Magnetic fields and forces on wires

Electromagnetism 1 Testing a camera focusing actuator

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

OCR A H556 | A-level physics | Module 6 | 45 marks

Specification points covered

6.3.1(a–d) Sources and patterns of magnetic fields; Fleming's left-hand rule.

6.3.1(e)(i–ii), (f) Force on a wire, measuring uniform flux density and the tesla.

Prior learning applied: resultant forces, Newton's third law, springs and uncertainty.

Use $g = 9.81\ m\ s^{-2}$. The length symbol ℓ means wire length, not current I.

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

1 Read the actuator brief

A camera focuses by moving a lens horizontally. A voice coil in a permanent magnet's radial gap field pushes the lens against a return spring.

For actuator calculations, all active wire is perpendicular to the local field and its force contributions act along the lens axis. The total active length is 0.400 m. The nominal gap flux density is 0.180 T.

Positive drive current gives a rightward magnetic force on the lens coil.

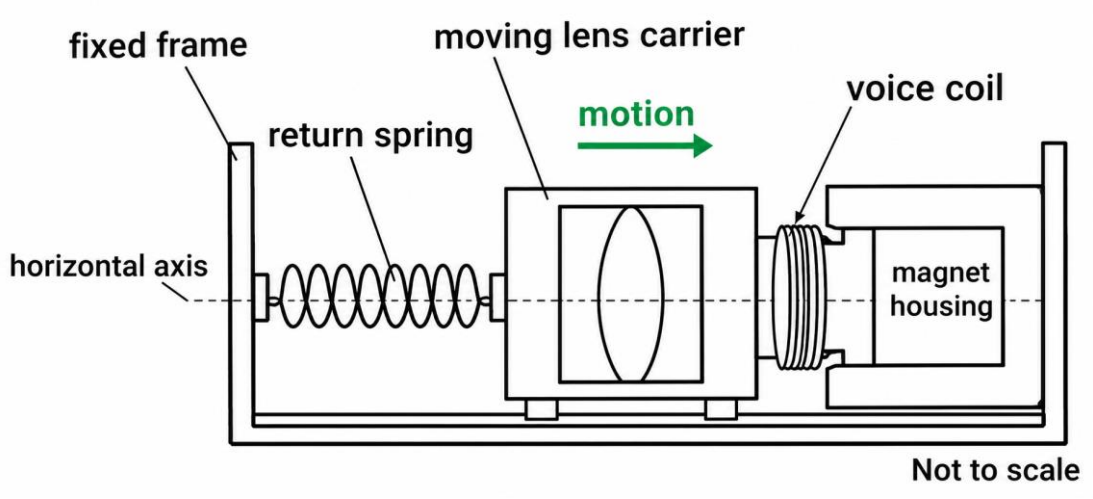


Figure 1 Horizontal focusing actuator

1(a) A permanent magnet produces the actuator's gap field. What produces the magnetic field of its current-carrying coil? **[1 mark]**

1(b) Define magnetic flux density using a straight wire perpendicular to the field, and state its SI unit. **[2 marks]**

2 Map the fields and directions

2(a) Viewed end-on, the current in a long straight lead is into the page. Sketch at least three magnetic field lines. Show their direction and how the field becomes weaker farther from the lead. **[2 marks]**

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2(b) A separate flat circular coil has a horizontal axis. Its current is clockwise when viewed from the right. Sketch a side view of its magnetic field pattern, show the field direction through its centre, and label the right face N or S. **[3 marks]**

2(c) The actuator electronics also contain a long solenoid. Describe its field well inside the solenoid and near an end. State where a uniform-field model is the better approximation. **[2 marks]**

2(d) In Figure 2 in Question 4, the gap field is from N to S and conventional current is out of the page. State the force direction on the wire. What happens to that force direction if only the current is reversed? **[2 marks]**

3 Use the magnetic force

3(a) Calculate the magnetic force on the actuator coil at a current of 0.150 A. **[1 mark]**

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3(b) What actuator current is needed for a magnetic force of 0.0180 N at the nominal field? **[1 mark]**

3(c) A separate straight wire has 50.0 mm in the same 0.180 T field and carries 0.800 A. The angle between the wire and the field is 30.0°. Calculate its magnetic force magnitude. **[2 marks]**

3(d) The straight wire is turned parallel to B. State its force magnitude and explain. **[1 mark]**

4 Calibrate the gap field

Figure 2 shows a fixed wire supported independently of the magnet. Only the magnet rests on the balance. The wire is perpendicular to the uniform field. The balance resolves 0.01 g.

Table 1 records changes relative to the zero-current reading. The active wire length stays 50.0 mm.

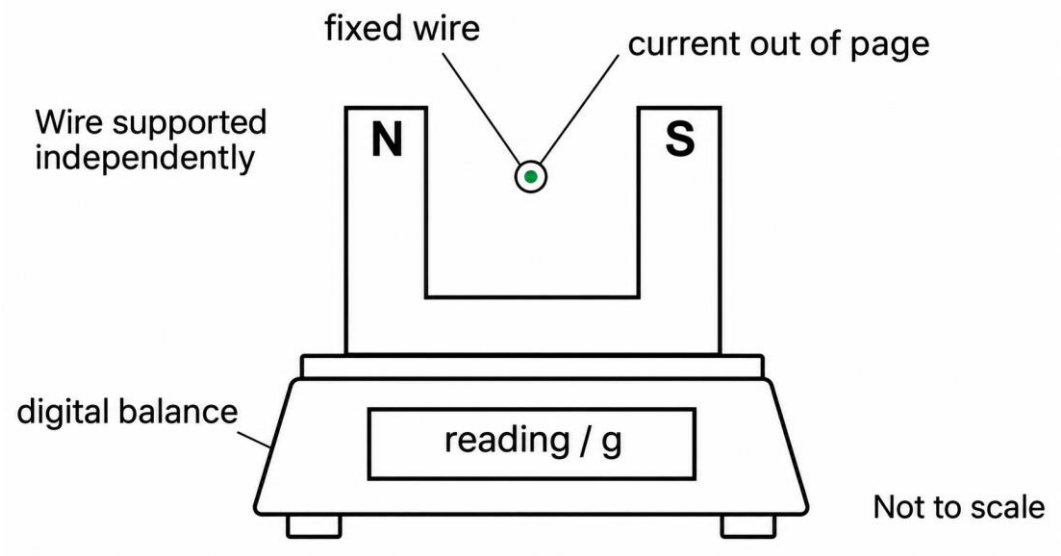


Figure 2 Separate wire and balance calibration

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Table 1

I / A	Change in balance indication / g
0.00	0.00
0.20	0.18
0.40	0.37
0.60	0.55
0.80	0.73
1.00	0.92

4(a) The balance indicates 142.60 g with current off and 143.33 g with current on. Calculate the magnetic force magnitude on the magnet. State its direction and the direction of the magnetic force on the wire. **[2 marks]**

4(b) For this reading the current is 0.800 A and the wire length in the uniform field is 50.0 mm. The wire is perpendicular to B. Calculate B. **[1 mark]**

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4(c) Use Table 1 to plot magnetic force magnitude against current in the blank space. Find B from a suitable line gradient. Show the coordinates used; use at least half the current range. **[3 marks]**

4(d) For the single reading in 4(b), I = (0.800 ± 0.010) A and ℓ = (50.0 ± 1.0) mm. Ignore balance uncertainty for this calculation. Estimate the absolute uncertainty in B and judge agreement with 0.180 T. **[3 marks]**

5 Evaluate a measurement

5(a) A technician writes: “Our value is close to 0.180 T, so the experiment is perfect. Repeating the readings will remove any constant zero offset.” Correct both claims. **[2 marks]**

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5(b) Give two controls or improvements for the wire-and-balance experiment, explaining why each matters. **[2 marks]**

5(c) Write a coherent plan for checking the manufacturer's quoted B using the wire and balance. Explain how measurements lead to a value of B and how you would judge the claim. Include a graph and uncertainty approach; a sketch may support your answer. **[6 marks]**

6 Choose the actuator driver

The lens moves horizontally. Gravity and its supporting force act vertically and do not enter this horizontal balance. Spring force and friction oppose the required rightward motion.

6(a) The return spring has k = 5.00 N m^{-1}. At x = 3.00 mm, find the current needed to hold the lens stationary. Ignore friction for this holding calculation. **[1 mark]**

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6(b) At that displacement, the 8.00 g lens must accelerate rightwards at 0.500 m s^{-2}. Friction is 1.00 mN leftwards. Calculate the required magnetic force and current at the nominal B. **[3 marks]**

6(c) Drivers can provide at most 0.250 A or 0.300 A. Choose a driver for 6(b), then check whether it still works if B is only 0.174 T. Take the other data as exact. **[3 marks]**

6(d) A pupil says, “The wire and magnet exert equal and opposite magnetic forces, so neither can accelerate.” Explain the error. **[2 marks]**

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