20. Magnetic Fields

20.2 Force on a current-carrying conductor

Paper 4

Question Paper

1 **(a)** Define magnetic flux density.

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..... [2]

2 A metal wheel consists of an axle A, eight spokes and a rim, as shown in Fig. 1.1.

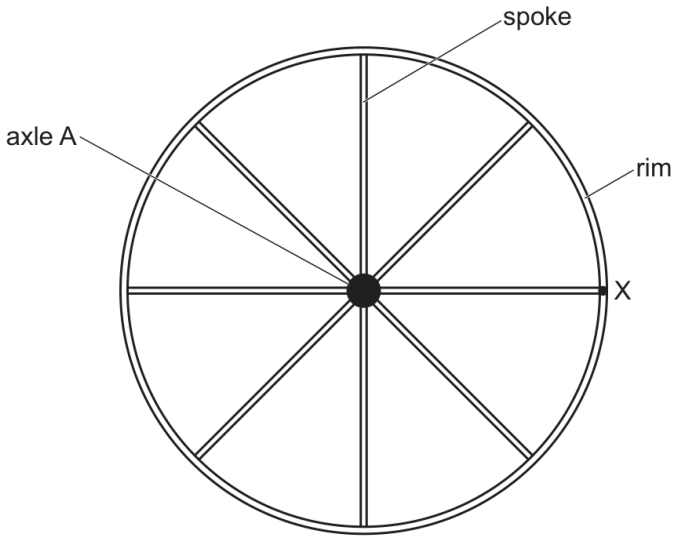


Fig. 1.1

Point X is on the rim at the end of one of the spokes.

The rim has a radius of 0.85 m.
The wheel is rotating clockwise with an angular speed of 140 rad s^{-1}.

(b) There is a uniform magnetic field of flux density 0.18 T into the plane of the page.

(v) Use Lenz's law to explain whether the potential is higher at end A or end X of the spoke.

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3 **(c)** A second long, straight wire Q, carrying a current of 5.0 A out of the page, is placed parallel to wire P, as shown in Fig. 6.2.

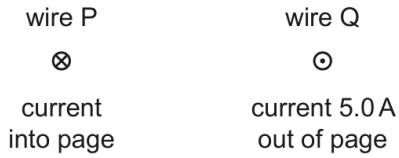


Fig. 6.2

The flux density of the magnetic field at wire Q due to the current in wire P is 2.6 mT.

(i) Calculate the magnetic force per unit length exerted on wire Q by wire P.

force per unit length = ... $N\,m^{-1}$ [2]

(ii) State the direction of the force exerted on wire Q by wire P.

..... [1]

4 A heavy aluminium disc has a radius of 0.36 m. The disc rotates with the wheels of a vehicle and forms part of an electromagnetic braking system on the vehicle.

In order to activate the braking system, a uniform magnetic field of flux density 0.17 T is switched on. This magnetic field is perpendicular to the plane of rotation of the disc, as shown in Fig. 6.1.

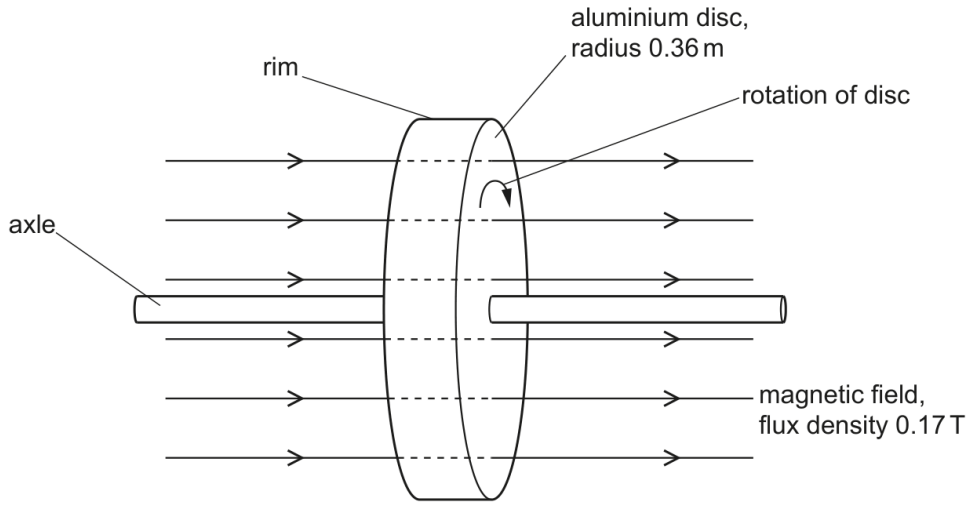


Fig. 6.1

(c) The axle and the rim are connected into an external circuit that enables the energy of the rotation of the disc to be stored for future use. The direction of rotation is shown in Fig. 6.1.

Use Lenz's law of electromagnetic induction to determine whether the current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

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5 **(a)** State the **two** conditions that must be satisfied for a copper wire, placed in a magnetic field, to experience a magnetic force.

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[2]

6 **(a)** Define magnetic flux density.

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(b) An insulated rectangular coil of wire, consisting of 40 turns, is suspended in a cradle from a newton meter, as shown in Fig. 7.1.

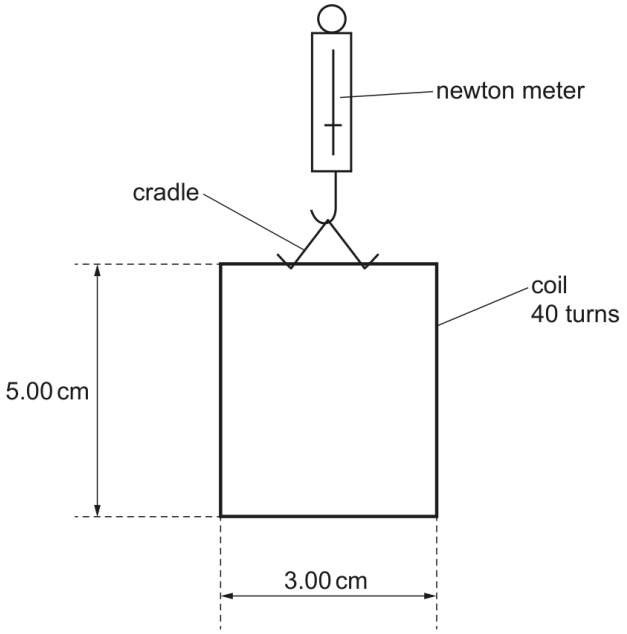


Fig. 7.1

The vertical sides of the coil have a length of 5.00 cm and the horizontal sides have a length of 3.00 cm. The initial reading on the newton meter is 0.563 N.

A U-shaped magnet rests on a top-pan balance that is set to a reading of 0.00 g.
The lower edge of the coil is lowered into the region between the poles of the U-shaped magnet, as shown in the side view in Fig. 7.2.

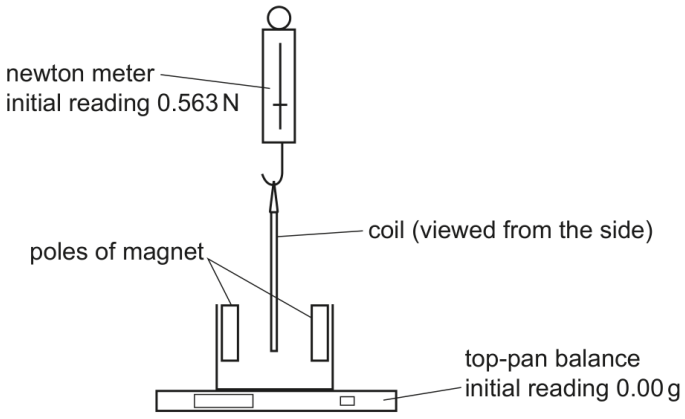


Fig. 7.2

The magnetic field in the region between the poles is uniform.
The lower edge of the coil is entirely within the uniform magnetic field.

A current of 3.94 A is now passed through the coil. This causes the reading on the top-pan balance to change to 2.16 g.

(i) Explain why the current causes a vertical force to act on the coil.

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..... [2]

(ii) Determine, to three significant figures, the flux density *B* of the uniform magnetic field.

B = ... T [3]

(iii) Determine what is now the reading on the newton meter. Explain your reasoning.

reading = ... N [2]

7 **(a)** Define the *tesla*.

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..... [2]

(b) A stiff metal wire is used to form a rectangular frame measuring 8.0 cm × 6.0 cm. The frame is open at the top, and is suspended from a sensitive newton meter, as shown in Fig. 8.1.

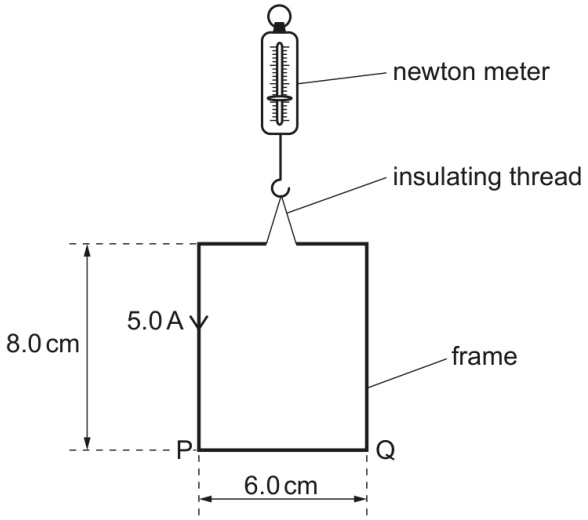


Fig. 8.1

The open ends of the frame are connected to a power supply so that there is a current of 5.0 A in the frame in the direction indicated in Fig. 8.1.

The frame is slowly lowered into a uniform magnetic field of flux density *B* so that all of side PQ is in the field. The magnetic field lines are horizontal and at an angle of 50° to PQ, as shown in Fig. 8.2.

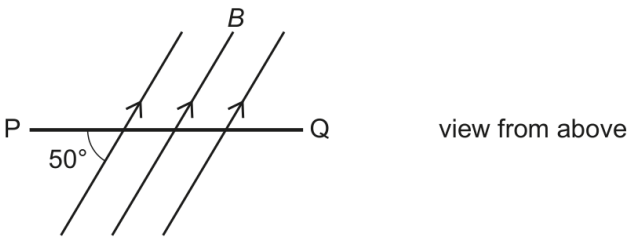


Fig. 8.2

When side PQ of the frame first enters the magnetic field, the reading on the newton meter changes by 1.0 mN.

(i) Determine the magnetic flux density B, in mT.

B = ... mT [2]

(ii) State, with a reason, whether the change in the reading on the newton meter is an increase or a decrease.

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(iii) The frame is lowered further so that the vertical sides start to enter the magnetic field.

Suggest what effect this will have on the frame.

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8 **(a)** Define the *tesla*.

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..... [3]

(b) A magnet produces a uniform magnetic field of flux density *B* in the space between its poles.

A rigid copper wire carrying a current is balanced on a pivot. Part PQLM of the wire is between the poles of the magnet, as illustrated in Fig. 8.1.

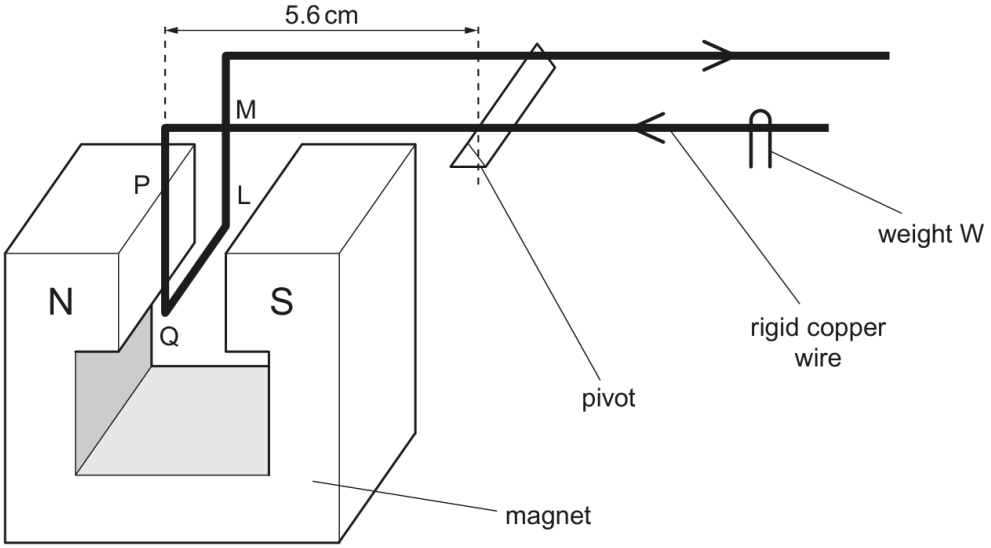


Fig. 8.1 (not to scale)

The wire is balanced horizontally by means of a small weight W.

The section of the wire between the poles of the magnet is shown in Fig. 8.2.

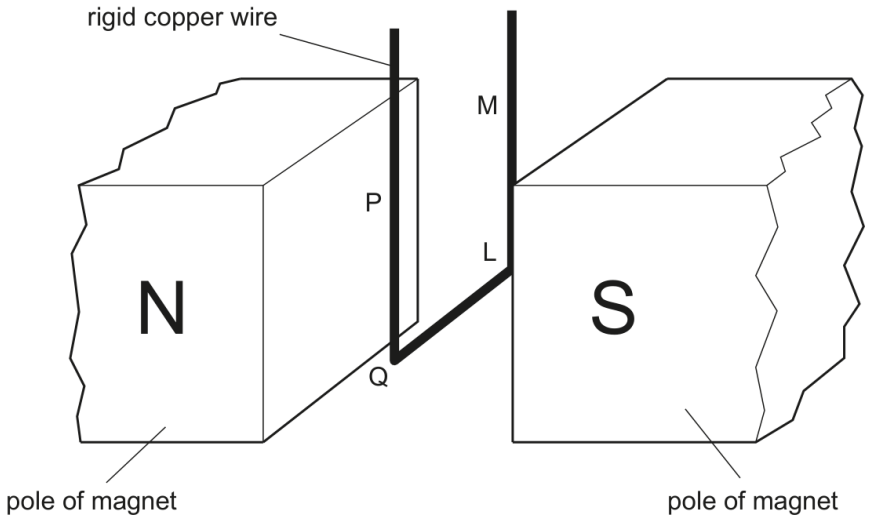


Fig. 8.2 (not to scale)

Explain why:

(i) section QL of the wire gives rise to a moment about the pivot

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..... [3]

(ii) sections PQ and LM of the wire do not affect the equilibrium of the wire.

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..... [2]

(c) Section QL of the wire has length 0.85 cm.

The perpendicular distance of QL from the pivot is 5.6 cm.

When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium. The mass of W is 1.3×10^{-4} kg.

(i) Show that the change in moment of W about the pivot is 3.3×10^{-5} N m.

[2]

(ii) Use the information in **(i)** to determine the magnetic flux density B between the poles of the magnet.

B = ... T [3]

9 **(b)** Two long straight parallel wires P and Q are situated a distance 3.1 cm apart, as illustrated in Fig. 8.3.

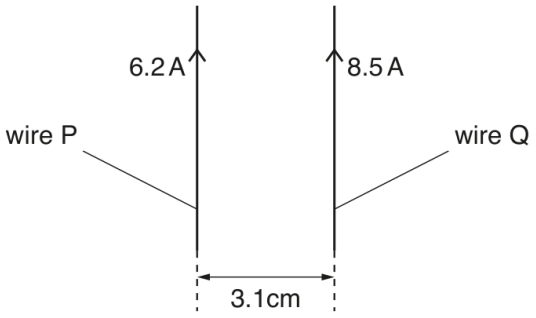


Fig. 8.3

The current in wire P is 6.2 A. The current in wire Q is 8.5 A.

The magnetic flux density B at a distance x from a long straight wire carrying current I is given by the expression

$$B = \frac{\mu_0 I}{2\pi x}$$

where μ_0 is the permeability of free space.

Calculate:

(ii) the force per unit length, in $\mathrm{N\,m^{-1}}$, acting on wire Q due to the current in wire P.

force per unit length = ... $\mathrm{N\,m^{-1}}$ [2]

10 A rigid copper wire is held horizontally between the pole pieces of two magnets, as shown in Fig. 9.1.

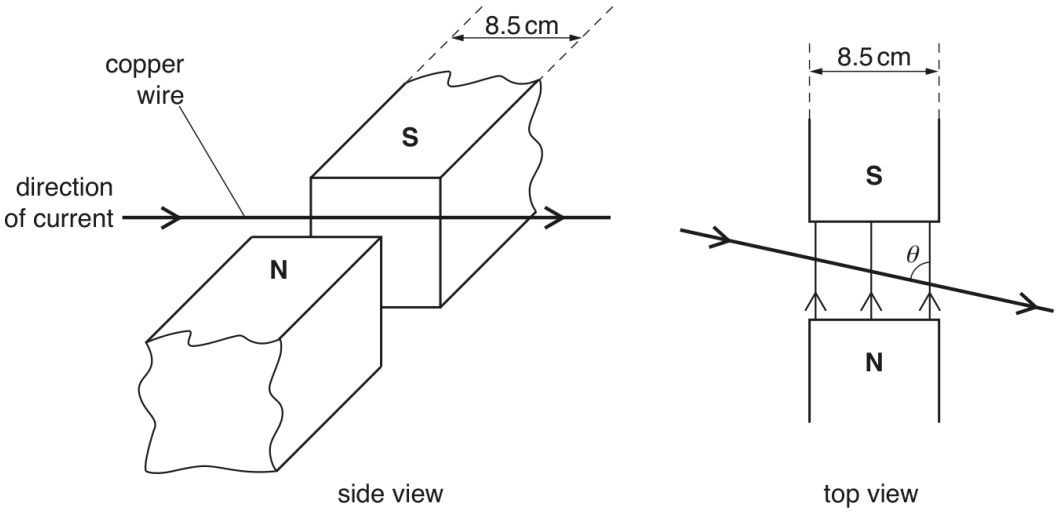


Fig. 9.1

The width of each pole piece is 8.5 cm.
The uniform magnetic flux density B in the region between the poles of the magnets is 3.7 mT and is zero outside this region.
The angle between the wire and the direction of the magnetic field is θ.
The current in the wire is in the direction shown on Fig. 9.1.

(a) By reference to the **side** view of Fig. 9.1, state and explain the direction of the force on the **magnets**.

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.....[2]

(b) The constant current in the wire is 5.1 A.

(i) For angle θ equal to 90°, calculate the force on the wire.

force = ... N [2]

(ii) The angle θ is changed to 60°.

The length of wire in the magnetic field is $\left(\frac{8.5}{\sin 60°}\right)$ cm.

Calculate the force on the wire.

force = ... N [1]

(c) The constant current in the wire is now changed to an alternating current of frequency 20 Hz and root-mean-square (r.m.s.) value 5.1 A.

The angle between the wire and the direction of the magnetic field is 90°.

On Fig. 9.2, sketch a graph to show the variation with time *t* of the force *F* on the wire for two cycles of the alternating current.

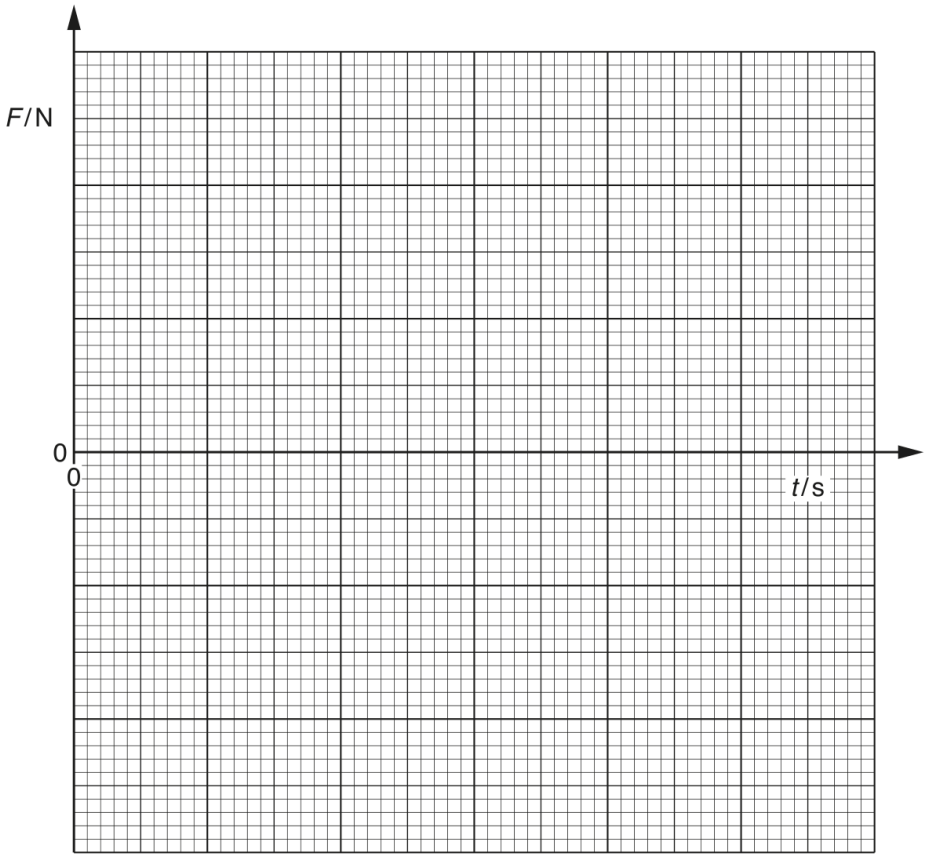


Fig. 9.2

[3]

11 (a) Define *magnetic flux density*.

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.....[3]

(b) A stiff copper wire is balanced horizontally on a pivot, as shown in Fig. 8.1.

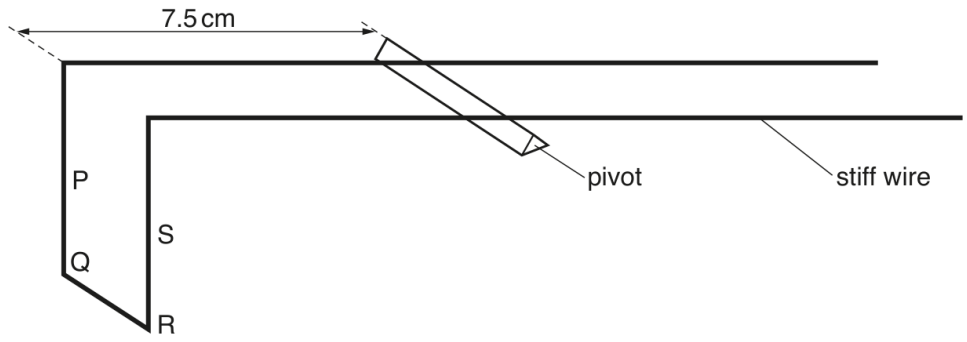


Fig. 8.1

Sections PQ, QR and RS of the wire are situated in a uniform magnetic field of flux density *B* produced between the poles of a permanent magnet.
The perpendicular distance of PQRS from the pivot is 7.5 cm.

When a current of 2.7 A is passed through the wire, a small mass of 45 mg is placed a distance 8.8 cm from the pivot in order to restore the balance of the wire, as shown in Fig. 8.2.

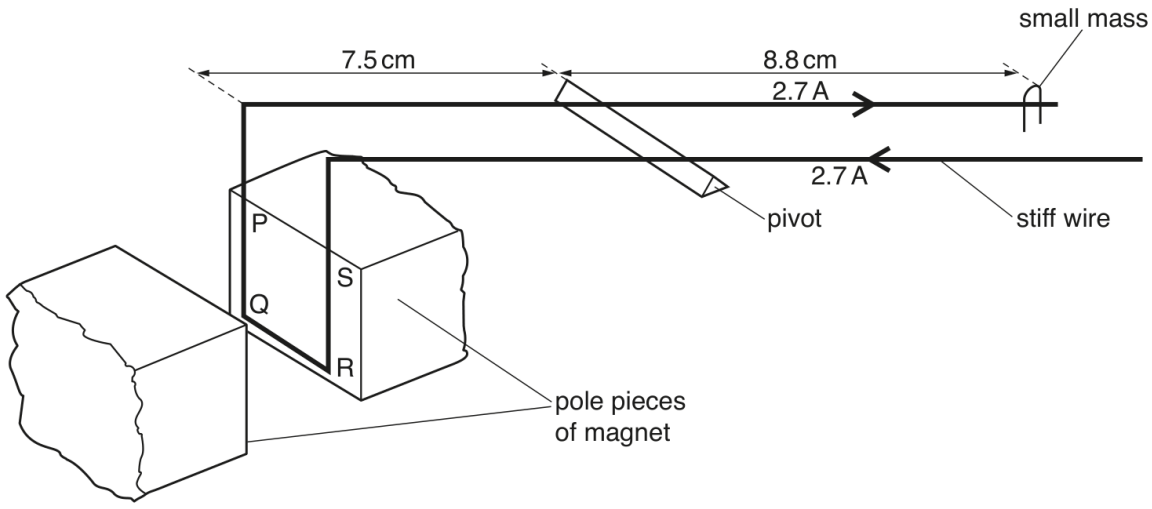


Fig. 8.2

(i) Explain why, when the current is switched on, the current in the sections PQ and RS of the wire does not affect the balance of the wire.

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.....[2]

(ii) The length of section QR of the wire is 1.2 cm.
Calculate the magnetic flux density *B*.

B = ... T [3]