PapaCambridge

Cambridge International AS & A Level

PHYSICS

Paper 4

Topical Past Paper Questions
+ Answer Scheme

2016 - 2021

PapaCambridge

Chapter 13

Electromagnetic induction

293. 9702_m21_qp_42 Q: 9

(a) Define *magnetic flux linkage*.

....

....

.... [2]

(b) A solenoid of diameter 6.0 cm and 540 turns is placed in a uniform magnetic field as shown in Fig. 9.1.

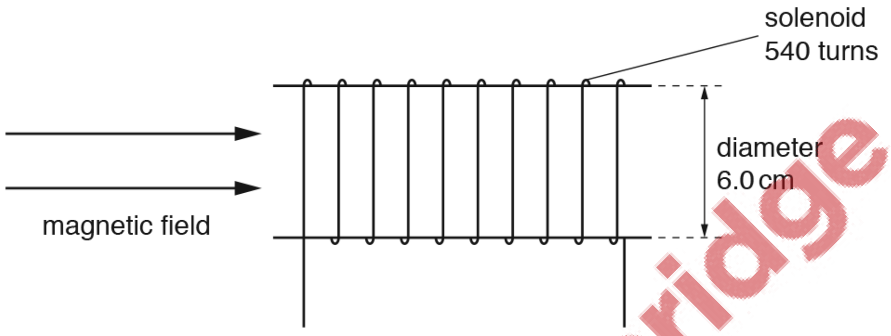

Fig. 9.1

The variation with time t of the magnetic flux density is shown in Fig. 9.2.

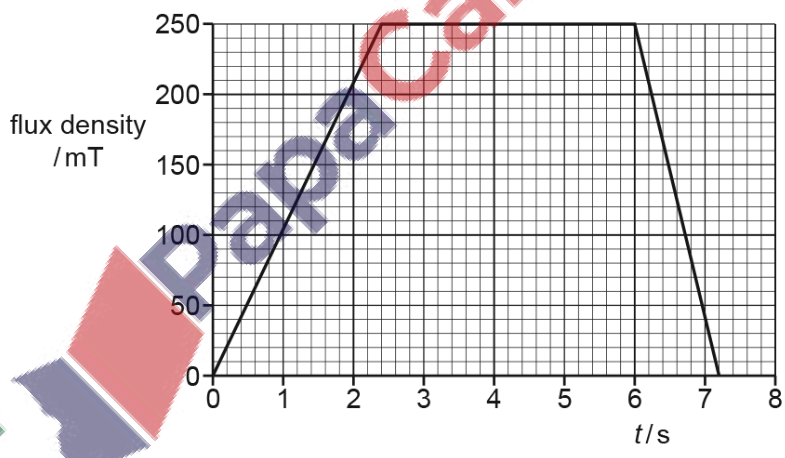

Fig. 9.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

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

(c) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 9.3.

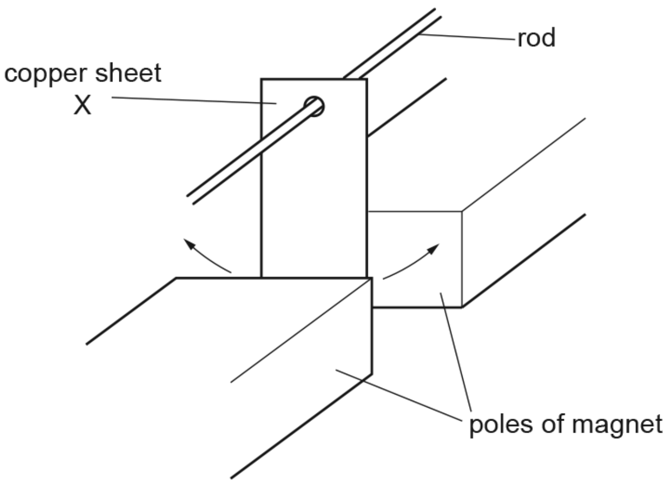

Fig. 9.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig. 9.4.

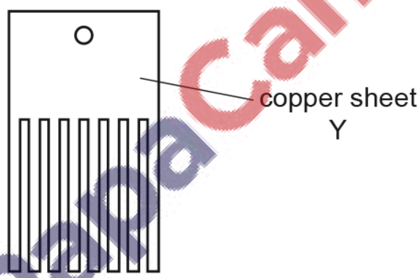

Fig. 9.4

The motion sensor is again used to record the displacement.

The graph in Fig. 9.5 shows the variation with time *t* of the displacement *s* of each copper sheet.

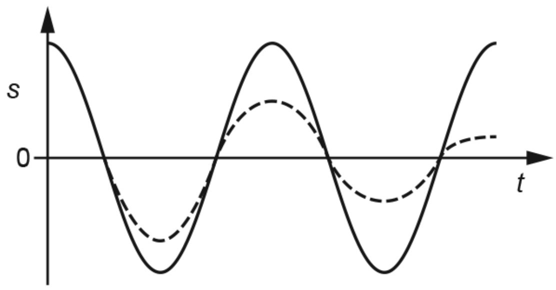

Fig. 9.5

(i) State the name of the phenomenon illustrated by the gradual reduction in the amplitude of the dashed line.

.... [1]

(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

....

....

....

....

....

.... [4]

[Total: 10]

294. 9702_s21_qp_41 Q: 10

(a) State Lenz's law.

....

....

.... [2]

(b) A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 10.1.

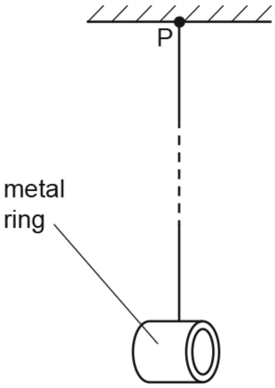

Fig. 10.1

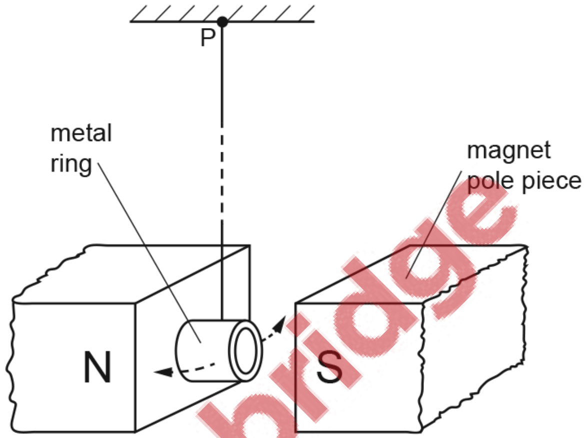

Fig. 10.2

The ring is displaced a distance *d* and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 10.2.

The ring is again displaced a distance *d* and then released.
Explain why the ring completes fewer oscillations before coming to rest.

....

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....

.... [4]

(c) The ring in **(b)** is now cut so that it has the shape shown in Fig. 10.3.

Fig. 10.3

Explain why, when the procedure in **(b)** is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

....

....

....

....

.... [3]

[Total: 9]

295. 9702_s21_qp_42 Q: 9

(a) State **two** situations in which a charged particle in a magnetic field does **not** experience a force.

1. ....

....

2. ....

.... [2]

(b) A loosely coiled metal spring is suspended from a fixed point, as shown in Fig. 9.1.

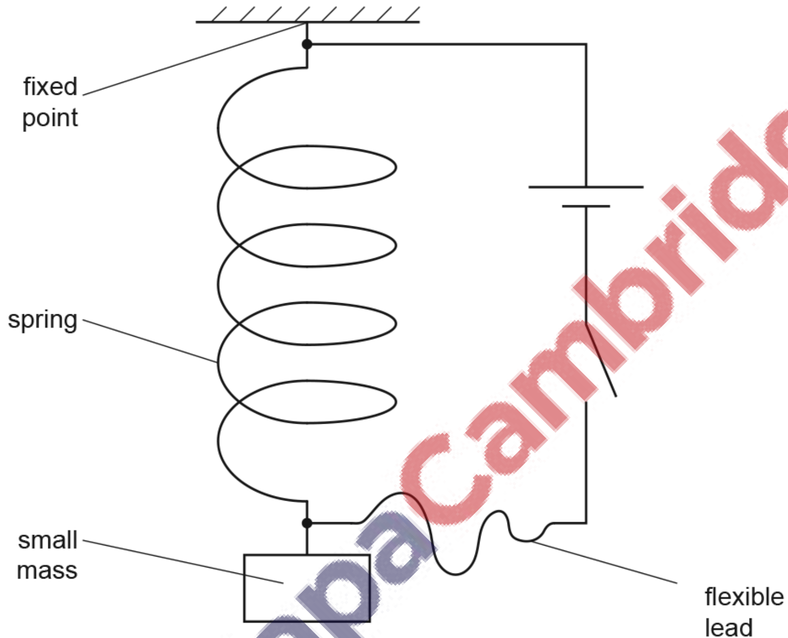

Fig. 9.1

Electrical connections are made to the ends of the spring by means of a flexible lead.

The length of the spring is measured before the switch is closed and then again after the switch is closed.

When the switch is closed, a magnetic field is set up around each coil of the spring.

By reference to these magnetic fields, explain why there is a change in length of the spring. State whether the spring extends or contracts.

....

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....

.... [4]

(c) With the switch in **(b)** closed, the small mass on the free end of the spring is now made to oscillate vertically.

Use the principles of electromagnetic induction to explain why small fluctuations in the current in the spring are found to occur.

....

....

....

.... [3]

[Total: 9]

296. 9702_s21_qp_43 Q: 10

(a) State Lenz's law.

....

....

.... [2]

(b) A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 10.1.

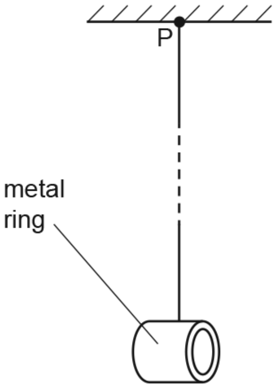

Fig. 10.1

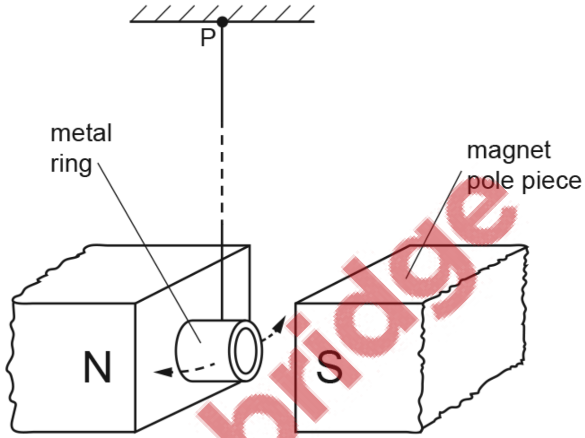

Fig. 10.2

The ring is displaced a distance *d* and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 10.2.

The ring is again displaced a distance *d* and then released.
Explain why the ring completes fewer oscillations before coming to rest.

....

....

....

....

....

.... [4]

(c) The ring in **(b)** is now cut so that it has the shape shown in Fig. 10.3.

Fig. 10.3

Explain why, when the procedure in **(b)** is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

....

....

....

....

.... [3]

[Total: 9]

297. 9702_m20_qp_42 Q: 3

(a) A body undergoes simple harmonic motion.

The variation with displacement x of its velocity v is shown in Fig. 3.1.

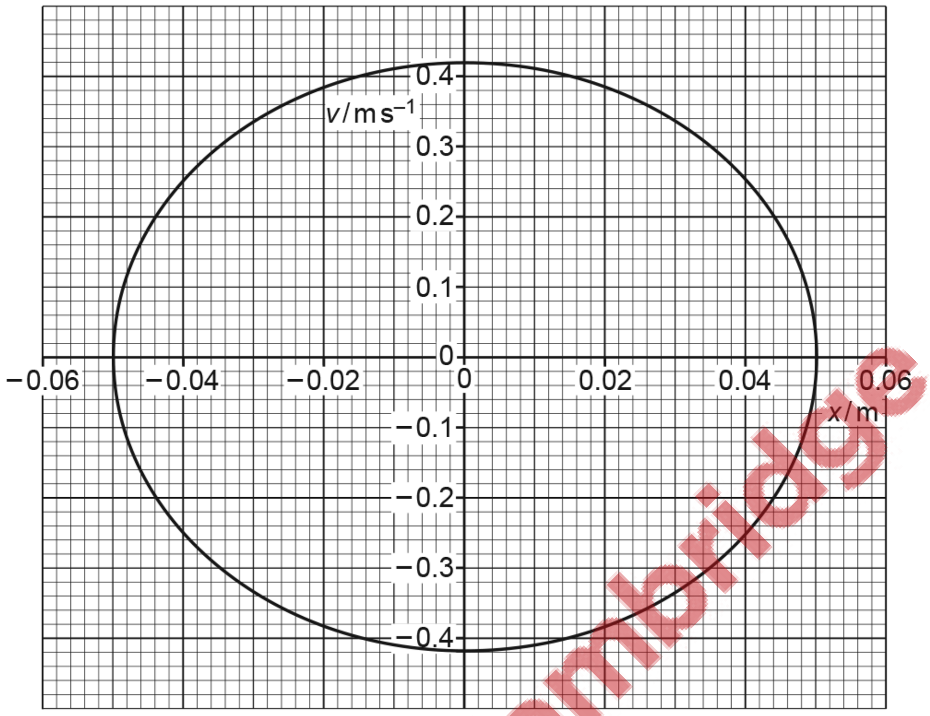

Fig. 3.1

(i) State the amplitude x_o of the oscillations.

x_o = ... m [1]

(ii) Calculate the period T of the oscillations.

T = ... s [3]

(iii) On Fig. 3.1, label with a P a point where the body has **maximum** potential energy. [1]

(b) A bar magnet is suspended from the free end of a spring, as shown in Fig. 3.2.

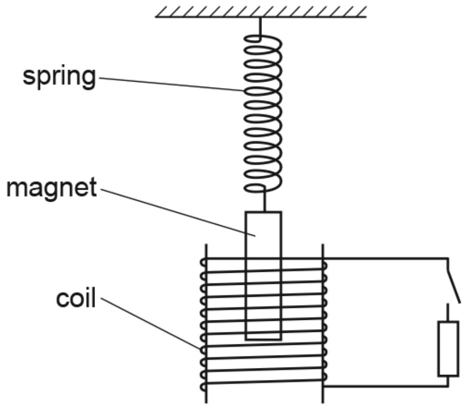

Fig. 3.2

One pole of the magnet is situated in a coil of wire. The coil is connected in series with a switch and a resistor. The switch is open.

The magnet is displaced vertically and then released. The magnet oscillates with simple harmonic motion.

(i) State Faraday's law of electromagnetic induction.

....

....

....

.... [2]

(ii) The switch is now closed. Explain why the oscillations of the magnet are damped.

....

....

....

....

....

.... [3]

[Total: 10]

298. 9702_s20_qp_41 Q: 9

(a) A coil of wire is situated in a uniform magnetic field of flux density *B*.
The coil has diameter 3.6 cm and consists of 350 turns of wire, as illustrated in Fig. 9.1.

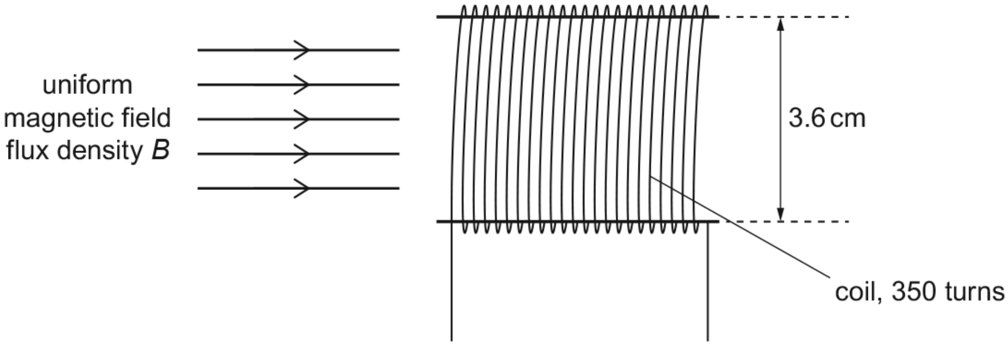

Fig. 9.1

The variation with time t of B is shown in Fig. 9.2.

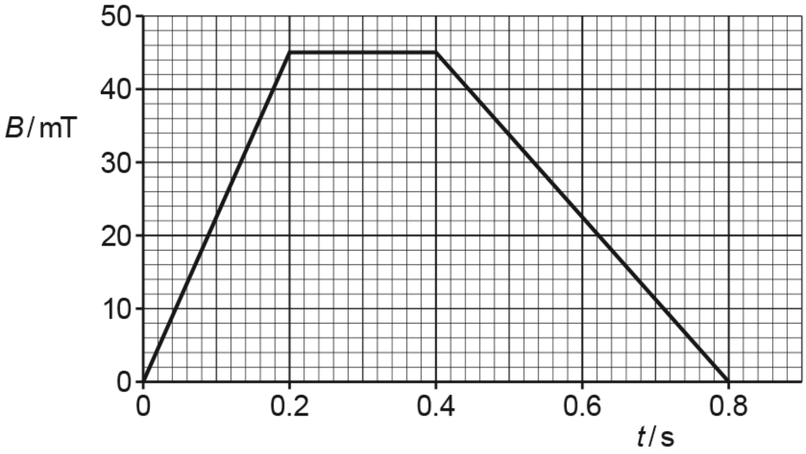

Fig. 9.2

(i) Show that, for the time $t = 0$ to time $t = 0.20$ s, the electromotive force (e.m.f.) induced in the coil is 0.080 V.

[2]

(ii) On the axes of Fig. 9.3, show the variation with time t of the induced e.m.f. E for time $t = 0$ to time $t = 0.80$ s.

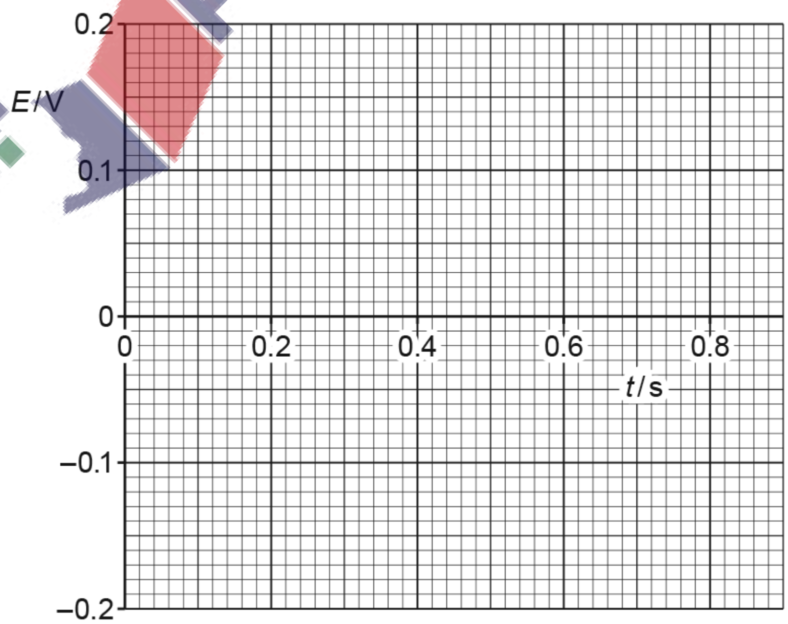

Fig. 9.3

[4]

(b) A bar magnet is held a small distance above the surface of an aluminium disc by means of a rod, as illustrated in Fig. 9.4.

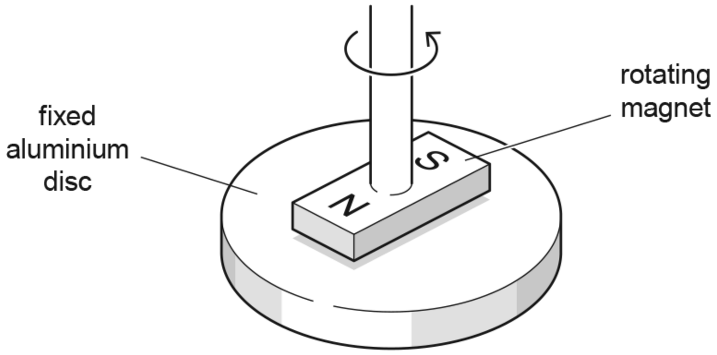

Fig. 9.4

The aluminium disc is supported horizontally and held stationary.

The magnet is rotated about a vertical axis at constant speed.

Use laws of electromagnetic induction to explain why there is a torque acting on the aluminium disc.

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....

....

....

....

.... [4]

[Total: 10]

299. 9702_s20_qp_43 Q: 9

(a) A coil of wire is situated in a uniform magnetic field of flux density *B*.
The coil has diameter 3.6 cm and consists of 350 turns of wire, as illustrated in Fig. 9.1.

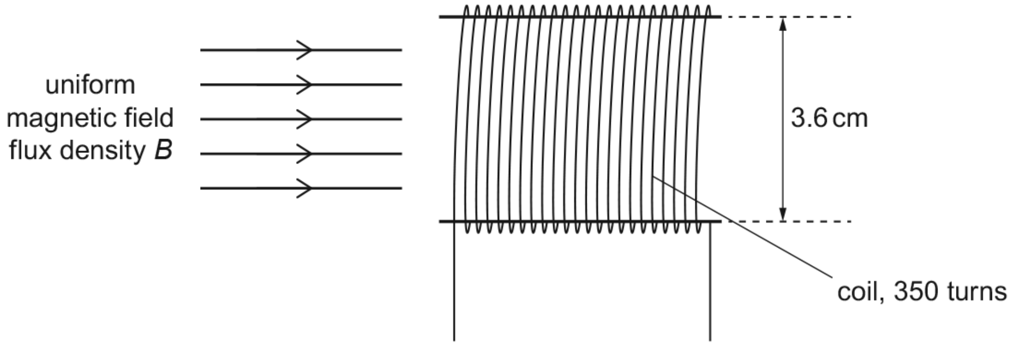


Fig. 9.1

The variation with time t of B is shown in Fig. 9.2.

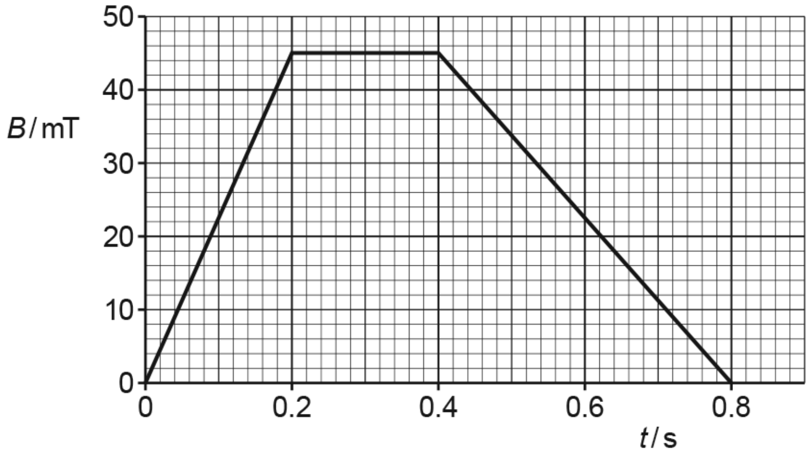


Fig. 9.2

(i) Show that, for the time t = 0 to time t = 0.20 s, the electromotive force (e.m.f.) induced in the coil is 0.080 V.

[2]

(ii) On the axes of Fig. 9.3, show the variation with time t of the induced e.m.f. E for time t = 0 to time t = 0.80 s.

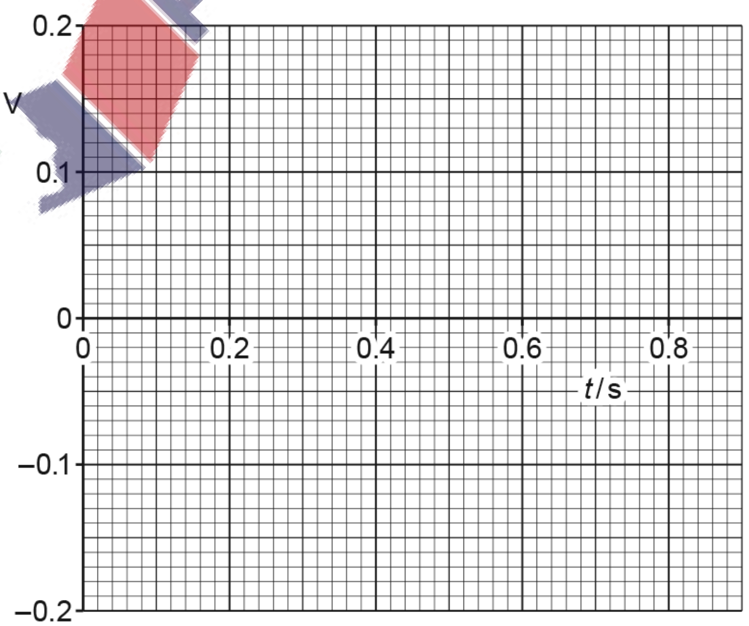


Fig. 9.3

[4]

(b) A bar magnet is held a small distance above the surface of an aluminium disc by means of a rod, as illustrated in Fig. 9.4.

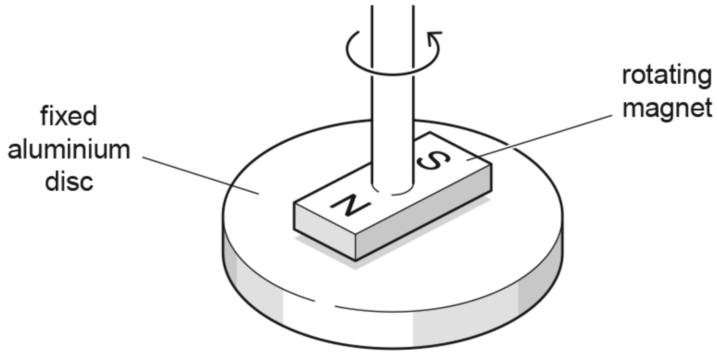


Fig. 9.4

The aluminium disc is supported horizontally and held stationary.

The magnet is rotated about a vertical axis at constant speed.

Use laws of electromagnetic induction to explain why there is a torque acting on the aluminium disc.

....

....

....

....

....

.... [4]

[Total: 10]

300. 9702_m19_qp_42 Q: 10

(a) A cross-section through a current-carrying solenoid is shown in Fig. 10.1.

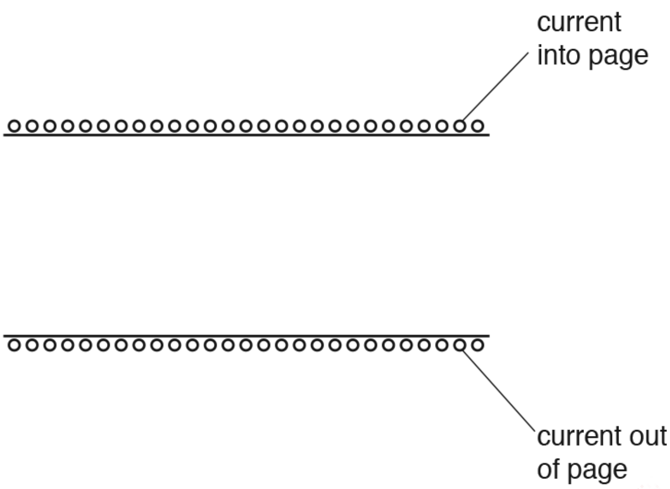


Fig. 10.1

On Fig. 10.1, draw field lines to represent the magnetic field inside the solenoid. [3]

(b) State Faraday's law of electromagnetic induction.

....

....

.... [2]

(c) A coil of insulated wire is wound on to a soft-iron core.

The coil is connected in series with a battery, a switch and an ammeter, as shown in Fig. 10.2.

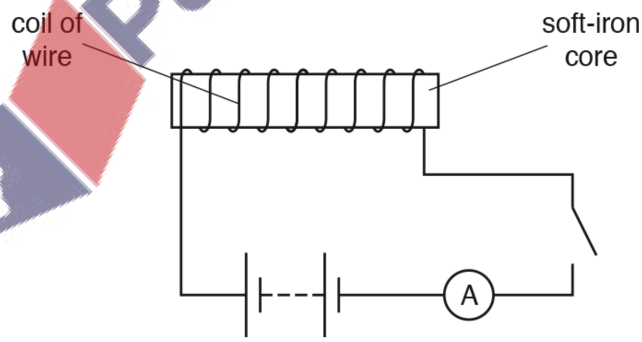


Fig. 10.2

Use laws of electromagnetic induction to explain why, when the switch is closed, the current increases **gradually** to its maximum value.

....

....

....

....

.... [3]

[Total: 8]

301. 9702_s19_qp_41 Q: 8

A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1.

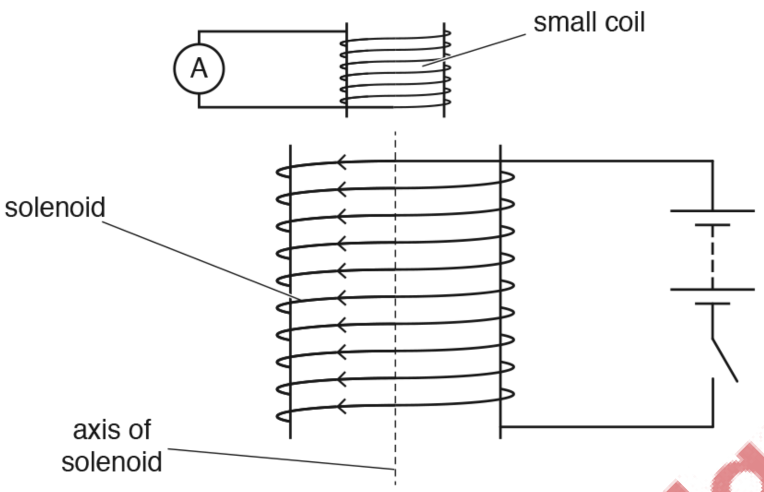


Fig. 8.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid.

(a) **(i)** State what is meant by a *magnetic field*.

....

.... [1]

(ii) On Fig. 8.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid. Label this arrow P. [1]

(b) As the current in the solenoid is switched on, there is a current induced in the small coil. This induced current gives rise to a magnetic field in the small coil.

(i) State Lenz's law.

....

....

.... [2]

(ii) Use Lenz's law to state and explain the direction of the magnetic field due to the induced current in the small coil. On Fig. 8.1, mark this direction with an arrow inside the small coil.

....

....

....

.... [3]

(c) The small coil has an area of cross-section $7.0 \times 10^{-4}\,m^2$ and contains 75 turns of wire.

A constant current in the solenoid produces a uniform magnetic flux of flux density 1.4 mT throughout the small coil.

The direction of the current in the solenoid is reversed in a time of 0.12 s.

Calculate the average e.m.f. induced in the small coil.

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

[Total: 10]

302. 9702_s19_qp_43 Q: 8

A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1.

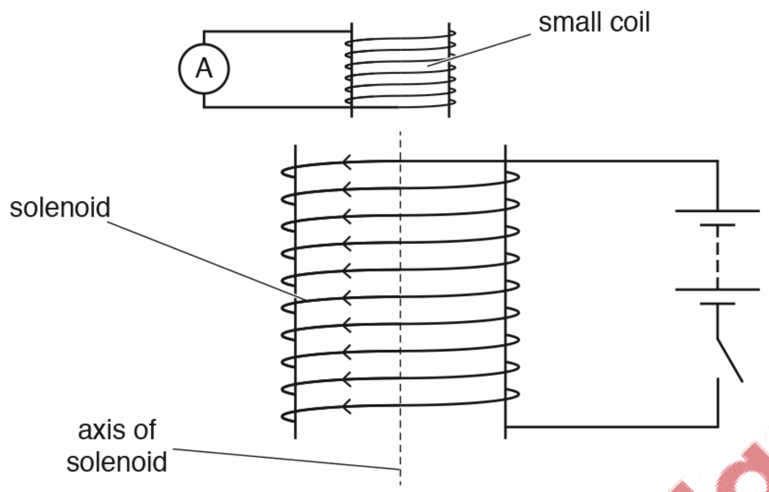


Fig. 8.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid.

(a) **(i)** State what is meant by a *magnetic field*.

....

.... [1]

(ii) On Fig. 8.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid. Label this arrow P. [1]

(b) As the current in the solenoid is switched on, there is a current induced in the small coil. This induced current gives rise to a magnetic field in the small coil.

(i) State Lenz's law.

....

....

.... [2]

(ii) Use Lenz's law to state and explain the direction of the magnetic field due to the induced current in the small coil. On Fig. 8.1, mark this direction with an arrow inside the small coil.

....

....

....

.... [3]

(c) The small coil has an area of cross-section $7.0 \times 10^{-4}\,m^2$ and contains 75 turns of wire.

A constant current in the solenoid produces a uniform magnetic flux of flux density 1.4 mT throughout the small coil.

The direction of the current in the solenoid is reversed in a time of 0.12 s.

Calculate the average e.m.f. induced in the small coil.

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

[Total: 10]

303. 9702_m18_qp_42 Q: 10

(a) **(i)** Define *magnetic flux*.

....

....

....[2]

(ii) State Faraday's law of electromagnetic induction.

....

....

....

....[2]

(b) A solenoid has a coil C of wire wound tightly about its centre, as shown in Fig. 10.1.

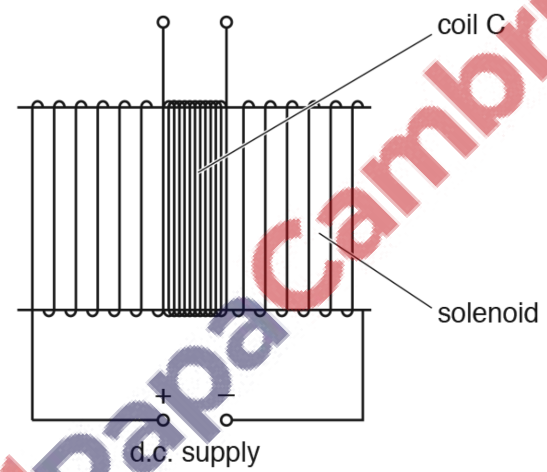


Fig. 10.1

The coil C has 96 turns.

The uniform magnetic flux Φ (in weber) in the solenoid is given by the expression

$$\Phi = 6.8 \times 10^{-6} \times I$$

where I is the current (in amperes) in the solenoid.

Calculate the average electromotive force (e.m.f.) induced in coil C when a current of 3.5 A is reversed in the solenoid in a time of 2.4 ms.

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

(c) The d.c. supply in Fig. 10.1 is now replaced with a sinusoidal alternating supply.

Describe qualitatively the e.m.f. that is now induced in coil C.

....

....

....[2]

[Total: 8]

304. 9702_s18_qp_41 Q: 10

(a) State Faraday's law of electromagnetic induction.

....

....

....

....[2]

(b) A coil of insulated wire is wound on to one end of a ferrous core and connected to a battery, as shown in Fig. 10.1.

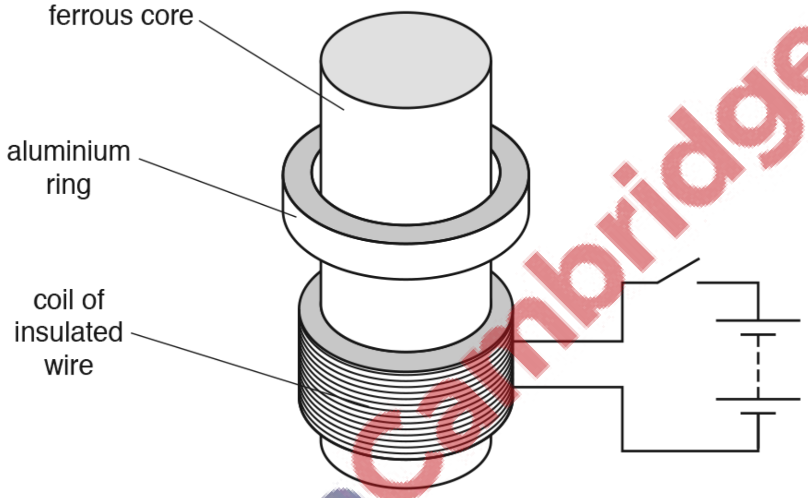


Fig. 10.1

An aluminium ring is placed on the core. The ring can move freely along the length of the core.

The switch is initially open.

Use Faraday's law and Lenz's law to explain why the aluminium ring jumps upwards when the switch is closed.

....

....

....

....

....

....

....[4]

[Total: 6]

305. 9702_s18_qp_42 Q: 9

(a) State what is meant by the *magnetic flux linkage* of a coil.

....

....

....

....[3]

(b) A coil of wire has 160 turns and diameter 2.4 cm. The coil is situated in a uniform magnetic field of flux density 7.5 mT, as shown in Fig. 9.1.

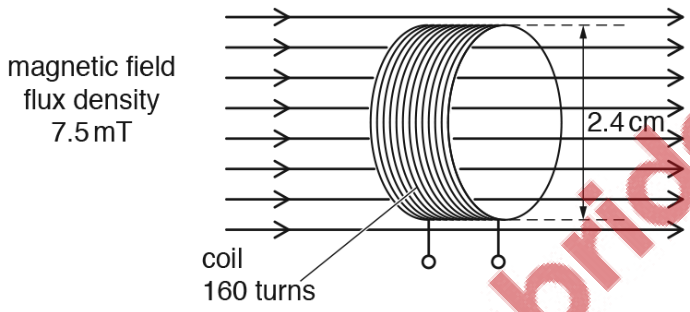


Fig. 9.1

The direction of the magnetic field is along the axis of the coil.

The magnetic flux density is reduced to zero in a time of 0.15 s.

Show that the average e.m.f. induced in the coil is 3.6 mV.

[2]

The magnetic flux density *B* in the coil in **(b)** is now varied with time *t* as shown in Fig. 9.2.

Fig. 9.2

Use data in **(b)** to show, on Fig. 9.3, the variation with time *t* of the e.m.f. *E* induced in the coil.

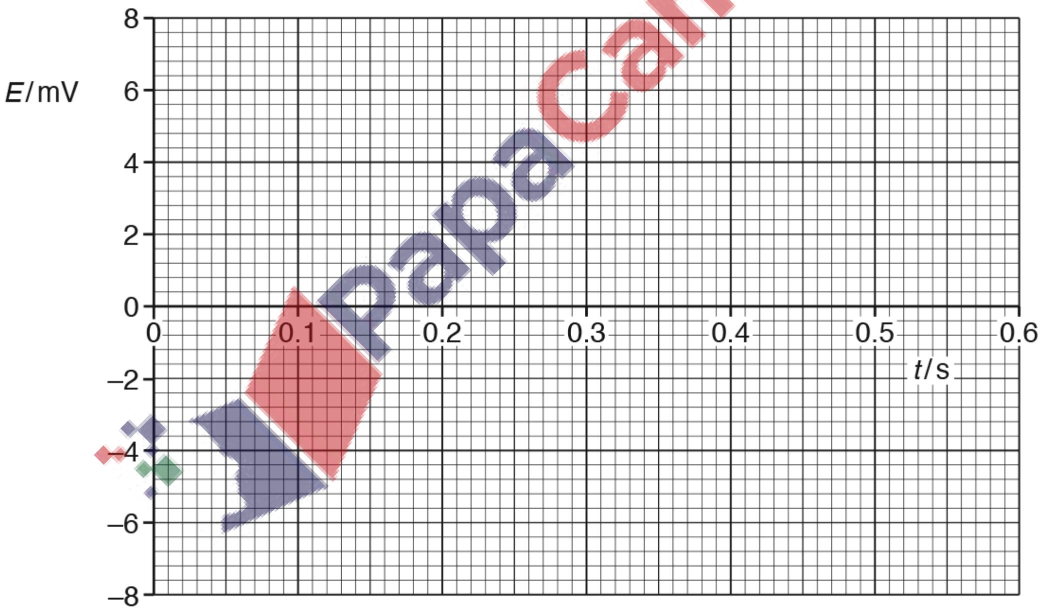


Fig. 9.3

[4]

[Total: 9]

306. 9702_s18_qp_43 Q: 10

(a) State Faraday's law of electromagnetic induction.

....

....

....

....[2]

(b) A coil of insulated wire is wound on to one end of a ferrous core and connected to a battery, as shown in Fig. 10.1.

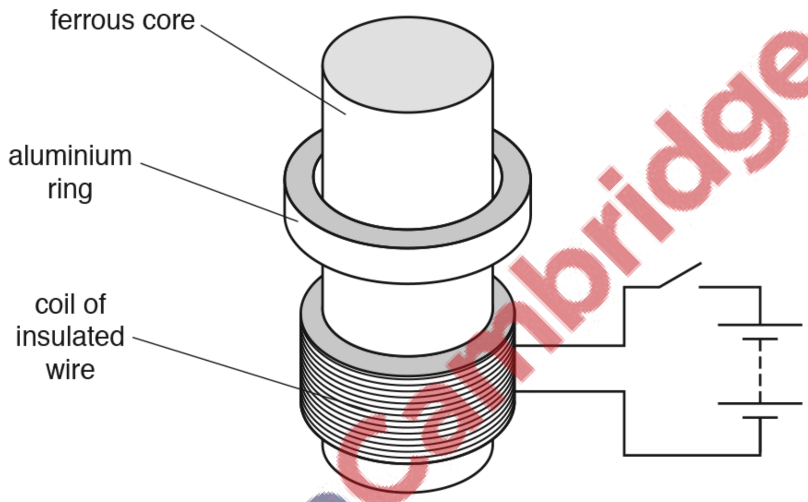


Fig. 10.1

An aluminium ring is placed on the core. The ring can move freely along the length of the core.

The switch is initially open.

Use Faraday's law and Lenz's law to explain why the aluminium ring jumps upwards when the switch is closed.

....

....

....

....

....

....

....[4]

[Total: 6]

307. 9702_w18_qp_41 Q: 9

(a) State Faraday's law of electromagnetic induction.

....

....

....[2]

(b) A solenoid S is wound on a soft-iron core, as shown in Fig. 9.1.

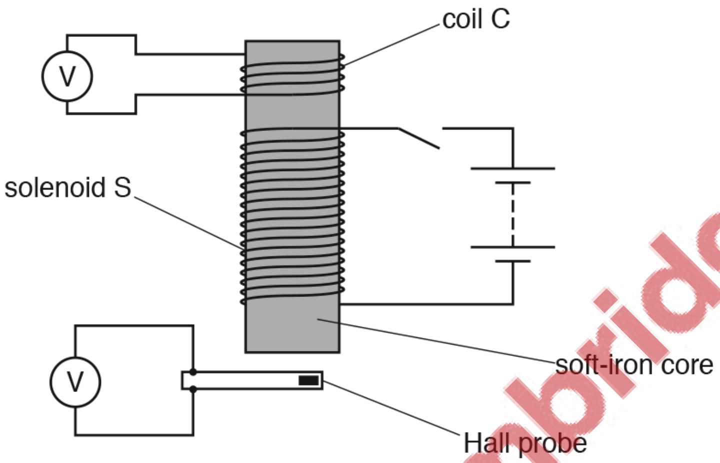


Fig. 9.1

A coil C having 120 turns of wire is wound on to one end of the core. The area of cross-section of coil C is 1.5 cm^2.

A Hall probe is close to the other end of the core.

When there is a constant current in solenoid S, the flux density in the core is 0.19 T. The reading on the voltmeter connected to the Hall probe is 0.20 V.

The current in solenoid S is now reversed in a time of 0.13 s at a constant rate.

(i) Calculate the reading on the voltmeter connected to coil C during the time that the current is changing.

reading = ... V [2]

(ii) Complete Fig. 9.2 for the voltmeter readings for the times before, during and after the direction of the current is reversed.

	before current changes	during current change when current is zero	after current changes
reading on voltmeter connected to coil C / V	....	....	....
reading on voltmeter connected to Hall probe / V	0.20	....	....

Fig. 9.2

[4]

[Total: 8]

308. 9702_w18_qp_42 Q: 9

(a) A Hall probe is placed near one end of a solenoid that has been wound on a soft-iron core, as shown in Fig. 9.1.

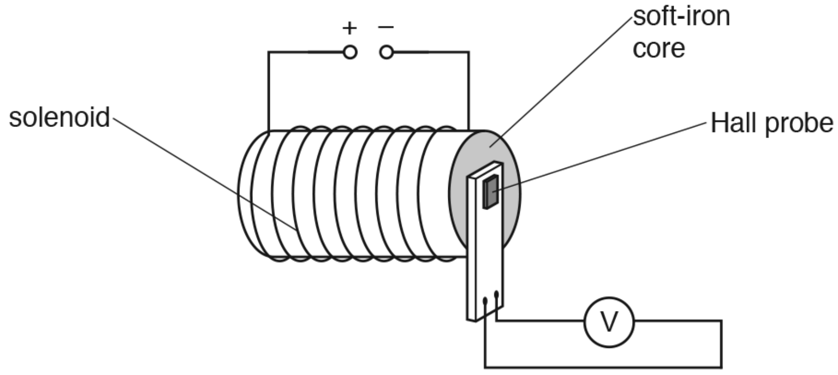


Fig. 9.1

The current in the solenoid is switched on.
The Hall probe is rotated until the reading V_H on the voltmeter is maximum.

The current in the solenoid is then varied, causing the magnetic flux density to change.
The variation with time *t* of the magnetic flux density *B* at the Hall probe is shown in Fig. 9.2.

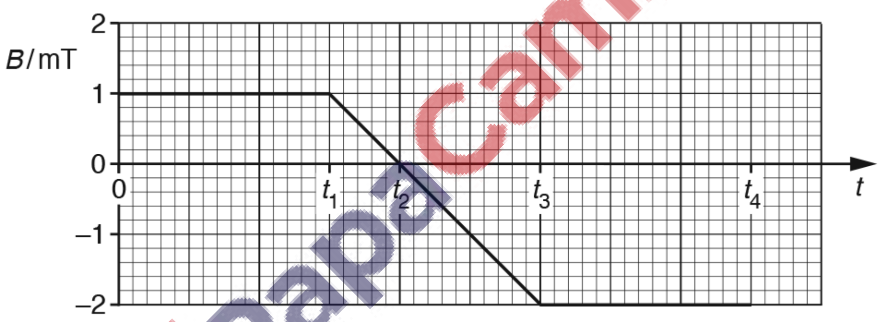


Fig. 9.2

At time $t = 0$, the Hall voltage is V_0.
On Fig. 9.3, draw a line to show the variation with time *t* of the Hall voltage V_H for time $t = 0$ to time $t = t_4$.

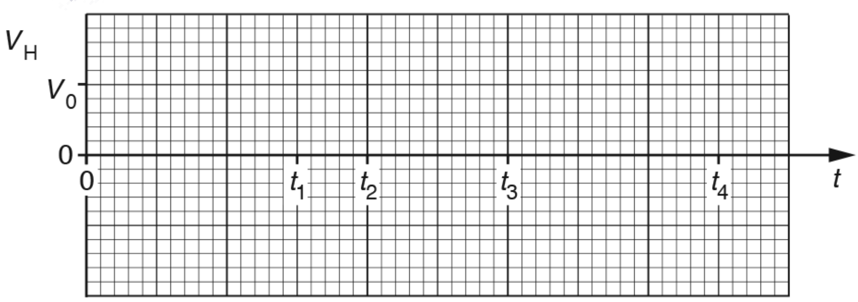


Fig. 9.3

[2]

(b) The Hall probe in **(a)** is now replaced by a small coil of wire connected to a sensitive voltmeter, as shown in Fig. 9.4.

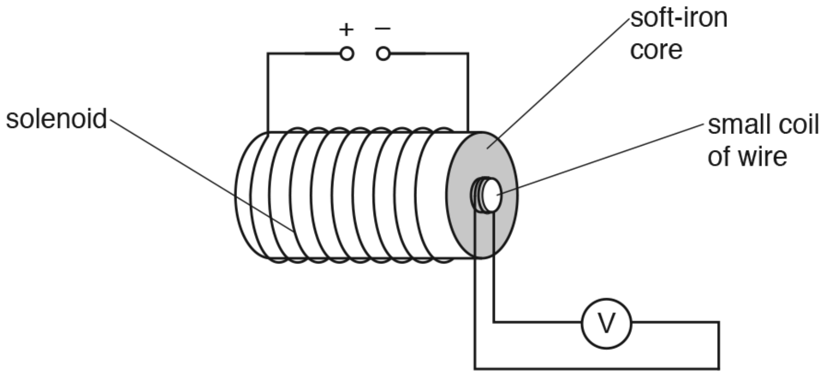


Fig. 9.4

The magnetic flux density, normal to the plane of the small coil, is again varied as shown in Fig. 9.2.

On Fig. 9.5, draw a line to show the variation with time t of the e.m.f. E induced in the small coil for time $t = 0$ to time $t = t_4$.

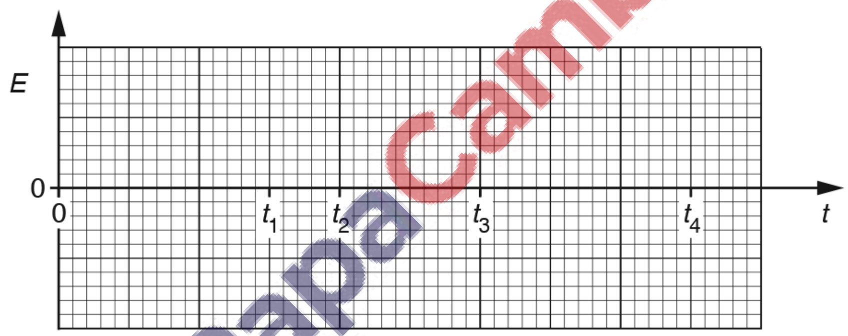


Fig. 9.5

[3]

[Total: 5]

309. 9702_w18_qp_43 Q: 9

(a) State Faraday's law of electromagnetic induction.

....

....

....[2]

(b) A solenoid S is wound on a soft-iron core, as shown in Fig. 9.1.

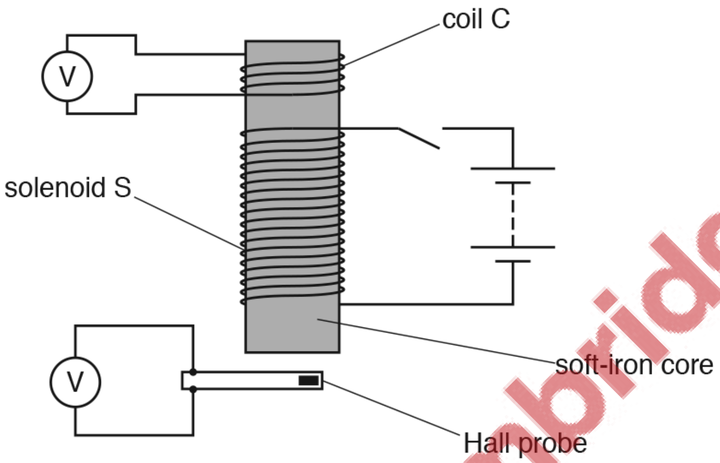


Fig. 9.1

A coil C having 120 turns of wire is wound on to one end of the core. The area of cross-section of coil C is 1.5 cm^2.

A Hall probe is close to the other end of the core.

When there is a constant current in solenoid S, the flux density in the core is 0.19 T. The reading on the voltmeter connected to the Hall probe is 0.20 V.

The current in solenoid S is now reversed in a time of 0.13 s at a constant rate.

(i) Calculate the reading on the voltmeter connected to coil C during the time that the current is changing.

reading = ... V [2]

(ii) Complete Fig. 9.2 for the voltmeter readings for the times before, during and after the direction of the current is reversed.

	before current changes	during current change when current is zero	after current changes
reading on voltmeter connected to coil C / V	....	....	....
reading on voltmeter connected to Hall probe / V	0.20	....	....

Fig. 9.2

[4]

[Total: 8]

310. 9702_s17_qp_42 Q: 3

A bar magnet of mass 250 g is suspended from the free end of a spring, as illustrated in Fig. 3.1.

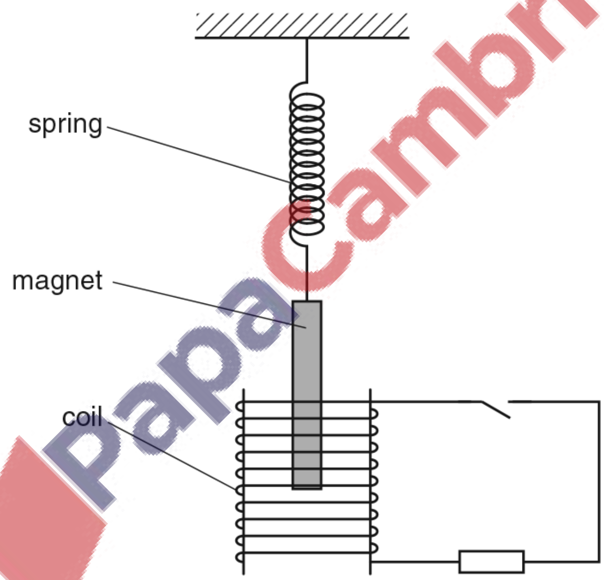


Fig. 3.1

The magnet hangs so that one pole is near the centre of a coil of wire.

The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate with one pole remaining inside the coil. The other pole remains outside the coil.

At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 6.0$ s, the switch in the circuit is closed.

The variation with time *t* of the vertical displacement *y* of the magnet is shown in Fig. 3.2.

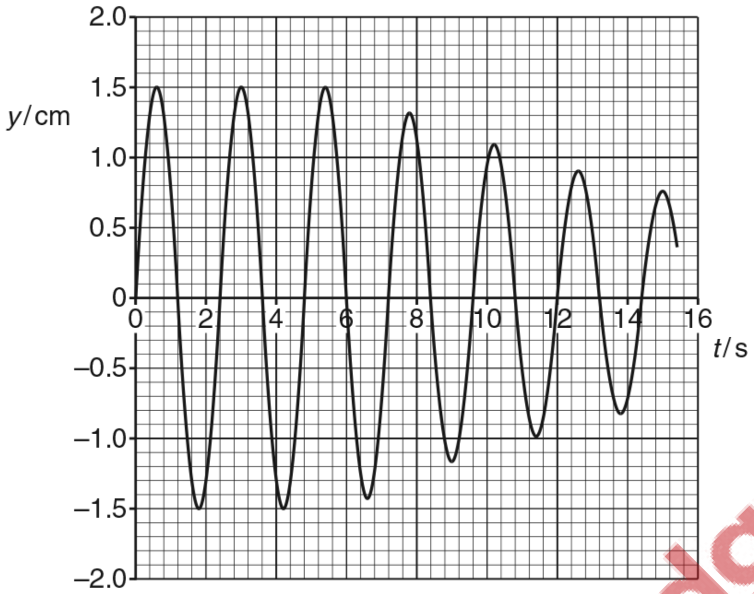


Fig. 3.2

(a) For the oscillating magnet, use data from Fig. 3.2 to calculate, to two significant figures,

(i) the frequency *f*,

f = ... Hz [2]

(ii) the energy of the oscillations during the time *t* = 0 to time *t* = 6.0 s.

energy = ... J [3]

(b) **(i)** State Faraday's law of electromagnetic induction.

....

....

....

....[2]

(ii) Use Faraday's law and energy conservation to explain why the amplitude of the oscillations of the magnet reduces after time $t = 6.0\,s$.

....

....

....

....

....

....[3]

[Total: 10]

311. 9702_w17_qp_41 Q: 5

(a) **(i)** State Coulomb's law for the force between two point charges.

....

.... [1]

(ii) Two point charges are situated in a vacuum and separated by a distance R. The force between the charges is F_C.

On Fig. 5.1, sketch a graph to show the variation of the force F between the charges with separation x for values of x from $x = R$ to $x = 4R$.

[3]

Fig. 5.1

(b) Two coils C and D are placed close to one another, as shown in Fig. 5.2.

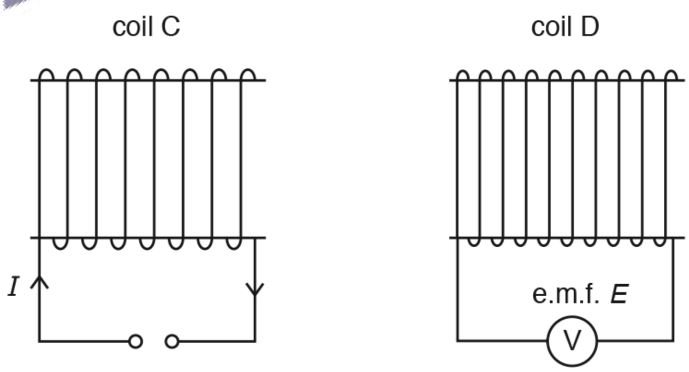


Fig. 5.2

The variation with time t of the current I in coil C is shown in Fig. 5.3.

On Fig. 5.4, show the variation with time t of the e.m.f. E induced in coil D for time t = 0 to time $t = t_5$.

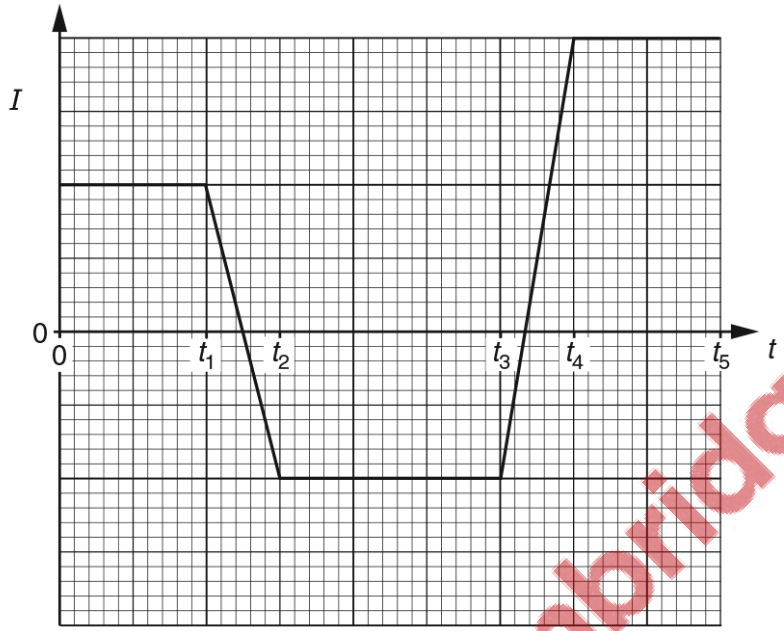


Fig. 5.3

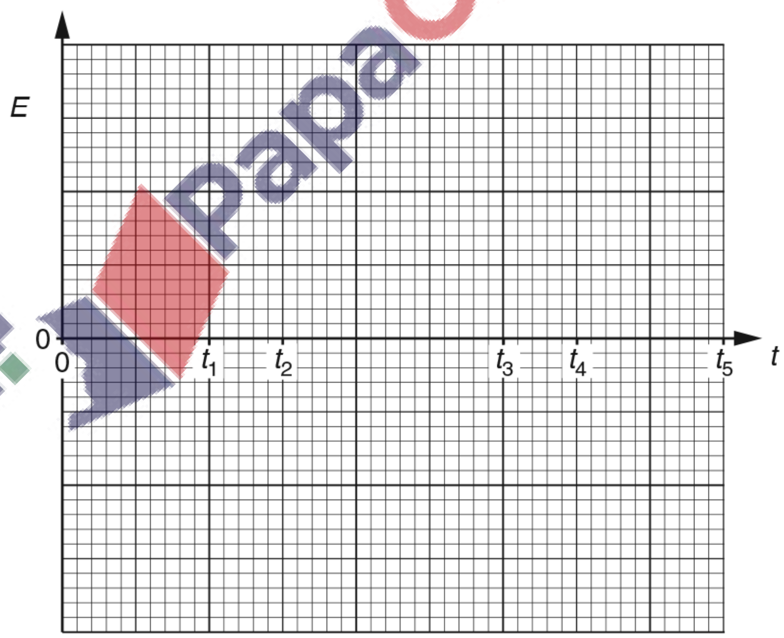


Fig. 5.4

[4]

[Total: 8]

312. 9702_w17_qp_43 Q: 5

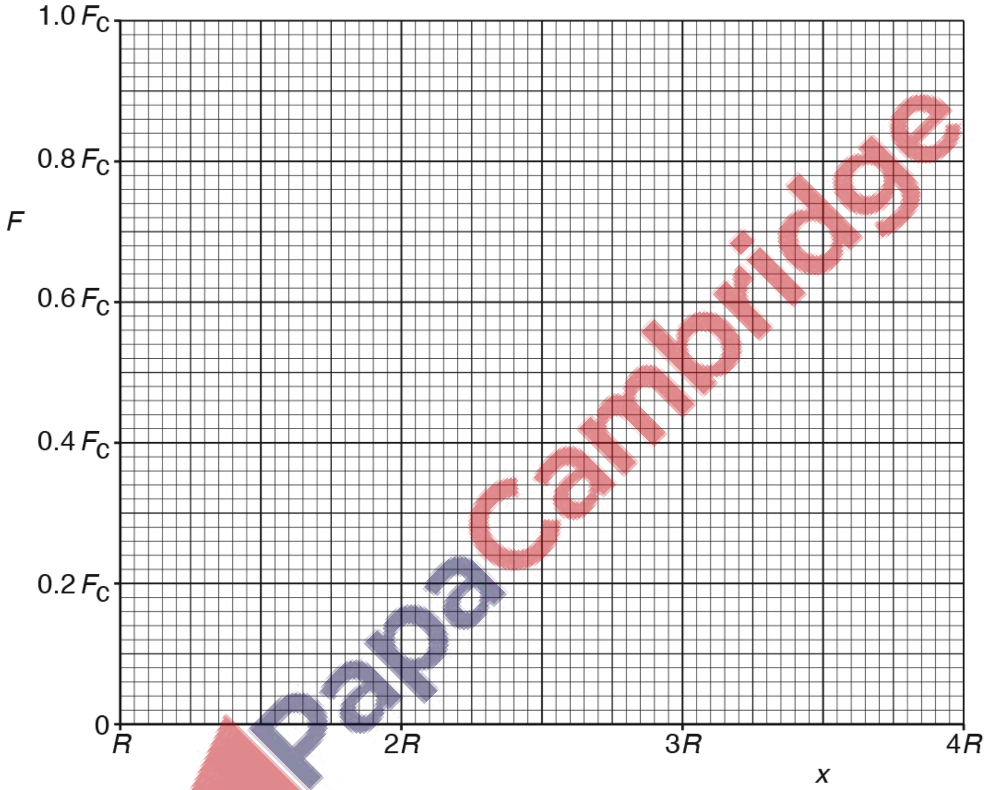
(a) **(i)** State Coulomb's law for the force between two point charges.

....

.... [1]

(ii) Two point charges are situated in a vacuum and separated by a distance R. The force between the charges is F_C.

On Fig. 5.1, sketch a graph to show the variation of the force F between the charges with separation x for values of x from $x = R$ to $x = 4R$.



[3]

Fig. 5.1

(b) Two coils C and D are placed close to one another, as shown in Fig. 5.2.

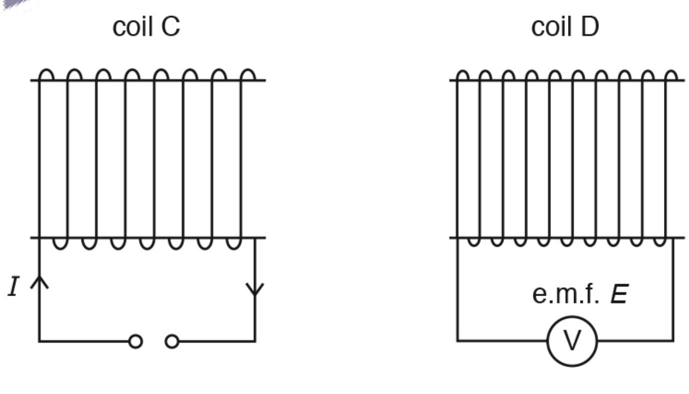


Fig. 5.2

The variation with time t of the current I in coil C is shown in Fig. 5.3.

On Fig. 5.4, show the variation with time t of the e.m.f. E induced in coil D for time t = 0 to time $t = t_5$.

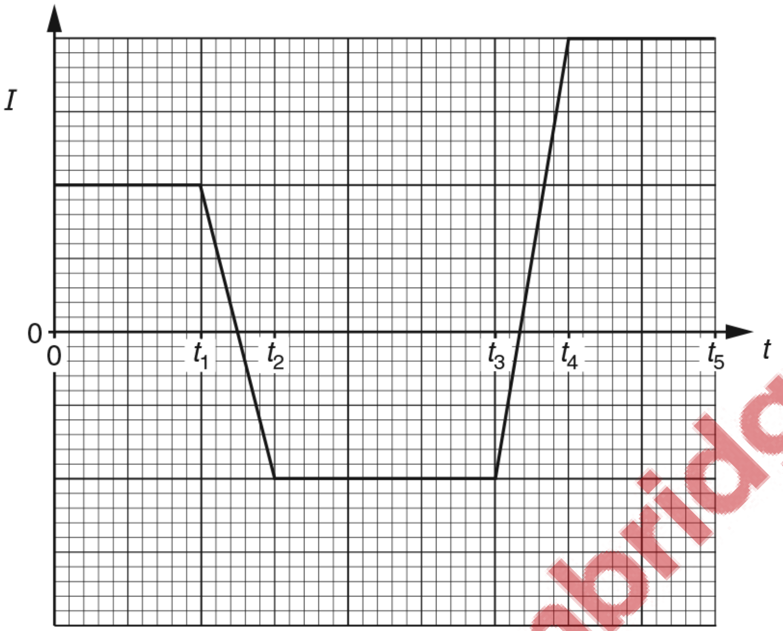


Fig. 5.3

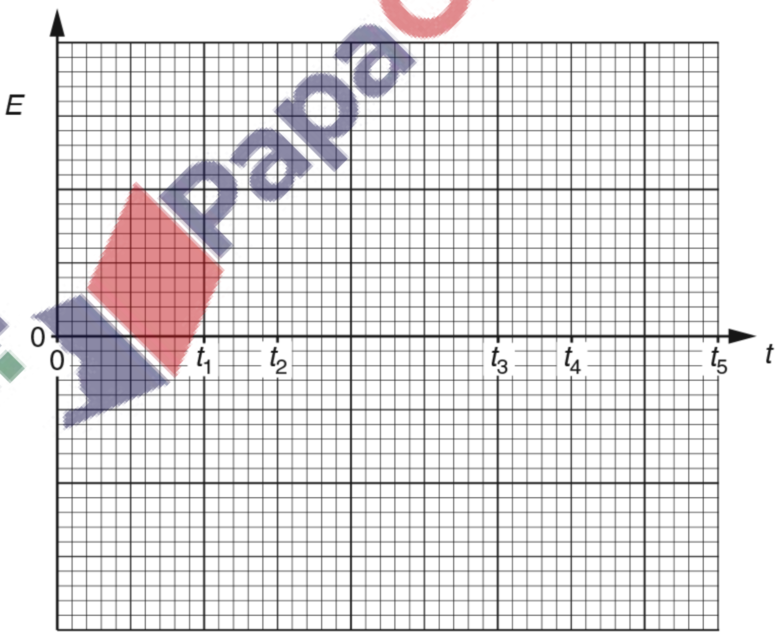


Fig. 5.4

[4]

[Total: 8]

313. 9702_m16_qp_42 Q: 10

A small coil of wire is situated in a non-uniform magnetic field, as shown in Fig. 10.1.

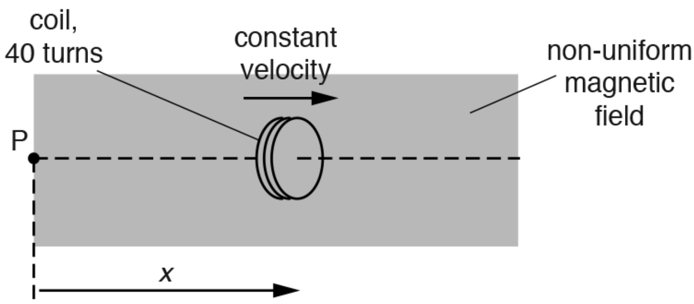


Fig. 10.1

The coil consists of 40 turns of wire and moves with a constant speed in a straight line. The coil has displacement x from a fixed point P.

The variation with x of the magnetic flux Φ in the coil is shown in Fig. 10.2.

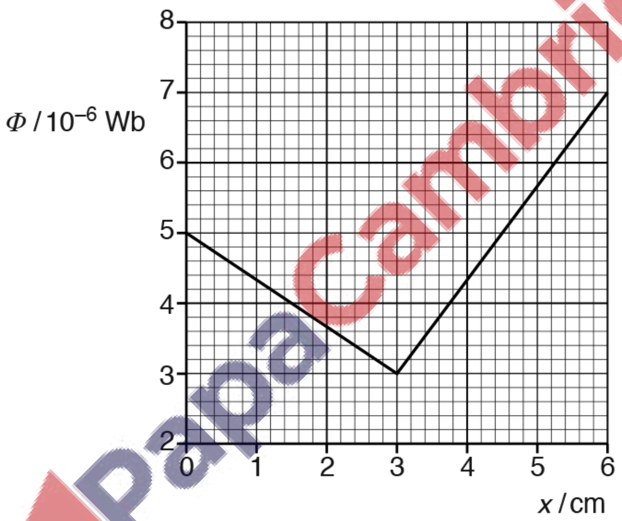


Fig. 10.2

(a) The coil is moved at constant speed between point P and the point where x = 3.0 cm.

(i) Calculate the change in magnetic flux linkage of the coil.

change in flux linkage = ... Wb [1]

(ii) The e.m.f. induced in the coil is 5.0×10^{-4} V. Determine the speed of the coil.

speed = ... $m s^{-1}$ [2]

(b) On Fig. 10.3, sketch the variation with *x* of the e.m.f. *E* induced in the coil for values of *x* from *x* = 0 to *x* = 6.0 cm.

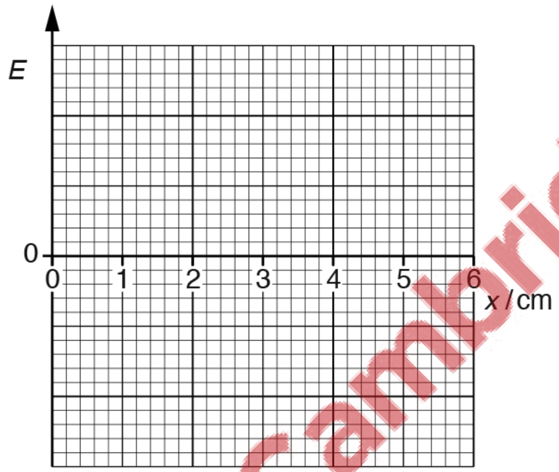


Fig. 10.3

[2]

[Total: 5]

314. 9702_w16_qp_41 Q: 9

(a) State Faraday's law of electromagnetic induction.

....

....

....

.... [2]

(b) The diameter of the cross-section of a long solenoid is 3.2 cm, as shown in Fig. 9.1.

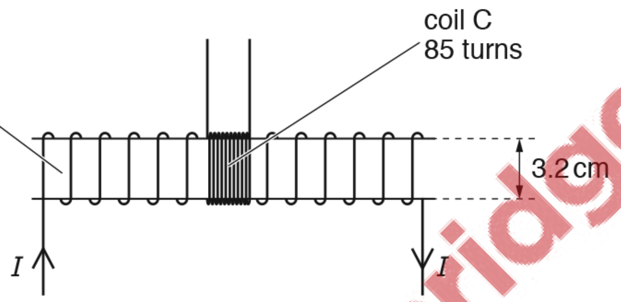


Fig. 9.1

A coil C, with 85 turns of wire, is wound tightly around the centre region of the solenoid.

The magnetic flux density B, in tesla, at the centre of the solenoid is given by the expression

$$B = \pi \times 10^{-3} \times I$$

where I is the current in the solenoid in ampere.

Show that, for a current I of 2.8 A in the solenoid, the magnetic flux linkage of the coil C is 6.0×10^{-4} Wb.

[1]

(c) The current I in the solenoid in **(b)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil C.

e.m.f. = ... mV [2]

(d) The current I in the solenoid in **(b)** is now varied with time t as shown in Fig. 9.2.

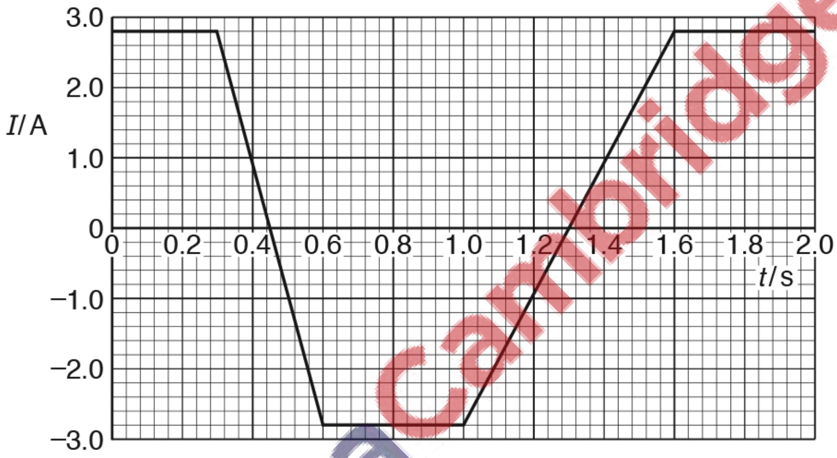


Fig. 9.2

Use your answer to **(c)** to show, on Fig. 9.3, the variation with time t of the e.m.f. E induced in coil C.

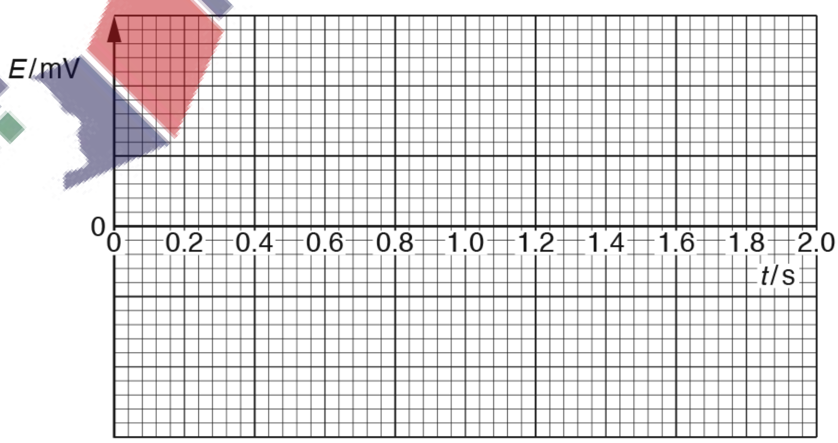


Fig. 9.3

[4]

[Total: 9]

315. 9702_w16_qp_43 Q: 9

(a) State Faraday's law of electromagnetic induction.

....

....

....

.... [2]

(b) The diameter of the cross-section of a long solenoid is 3.2 cm, as shown in Fig. 9.1.

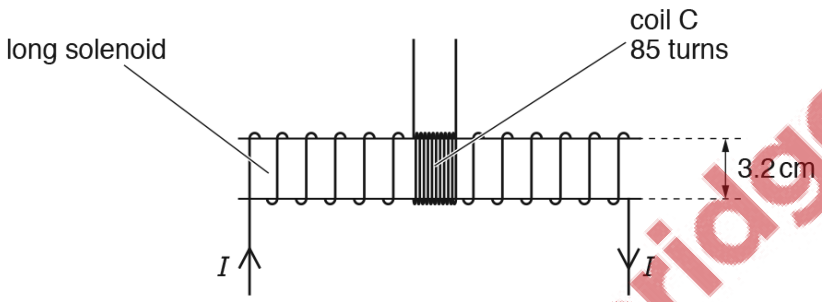


Fig. 9.1

A coil C, with 85 turns of wire, is wound tightly around the centre region of the solenoid.

The magnetic flux density B, in tesla, at the centre of the solenoid is given by the expression

$$B = \pi \times 10^{-3} \times I$$

where I is the current in the solenoid in ampere.

Show that, for a current I of 2.8 A in the solenoid, the magnetic flux linkage of the coil C is 6.0×10^{-4} Wb.

[1]

(c) The current I in the solenoid in **(b)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil C.

e.m.f. = ... mV [2]

(d) The current I in the solenoid in **(b)** is now varied with time t as shown in Fig. 9.2.

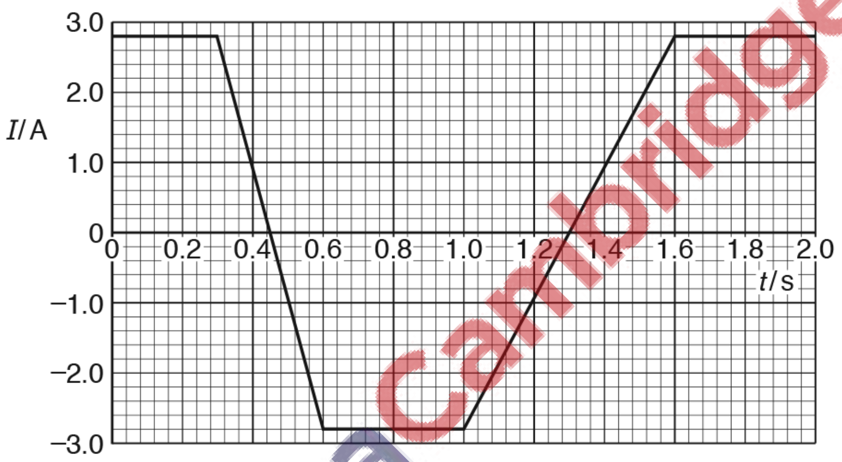


Fig. 9.2

Use your answer to **(c)** to show, on Fig. 9.3, the variation with time t of the e.m.f. E induced in coil C.

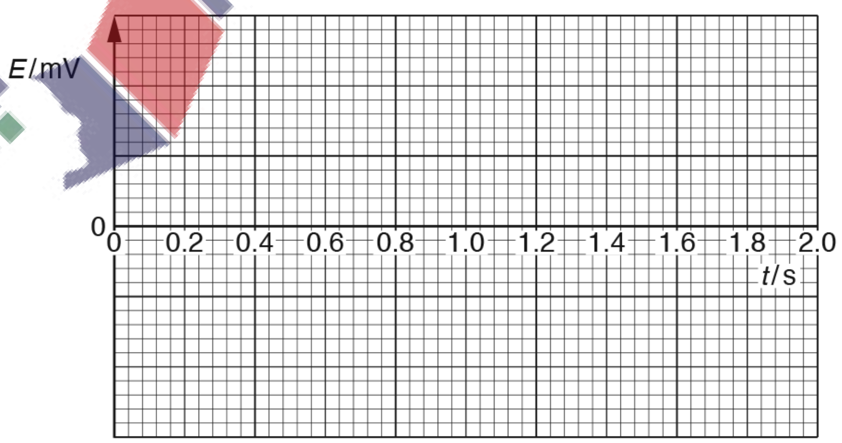


Fig. 9.3

[4]

[Total: 9]