TOPIC 22 Electromagnetic Induction

1 Fig. 1 represents two coils X and Y wound on a soft-iron core. A deflection of the centre-reading galvanometer G is observed

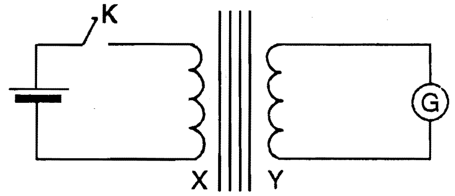


Fig. 1

- **A** momentarily on closing **K**, but not on opening **K** again.
- **B** not on closing **K**, but momentarily on opening **K** again.
- **C** on closing **K**, and for as long as **K** remains closed.
- **D** neither on closing **K** nor on opening **K** again.
- **E** momentarily on closing **K**, and momentarily on opening **K** again.

J77/II/21

2 The e.m.f. E_b of a battery is given by $E_b = P/I$ where P is the power dissipated when a current I flows. The e.m.f. E_c induced in a coil by a changing magnetic flux is equal to the rate of change of flux, $E_c = d\Phi/dt$.

Which of the following is a unit for magnetic flux?

- **A** $ms^{-1}A$
- **B** $ms^{-2}A^{-1}$
- **C** $kg\,m^2s^{-2}A$
- **D** $kg\,ms^2A^{-1}$
- **E** $kg\,m^2s^{-2}A^{-1}$

J79/II/25; N79/II/17; J90/I/3

3 In the diagram below (Fig. 2), the solenoid, of length l and closely and uniformly wound, carries an alternating current of constant amplitude. A search coil is placed in different positions along the solenoid.

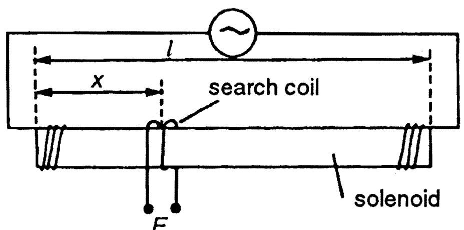
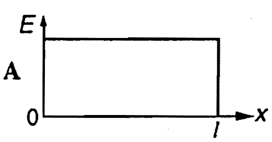


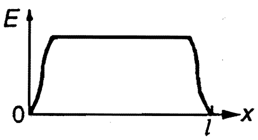
Fig. 2

Which one of the following graphs most nearly shows how the amplitude of the e.m.f. E induced in the search coil varies with its position?

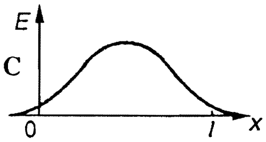
A



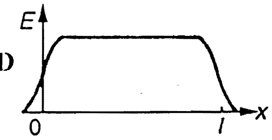
B



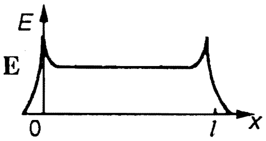
C



D



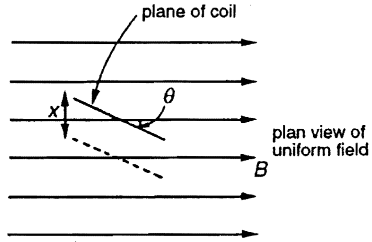
E



N81/II/19

4 A plane coil of wire containing N turns each of area A is placed so that the plane of the coil makes an angle θ with the direction of a uniform magnetic field of flux density B. The coil is now moved through a distance x in time t to the position shown dotted in Fig. 3.

Fig. 3

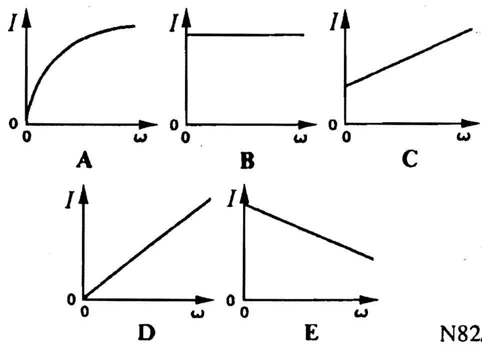


What is the e.m.f. induced in the coil?

- **A** zero
- **B** NAB/t
- **C** $NAB\,x/t$
- **D** $(NB\,x\cos\theta)/t$
- **E** $(NAB\,x\cos\theta)/t$

J82/II/20

5 A d.c. electric motor that has a permanent magnet as its field magnet is joined to a battery of constant e.m.f. and negligible internal resistance. When the motor is used to drive various loads, the corresponding values of its speed of rotation ω and the current I passing through it are measured. Which one of the following graphs most nearly shows how I varies with ω?



N82/II/23

6 A rectangular coil of wire, initially placed as shown in Fig. 4, is rotated with constant angular velocity in a magnetic field which acts in the direction of XX'. The sinusoidal e.m.f. represented by Fig. 5 is observed to be produced across the ends of the coils.

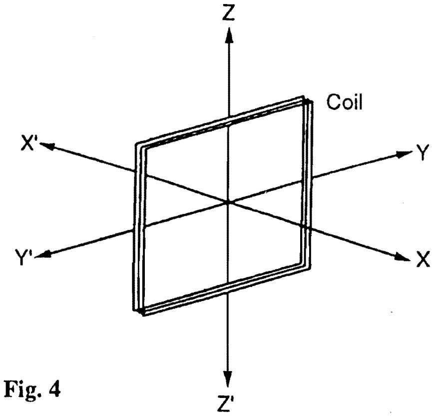


Fig. 4

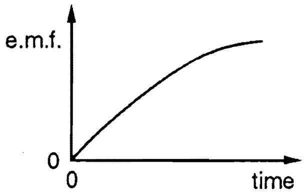


Fig. 5

Which one of the following movements would have given this result?

A rotation of a quarter revolution about axis YY'.
B rotation of a half revolution about axis XX'.
C rotation of a half revolution about axis ZZ'.
D rotation of a quarter revolution about axis XX'.
E rotation of a half revolution about axis YY'.

N83/II/21

7 An electric motor driven from a constant voltage supply is used to raise a load. If the load is increased which one of the following sets of changes occurs?

	speed of rotation	*induced e.m.f. in coil (back-e.m.f.)*	*current in coil*
A	decreases	decreases	increases
B	increases	increases	decreases
C	decreases	decreases	decreases
D	increases	decreases	increases
E	decreases	increases	decreases

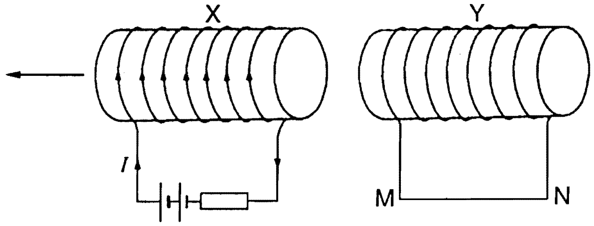
J84/II/20

8 The self-inductance of a solenoid may be increased by inserting a soft iron core. The function of the core is to

A decrease the electrical resistance of the solenoid.
B reduce the effect of the Earth's magnetic field.
C increase the mutual inductance between the solenoid and the core.
D increase the flux linking the circuit when a current flows.
E reduce eddy currents.

N85/I/18

9 X and Y are solenoids wound on cardboard tubes. X carries constant current *I* as shown below and moves with constant speed away from Y along the common axis of the two tubes.

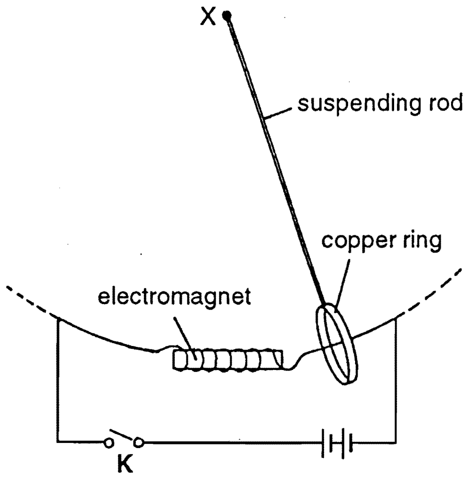


As a result of electromagnetic induction a current will flow in the straight wire MN and there will be a force between X and Y. Which one of the following correctly describes both the current and the force?

	Nature and direction of current in straight wire MN	*Nature of force*
A	diminishing, N to M	attraction
B	diminishing, M to N	repulsion
C	diminishing, N to M	repulsion
D	constant, M to N	repulsion
E	constant, N to M	attraction

N85/I/19

10 A copper ring is suspended by a long, light rod pivoted at X so that it may swing as a pendulum, as shown in the diagram below. An electromagnet is mounted so that the ring passes over it as it swings.

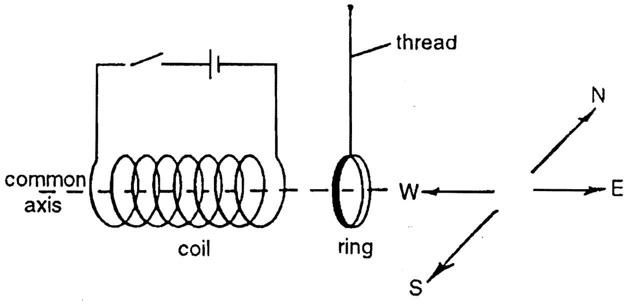


The ring is set into oscillation with switch **K** open. What happens to the motion after switch **K** has been closed?

A The periodic time will decrease.
B The amplitude will increase because the ring is accelerated towards the magnet.
C The ring will be brought to rest with the rod inclined to the vertical.
D The oscillation will continue at constant amplitude while the battery can supply energy.
E The oscillation will be heavily damped.

J86/I/19

11 An aluminium ring hangs vertically from a thread with its axis pointing east-west. A coil is fixed near to the ring and coaxial with it.

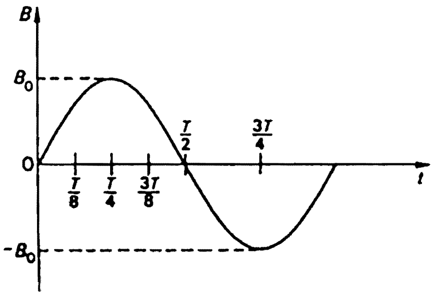


What is the initial motion of the aluminium ring when the current in the coil is switched on?

A remains at rest
B moves towards S
C moves towards W
D moves towards N
E moves towards E

N86/I/20

12 A magnetic field is applied perpendicular to the plane of a flat coil of copper wire. The time variation of the magnetic flux density is given by $B_0 \sin(2\pi t/T)$, as shown graphically below.

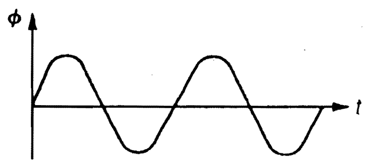


At which of the following values of t is the magnitude of the e.m.f. induced in the coil a maximum?

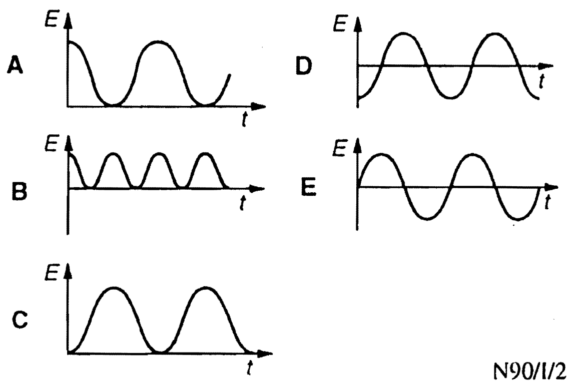
A $\frac{T}{8}$ B $\frac{T}{4}$ C $\frac{3T}{8}$ D $\frac{T}{2}$ E $\frac{3T}{4}$

N87/I/20

13 The magnetic flux ϕ through a coil varies with time t as shown in the diagram.

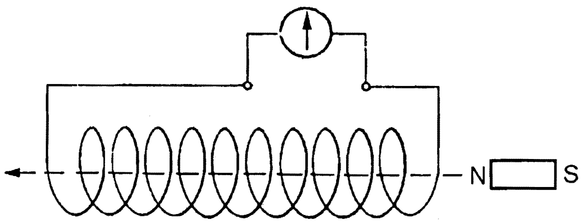


Which graph best represents the variation with t of the e.m.f. E induced in the coil?

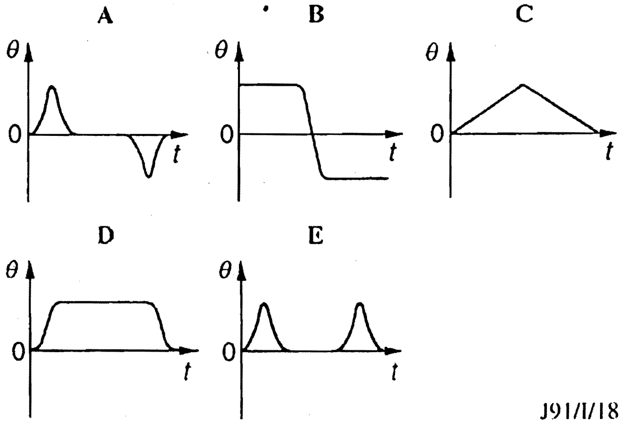


N90/I/21

14 A short bar magnet passes at a steady speed right through a long solenoid. A galvanometer is connected across the solenoid.

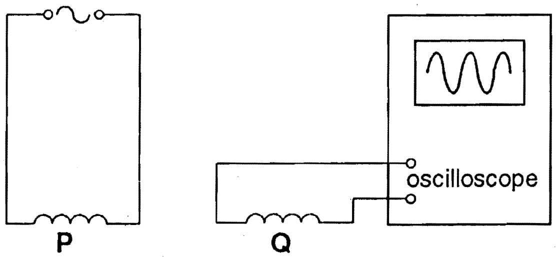


Which graph best represents the variation of the galvanometer deflection θ with time t?



J91/I/18

15 A coil **P** is connected to a 50 Hz alternating supply of constant peak voltage. Coil **P** lies close to a separate coil **Q** which is connected to the Y-input terminals of an oscilloscope. A sinusoidal trace appears on the screen of the oscilloscope.

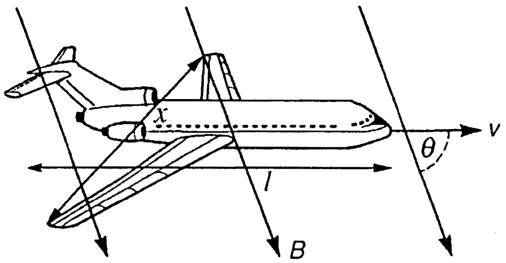


What would be the effect on the trace of linking the coils by a soft-iron core?

	height of trace	*number of cycles on screen*
A	increases	increases
B	increases	stays the same
C	stays the same	increases
D	stays the same	stays the same

N91/I/20; J96/I/20

16 The diagram represents an aircraft of length l, wingspan x, flying horizontally at speed v in a region where the Earth's magnetic field, of uniform flux density B, is inclined at an angle θ to the Earth's surface.

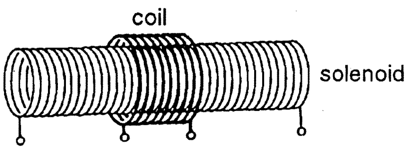


Which expression gives the magnitude of the e.m.f. generated between the wingtips by electromagnetic induction?

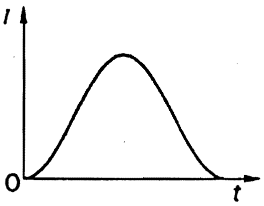
A	$Blv \sin\theta$	**C**	Bxv
B	Blv	**D**	$Bxv \sin\theta$

J92/I/20; J95/I/19

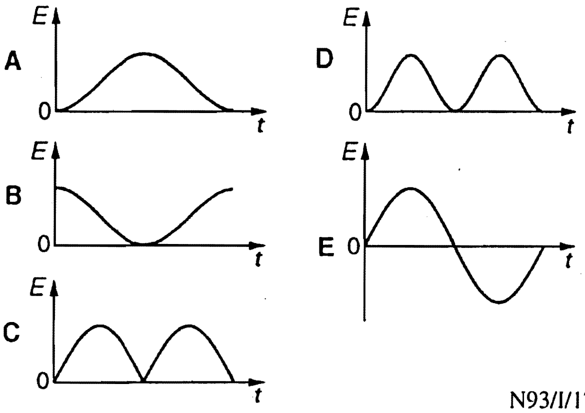
17 The diagram shows a short coil wound over the middle part of a long solenoid.



The solenoid current I is varied with time t as shown in the sketch graph. As a consequence, the flux density of the magnetic field due to the solenoid varies with time. The relation between B and I is $B = \mu_0 nI$.



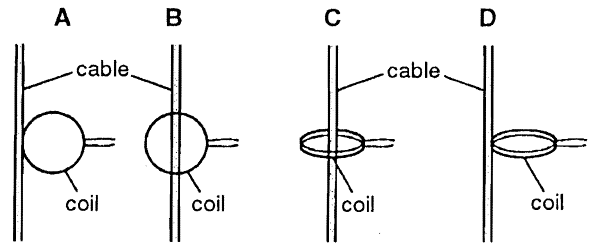
Which graph shows how the e.m.f. E induced in the short coil varies with time t?



N93/I/17

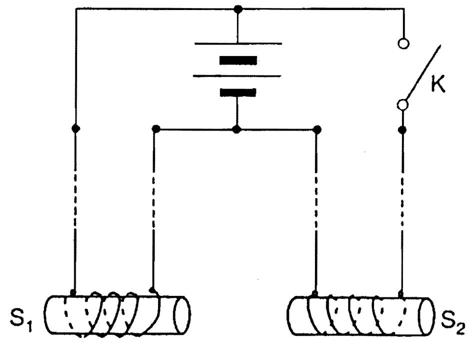
18 Large alternating currents in a cable can be measured by monitoring the e.m.f. induced in a small coil situated near the cable. This e.m.f. is induced by the varying magnetic field set up around the cable.

In which arrangement of coil and cable will the e.m.f. induced be a maximum?



J94/I/18

19 Two identical solenoids S_1 and S_2 are suspended coaxially and symmetrically by four long thin wires so that they may swing freely, as shown in the diagram.

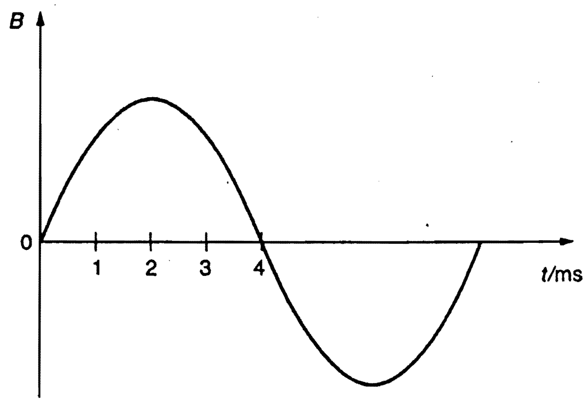


When the switch K is closed, what happens to the solenoids?

A One turns in a clockwise direction, and the other in an anticlockwise direction.
B They both turn in a clockwise direction.
C They move away from each other.
D They move towards each other.

N96/I/19

20 An e.m.f. is induced in a wire subjected to a changing magnetic field. The flux density B of this field varies with time t as shown.

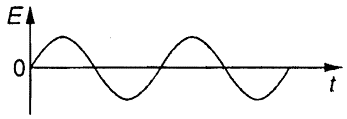


At which value of t is the magnitude of the e.m.f. induced in the wire a maximum?

A	1 ms	**C**	3 ms
B	2 ms	**D**	4 ms

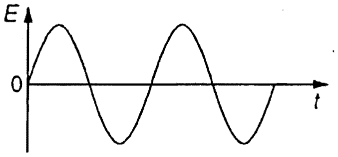
N97/I/19

21 When a coil is rotated in a magnetic field, the induced e.m.f. E varies as shown.

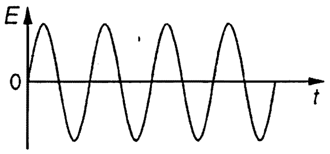


Which of the following graphs, drawn to the same scale, would be obtained if the speed of rotation of the coil were doubled?

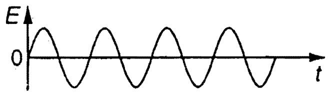
A



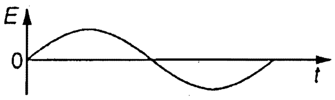
B



C



D



J98/I/19

22 Diagram 1 shows an aluminium rod, moving at right angles to a uniform magnetic field. Diagram 2 shows the variation with time t of the distance s from O.

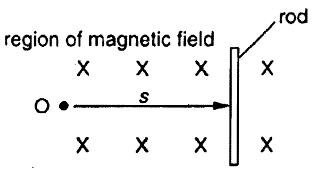


diagram 1

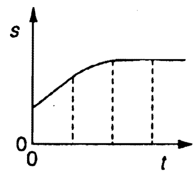
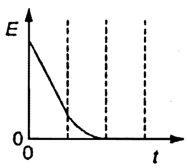


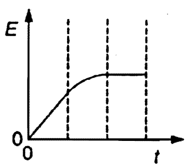
diagram 2

Which graph best shows the variation with t of the e.m.f. E induced in the rod?

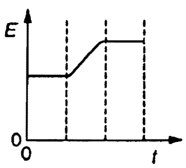
A



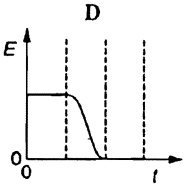
B



C



D



J99/I/20

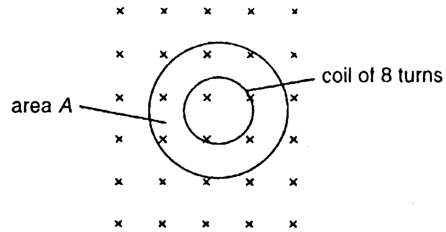
23 A flat circular coil of 120 turns, each of area 0.070 m^2, is placed with its axis parallel to a uniform magnetic field. The flux density of the field is changed steadily from 80 mT to 20 mT over a period of 4.0 s.

What is the e.m.f. induced in the coil during this time?

A 0
B 130 mV
C 170 mV
D 500 mV

J2000/I/20

24 A uniform magnetic field of flux density B passes normally through a plane area A. In this plane lies a coil of eight turns of wire, each of area $\frac{1}{4}A$.



What is the magnetic flux linkage for the coil?

A $\frac{1}{4}BA$
B BA
C $2BA$
D $8BA$

N2000/I/20

25 A plane circular coil of 50 turns, each of diameter 0.01 m, rotates 25 times each second about a diameter which is perpendicular to a uniform magnetic field of flux density 5.0×10^{-5} T.

(a) Calculate

(i) the maximum instantaneous value of the induced e.m.f.,

*(ii) the r.m.s. value of the e.m.f.

(b) If the coil were fixed and the field were rotated at the same rate and in the same direction, what difference would this make to the induced e.m.f.?

J76/I/6

26 A flat search coil containing 50 turns each of area 2.0×10^{-4} m^2 is connected to a galvanometer; the total resistance of the circuit is 100 Ω. The coil is placed so that its plane is normal to a magnetic field of flux density 0.25 T.

(a) What is the change in magnetic flux linking the circuit when the coil is moved to a region of negligible magnetic field?

(b) What charge passes through the galvanometer?

J78/I/8

27 Explain why transformers sometimes emit a humming noise when connected to the 50 Hz a.c. supply. What is the frequency of the hum?

J79/I/7

28 A flat search coil of 500 turns, each of area 2.5×10^{-4} m^2, is connected to a galvanometer. The total resistance of the circuit is 200 Ω. The coil is first placed between the poles of an electromagnet, with its plane normal to the uniform magnetic flux; it is then removed to a point where the magnetic flux density is very small. As a result of this operation, a charge of 7.5×10^{-6} C is found to circulate in the circuit.

Find the magnetic flux density between the poles of the electromagnet. J84/I/9

29 *(b)* A copper disc spins freely between the poles of an unconnected electromagnet as shown in Fig. 6.

Describe and explain what will happen to the speed of rotation of the disc when a direct current is switched on in the electromagnet.

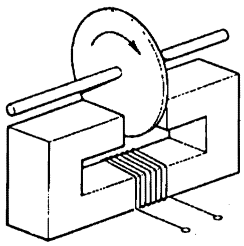


Fig. 6

[4] J91/II/5 (part)

30 A long bar magnet is suspended from a helical spring so that one pole of the magnet lies within a short cylindrical coil as shown in Fig. 7.

The magnet is given a small vertical displacement and is then released so that one pole of the magnet oscillates within the coil.

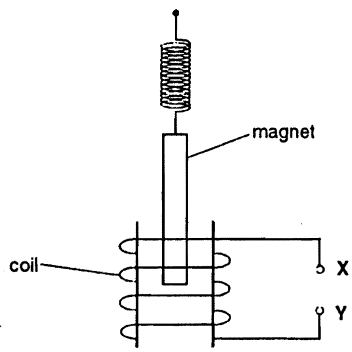


Fig. 7

(a) An induced e.m.f. is measured across the terminals **XY** of the coil. [2]

(i) Sketch on the axes of Fig. 8, a line to show how the induced e.m.f. might vary with time. [2]

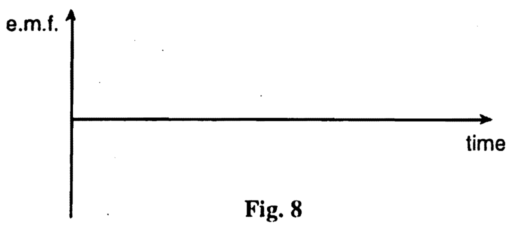


Fig. 8

(ii) Using the principles of electromagnetic induction, explain the variation of the induced e.m.f. shown in your graph. [3]

(b) State and explain a change that occurs in the amplitude of the oscillations of the magnet when a resistor is connected across **XY**. [3]

N92/II/6

31 *(b)* A current-carrying solenoid is placed near to a search coil as shown in **Fig. 9**.

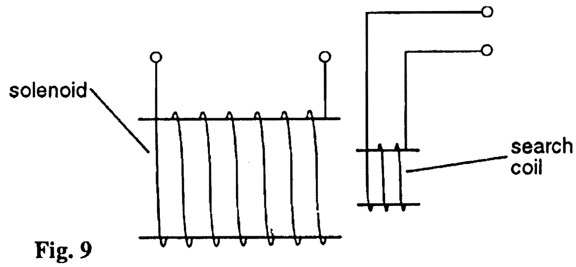


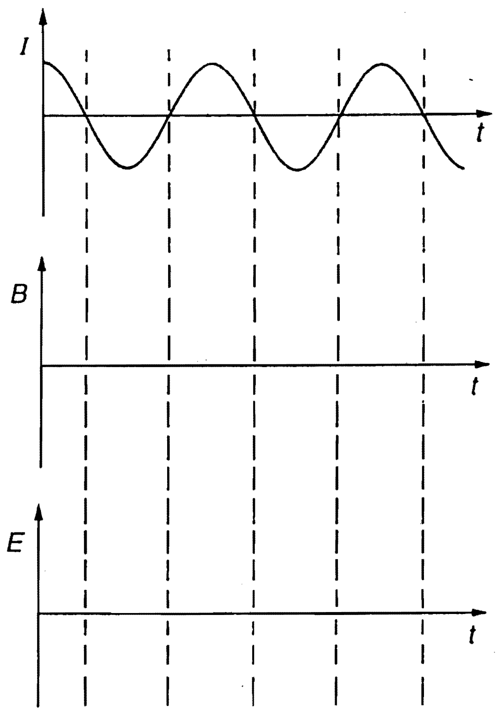
Fig. 9

The variation with time *t* of the current *I* in the solenoid is shown in **Fig. 10**.

Fig. 10

Fig. 11

Fig. 12



(i) Sketch on **Fig. 11** the variation with *t* of the magnetic flux density *B* in the solenoid.

(ii) Sketch on **Fig. 12** the variation with *t* of the e.m.f. *E* induced in the search coil. [3]

(c) For the experiment outlined in *(b)*, briefly describe and explain the effect on the amplitude and frequency of *E* if, separately

(i) a ferrous core is slowly introduced into the solenoid,

(ii) the frequency of the current in the solenoid is increased, whilst maintaining the same amplitude. [6]

J93/II/4 (part)

32 *(b)* A coil, consisting of many turns of insulated metal wire wrapped around a soft-iron core, is connected in series with a battery, a switch and a lamp, as shown in Fig. 13.

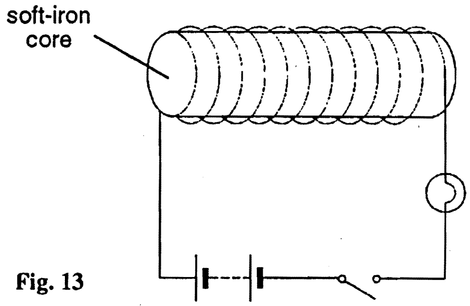


Fig. 13

(i) State what happens to the magnitude of the magnetic flux in the coil as the current increases from zero when the switch is closed.

(ii) Hence explain why an e.m.f. is induced in the coil as the current increases.

(iii) Hence explain why there is a noticeable delay before the lamp lights up after the switch is closed.

(iv) State and explain what will happen to the length of the delay if the soft-iron core is replaced by one made of wood. [6] J95/II/4 (part)

33 *(b)* In order to monitor the alternating current in a wire, a small search coil, connected to a cathode-ray oscilloscope, is held near the wire. By reference to the laws of electromagnetic induction, explain why

(i) the search coil should be placed in the position shown in Fig. 14 rather than that shown in Fig. 15,

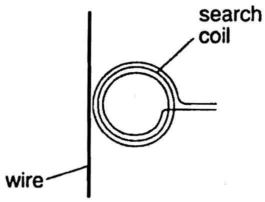


Fig. 14

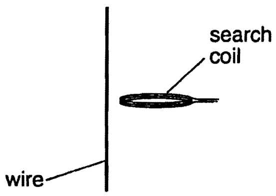


Fig. 15

(ii) the current must be alternating. [5]

(c) Suggest one advantage of a Hall probe over a search coil for monitoring the current, using the technique in *(b)*. [1] N96/II/3 (part)

34 A protective device in a mains circuit consists of a transformer with two primary coils A and B and a secondary coil, as shown in Fig. 16. The primary coils each have the same number of turns and are wound in opposite directions on the core.

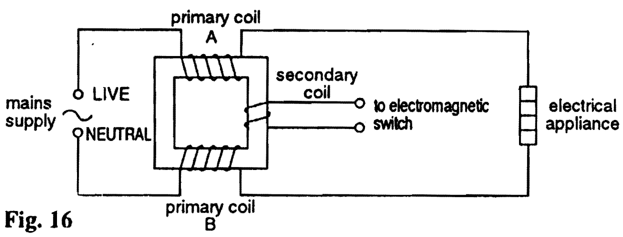


Fig. 16

The mains supply is connected in series with the two primary coils and the electrical appliance. The secondary coil is connected to an electromagnetic switch.

(a) (i) At one particular moment, the live lead is positive with respect to the neutral lead. On Fig. 16, mark arrows to indicate the directions of the magnetic field in the transformer core due to

1. the primary coil A alone (label this arrow A),
2. the primary coil B alone (label this arrow B).

(ii) Hence explain why there is no e.m.f. induced in the secondary coil. [5]

(b) A fault develops in the electrical appliance such that there is a current to earth. As a result, the current in primary coil A is no longer equal to that in coil B. State and explain the effect of this fault on

(i) the magnitude of the flux in the core of the transformer,

(ii) the e.m.f. induced in the secondary coil. [3] N98/II/3

35 A helical spring is clamped vertically. The free end of the spring is attached to a sheet of aluminium and a mass, as illustrated in Fig. 17.

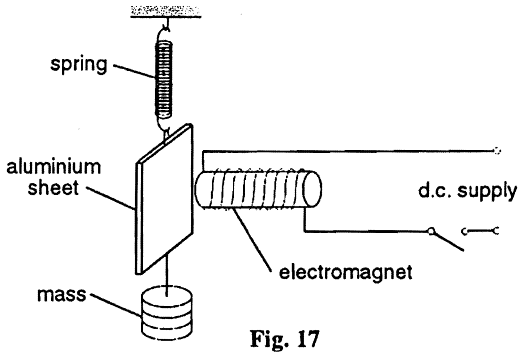


Fig. 17

An electromagnet is placed near to the centre of the aluminium sheet. The mass is displaced vertically and, with the electromagnet switched off, the mass is released. The variation with time t of the displacement x of the mass is shown in Fig. 18.

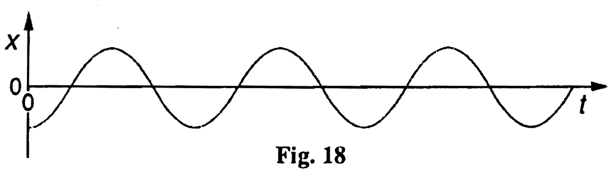


Fig. 18

(a) The electromagnet is switched on and the experiment is repeated with the same initial displacement. Damped oscillations are observed.

(i) On Fig. 18, sketch the new variation with time t of the displacement x of the mass. [2]

(ii) 1. State Faraday's law of electromagnetic induction.

2. Explain why the oscillations of the mass are damped. [6]

(b) Suggest how critical damping could be demonstrated using the apparatus of Fig. 17. [4]

N99/II/5

36 A simple iron-cored transformer is illustrated in Fig. 19.

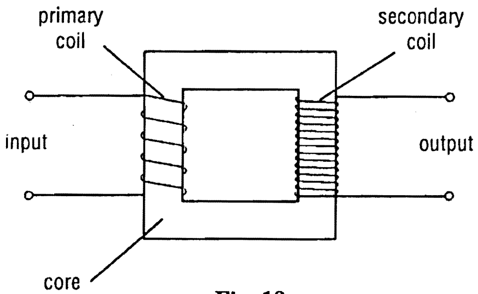


Fig. 19

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

(ii) Use Faraday's law to explain why a transformer will operate for an alternating input voltage but not for a direct voltage. [3]

(b) (i) State Lenz's law.

(ii) Use the laws of electromagnetic induction to suggest why the input voltage and the output e.m.f. have the same frequency. [3]

N2000/II/6

Long Questions

***37** Alternating current passes down a long, straight wire. A nearby search coil is connected to the *y*-plates of a cathode ray oscilloscope. The coil is turned to the position that gives the maximum *y*-deflection on the c.r.o. The distance x between coil and wire is then varied and at each distance the maximum amplitude a of the trace is noted.

(a) Show how the coil is arranged relative to the wire.

(b) State how a varies with x.

(c) Explain how this relationship between a and x arises.

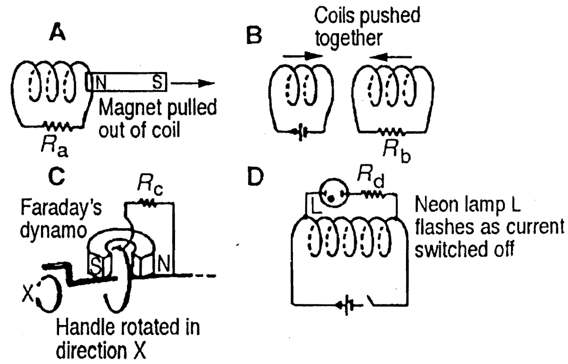
N76/III/4 (part)

38 State the laws of *electromagnetic induction*. Use them to explain what happens when a current in a coil is switched off.

Discuss in detail the potential difference produced at the output terminals of a transformer when *direct* current is switched on, then switched off, in the primary. Illustrate your answer with appropriate sketch graphs.

N78/III/3 (part)

39 State the *law of electromagnetic induction*. Show how Lenz's law is consistent with the principle of conservation of energy.



Draw four arrows, labelled *A*, *B*, *C* and *D*, showing the directions of the currents induced in the resistors in the experiments illustrated. (Do not copy the diagrams.) Explain how the e.m.f. arises in cases *C* and *D*.

A copper disc of area A rotates at frequency f at the centre of a long solenoid of turns per unit length n and carrying a current I. The plane of the disc is normal to the flux. The rotation rate is adjusted so that the e.m.f. generated between the centre of the copper disc and its rim is 1% of the potential difference across the ends of the solenoid. Deduce an expression for the e.m.f between the centre of the disc and the rim. Hence find the resistance of the solenoid in terms of μ_0, A, f and n.

J80/III/3

40 State *Faraday's law of electromagnetic induction* and describe how you would verify it experimentally.

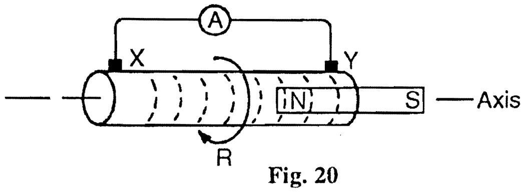


Fig. 20

The diagram (Fig. 20) shows a fixed magnet, NS, half of which lies inside a long, close-fitting copper tube. The copper tube rotates about its axis in the direction R. Electrical contacts are made at X and Y by stationary carbon brushes connected to a milliammeter A. When the tube rotates at 5 revolutions per second, the milliammeter reads 10 mA. The meter resistance is 5 Ω and all other resistances in the circuit are negligible. Calculate

(a) the potential difference between X and Y,

(b) the total flux issuing from the north pole N of the magnet.

Explain clearly

(i) in which direction the current flows through the ammeter,

(ii) whether or not a current would flow if the tube were stopped and the magnet rotated about its axis,

(iii) how your answer to *(b)* would differ if the tube and brushes had a resistance of 1 Ω.

N80/III/3

41 State the *laws of electromagnetic induction*. Describe, and explain in terms of these laws, what happens when a powerful electromagnet is switched off, with special reference to the e.m.f.'s and the current flow.

What is the origin of the back e.m.f. in an electric motor? Describe and explain what happens when a simple permanent magnet d.c. motor, connected to a source of constant e.m.f., is switched on

(a) with very little friction or mechanical loading,

(b) with considerable mechanical loading.

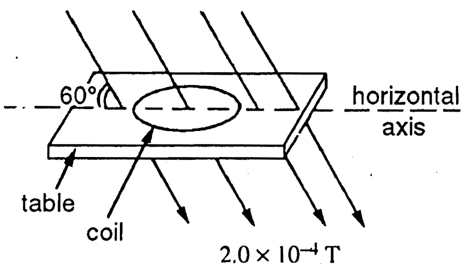
Illustrate your answers with *four* sketch graphs, using similar time scales, to show, in each case, how (i) the current, (ii) the speed, vary with time.

A toy car, driven by such a motor, runs steadily on level ground at 0.5 m s^{-1} and takes 1 A from a 12 V supply. When it runs into an obstruction and the wheels stop, the current taken is 3 A. What current will it take when running uphill at 0.4 m s^{-1} ?

Steam engines are often fitted with a device to limit their top speed. Why is no equivalent device generally necessary for electric motors?

J83/III/4

42 What is meant by *(a) magnetic flux*, *(b) flux linkage*? Give mathematical statements of (i) Faraday's law of electromagnetic induction, (ii) the relation between current and potential difference, (iii) the relation between current and charge. Hence derive an expression for the charge which flows in a closed circuit when the flux linkage changes.



A magnetic field of flux density 2.0×10^{-4} T passes, as shown, down through a short-circuited coil of wire, the field making an angle of 60° with the plane of the horizontal non-magnetic table on which the coil rests. The coil has 500 turns, a total resistance 5.0 Ω and an area of 25 cm^2.

How much charge flows if the coil is turned over once? Discuss whether there would be any effect on the charge of increasing the number of turns in the coil.

The thermal capacity of the coil is 15 J K^{-1}. Find its initial rate of rise of temperature when the coil is rotated at 100 Hz about the horizontal axis shown. State clearly any simplifying assumption you employ.

N83/III/5 (part)

43 Draw a diagram to show the essential features of a simple (permanent magnet), direct current electric motor. Mark the polarity of the magnet, the direction of the armature current, and the corresponding direction of rotation.

Such a motor runs freely, with negligible load, at 16 revolutions per second when connected to a 240 V d.c. mains supply. The armature resistance is 4.0 Ω and the armature current is 0.30 A. When the motor raises a certain load, the armature current changes to 12.8 A. Estimate the rotational speed of the motor.

Explain why the power expended in simply raising the load is not quite equal to 240 (12.8 – 0.3) W.

N84/III/5 (part)

44 State the *laws of electromagnetic induction*. Hence explain the potential danger associated with switching off the current in a large electromagnet. [4]

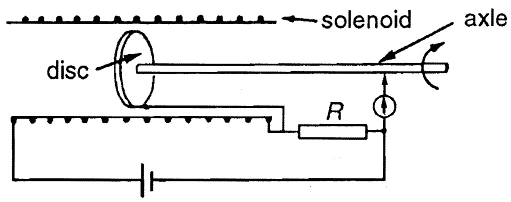


Fig. 21

Fig. 21 shows a long solenoid which has a small copper disc mounted at its centre. The disc spins on an axle which lies along the axis of the solenoid. The solenoid is connected in series with a d.c. supply and a resistor of resistance R. By means of brushes, one terminal of the resistor is connected to the rim of the disc and the other is connected to the axle via a centre-zero galvanometer. Explain briefly why an e.m.f. is generated between the axle and the rim of the disc when the disc rotates. [3]

Also explain why, as the speed of rotation of the disc is increased,

(a) the e.m.f. generated increases in magnitude,

(b) the galvanometer deflection might be seen to change direction. [5]

If the disc has area A and is rotating at f revolutions per unit time when the galvanometer registers no deflection, show that the resistance is given by the expression

$$R = \mu_0 nAf$$

where n is the number of turns per unit length of the solenoid. [3]

Comment on the significance of this method for the determination of resistance. [2]

(You may assume that the magnetic flux density B at the centre of the solenoid is given by the expression

$$B = \mu_0 nI$$

where I is the current in the solenoid.) N87/III/12

45 *(a)* Define *magnetic flux density* and *magnetic flux*. [5]

(b) A large flat coil is connected in series with an ammeter and a 50 Hz sinusoidal alternating supply whose r.m.s. output can be varied. At the centre of this coil is situated a much smaller coil which is connected to the Y-plates of a cathode-ray oscilloscope (c.r.o.). The planes of the two coils are coincident (see Fig. 22).

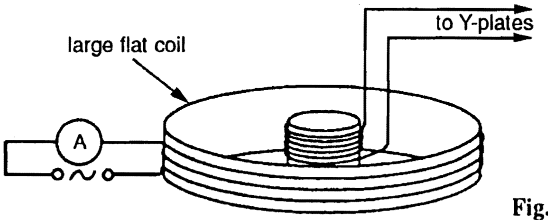


Fig. 22

(i) Draw sketch graphs, one in each case, to show the variation with time of (1) the magnetic flux, and (2) the induced e.m.f., in the small coil. Give physical explanations for the shapes of your graphs. [6]

Hence, describe how you could use this apparatus to demonstrate how the magnetic flux density at the centre of a large flat coil varies with the number of turns on the coil. [6]

(ii) Explain how the trace on the screen of the cathode-ray oscilloscope would be affected if the angle between the planes of the two coils were slowly to increase from zero to 90° whilst maintaining a constant r.m.s. current in the large coil. [5]

J88/III/11

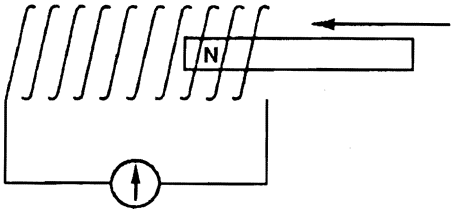
46 *(a)* Distinguish between *magnetic flux density* and *magnetic flux*. [2]

(b) (i) State *Faraday's law of electromagnetic induction.* [2]

(ii) State *Lenz's law* and explain why it is an example of the law of conservation of energy. [4]

(c) The north pole of a bar magnet is pushed into a solenoid to which is connected a galvanometer as shown in Fig. 23.

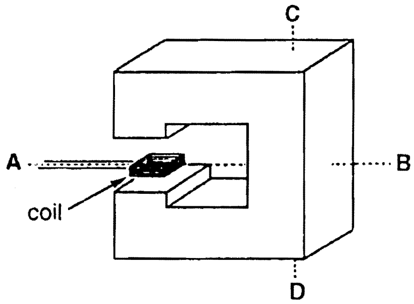
Fig. 23



Use Lenz's law to predict the direction of the current induced in the solenoid. Explain your reasoning. [4]

(d) A small square coil has its plane set at right angles to the uniform magnetic field between the pole pieces of a horseshoe magnet as shown in Fig. 24.

Fig. 24



The magnet is now rotated at constant angular velocity about the axis **AB**. Draw sketch graphs, on the same time axis, to show the variation of

(i) the magnetic flux through the coil,

(ii) the e.m.f. induced in the coil. [3]

Draw a second set of graphs for the case where the magnet rotates at constant angular velocity about the axis CD. (You may assume that the magnetic flux density in the region outside the pole pieces is zero.) [7]

N89/III/12

47 *(b)* Calculate the resistance per metre of a copper wire of diameter 0.050 mm and resistivity 1.7×10^{-8} Ωm. [2]

(c)

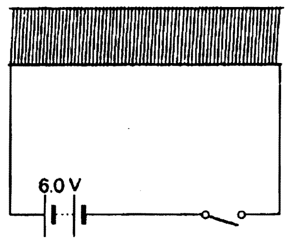


Fig. 25

The wire in *(b)* is to be used to construct an electromagnet in the form of a hollow solenoid by winding one layer of close-packed turns onto a plastic tube of length 200 mm and diameter 30 mm. The solenoid is connected in series with a switch and a battery of e.m.f. 6.0 V and negligible internal resistance, as shown in Fig. 25.

Calculate

(i) the resistance of the wire of the solenoid,

(ii) the maximum magnetic flux density produced by the electromagnet. [6]

(The magnetic flux density B at the centre of a solenoid is given by $B = \mu_0 nI$.)

(d) State and explain the effects on the maximum flux density of each of the following changes.

(i) The plastic tube is filled with iron filing.

(ii) The diameter of the tube is reduced but the number of turns of wire on the coil and the total length of wire in the circuit are not changed.

(iii) Twice the length of similar wire is used so that the coil consists of two close-packed layers. [9]

J9●/III/2 (part)

48 *(b)* The north pole of the magnet is now placed inside a coil of wire, as shown in Fig. 26.

The terminals of the coil are connected to the Y-plates of a cathode-ray oscilloscope (c.r.o.) which may be assumed to have infinite input resistance.

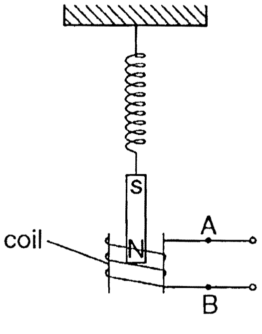


Fig. 26

(i) Sketch a graph to show how the induced e.m.f. in the coil will vary with time t when the magnet oscillates in the coil. Mark relevant times (for example, t_1, t_2, t_3) on the t-axis of your graph.

(ii) Use the laws of electromagnetic induction to explain the shape of your graph. [7]

(c) A high resistance resistor is now connected in parallel with the c.r.o. between the points A and B (see Fig. 26).

(i) Draw a second graph to show how the e.m.f. will vary with time t.

(ii) Explain, in terms of the principle of conservation of energy, why this graph is different from your first graph.

(iii) Describe, with the aid of a sketch graph, the changes which would occur in the shape of the graph drawn in *(c)*(i) if the resistance of the resistor has been reduced to a very low value. [10]

J94/III/3 (part)

49 *(a)* A straight wire AB is moved across a magnetic field, as shown in Fig. 27.

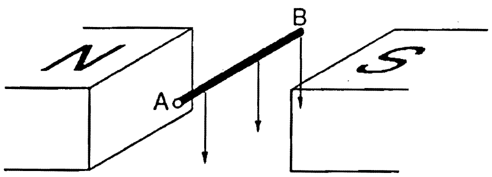


Fig. 27

State three factors which determine the value of the induced e.m.f. measured between A and B. [3]

(b) The wire AB is then replaced by a single loop of wire which is rotated with constant angular velocity in the magnetic field, as shown in Fig. 28.

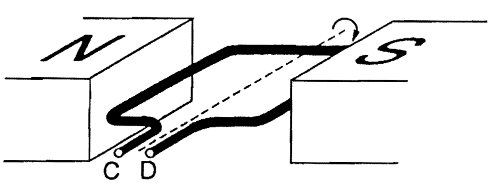


Fig. 28

Sketch a graph of the e.m.f. induced across CD, the two ends of the loop, against time t. You should assume that $t = 0$ for the coil in the position shown, that $t = T$ after one complete revolution and that the magnetic field within which the coil rotates is uniform. Mark these values on the time axis of your graph. [5]

N94/III/4 (part)

50 *(a)* Describe an experiment to illustrate *electromagnetic induction.* [4]

(b) A revolving aluminium disc has small magnets equally spaced around its rim as shown in Fig. 29. The magnets are all aligned in the same direction with the north poles on the same side of the disc.

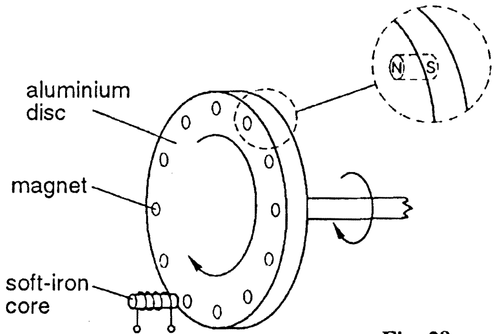


Fig. 29

A coil, wound on a soft-iron core, is fixed so that the north poles of the magnets pass close by the end of the coil without touching it. The terminals of the coil are connected to a detector which monitors the e.m.f. induced in the coil.

(i) Draw a sketch graph to show the possible variation with time of the e.m.f. induced in the coil as one magnet passes the coil. [3]

(ii) Explain, on the basis of the laws of electromagnetic induction, the shape of your graph. [6]

(c) The disc in *(b)* has N magnets attached to its rim and each magnet produces a signal in the output of the detector as it passes under the coil. If the time between corresponding points in successive signals is T, show that the rotational speed R of the disc, measured in revolutions per unit time, is given by the expression

$$R = 1/NT.$$ [2]

(d) A similar device to that in *(b)* is used in a make of car. The two front wheels are monitored in order to detect differences in their rotational speeds. The disc attached to each wheel has 60 magnets and, at one particular instant, both wheels are rotating at 15.0 revolutions per second.

(i) Calculate the time T between signals at this speed.

(ii) The speed of one wheel suddenly changes so that the values of T differ by 10% for the two wheels. What are the possible rotational speeds of this wheel? [5]

N95/III/4