Year 12 Science: Electric fields and charges between parallel plates

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Plates 4.0 cm apart have 200 V across them. What is the field strength?

2. What force does a proton feel in that field?

3. A dust grain carries a charge of 4.8×10^{-18} C. How many extra electrons does it have?

4. An electron crosses from the negative to the positive plate of a pair 3.0 mm apart with 1500 V across them. How much energy does it gain?

5. A field of 2.0×10^{4} V m^{-1} pushes a charged drop with a force of 6.4×10^{-14} N. What is the drop's charge?

Exam-style question: a model smoke filter

Mere's class builds a model chimney filter: smoke rises between two vertical metal plates 4.0 cm apart, connected to a 3000 V supply. One smoke particle picks up 120 extra electrons. Ignore gravity.

6. Describe the electric field between the plates.

7. Calculate the electric field strength between the plates.

8. Calculate the size of the electric force on the smoke particle, and state its direction.

9. The particle starts next to the negative plate. Calculate the energy the field gives it by the time it reaches the positive plate.

10. The supply is turned down to 1500 V. Discuss how this changes the force on the particle and the energy it gains crossing the gap.

Fix the mistake

11. Correct this statement: "E = 5.0×10^{4} V m^{-1}, so the electron gains 5.0×10^{4} J of energy."

12. Correct this statement: "Field lines go from the negative plate to the positive plate, the way the electrons move."

13. Correct this statement: "With the plates 5.0 mm apart, E = 250 ÷ 5.0 = 50 V m^{-1}."

14. Correct this statement: "A drop with 4 extra electrons has a charge of 4 C."

Answer key (for parents and tutors)

1. Plates 4.0 cm apart have 200 V across them. What is the field strength?
   $E = V \div d = 200 \div 0.040 = 5.0 \times 10^{3}$ V m^{-1} (5000 V m^{-1}).

2. What force does a proton feel in that field?
   $F = Eq = 5.0 \times 10^{3} \times 1.6 \times 10^{-19} = 8.0 \times 10^{-16}$ N, in the direction of the field.

3. A dust grain carries a charge of 4.8×10^{-18} C. How many extra electrons does it have?
   $n = q \div e = 4.8 \times 10^{-18} \div 1.6 \times 10^{-19} = 30$ electrons.

4. An electron crosses from the negative to the positive plate of a pair 3.0 mm apart with 1500 V across them. How much energy does it gain?
   $E = 1500 \div 0.0030 = 5.0 \times 10^{5}$ V m^{-1}; $E_p = Eqd = 5.0 \times 10^{5} \times 1.6 \times 10^{-19} \times 0.0030 = 2.4 \times 10^{-16}$ J.

5. A field of 2.0×10^{4} V m^{-1} pushes a charged drop with a force of 6.4×10^{-14} N. What is the drop's charge?
   $q = F \div E = 6.4 \times 10^{-14} \div 2.0 \times 10^{4} = 3.2 \times 10^{-18}$ C.

6. Describe the electric field between the plates.
   Uniform: straight, parallel, evenly spaced lines at right angles to the plates, pointing from the positive plate to the negative plate (Achieved).

7. Calculate the electric field strength between the plates.
   $E = V \div d = 3000 \div 0.040 = 7.5 \times 10^{4}$ V m^{-1} (Achieved).

8. Calculate the size of the electric force on the smoke particle, and state its direction.
   $q = ne = 120 \times 1.6 \times 10^{-19} = 1.92 \times 10^{-17}$ C; $F = Eq = 7.5 \times 10^{4} \times 1.92 \times 10^{-17} = 1.4 \times 10^{-12}$ N, towards the positive plate because the particle is negative (Merit: two linked steps and a direction).

9. The particle starts next to the negative plate. Calculate the energy the field gives it by the time it reaches the positive plate.
   $E_p = Eqd = 7.5 \times 10^{4} \times 1.92 \times 10^{-17} \times 0.040 = 5.8 \times 10^{-14}$ J; check: $qV = 1.92 \times 10^{-17} \times 3000 = 5.76 \times 10^{-14}$ J (Merit).

10. The supply is turned down to 1500 V. Discuss how this changes the force on the particle and the energy it gains crossing the gap.
    Achieved: a smaller voltage gives a weaker field and a smaller force. Merit: d is fixed, so halving V halves E ($E = V/d$), and with the same charge $F = Eq$ halves too. Excellence: E and F both halve while the particle still crosses the same 0.040 m, so $E_p = Eqd$ halves to 2.9×10^{-14} J (the same as qV with half the voltage); the particle arrives later and with half the energy.

11. Correct this statement: "$E = 5.0 \times 10^{4}$ V m^{-1}, so the electron gains 5.0×10^{4} J of energy."
    That is the field strength, not an energy; the energy is $E_p = Eqd$, which here is only 4.0×10^{-17} J.

12. Correct this statement: "Field lines go from the negative plate to the positive plate, the way the electrons move."
    Field lines show the push on a positive charge, so they always run from the positive plate to the negative plate.

13. Correct this statement: "With the plates 5.0 mm apart, $E = 250 \div 5.0 = 50$ V m^{-1}."
    Convert to metres first: $E = 250 \div 0.0050 = 5.0 \times 10^{4}$ V m^{-1}, a thousand times bigger.

14. Correct this statement: "A drop with 4 extra electrons has a charge of 4 C."
    Each electron carries 1.6×10^{-19} C, so $q = ne = 4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19}$ C.