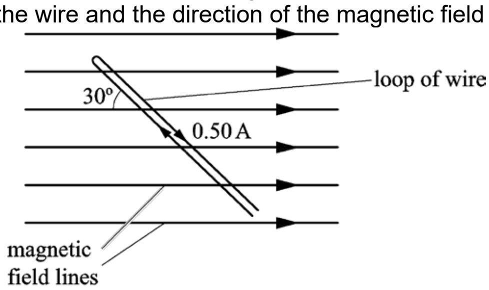
Electromagnetism

1. A rigid loop of insulated wire is placed in a uniform magnetic field of flux density 80 mT. The current in this loop is 0.50 A and the angle between the wire and the direction of the magnetic field is 30°.



What is the magnitude of the force experienced by a 1.0 cm section of the loop?

A. 0 N
B. 2.0×10^{-4} N
C. 3.5×10^{-4} N
D. 4.0×10^{-4} N

Your answer

[1]

2. A coil with 500 turns is placed in a uniform magnetic field.
The average cross-sectional area of the coil is 3.0×10^{-4} m^2.
The magnetic flux through the plane of the coil is reduced from 1.8×10^{-4} Wb to zero in a time *t*.
The average electromotive force (e.m.f.) induced across the ends of the coil is 0.75 V.

What is the value of *t* ?

A 3.6×10^{-5} s
B 2.4×10^{-4} s
C 0.12 s
D 8.3 s

Your answer **[1]**

3. A beam of charged particles is not deflected when it passes through a region where both electric and magnetic fields are present.

Which statement is **not** correct?

A All the particles have the same speed.
B The resultant force on each particle is zero.
C The magnetic force is equal to the electric force on each particle.
D The magnetic field and the electric field are in the same direction.

Your answer **[1]**

4. A current-carrying solenoid has *N* turns and radius *r*. The magnetic flux density within the core of the solenoid is *B*.

What is the magnetic flux linkage for this solenoid?

A NB
B $\pi r^2 B$
C $2\pi rBN$
D $\pi r^2 BN$

Your answer

[1]

5. An electron moves in a circle of radius 2.0 cm in a uniform magnetic field of flux density 170 mT.

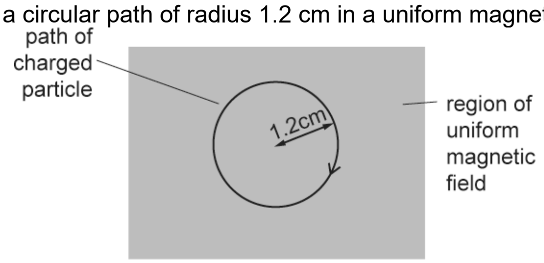
What is the momentum of this electron?

A 3.4×10^{-3} kg m s^{-1}
B 5.4×10^{-17} kg m s^{-1}
C 1.4×10^{-18} kg m s^{-1}
D 5.4×10^{-22} kg m s^{-1}

Your answer

[1]

6. A charged particle moves in a circular path of radius 1.2 cm in a uniform magnetic field.



The direction of the magnetic field is perpendicular to the plane of the paper.

The particle has mass *m*, charge +*Q* and speed *v*.

Another particle of mass 3*m*, charge +2*Q* and speed *v* moves in a circular path of radius *R* in the same magnetic field.

What is the value of *R*?

A 0.8 cm
B 1.2 cm
C 1.8 cm
D 7.2 cm

Your answer

[1]

7. A student is doing an experiment on the magnetic force experienced by a current-carrying wire in a uniform magnetic field. The magnetic flux density *B* can be varied.

For a particular flux density, the current in the wire is 2.0A. The length of the wire in the field is 0.12 m. The angle between the current and the magnetic field is 30°. The force experienced by the wire is 7.7×10^{-2} N.

The student calculates *B* and records the results in a table.

Which row shows the correct table heading for *B* and the correct value for *B*?

	Table heading for *B*	**Value for *B***
A	*B* / T	0.37
B	*B* / T	0.64
C	*B* / Wb	0.37
D	*B* / Wb	0.64

Your answer ☐ **[1]**

8. The number of turns on the coils of four ideal iron-cored transformers **A, B, C** and **D** are shown in the table below.

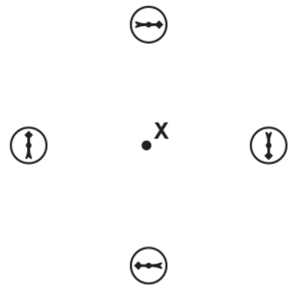
Transformer	**Number of turns on the secondary coil**	**Number of turns on the primary coil**
A	100	100
B	50	200
C	200	50
D	500	100

Each transformer is connected in turn to an alternating 240 V supply.

Which transformer will give the largest output current?

Your answer ☐ **[1]**

9. The diagram shows four magnetic compasses placed at the same distance from point **X**.

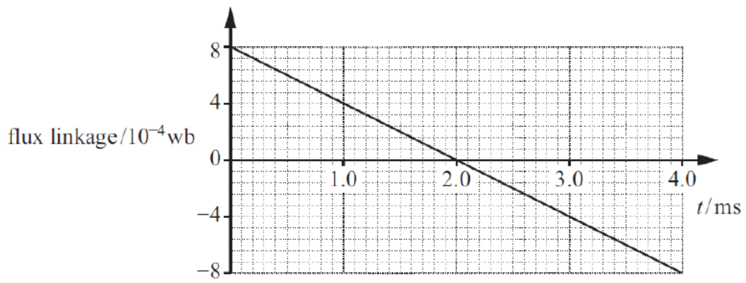


Which of the following is most likely to be at point **X**?

A permanent magnet
B current-carrying solenoid
C current-carrying flat coil
D straight current-carrying wire

Your answer [1]

10. A coil with three turns of wire is used in an experiment.
The graph shows the variation of magnetic flux linkage with time *t* for this coil.



What is the e.m.f. induced across the ends of the coil?

A. 0 V
B. 0.20 V
C. 0.40 V
D. 1.2 V

Your answer

[1]

11. Which law indicates that charge is conserved?

A Lenz's law
B Coulomb's law
C Kirchhoff's first law
D Faraday's law of electromagnetic induction

Your answer [1]

12. Faraday's law of electromagnetic induction is written below with two terms missing.

The .... induced in a circuit is directly proportional to the rate of change of

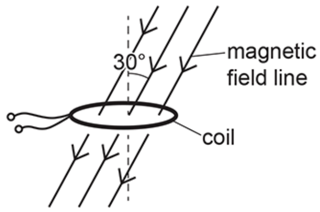
magnetic flux ....

What are the **two** missing terms?

A current, density
B current, linkage
C electromotive force, density
D electromotive force, linkage

Your answer [1]

13. A flat coil has 200 turns and a cross-sectional area of 1.20×10^{-4} m^2.



The coil is placed horizontally in a uniform magnetic field. The magnetic flux density is 0.050 T.
The magnetic field is at an angle of 30.0° to the vertical.

What is the magnetic flux linkage for this coil?

A 3.00×10^{-6} Wb
B 5.20×10^{-6} Wb
C 6.00×10^{-4} Wb
D 1.04×10^{-3} Wb

Your answer [1]

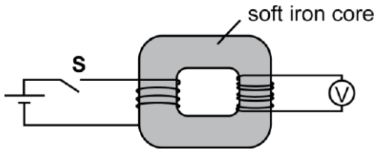
14. A charged particle travelling with speed v describes a circular path of radius R in a plane perpendicular to a uniform magnetic field. The orbital period of this particle is T.
The same particle now travels with speed $2v$ in a circular path in the same plane as before.

What is the orbital period of the particle now?

A $0.25T$
B $0.5T$
C T
D $2T$

Your answer [1]

15. The diagram below shows a transformer.



The primary coil is connected to a switch **S** and a cell. The secondary coil is connected to a voltmeter. The switch is then **closed**.

Which statement is correct?

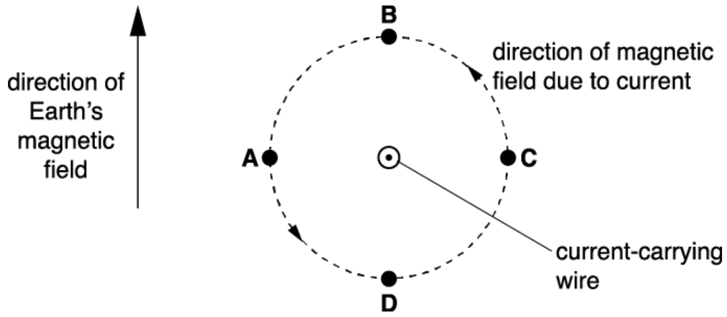
The voltmeter reading….

A does not change.
B increases and then stays constant.
C increases and then decreases to zero.
D increases and then changes direction.

Your answer

[1]

16. The diagram below shows a current-carrying wire coming out from the plane of the paper. The current in the wire produces a magnetic field in an **anticlockwise** direction around the wire.



The direction of the Earth's magnetic field is also shown.
The Earth's magnetic field interacts with the magnetic field of the current-carrying wire.

At which point **A**, **B**, **C** or **D** is the resultant magnetic field strength a **minimum**?

Your answer

[1]

17. Fig. 22.1 shows the circular track of a positron moving in a uniform magnetic field.

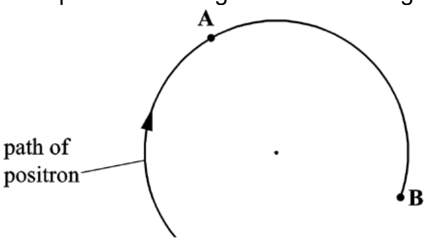


Fig. 22.1

The magnetic field is perpendicular to the plane of **Fig. 22.1**.
The speed of the positron is 5.0×10^7 m s^{-1} and the radius of the track is 0.018 m.

State the direction of the force acting on the positron when at point **A** and explain why this force does **not** change the speed of the positron.

[2]

18. A nucleus of hydrogen-3 (^3_1H) is unstable and it emits a beta-minus particle (electron).

The emitted beta-minus particle enters a region of uniform magnetic field.
Fig. 22.1 shows the path of the particle **before** it enters the magnetic field.

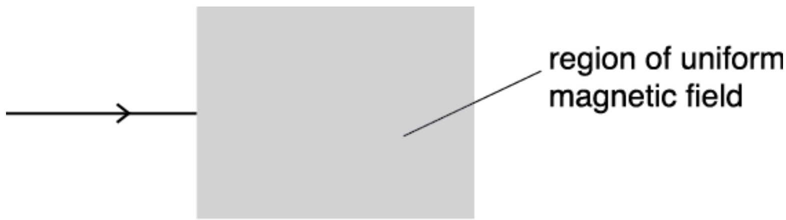


Fig. 22.1

The direction of the magnetic field is into the plane of the paper.
Describe and explain the path of the particle in the magnetic field.

----

[2]

19. Fig. 5.1 shows a horizontal copper wire placed between the opposite poles of a permanent magnet. The wire is held in tension *T* by the clamps at each end. The length of the wire in the magnetic field of flux density 0.032 tesla is 6.0 cm.

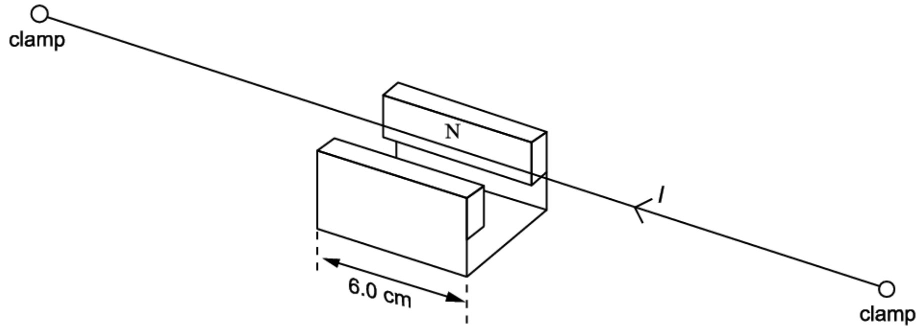


Fig. 5.1

A direct current *I* of 2.5 A is passed through the wire as shown.

i. On Fig. 5.1 draw an arrow to indicate the direction of the force *F* on the wire.

[1]

ii. Calculate the magnitude of *F.*

F = ... N **[1]**

20. An astronomer uses a spectrometer and diffraction grating to view a hydrogen emission spectrum from a star. The light is incident normally on the grating.

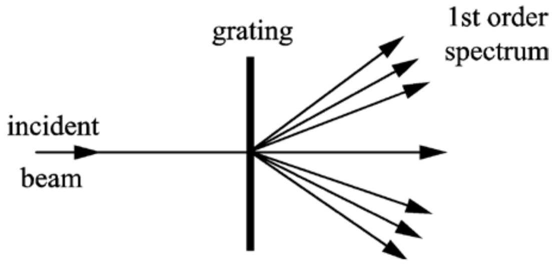


Fig. 6.1

First order diffraction maxima are observed at angles of 12.5°, 14.0° and 19.0° to the direction of the incident light as shown in **Fig. 6.1.**
Two of the wavelengths are 4.33×10^{-7} m and 4.84×10^{-7} m.
Calculate the wavelength of the third line.

wavelength = ... m **[2]**

21. Fig. 21.1 shows a coil of a simple generator rotating in a uniform magnetic field.

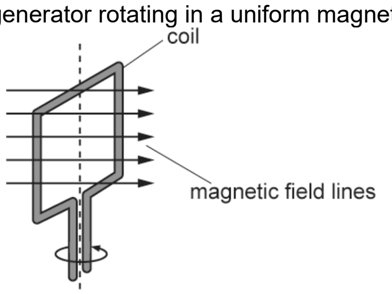


Fig. 21.1

Fig. 21.3 shows the variation of the e.m.f. induced across the ends of the coil with time *t*.

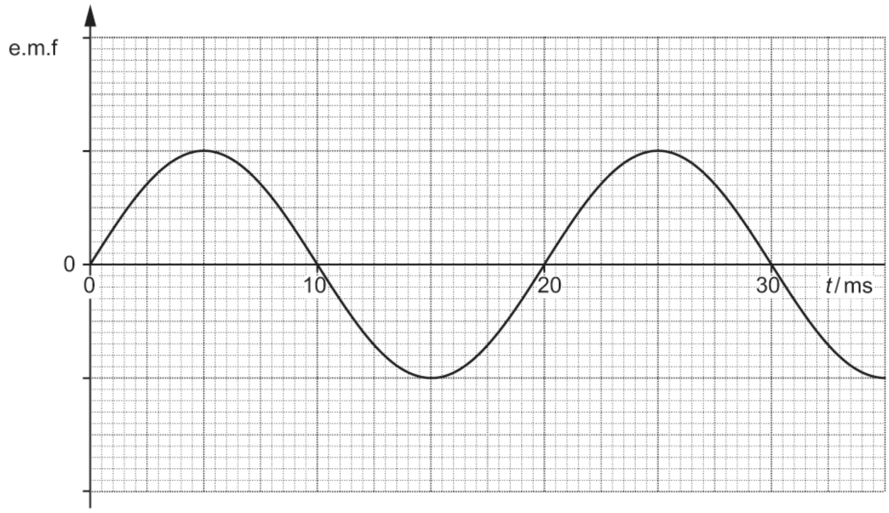
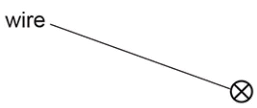


Fig. 21.3

The magnitude of the magnetic flux density of the uniform field is now halved and the coil is rotated at twice its previous frequency.

On Fig. 21.3 sketch the new variation of the e.m.f. induced with time *t*. **[2]**

22. The diagram below shows the top-view of a long current-carrying wire.



The direction of the current in the wire is into the plane of the paper.

Draw at least **three** field lines to indicate the magnetic field pattern around this wire.

[2]

23. Fig. 24 shows two horizontal metal plates in a vacuum.

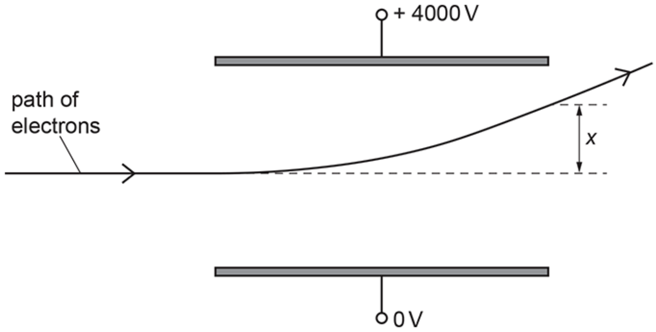


Fig. 24

Beta-minus particles (electrons) emitted from a radioactive source have a range of speeds.

Describe and explain how a uniform magnetic field can be applied in the space between the charged plates to select beta-minus particles with a specific speed. No calculations are required.

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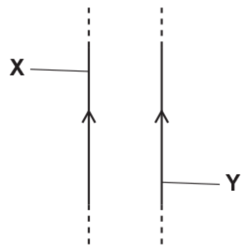
[3]

24. The diagram below shows two long vertical current-carrying wires **X** and **Y**.



The direction of the current in each wire is the same.

Explain why wire **Y** experiences a force and deduce the direction of this force.

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[3]

25. Fig. 22.1 shows the circular track of a positron moving in a uniform magnetic field.

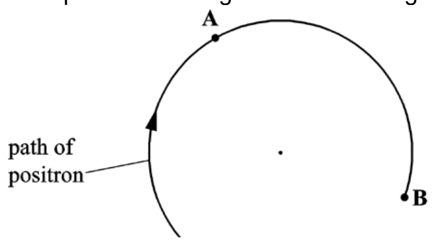

Fig. 22.1

The magnetic field is perpendicular to the plane of **Fig. 22.1**.
The speed of the positron is 5.0×10^7 m s^{-1} and the radius of the track is 0.018 m.

Calculate the magnitude of the magnetic flux density of the magnetic field.

magnetic flux density = ... T **[3]**

26. Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.

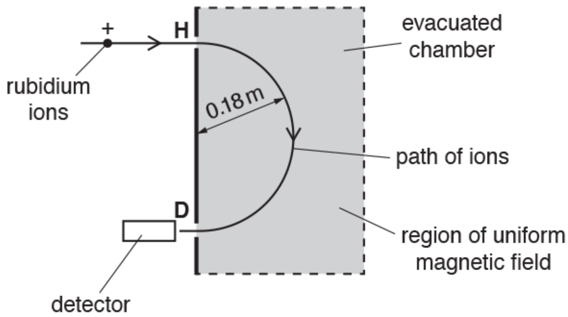

Fig. 20

A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.

A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.

Each rubidium ion has charge $+1.6 \times 10^{-19}$ C and speed 4.8×10^4 m s^{-1}.
The radius of the semi-circular path of the ions is 0.18 m.
The mass of a rubidium ion is 1.4×10^{-25} kg.

Calculate the magnitude of the magnetic flux density *B* of the magnetic field.

B = ... *T* **[3]**

27. An astronomer uses a spectrometer and diffraction grating to view a hydrogen emission spectrum from a star. The light is incident normally on the grating.

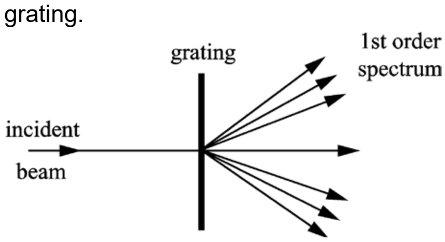

Fig. 6.1

In order to increase the accuracy of the values for wavelength, the student decides to look for higher order diffraction maxima.

i. State how this increases the accuracy.

-- **[1]**

ii. Calculate how many orders n can be observed for the shorter wavelength given in **(a)**.

n = ... **[2]**

28. Fig. 3.1 shows the design of a 'mechanical' torch.

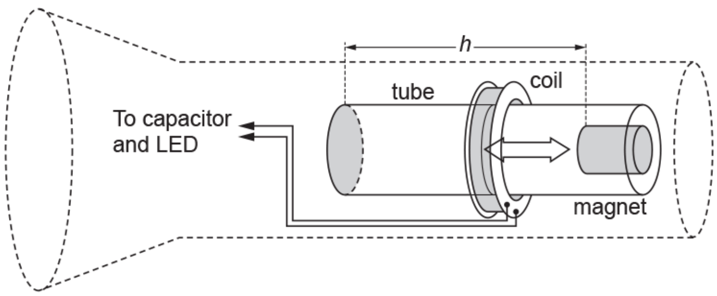

Fig. 3.1

There is no battery in the torch. Instead, when the torch is inverted, the magnet falls a short vertical distance h through the coil of wire, as shown in Fig. 3.2. This induces an electromotive force (e.m.f.) across the ends of the coil. The e.m.f. is used to store charge in a capacitor, which lights a light-emitting diode (LED) when it discharges.

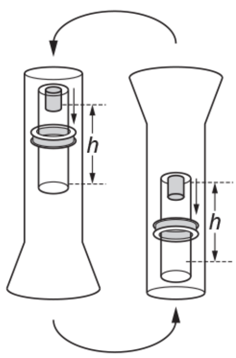

Fig. 3.2

Fig. 3.3 shows the variation with time of the e.m.f. generated as the magnet falls the distance h.

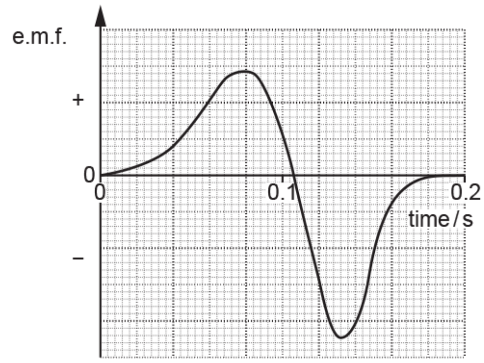

Fig. 3.3

Explain the shape of the curve in Fig. 3.3.

[3]

29. A small thin rectangular slice of semiconducting material has width *a* and thickness *b* and carries a current *I*. The current is due to the movement of electrons. Each electron has charge –*e* and mean drift velocity *v*.
A uniform magnetic field of flux density *B* is perpendicular to the direction of the current and the top face of the slice as shown in Fig. 2.1.

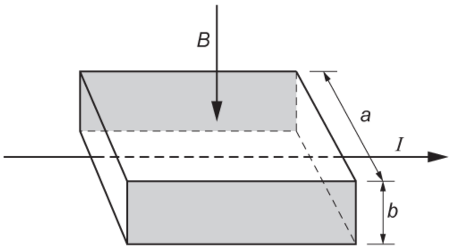

Fig. 2.1

As soon as the current is switched on, the moving electrons in the current are forced towards the shaded rear face of the slice where they are stored. This causes the shaded faces to act like charged parallel plates. Each electron in the current now experiences both electric and magnetic forces. The resultant force on each electron is now zero.

Write the expressions for the electric and magnetic forces acting on each electron and use these to show that the magnitude of the potential difference *V* between the shaded faces is given by

$$V = Bva.$$

[3]

30. Fig. 5.3 shows the poles of a powerful electromagnet producing a uniform field in the gap between them. The dimension of each pole is 0.10 m by 0.080 m. There is no field outside the gap. A circular coil of 80 turns is placed so that it encloses the total flux of the magnetic field.

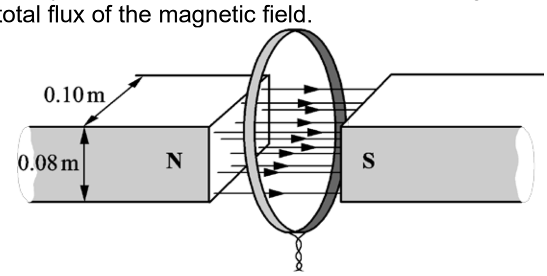

Fig. 5.3

i. The current in the electromagnet is reduced so that the field falls linearly from 0.20 T to zero in 5.0 s.

Calculate the initial flux in the gap and hence the e.m.f. generated in the coil during this time.

induced e.m.f. = ... V **[2]**

ii. The coil is part of a circuit of total resistance R so that a current is generated in the circuit while the field is collapsing.

Draw on the coil in **Fig. 5.3** the direction of this induced current.

State how you applied the laws of electromagnetic induction to deduce the direction of this current.

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[2]

31. A small thin rectangular slice of semiconducting material has width a and thickness b and carries a current I. The current is due to the movement of electrons. Each electron has charge $-e$ and mean drift velocity v.
A uniform magnetic field of flux density B is perpendicular to the direction of the current and the top face of the slice as shown in Fig. 2.1.

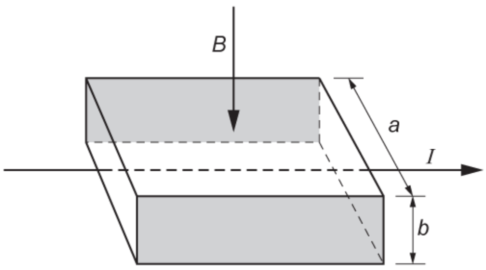

Fig. 2.1

Here are some data for the slice in a particular experiment.
number of conducting electrons per cubic metre, $n = 1.2 \times 10^{23}\ m^{-3}$
$a = 5.0$ mm
$b = 0.20$ mm
$I = 60$ mA
$B = 0.080$ T

Use this data to calculate

i. the mean drift velocity v of electrons within the semiconductor

v = ... m s^{-1} **[3]**

ii. the potential difference V between the shaded faces of the slice.

V = ... V **[1]**

32. Fig. 6.2 shows a soft iron ring of variable circular cross-section. It has four coils containing 2, 3, 4 and 5 turns wound around it. The cross-sectional area of the ring is different for each coil.

A cell is connected across the coil with three turns.

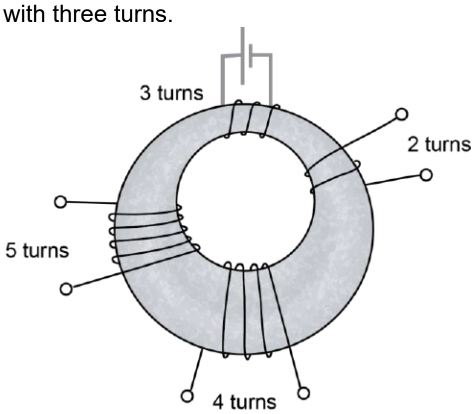

Fig. 6.2

i. Draw on Fig. 6.2 the complete paths of **two** lines of magnetic flux produced by the three-turn coil when there is a current in it.

[1]

ii. State which **one** of the following three quantities,

magnetic flux *magnetic flux density* *magnetic flux linkage*

is most nearly the same for all four coils in Fig. 6.2. Give a reason for your answer.

---

[1]

iii. Write down **one** of the **other** two quantities in **(ii)** above. State in which coil this quantity has the largest value. Give a reason for your answer.

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[2]

33. An astronomer uses a spectrometer and diffraction grating to view a hydrogen emission spectrum from a star. The light is incident normally on the grating.

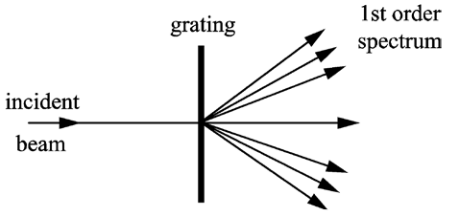

Fig. 6.1

These three emission lines all arise from transitions to the same final energy level. The part of the energy level diagram of hydrogen relevant to these transitions is shown in **Fig. 6.2**.

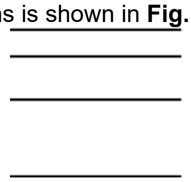

Fig. 6.2

i. Draw lines between the energy levels to indicate the transitions which cause the three emission lines and label them with their wavelengths.

[1]

ii. There are other possible transitions between the energy levels shown in **Fig. 6.2**. The least energetic of these produces photons of 4.8×10^{-20} J.

Calculate the wavelength of these photons.

State in which region of the electromagnetic spectrum this wavelength is found.

wavelength .... m

region: ....

[3]

34. A positively charged particle is travelling in a uniform field.
Fig. 21.1 shows the particle travelling at right angles to the direction of the field.

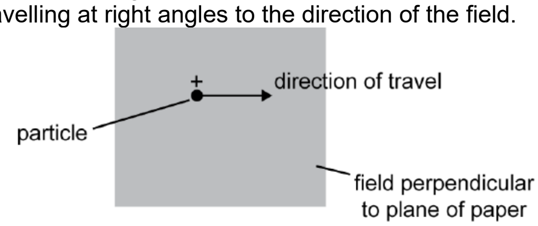

Fig. 21.1

Describe the motion of the particle in terms of the force it experiences when the field is

i. a magnetic field

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[2]

ii. an electric field.

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[2]

35.

i. State **Faraday's law of electromagnetic induction**.

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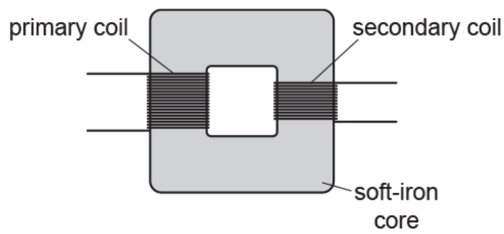
[1]

ii. The diagram below shows a simple transformer constructed by a student.



Describe how the student can do an experiment in the laboratory to show that the maximum electromotive force (e.m.f.) *E* induced in the secondary coil is directly proportional to the number of turns *N* on the secondary coil.

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[3]

36. Fig. 21.1 shows a coil of a simple generator rotating in a uniform magnetic field.

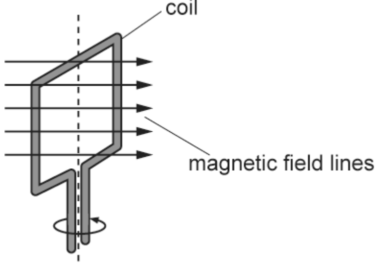


Fig. 21.1

The coil has 85 turns of insulated wire. The cross-sectional area of the coil is 14 cm^2.

Fig. 21.2 shows the variation of magnetic flux density *B* through the plane of the coil with time *t* as it rotates.

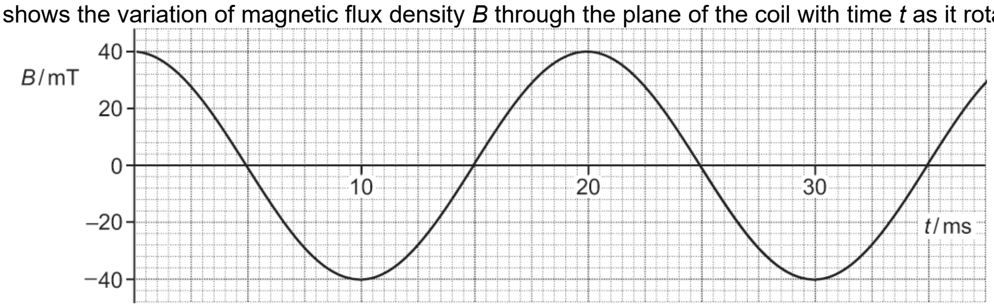


Fig. 21.2

i. Explain why the electromotive force (e.m.f.) induced across the ends of the coil is a **maximum** at the times when *B* = 0.

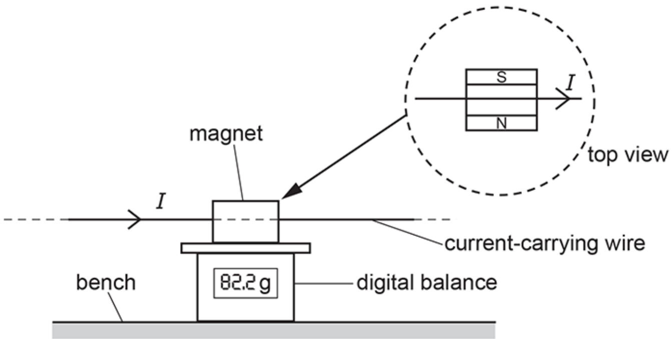
---

[1]

ii. Draw a tangent to the curve in Fig. 21.2 when $B = 0$, and hence determine the **maximum** e.m.f. induced across the ends of the coil.

maximum e.m.f. = ... V **[3]**

37. The arrangement shown in the diagram below is used to determine the magnetic flux density between the poles of a permanent magnet



The magnet is placed on the digital balance. The current-carrying wire is horizontal and at right angles to the magnetic field between the poles of the magnet. The wire is fixed.

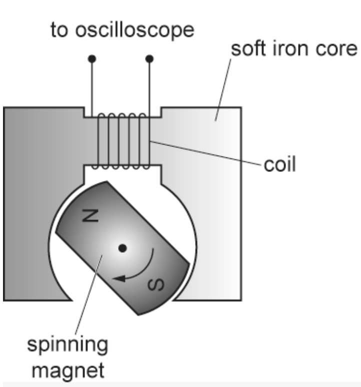
The following results are collected.

- length of the wire in the uniform field of the magnet = 6.0 ± 0.2 cm
- balance reading with no current in wire = 80.0 g
- balance reading with current in wire = 82.2 g
- current in wire = 5.0 ± 0.1 A

Calculate the magnetic flux density B, including the absolute uncertainty.
Ignore the absolute uncertainty in the balance readings.
Write your value for B to **2** significant figures and the absolute uncertainty to **1** significant figure.

B = ... ± .... T **[4]**

38. A magnet rotates inside a shaped soft iron core. A coil is wrapped around the iron core as shown in Fig. 5.1. The coil is connected to an oscilloscope.



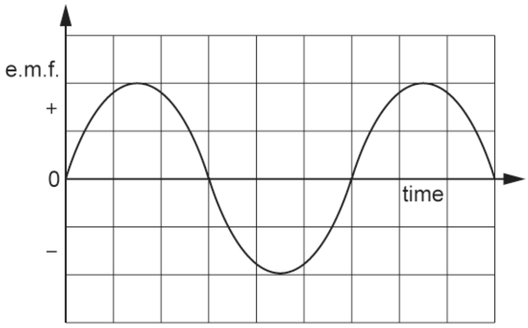


Fig. 5.1

Fig. 5.2

The spinning magnet induces an e.m.f. in the coil. A graph of the e.m.f. displayed on the oscilloscope screen is shown in Fig. 5.2.

i. Explain the shape of the graph in terms of the magnetic flux linking the coil.

---

[2]

ii. On Fig. 5.3 sketch a graph of the magnetic flux linkage of the coil against time. The variation of the induced e.m.f. across the coil is shown as a dotted line.

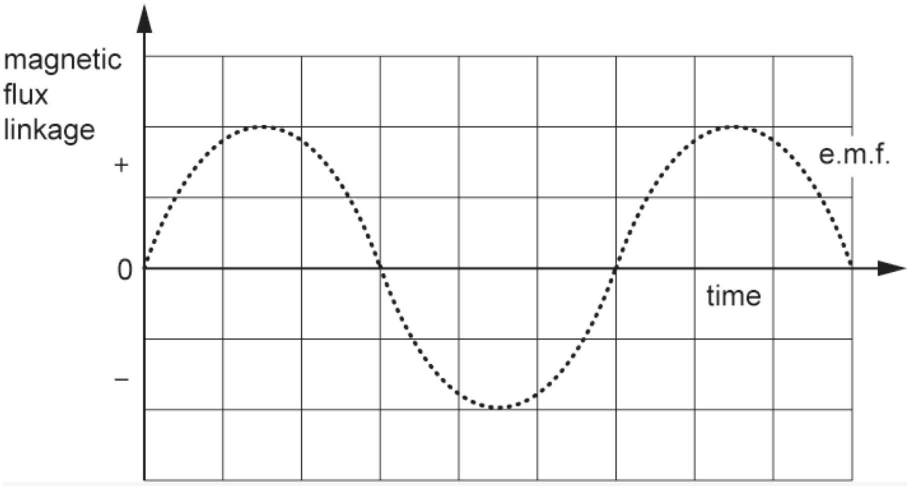


Fig. 5.3

[1]

iii. The coil shown in Fig. 5.1 has 150 turns. The maximum induced e.m.f. V_0 across the coil is 1.2 V when the magnet is rotating at 24 revolutions per second.

Calculate the maximum **magnetic flux** through the coil using the equation

$$V_0 = 2\pi \times (\text{frequency}) \times (\text{maximum magnetic flux linkage})$$

Give a unit with your answer.

maximum flux = unit **[2]**

39. A thin rectangular slice of semiconductor is mounted and used as a measuring instrument called a Hall probe.

A cell is connected to provide the current in the slice. The potential difference across the slice is measured by a separate voltmeter.

A student wants to measure the magnetic flux density between the poles of two magnets mounted on a steel yoke as shown in Fig. 2.2. The magnitude of the flux density is between 0.02 T and 0.04 T.

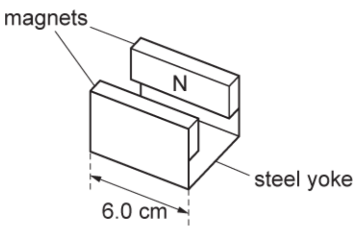


Fig. 2.2

i. Suggest **one** reason why this Hall probe is **not** a suitable instrument to measure the magnetic flux density for the arrangement shown in Fig. 2.2.

--- **[1]**

ii. Another method of measuring the magnetic flux density for the arrangement shown in Fig. 2.2 is to insert a current-carrying wire between the poles of the magnet.

Explain how the magnetic flux density can be determined using this method and discuss which measurement in the experiment leads to the greatest uncertainty in the value for the magnetic flux density.

--- **[4]**

40. This question is about an electric cooker, which consists of an oven and an electromagnetic induction hob.

The electromagnetic induction hob is shown in **Fig. 4.1.**

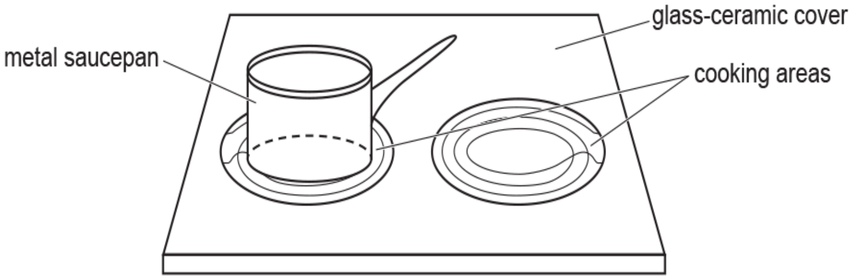


Fig. 4.1

Each cooking area has a coil below the glass-ceramic cover. When switched on, the coils carry a high-frequency **alternating** current.

A metal saucepan is placed above one of the coils. A large alternating current is induced in the saucepan base, and this causes the saucepan to heat up.

i. **Fig. 4.2**shows one of the coils at a time when the current is in the direction indicated by the arrows.

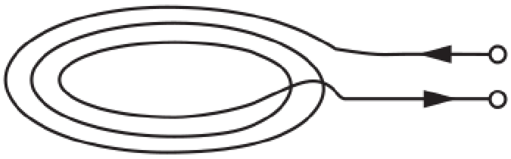


Fig. 4.2

On **Fig. 4.2**, sketch the magnetic field pattern for the current-carrying coil.

[2]

ii. Fig. 4.3 shows the path of the large alternating current induced in the metal base of the saucepan

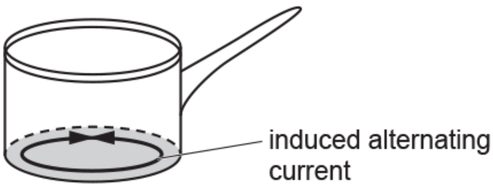


Fig. 4.3

Explain the origin of this large current.

----

[2]

iii. Explain why it would be safe for a person to place a hand on the cooking area before the saucepan is put onto it.

---

[2]

41 (a). A student conducts an experiment to confirm that the uniform magnetic flux density *B* between the poles of a magnet is 30 mT.

A current-carrying wire of length 5.0 cm is placed perpendicular to the magnetic field.

The current *I* in the wire is changed and the force *F* experienced by the wire is measured. Fig. 22.1 shows the graph plotted by the student.

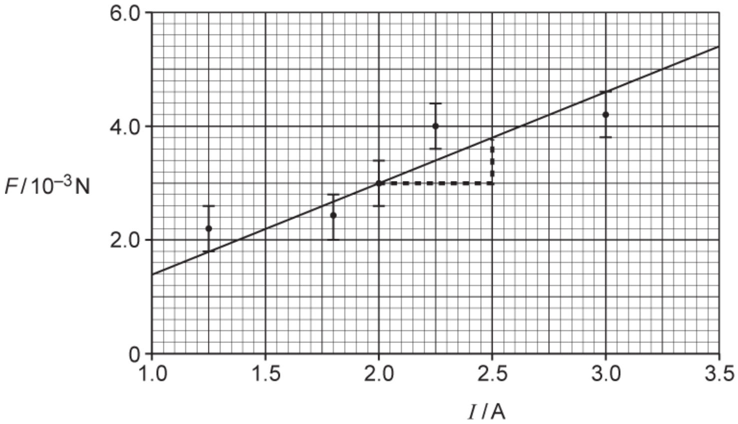


Fig. 22.1

The student's analysis is shown on the graph of Fig. 22.1 and in the space below.

$F = BIL$

$$\text{gradient} = BL = \frac{(3.8 - 3.0) \times 10^{-3}}{2.5 - 2.0} = 0.0016$$

$$B = \frac{0.0016}{0.05} = 0.032\ \text{T} = 32\ \text{mT}$$

This is just 2 mT out from the 30 mT value given by the manufacturer, so the experiment is very accurate.

Evaluate the information from Fig. 22.1 and the analysis of the data from the experiment. No further calculations are necessary.

---

[6]

(b). Fig. 22.2 shows a transformer circuit.

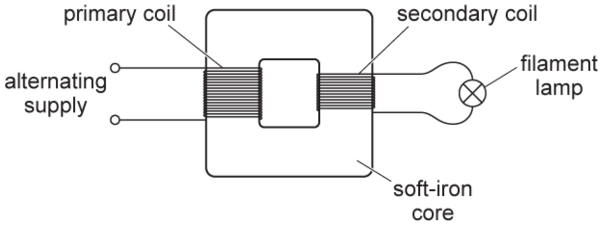


Fig. 22.2

The primary coil is connected to an alternating voltage supply. A filament lamp is connected to the output of the secondary coil.

i. Use Faraday's law of electromagnetic induction to explain why the filament lamp is lit.

---

[3]

ii. The primary coil has 400 turns and the secondary coil has 20 turns. The potential difference across the lamp is 12 V and it dissipates 24 W. The transformer is 100% efficient.

1. Calculate the current in the primary coil.

current = ... A **[2]**

2. The alternating voltage supply is replaced by a battery and an open switch in series. The switch is closed. The lamp is lit for a short period of time and then remains off. Explain this observation.

---

[2]

42. A student is given a transformer with coils **X** and **Y**, as shown in Fig. 5.4.

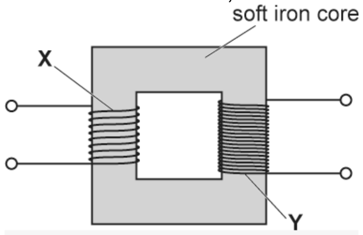


Fig. 5.4

The student is intending to investigate how the maximum induced e.m.f. V_0 in coil **Y** depends on the frequency f of the alternating current in coil **X**.

The changing magnetic flux density in coil **X** induces an e.m.f. in coil **Y**. Faraday's law indicates that the maximum induced e.m.f. V_0 should be directly proportional to f.

Describe how you would investigate the suggested relationship between V_0 and f in the laboratory using these coils. In your description include all of the equipment used and how you would analyse the data collected.

Use the space below to draw a suitable diagram.

[6]

43. * **Fig. 5.1** shows a simple a.c. generator being tested by electrical engineers.

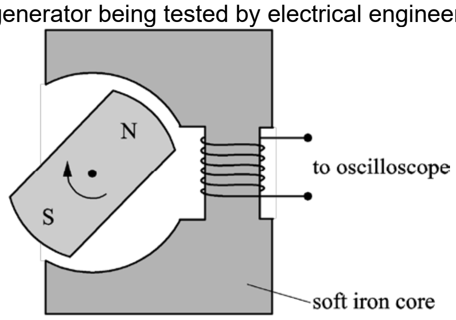


Fig. 5.1

It consists of a magnet, on the shaft of a **variable speed** motor, being rotated inside a cavity in a soft iron core. The output from the coil, wound on the iron core, is connected to an oscilloscope. The grid of **Fig. 5.2** shows a typical output voltage which would be displayed on the oscilloscope screen.

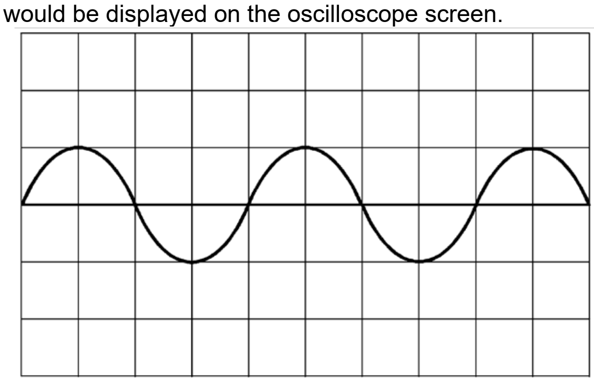


Fig. 5.2

According to Faraday's law the e.m.f. induced is directly proportional to the rate of change of flux linkage. In the context of this experiment, the maximum e.m.f. induced is directly proportional to the frequency of rotation of the magnet.

Use the apparatus above to plan an experiment to validate Faraday's law of electromagnetic induction. In your description include how the data is collected and analysed.

[6]

44 (a). Fig. 5.1 shows a horizontal copper wire placed between the opposite poles of a permanent magnet. The wire is held in tension *T* by the clamps at each end. The length of the wire in the magnetic field of flux density 0.032 tesla is 6.0 cm.

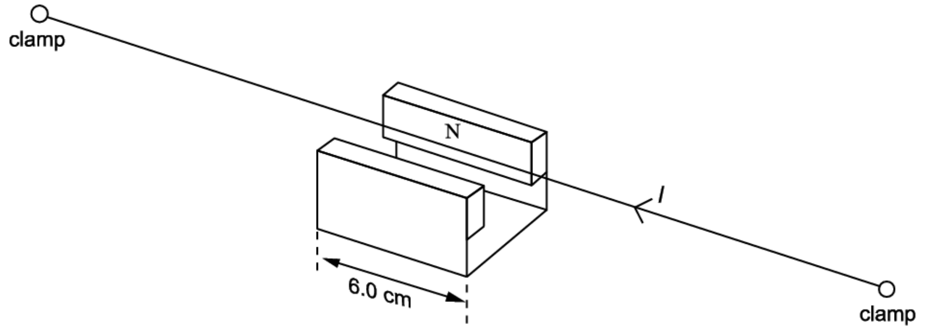


Fig. 5.1

The direct current is changed to an alternating current of constant amplitude and variable frequency, causing the wire to oscillate. The frequency of the current is increased until the fundamental natural frequency of the wire is found as shown in Fig. 5.2. This is 70 Hz.

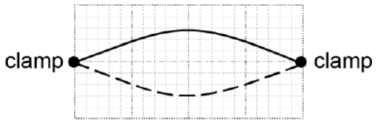


Fig. 5.2

i. In the situation shown in Fig. 5.2 the amplitude of the oscillation of the centre point of the wire is 4.0 mm. Calculate the maximum acceleration of the wire at this point.

maximum acceleration = ... m s^{-2} **[2]**

ii. The frequency is increased until another stationary wave pattern occurs. The amplitude of this stationary wave is much smaller.

1. Sketch this pattern on Fig. 5.3 and state the frequency

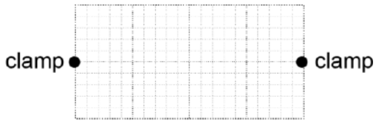


Fig. 5.3

frequency = ... Hz **[1]**

2. Explain why the amplitude is so small. Suggest how the experiment can be modified to increase the amplitude.

-----

[3]

(b). The speed *v* of a transverse wave along the wire is given by $v = \sqrt{\frac{T}{\mu}}$ where *T* is the tension and μ is the mass per unit length of the wire.

i. Assume that both the length and mass per unit length remain constant when the tension in the wire is halved.
Calculate the frequency of the new fundamental mode of vibration of the wire.

frequency = ... Hz **[1]**

ii. In practice the mass per unit length changes because the wire contracts when the tension is reduced.
For the situation in which the tension is halved the strain reduction is found to be 0.4%.

1. Calculate the percentage change in *μ.* State both the size and sign of the change.

percentage change in *μ* = ... % **[1]**

2. Write down the percentage error this causes in your answer to **(i)**. State, giving your reasoning, whether the actual frequency would be higher or lower than your value.

---

[2]

45. * A student is to investigate the magnetic field inside and around a solenoid.

It is suggested that the magnetic field strength *B* inside a long solenoid is determined by various quantities, namely $B \propto \frac{NI}{L}$

where *N* is the number of turns, *L* is the length of the solenoid and *I* is the current in the wire.

Apparatus is set up for an experiment as shown in Figure 6.1.

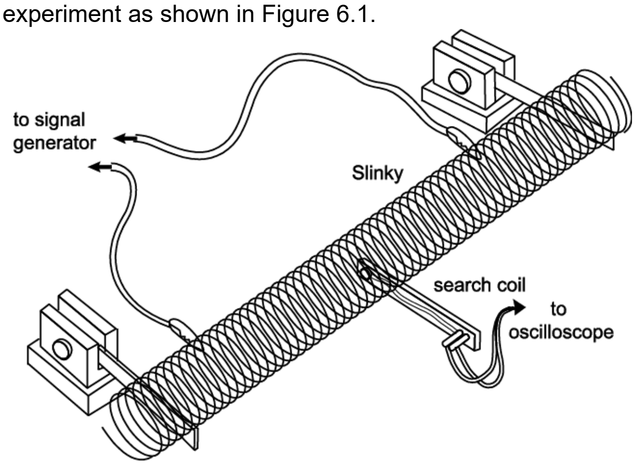


Fig. 6.1

A Slinky is a long spring about 70 mm in diameter which can be stretched easily and uniformly. The search coil has 5000 turns and the signal generator can produce a constant alternating current at a frequency between 0 and 1 kHz.

Plan an experiment using this equipment to investigate the validity of the relationship between *B,* at the centre of the solenoid, and **one** of the variables *N* or *L*. Explain how you will make your measurements, how sensitive they will be and the steps that you will take to make this a valid test.

[6]

END OF QUESTION PAPER