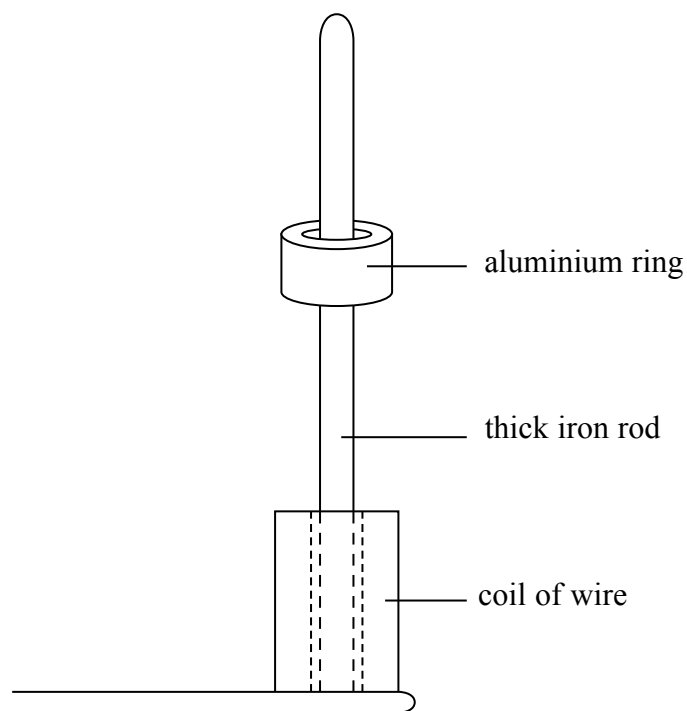


6 A coil of wire is placed around the lower end of an iron rod. The coil is supplied with an alternating current.

A thick aluminium ring is placed around the iron rod above the coil. The coil remains in the position shown.



(a) An alternating current is induced in the aluminium ring.

Explain, using Lenz's law, why the aluminium ring remains in the position shown.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) The current is switched off and the aluminium ring comes to rest on top of the coil. The supply to the coil is changed and a direct current (dc) is switched on. An upwards force F acts on the ring for 0.05 s accelerating it to a final speed, v . The ring then moves freely through a height of 30 cm.

Mean diameter of ring = 4.8 cm

Mass of ring = 0.019 kg

Magnetic field strength = 0.032 T

(i) Use conservation of energy to calculate the speed v of the ring after 0.05 s.

(2)

$v =$

(ii) Use the idea of impulse to calculate the magnitude of the mean force F acting on the ring and hence the mean current I in the ring.

(6)

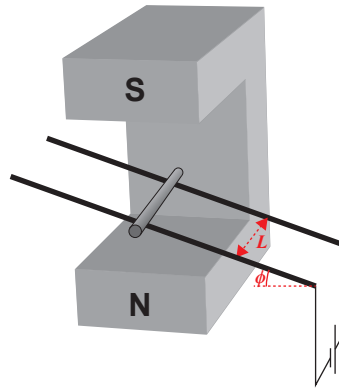
$F =$

$I =$

(Total for Question 6 = 12 marks)

QUESTION ONE: THE MAGNETIC ROLLER

A pair of parallel, conducting metal rails are connected to a voltage source, as shown in the diagram. The fixed rails slope down at angle ϕ to the horizontal between the poles of a large magnet. The force on a current carrying conductor in a magnetic field is given by the relationship $F = BIL$. The voltage induced when a conductor moves through a magnetic field is given by $V = BvL$. Both of these relationships apply in the case where the magnetic field and the conductor are at right angles to each other, and when the velocity is at right angles to both.



- (a) Show that a conducting roller can be placed across the rails and remain stationary in the position shown, if the magnetic field strength is given by $B = \frac{mg \tan \phi}{IL}$,

where m = mass of the roller, I = current through the roller, and L = the separation of the rails.

- (b) The voltage source is now replaced with a small-valued resistor, of resistance R . The metal roller moves down the rails and enters the magnetic field. It slows down and continues at a constant velocity while it is inside the magnetic field.

Explain why this occurs.

QUESTION TWO: INDUCTANCE (8 marks)

A 75 W electric light bulb (with zero inductance) is designed to run from a 50 Hz AC supply of 120 V_{rms}. If the only supply available is 240 V_{rms} and 50 Hz, the bulb can be operated at the correct power by placing in series with it, either:

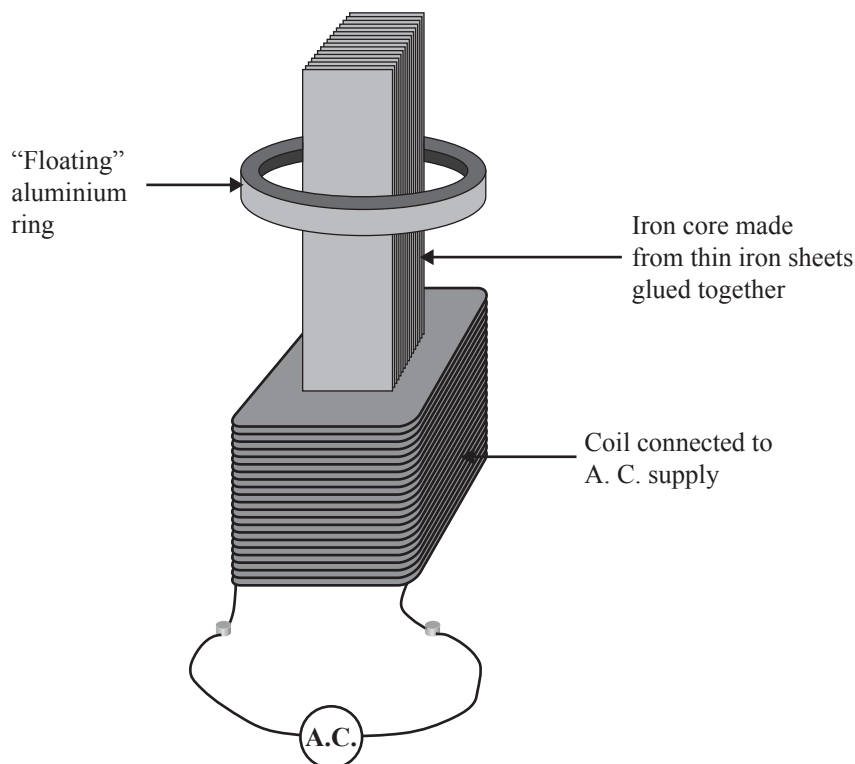
- (i) a resistance R, or
- (ii) an inductance L.

(a) Find the values of R and L and the power drawn from the supply in each case.

(i) _____

(ii) _____

(b) When an alternating voltage is applied across a coil wrapped around an iron core, an aluminium ring around the core will “float” at some height above the coil.



Explain why this happens.

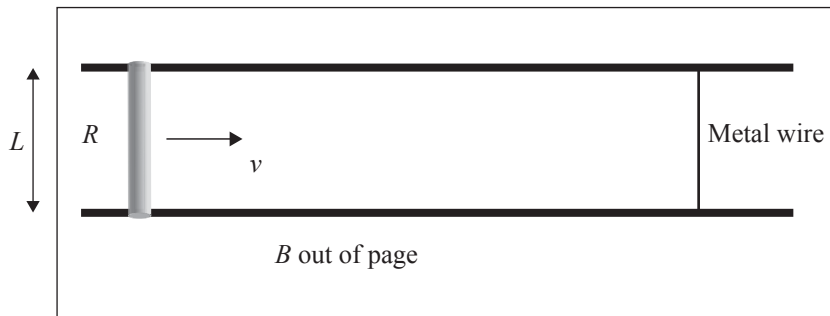
- (c) Explain, possibly with the aid of a diagram, how such a coil could be wound so that this effect would not take place.

- (d) To reduce the heating of the iron core, thin sheets of iron are glued together. The glue that holds the thin iron sheets together must have some specific electrical properties.

Suggest at least one electrical property of the glue, and state why it is important.

QUESTION THREE: ELECTROMAGNETIC INDUCTION (8 marks)

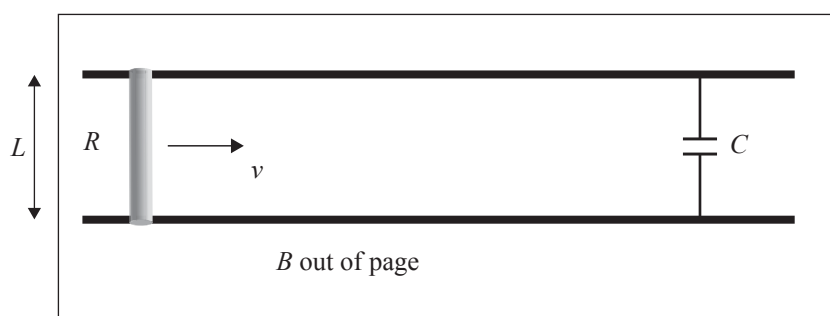
A metal roller of resistance R is placed on two long metal rails, which are connected via a metal wire. The whole system is placed in a uniform magnetic field, as shown in the diagram below. Initially the metal roller is given a small impulse towards the right.



- (a) Explain physically why the metal roller cannot continue to move with constant velocity towards the metal wire.

- (b) By applying a constant force to the right, the roller can be made to move with constant velocity. By applying Faraday's Law, derive a relationship for the voltage across the roller.

The metal wire is replaced by a capacitor, as shown below. The roller is again given a small impulse to the right.



QUESTION FOUR: A MAGLEV TRAIN**Theory**

A current-carrying wire produces a magnetic field of magnitude B at a distance r from the wire. The direction of B is given by a right-hand rule and the magnitude of B is given by the equation below where I is the current in the wire and $\mu_0 = 4\pi \times 10^{-7} \text{ N A}^{-2}$.

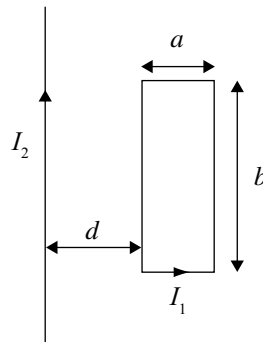
$$B = \frac{\mu_0 I}{2\pi r}$$

A wire carrying a current I in a magnetic field B experiences a force F . The direction of the force is given by an appropriate right-hand rule and the magnitude of F is calculated using the equation below, where l is the length of the wire.

$$F = BIl$$

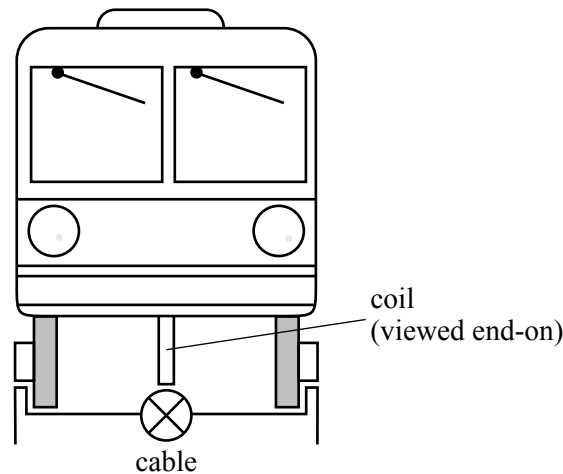
Situation

A long wire with current I_2 lies in the plane of a rigid rectangular loop carrying current I_1 . The rectangle has sides a and b and is a distance d from the long wire, as shown below.



- (i) Explain why there is a force acting on the loop.

Front view of Maglev train.



It is suggested that the force between a loop and a long current-carrying wire could be used in the design of a magnetically levitated train (Maglev). Many loops (a coil) are placed vertically in each carriage directly above a cable fixed to the track bed. If the dimensions are chosen so that $a \gg d$ and N is the number of loops in a coil then the force produced will be given by:

$$F = \frac{\mu_0 N I_1 I_2 b}{2\pi d}$$

where $\mu_0 = 4\pi \times 10^{-7} \text{ N A}^{-2}$ and the acceleration due to gravity = 9.80 m s^{-2} .

- (v) A carriage used to investigate this concept is 20 m long with a mass of $2 \times 10^4 \text{ kg}$ and a maximum allowed current in the cable and coil of 100 A. The coil has 5000 loops.

Calculate the distance d between the lower side of the coil and the cable.

distance = _____

- (vi) One of the designers is concerned that the distance d will change considerably when people get on the train. Estimate the value of d for a full carriage holding 70 people.
