For Examiner's Use

7 **(a)** Flat coils are commonly used as metal detectors to detect mines buried underground and concealed metal objects at access points in airports, prisons and military bases.

Fig. 7.1 shows a flat circular coil P carrying a current of 2.0 A. The coil has 300 turns and a mean diameter of 0.10 m.

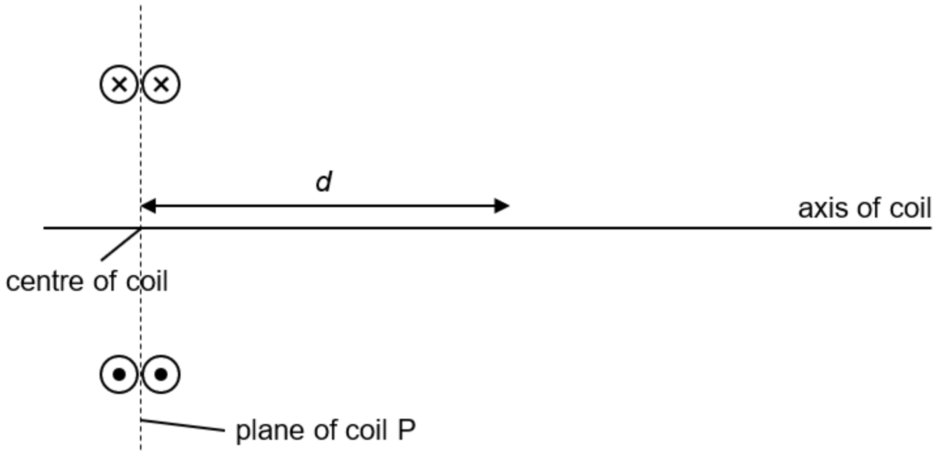

Fig. 7.1

The variation with distance d from the centre of the coil along its axis of the magnitude of the magnetic flux density B produced by the coil is shown in Fig. 7.2.

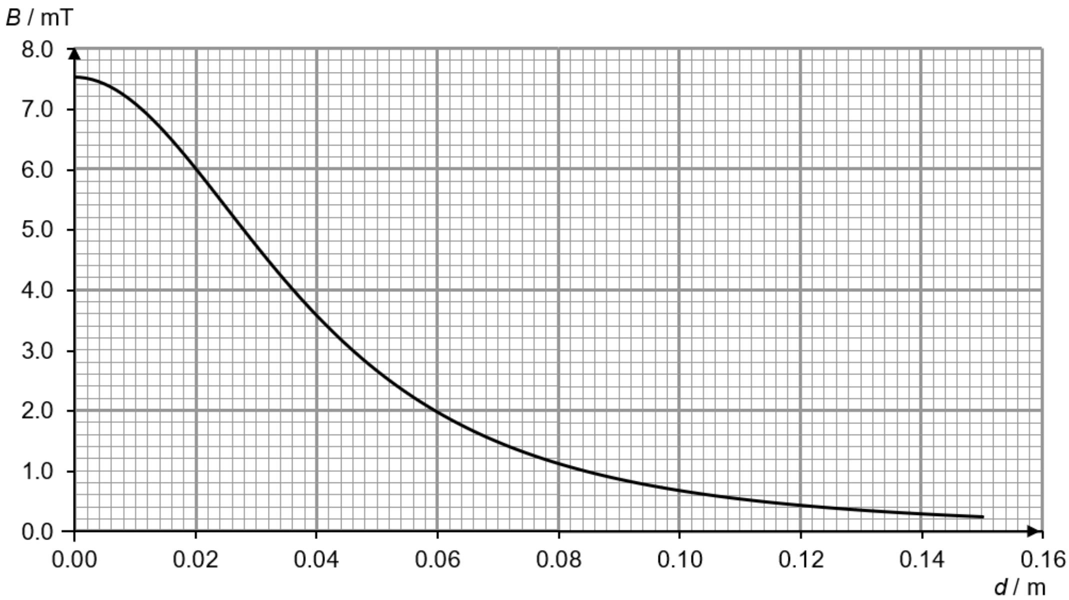

Fig. 7.2

(i) State the magnetic flux density at the centre of the coil B_C.

B_C = ……………………… T [1]

For Examiner's Use

(ii) Hence determine a value for the permeability of free space μ_o.

μ_o = ……………………… H m^{-1} [2]

(b) A smaller coil Q is placed with its axis aligned to coil P as shown in Fig. 7.3. Coil Q is moved away from coil P along the axis of the coils at a steady speed. The magnetic flux is always perpendicular to coil Q.

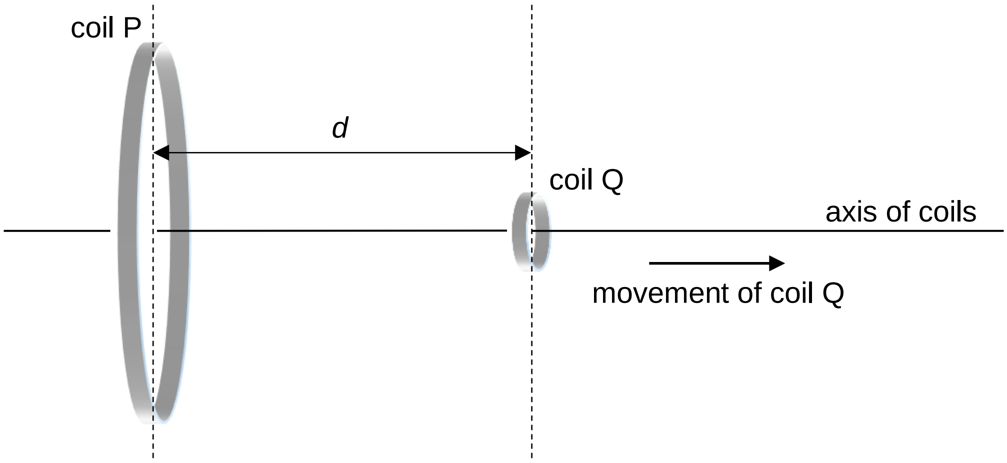

Fig. 7.3

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

…………………………………………………………………………………………..

…………………………………………………………………………………………..

………………………………………………………………………………………. [1]

For Examiner's Use

(ii) Estimate the value of *d* where the induced e.m.f. in coil Q is a maximum.

d = ……………………… m [1]

(iii) With reference to Fig. 7.2, explain why the value of *d* in **(b)(ii)** results in maximum induced e.m.f in coil Q.

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

……………………………………………………………………………….. [2]

(iv) State and explain the direction of induced current in coil Q as it is moved along the axis of the coils.

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

……………………………………………………………………………….. [2]

(v) Coil Q is moved from the centre of coil P to a position 0.040 m along the axis of the coils in 0.25 s.

1. Determine the change in magnetic flux density ΔB during this time interval.

ΔB = ……………………… T [1]

For Examiner's Use

2. Coil Q has 5000 turns, each of effective area 1.5×10^{-4} m^2.

Hence determine the magnitude of the average induced e.m.f. ε_{ave} in coil Q during this time interval.

ε_{ave} = ……………………… V [3]

For Examiner's Use

(c) **(i)** Explain what is meant by the *root-mean-square* value of an alternating current.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

……………………………………………………………………………….… [1]

(ii) The input voltage to an ideal transformer is as shown in Fig. 7.4. The turns ratio of the primary coil to the secondary coil is 50:1 and the mean input power is 20 W.

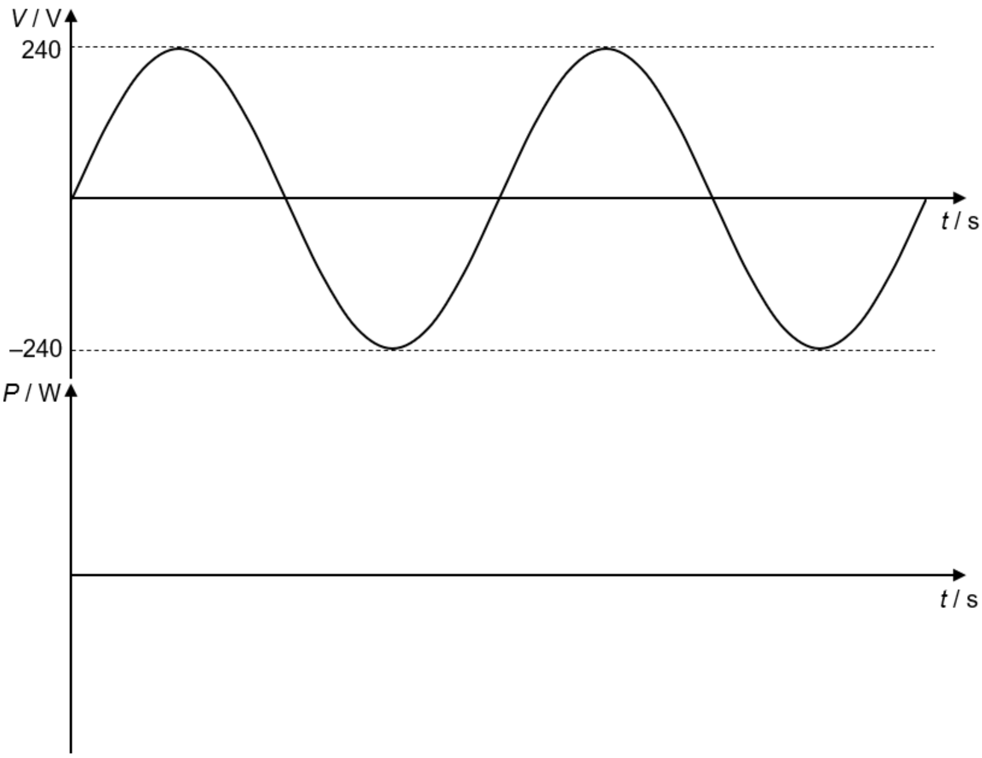

Fig. 7.4

1. On Fig. 7.4, sketch the variation with time t of the input power P to the transformer for two complete cycles. [2]

2. Determine the r.m.s. value of the output voltage.

r.m.s. output voltage = ……………………… V [2]

[Turn over

For Examiner's Use

(iii) Draw a labeled circuit diagram to show how a sinusoidal voltage V_{in} can be converted into half-wave rectified voltage V_{out}.

[1]

(iv) If the output voltage of **(c)(ii)** was half-wave rectified by the circuit in **(c)(iii)**, determine the value of the r.m.s. output voltage.

r.m.s. output voltage = ……………………… V [1]

[Total: 20]

End of Paper