B7 · Fields between plates

Student notes - follow the slides, fill the blanks, work the questions

Use E = ΔV/Δd between parallel plates and find force, acceleration and speed of a charge.

Name: _____ Date: _____

Slide 1 of 5 · Radial and uniform fields

A field is a region where a _____ feels a force. The arrows show the force on a _____ test charge.

Around a point charge the field is _____: arrows point _____ a positive source and _____ a negative one. Closer in, the arrows bunch up: a _____ field. The direction changes from place to place.

Between parallel plates the field is _____ (constant): parallel, evenly spaced arrows, the same at R, at S and between. The arrows point from the _____ plate to the _____ plate.

The force on a charge is F = _____, and F = ma links it to the acceleration. If E does not change along the path, neither does the _____.

Example. A small positive object is released from rest in each of two fields, a point-charge field (positive source) and the uniform field between plates, and nothing else acts on it. In each field, does its acceleration increase, decrease or stay the same as it moves, and what happens to its kinetic energy?

Work:

Answer: _____

Try it. Describe the direction and spacing of the field arrows (a) around a negative point charge and (b) between two plates when the top plate is positive. Sketch both.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 5 · The field between plates

A uniform field is the same everywhere between plates. A bigger _____ or a smaller _____ makes a _____ field.

Formula: E = _____. E is the field strength, in _____ (size only). ΔV is the potential difference between the plates, in _____. Δd is the gap between the plates, in _____.

Direction: from the _____ plate to the _____ plate. V/m and _____ are the same unit. Multiply both sides by Δd: ΔV = _____.

Plates only. For one _____ use $E = kQ/r^2$, where Q is the source charge and r is the distance from it. Write each rearranged form out.

On a graph of E against 1/Δd, $E = \Delta V \times (1/\Delta d)$ matches y = mx: y is _____, x is _____ and the slope is _____. Rewrite the equation to match y = mx first.

Example. Plates are 0.0150 m apart and connected to a 120 V battery. Find the field strength between the plates, then find the battery voltage needed for a field three times as strong with the same gap.

Work:

Answer: _____

Try it. The battery voltage is kept the same while the plate gap is changed. The field is graphed against 1/Δd. The line passes through C = (25 m^{-1}, 4.5×10^3 V/m) and D = (100 m^{-1}, 18.0×10^3 V/m). What does the slope represent, and what is its value?

Work:

Answer: _____

Slide 3 of 5 · Force, acceleration and speed between plates

Force gives _____. Energy gives _____. Only the electric force acts, so ma = _____. From B4: F = qE, where q is the particle's charge.

Field: E = _____. Acceleration: a = _____. Speed from rest: qΔV = _____, so v = _____. The field is uniform, so a is _____.

If the question gives E and not ΔV, find ΔV = _____ first. Use the electron's charge and mass from the data sheet. Keep every digit on your calculator and round _____.

Use the particle's own q and m. A proton has the same size of charge as an electron but a much bigger _____. Two routes that agree are a good check. A speed stays well below _____.

Example. An electron ($q = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) starts from rest in a uniform field of 4.00×10^{3} V/m. The plates are 0.0600 m apart. Find the final speed of the electron at the other plate.

Work:

Answer: _____

Try it. A proton ($q = 1.60 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg) starts from rest against the positive plate. The plates are 0.0150 m apart and the voltage is 300 V. Find its final speed using energy, then check the speed using the acceleration and the gap.

Work:

Answer: _____

Slide 4 of 5 · Method: parallel-plate problems

Step 1: find the field. E = _____, with the gap in _____.

Step 2: find the field direction. It points from the _____ plate to the _____ plate.

Step 3: find the force. F = _____, using the size of q. A positive charge is pushed _____ the field. A negative charge is pushed _____ it.

Step 4: find the acceleration. a = _____, in the same direction as the force. Step 5: find the speed. From rest, qΔV = _____, or check with v = _____. Check: a speed stays well below _____.

Example. An alpha particle ($q = 3.20 \times 10^{-19}$ C, $m = 6.65 \times 10^{-27}$ kg) starts from rest against the positive plate. The gap is 0.0200 m and the battery is 175 V. Find its acceleration and its speed at the other plate.

Work:

Answer: _____

Try it. An electron ($q = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) starts from rest against the negative plate. The gap is 0.0300 m and the battery is 450 V. Find its acceleration and its speed at the other plate. Write each step number beside your work.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 5 · Not starting from rest

If a particle is already moving when it enters (look for "_____"), it has initial kinetic energy ½mv_i², and the field adds more or takes some away.

Find ΔV = _____. Find the initial kinetic energy from the entering speed. Find the energy gained or lost: _____.

An electron moving toward the + plate: unlike charges _____, so it _____. Ek final = Ek initial _____. A proton moving toward the + plate: like charges _____, so it _____. Ek final = Ek initial _____.

Then v_f = _____. Check: a charge that speeds up ends _____, and a slowed charge ends _____, than its starting speed.

Example. An electron ($q = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) enters the gap at 2.00×10^{6} m/s toward the positive plate. The field is 3.00×10^{3} V/m and the gap is 0.0500 m. Find its speed at the positive plate.

Work:

Answer: _____

Try it. A proton ($q = 1.60 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg) enters the gap moving at 4.0×10^{5} m/s toward the positive plate, which repels it. The potential difference is 400 V. Find its speed at the positive plate, and say how you know the answer makes sense.

Work:

Answer: _____

B7 · practice

Fields between plates | Questions 1-2 of 8

Constants from the Alberta Physics 30 data sheets: $k = 8.99 \times 10^{9}$ N·m²/C², $e = 1.60 \times 10^{-19}$ C, electron mass $m_e = 9.11 \times 10^{-31}$ kg, proton mass $m_p = 1.67 \times 10^{-27}$ kg, $g = 9.81$ m/s².

Easy · B7-N01. Two parallel plates 0.0300 m apart are connected to a 150 V battery. Find the electric field strength between them in V/m.

Work:

Final answer (with unit and sign): _____

Easy · B7-N02. The gap between two plates is halved while the battery voltage stays the same. What happens to the field strength between them?

A. It doubles.
B. It halves.
C. It stays the same.
D. It becomes four times larger.

Work:

Final answer (with unit and sign): _____

B7 · practice

Fields between plates | Questions 3-4 of 8

Easy · B7-N03. A positive charge is released from rest at different places between large parallel plates. How does its acceleration compare from place to place?

A. It is larger near the positive plate.
B. It is larger near the negative plate.
C. It increases as the charge speeds up.
D. It is the same everywhere, because the field is uniform.

Work:

Final answer (with unit and sign): _____

Medium · B7-N04. An electron starts from rest in a uniform field of 2500 V/m across plates 0.08 m apart. Find its final speed.

Work:

Final answer (with unit and sign): _____

B7 · practice

Fields between plates | Questions 5-6 of 8

Medium · B7-N05. A proton starts at rest between plates 0.0400 m apart with a potential difference of 800 V. Use $e = 1.60 \times 10^{-19}$ C and proton mass $m_p = 1.67 \times 10^{-27}$ kg. Find its acceleration in m/s².

Work:

Final answer (with unit and sign): _____

Medium · B7-N06. Using the proton in the previous question, find its final speed when it reaches the far plate.

Work:

Final answer (with unit and sign): _____

B7 · practice

Fields between plates | Questions 7-8 of 8

Challenging · B7-N07. An electron enters the gap at 1.0×10^6 m/s toward the positive plate. The plates are 0.020 m apart with 3.0×10^3 V across them. Find its speed at the positive plate.

Work:

Final answer (with unit and sign): _____

Challenging · B7-N08. A graph of E against $1/\Delta d$ for a fixed battery is a straight line through the origin with slope 150 V. What does the slope represent, and what happens to E if the gap is doubled?

Work:

Final answer (with unit and sign): _____