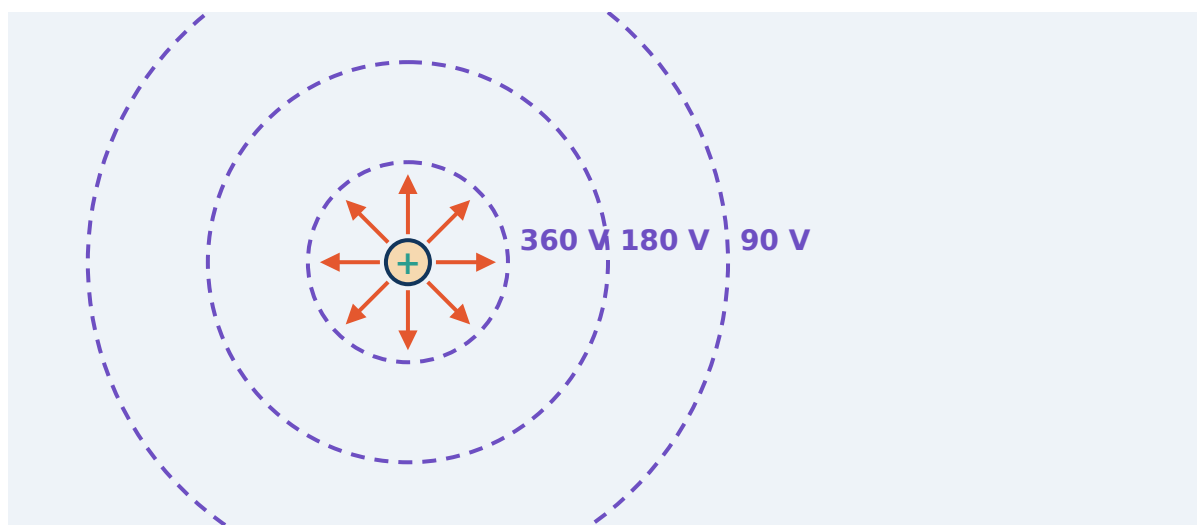
Problem 8 Potential of a point charge (medium)

A charge of +8.0 nC is fixed in air.

1. Calculate the potential at 0.20 m and at 0.40 m.
2. Find the potential difference between these points.
3. Calculate the work needed to move a +1.0 nC charge from 0.40 m to 0.20 m.

Problem 9 Equipotential rings (medium)

Rings of equal potential are drawn around a +4.0 nC charge at radii 0.10 m, 0.20 m and 0.40 m (shown).



Equipotential rings around a +4.0 nC charge, at radii 0.10 m, 0.20 m and 0.40 m.

1. Calculate the work to move +2.0 nC from the 0.40 m ring to the 0.10 m ring.
2. State the work done moving it once around the 0.20 m ring.

3. State the direction of the field at a point on the 0.20 m ring.

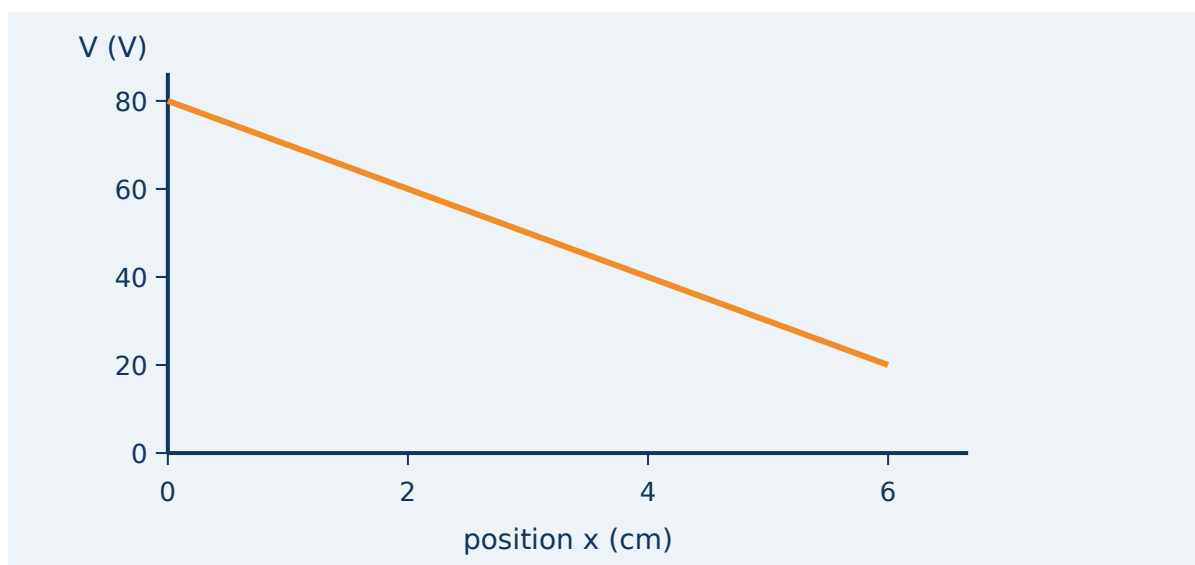
Problem 10 Proton down a potential (medium)

A proton is released from rest at a point where the potential is 400 V and moves to a point at 100 V in a vacuum.

1. Calculate its change in potential energy.
2. Calculate its final speed. Use $m = 1.67 \times 10^{-27}$ kg.

Problem 11 Field from a potential graph (medium)

The potential along the x axis between two plates is plotted against position (shown).



The potential falls steadily along the x axis.

1. Find the gradient of the graph.
2. Calculate the size and direction of the electric field.
3. Calculate the force on a proton in this field.

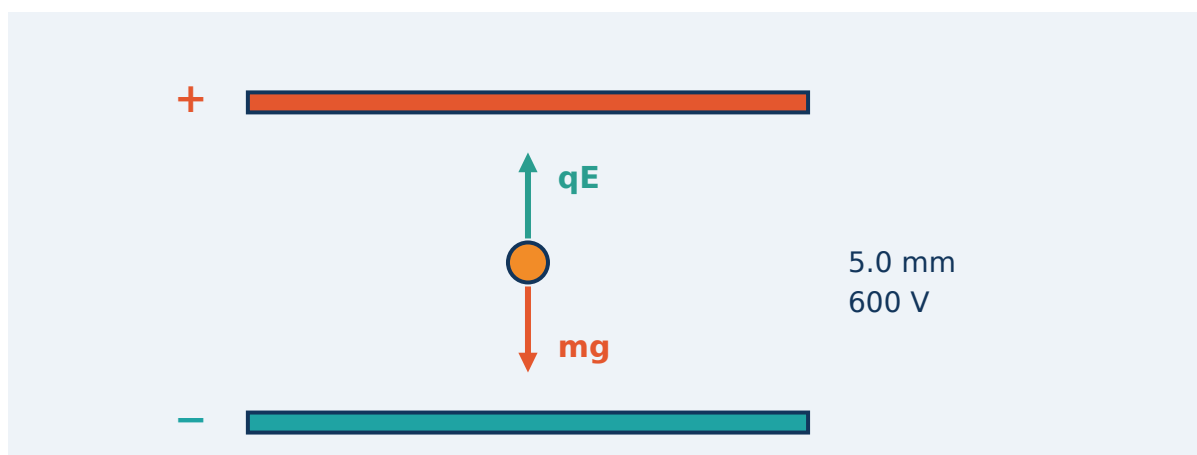
Problem 12 Midpoint between opposite charges (medium)

A $+3.0$ nC charge sits at $x = 0$ and a -3.0 nC charge at $x = 0.20$ m.

1. Calculate the field from each charge at $x = 0.10$ m.
2. Find the net field and its direction.
3. State the potential at that point.

Problem 13 Droplet held at rest (medium)

A droplet of mass 5.9×10^{-15} kg stays at rest between horizontal plates 5.0 mm apart connected to 600 V (shown). The upper plate is positive.



A droplet is held still: the electric force up balances the weight down.

1. Calculate the field between the plates.
2. Calculate the charge on the droplet.
3. Calculate how many excess electrons it carries and state its sign.

Problem 14 Energy of two charges (medium)

A $+2.0 \mu\text{C}$ charge is fixed. A second charge of $+3.0 \mu\text{C}$ and mass 0.010 kg is held 0.30 m away and then released.

1. Calculate the electric potential energy at the start.
2. Calculate its speed when it is very far away.

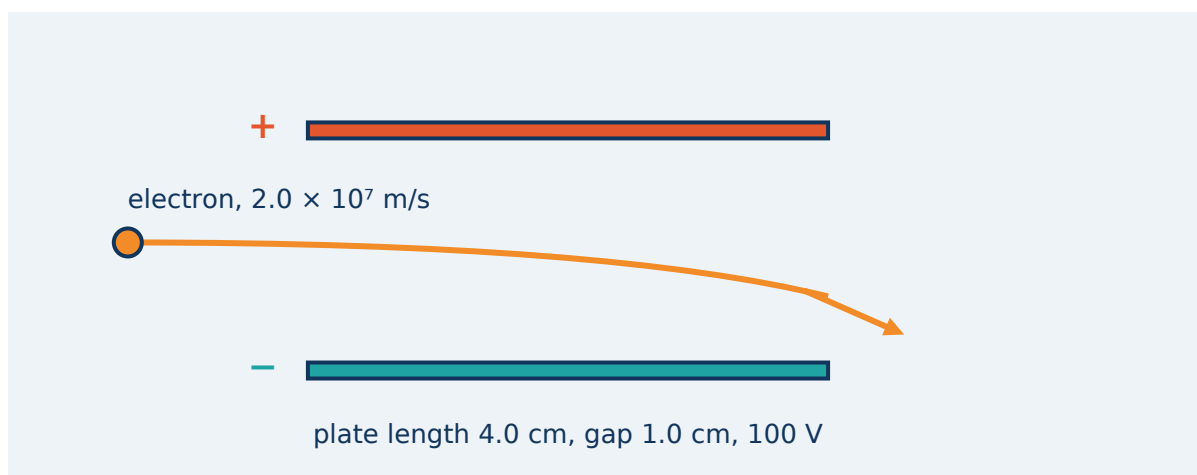
Problem 15 Charge inside a conductor (medium)

A hollow metal box stands in a strong external field during a thunderstorm in Kampala. Students sit inside a metal-bodied minibus.

1. State the field inside the metal of a conductor in equilibrium.
2. Explain where the excess charge goes.
3. Explain why people inside a closed metal vehicle are protected.

Problem 16 Electron beam deflection (hard)

An electron enters horizontally at $2.0 \times 10^7 \text{ m/s}$ halfway between two horizontal plates (shown). The plates are 4.0 cm long and 1.0 cm apart with 100 V across them.



The electron follows a curved path towards the positive plate.

1. Calculate the electric field and the vertical acceleration.
2. Calculate the time spent between the plates.
3. Calculate the vertical deflection and decide whether the electron escapes.
4. Calculate the angle of the exit path to the horizontal.

Problem 17 Opposite charges on a line (hard)

A $+2.0 \text{ nC}$ charge is at $(0, 0)$ and a -2.0 nC charge at $(0.40 \text{ m}, 0)$.

1. Calculate the potential and field at $(0.20 \text{ m}, 0)$.
2. Calculate the potential at $(0.10 \text{ m}, 0)$.
3. Calculate the work to move $+1.0 \text{ nC}$ from $(0.20 \text{ m}, 0)$ to $(0.10 \text{ m}, 0)$.

Problem 18 Ball in a horizontal field (hard)

A ball of mass 2.0 g carrying $+5.0 \text{ }\mu\text{C}$ hangs from a thread in a uniform horizontal field and rests with the thread at 20° to the vertical.

1. Draw the three forces in words and state their directions.
2. Calculate the field strength.
3. Calculate the potential difference across a 5.0 cm gap of this field.

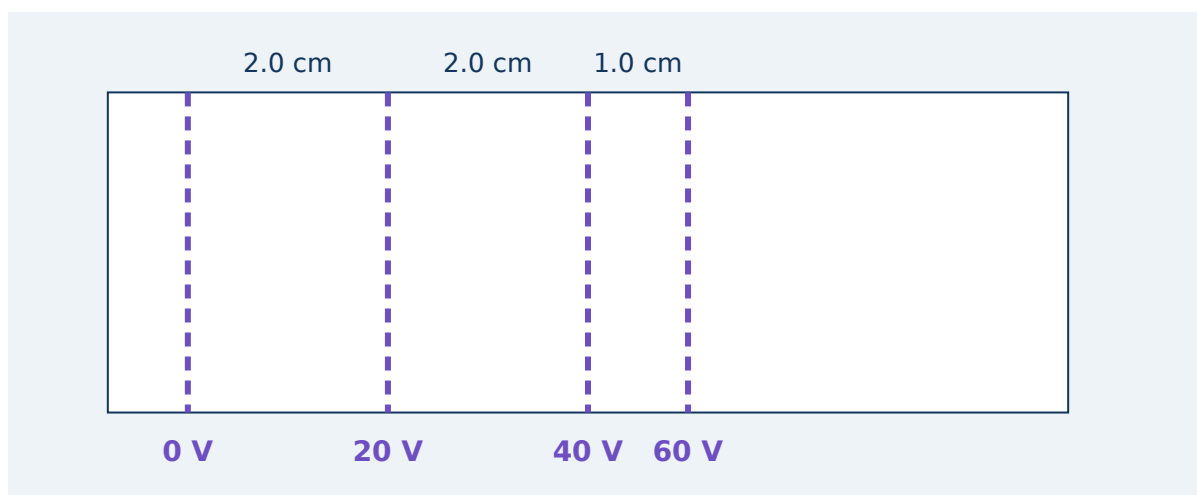
Problem 19 Closest approach (hard)

An alpha particle (charge $+2e$) with kinetic energy 5.0 MeV is fired straight at a fixed gold nucleus (charge $+79e$). Use $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$.

1. Convert the kinetic energy to joules.
2. Write the energy equation at the point of closest approach.
3. Calculate the closest distance.

Problem 20 Reading an equipotential map (hard)

An equipotential map shows lines at 0 V , 20 V , 40 V and 60 V (shown). The gaps are 2.0 cm , 2.0 cm and 1.0 cm .



Equipotential lines drawn at 0 V, 20 V, 40 V and 60 V.

1. Calculate the field between each pair of neighbouring lines.
2. State the direction of the field and justify it.
3. Calculate the work to move $+2.0 \mu\text{C}$ from the 0 V line to the 60 V line.
4. Explain what the map says about where a charge would accelerate most.