Uniform electric fields

Electric fields 2 An electrostatic microbead balance

35–40 minutes independent work + 15–20 minutes review

OCR A H556 | A-level physics | Module 6 | 40 marks

Specification points covered

6.2.3(a) Uniform fields and E = V/d. 6.2.1(c–d) Field lines and E = F/q.

Prior learning applied: weight/equilibrium (3.2), p.d. and W = VQ (4.2.2).

Use g = 9.81 m s^{-2} and e = 1.60 × 10^{-19} C.

Use a calculator and your OCR A data booklet. Show working, units and directions where relevant.

1 Read the balance

A feedback-controlled balance holds a microbead between horizontal plates while a technician measures its charge. Only vertical forces are considered; the feedback system's stability is outside this model.

Initially m = 1.20 × 10^{-9} kg, q = +3.00 × 10^{-13} C and the gap is 10.0 mm. The upper plate is at 0 V. The lower-plate potential +V is adjustable. Neglect drag and other forces.

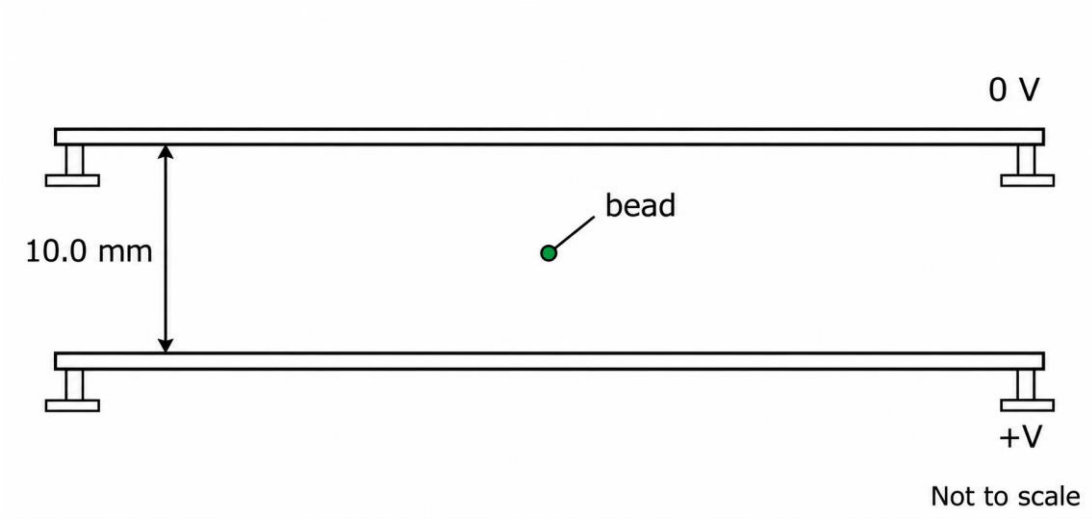


Figure 1 Adjustable plate potential

1(a) For the positive lower-plate setting in Figure 1, state the direction of the electric field between the plates. **[1 mark]**

1(b) A bead is to be held against its weight by the electric field. State the required sign of the bead's charge. **[1 mark]**

2 Draw a useful model

2(a) In the space below, sketch the two plates and at least four field lines in their central region. Show direction and how uniformity is represented. **[2 marks]**

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2(b) Explain where E = V/d is a good approximation and why the same model is less reliable close to a plate edge. **[2 marks]**

2(c) Draw a free-body diagram for a stationary positive bead. Label both forces and state the equilibrium condition. **[2 marks]**

3 Set the field strength

3(a) Set the lower plate to +400 V while the upper plate remains at 0 V. Calculate E in the 10.0 mm gap. **[1 mark]**

3(b) A separate test requires E = 6.50 × 10^4 V m^{-1} across an 8.00 mm gap. Find the required plate p.d. **[1 mark]**

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3(c) Relative to any initial setting, the p.d. is doubled and the gap is increased by a factor of 1.50. Find the factor by which E changes. **[1 mark]**

3(d) Show that V m^{-1} and N C^{-1} are equivalent units. **[1 mark]**

4 Use the balancing measurement

4(a) Calculate the weight of the original bead. **[1 mark]**

4(b) Determine the electric field required to balance this bead, whose charge is $+3.00 \times 10^{-13}$ C. **[1 mark]**

4(c) Find the balancing plate p.d. at the original 10.0 mm gap. **[1 mark]**

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4(d) A different positive bead of the same mass balances at 500 V in the 10.0 mm gap. Determine its charge and estimate the number of electrons missing from it. **[3 marks]**

4(e) A pupil says, ‘The bead is stationary, so its electric force is zero.’ Explain the error. **[2 marks]**

5 Interpret a potential profile

For this section only, the lower plate is at 400 V and the upper plate is at 0 V. y is measured upwards from the lower plate.

Table 1

y / mm	V / V
0	400
2.5	300
5.0	200
7.5	100
10.0	0

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5(a) Sketch V against y using Table 1, with labelled axes and units. Explain what the straight-line form tells you about the field magnitude. **[2 marks]**

5(b) Use the profile to find the magnitude of the p.d. between y = 2.0 mm and y = 7.0 mm. Check that it gives the same E as the full-gap calculation. **[2 marks]**

5(c) Both plate potentials are increased by 150 V. Explain what happens to the field and to the balancing force for an unchanged bead. **[2 marks]**

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6 Check the operating limits

6(a) A new bead has mass 1.80×10^{-9} kg and charge $+3.00 \times 10^{-13}$ C. The supply cannot exceed 500 V. Compare gaps of 8.00 mm and 12.0 mm and choose one that permits balance. **[3 marks]**

6(b) For the new bead, the charge may be 5% below its nominal value and the chosen gap may be 0.10 mm larger than 8.00 mm. Check whether the 500 V supply guarantees balance at this worst case. **[3 marks]**

6(c) At a previously balanced positive-bead setting, the plate polarities are reversed. State the direction of the resultant force immediately afterwards and explain. **[2 marks]**

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7 Explain and evaluate the measurement

7(a) Describe how the technician could determine the charge on a bead of known mass using this balance. Link the measurements to an equation for q, and explain two relevant controls or improvements. **[4 marks]**

7(b) Evaluate this response: ‘A larger voltage means a larger charge on the bead. At balance the field cancels gravity, and moving both plate voltages upwards increases the force.’ Identify and correct two distinct errors. **[2 marks]**

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