4 A circular coil P carrying an alternating current produces a changing magnetic field. When a second similar coil Q is placed with its centre a distance x from the centre of coil P, as shown in Fig. 4.1, an electromotive force (e.m.f.) is induced in coil Q.

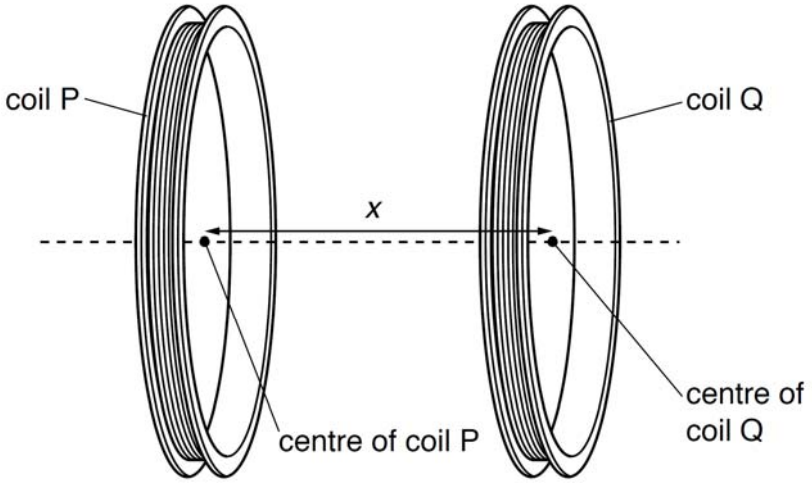

Fig. 4.1

It is suggested that the maximum value of e.m.f. E varies with the frequency f of the alternating current in coil P, as well as with x by the relationship

$$E = Zf^n e^{-kx}$$

where n, k and Z are constants.

Design an experiment to find values for k and n.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

(a) the equipment you would use
(b) the procedure to be followed
(c) how you would measure the centre-to-centre distance
(d) the control of variables
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

[11]

Qns 4

Marking Instructions	Mark
Diagram • both coils supported and labelled • *x* marked on diagram • circuit diagrams for current source at P and e.m.f. measurement at Q	**D1**
Method for generating and measuring different frequencies of AC e.g. connect output of a.c. power supply / signal generator to coil P set and record the frequency on the power supply. OR find frequency by $\frac{1}{\text{period}}$ measured on C.R.O. / voltage-against time on data logger	**F1**
Method for measuring maximum alternating e.m.f. across coil Q digital multi-meter set to measure r.m.s. voltage / voltage sensor connected to data logger / C.R.O	**M1**
Method for measuring *x* Use ruler	**R1**
method to measure *x* from centre to centre of coils P and Q e.g. measure the thickness of each coil and divide by 2 and add to the separate of coils OR average measurements from far ends and inner-facing ends of two coils	**C1**
Control variables Keep r.m.s OR peak current in coil P constant.	**K1**
Analysis: keep frequency constant, vary *x* Plot ln *E* against *x*, $\ln E = \left[\ln\left(Zf^n\right)\right]_{\text{constant}} - kx$ *k* = - gradient	**L1**
Analysis: keep fixed distance *x*, vary frequency Plot ln *E* against ln *f*, $\ln E = \left[\ln(Z) - kx\right]_{\text{constant}} + n \ln f$ *n* = gradient	**Z1**
Safety Do not touch hot coil / use gloves to position hot coil / use heat-proof gloves to position coil.	**S1**
Other details (max 2): **D1** Use large current / large number of turns / sufficiently high frequency (to produce sufficiently large magnetic field / induced e.m.f). **D2** Allow current to reach steady state accounting for heating effect in coils. **D3** Repeat measurements of *x* for different parts of the coil and average. **D4** Method to position ruler horizontally to measure *x* described e.g. use a spirit level or same height from bench at both ends. **D5** Method to keep coils parallel / co-axial e.g. adjust coil Q until maximum reading or use set square to ensure that coils are at right angles to the axis.	**E1** **E2**