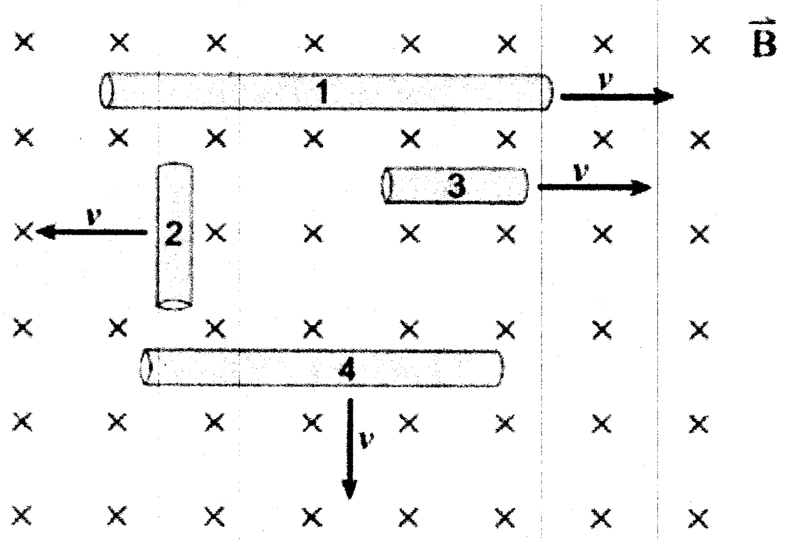
CORPUS CHRISTI COLLEGE SEQUERE DOMINUM	Year 12 *ATAR* Physics Unit 3 2018 *TASK 7* *Electromagnetism & Electromagnetic Induction Test* *5.0%* NAME: ....Solns.......... Data: See Data Sheet Approx. marks shown. MARK: ______ / 64

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Multiple Choice Questions (1 mark each) Circle only one correct answer. (4 marks)

1. Four conductors of different lengths are moved through a uniform magnetic field at the same speed. Which conductor will induce the greatest emf?



Emf ind = BvL

(A) 1 (B) 2 (C) 3 (D) 4

2. A **step-down** transformer has a 500 turn primary that operates at 120 V ac.
Which of the following sets of conditions best describes the number of secondary turns and secondary voltage of this transformer?

	SECONDARY TURNS	SECONDARY VOLTAGE
A.	40	9.6 V ac
B.	40	1 500 V ac
C.	2 000	30 V ac
D.	2 000	480 V ac

Fewer turns
Reduced voltage.

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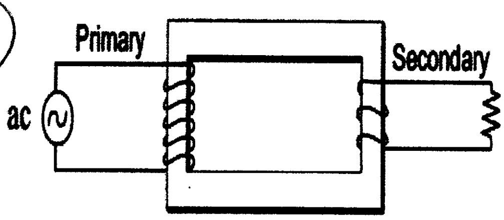
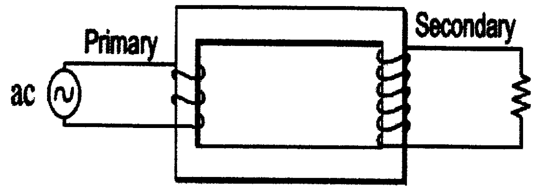
Step down T/F.

3. In which of the following diagrams is the secondary **current** greater than the primary **current**?

A.

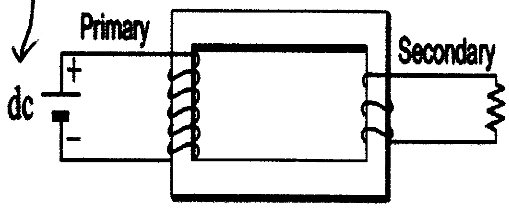


C.

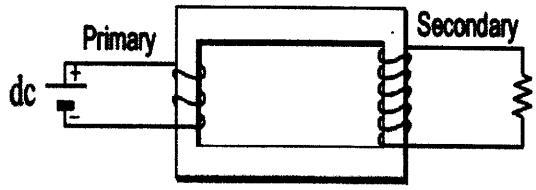


T/F do not operate on continuous DC

B.

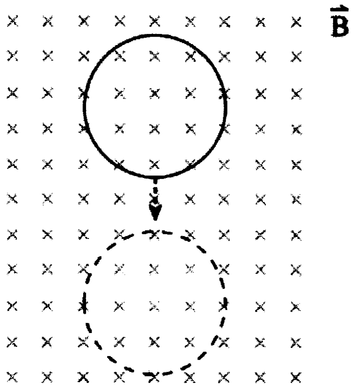


D.



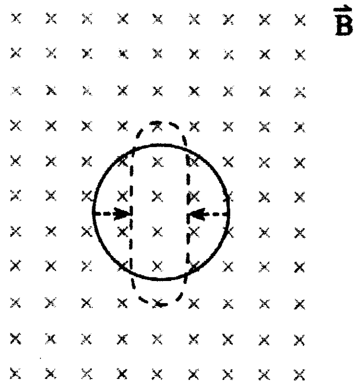
4. In which of the following situations would the greatest emf be induced in the coil? All changes occur in the same time interval.

A.



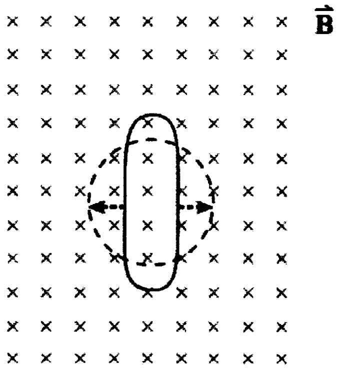
coil moves

B.



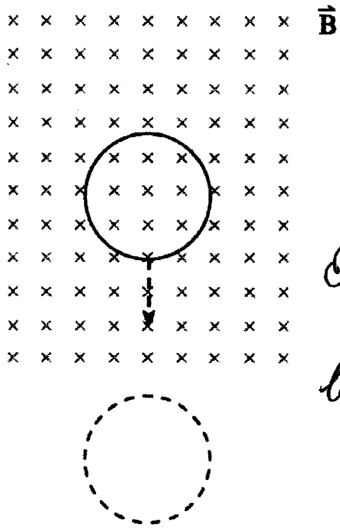
coil changes shape

C.



coil changes shape

D.



coil moves

$emf = -n\dfrac{\Delta\phi}{t}$

largest $\Delta\phi$ $\Rightarrow$ largest $\Delta(BA)$

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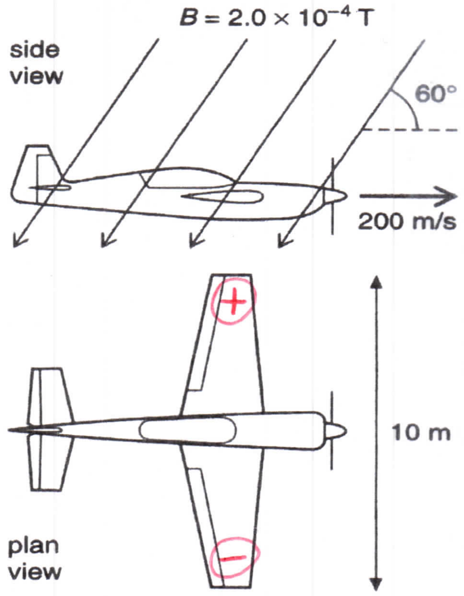
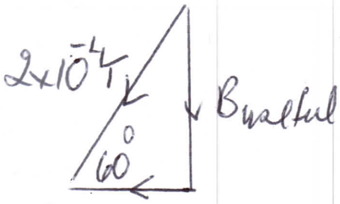
Short structured questions

5. An aeroplane with a wingspan of 10.0 m is flying horizontally at a velocity of 200 m s^{-1}. In the region the plane is flying, the Earth's magnetic field is 2.00 x 10^{-4} T, at an angle of 60.0° to the horizontal.

   Indicate clearly the polarity induced and determine the magnitude of emf induced across the wingtips of the plane? (5 marks)



Need vertical B field / Cut B_{vert}.



$B_{useful} = 2\times10^{-4} \sin 60^0$

$= 1.73\times10^{-4}$ T ✓

$EMF_{ind} = Bvl$ ✓

$= 1.73\times10^{-4} \times 200 \times 10$ ✓

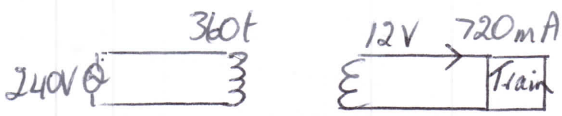
$= 0.3464$ ✓

$\therefore EMF_{ind} = 0.346$ V. (3sf)

Correct polarity ✓

6. An ideal transformer for a toy train set plugs into the 240 V mains supply and changes it to 12.0 V. The toy train draws 720 mA from the transformer.

   (a) If the primary is found to consist of 360 turns of wire, how many turns will the secondary have? (2 marks)



$\frac{N_s}{N_p} = \frac{V_s}{V_p}$

$\frac{N_s}{360} = \frac{12}{240}$ ✓ $\therefore N_s = 18$ turns ✓

   (b) Determine the current in the primary section of the transformer. (2 marks)

$\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$

$\frac{12}{240} = \frac{I_p}{720\,mA}$ ✓ $\therefore I_p = 36.0$ mA (3sf) ✓

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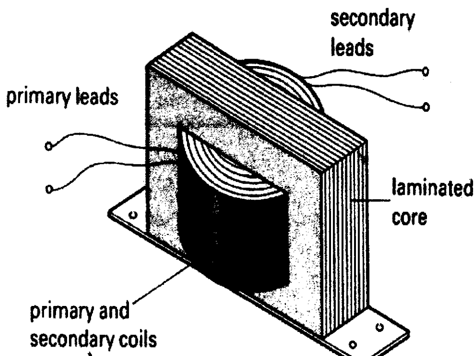
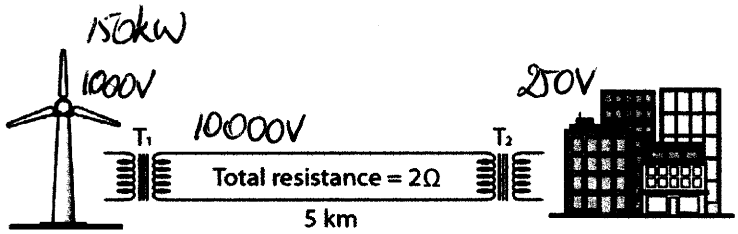
(c) Carefully explain why the core of a transformer consists of many thin laminated sheets bonded together instead of a single solid soft iron cast. (3 marks)



The changing flux threading through the coils of the transformer induce large eddy currents in thick solid Fe
Eddy currents cause heating $(H=I^2Rt)$ in the iron which reduces efficiency of the T/F.
Thin laminations reduce the eddy currents so reduce the power loss through heat so improve the efficiency

7. The diagram shows a wind turbine which runs a **150.0** kW generator with an output voltage of 1000 V. The voltage is increased by transformer T_1 to 10 000 V for transmission to a town **5.00** km away through power lines with a total resistance of **2.00 Ω.** Another transformer, T_2, at the town reduces the voltage to **250.0 V.** Assume that the transformers are 'ideal'.



When the system is running at full power,

(a) what is the current in the power line? (1 mark)

$P = VI$

$150 \times 10^3 = 10000 I$

$I = 15.0A$

(b) what is the voltage drop along the power line and the voltage at the input to the town transformer? (2 marks)

$V_{drop} = IR = 15 \times 2 = 30.0V$

$\therefore$ Voltage at town T/F $= 10000 - 30 = 9970V$

(c) how much power is lost in the power line? Is this a significant problem? (2 marks)

$P_{loss} = I^2R$
$= 15^2 \times 2 = 450W$

% loss $= \frac{450}{150000} \times 100 = 0.300\%$ $\therefore$ Not significant

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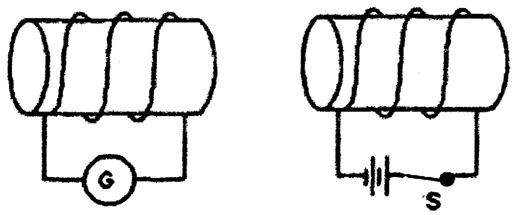
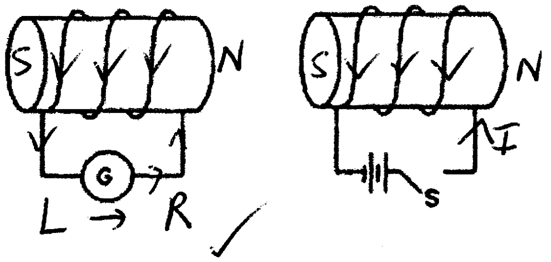
8. (a) Two coils are placed side by side so that the magnetic field produced by one of the coils passes through the other. **Indicate the direction of the induced current through the galvanometer G in the secondary coil if any.**

(i) If the switch **S** in the primary coil has been closed for 30 seconds. (1 mark)



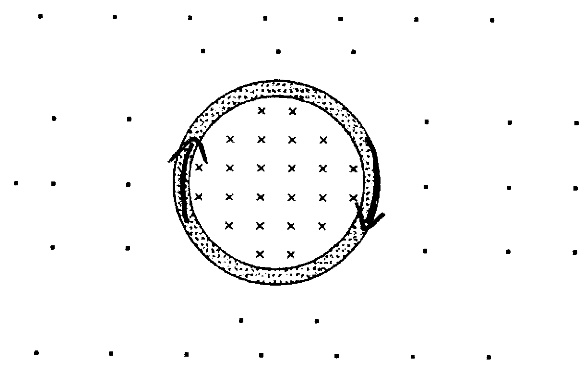
No current ✓
(steady state.
No $\Delta\phi$ thro coil
$\Rightarrow$ No EMF $\Rightarrow$ no I)

(ii) If the switch **S** in the primary coil is then opened. (1 mark)



galvanometer needle deflected to right momentarily.

(b) The figure shows the magnetic field seen when facing a current loop in the plane of the page.



(i) On the figure above show the direction of the current in the loop. clockwise (1 mark)

(ii) Is the north pole of this loop at the upper surface of the page or the lower surface of the page? Explain. (2 marks)

B field is produced by the current (not an external magnet). Lower surface of page is north pole since the north pole is the end from which the magnetic field emerges. ("out of North, into the South")

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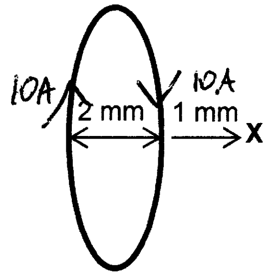
(c) Consider the not-to-scale diagram to the right.

A wire, carrying a clockwise current of 20.0 A, is looped back on itself with 2.00 mm maximum strength between the wires. What is the magnetic field at point X which is 1.00 mm to the right of the centre of the wire loop?

(4 marks)



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

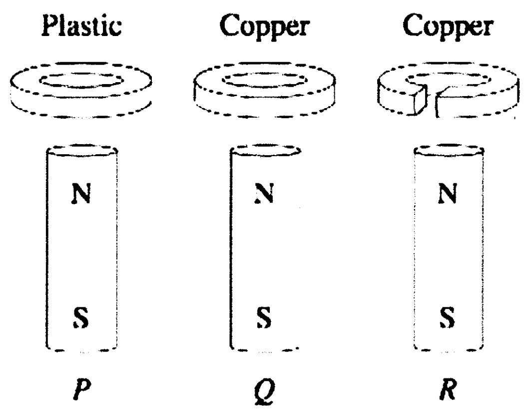
$B = 2\times10^{-7} \frac{20}{1\times10^{-3}}$ out of pg $+ 2\times10^{-7} \frac{20}{3\times10^{-3}}$ into pg ✓ ✓

$= 4\times10^{-3}$ out of pg $+ 1{\cdot}333\times10^{-3}$ into pg

$= 2{\cdot}666\times10^{-3}$ out of pg

$= 2{\cdot}67\times10^{-3}$ T out of pg ✓ ✓

9. Three rings are dropped at the same time over identical magnets as shown below.



(a)

Which of the following describes the order in which the rings *P*, *Q* and *R* reach the bottom of the magnets?

(A) They arrive in the order *P*, *Q*, *R*.

(B) They arrive in the order *P*, *R*, *Q*.

(C) Rings *P* and *R* arrive simultaneously, followed by *Q*.

(D) Rings *Q* and *R* arrive simultaneously, followed by *P*.

(1 mark)

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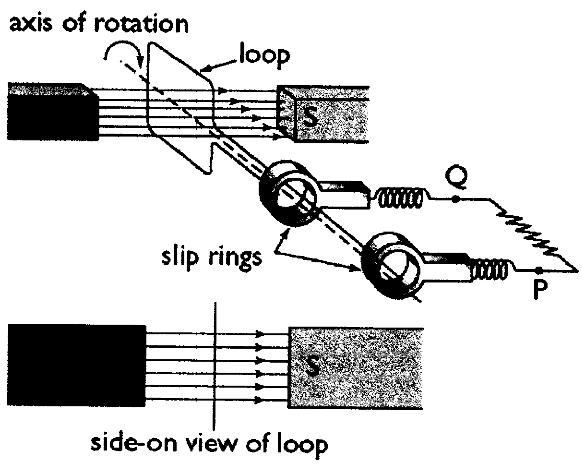
(b) Justify your answer using the relevant Physics laws. (3 marks)

Faraday's Law states that the rate of change in flux will induce an EMF ($EMF_{ind} = -N\frac{\Delta\Phi}{t}$) and, in a closed circuit, a current is induced.
Lenz's Law states that this current will induce an EMF so as to oppose the change that induced it.
P is plastic & an insulator so no current induced. (½)
R is not a complete circuit & so no current induced. (½)
In Q, as the Cu ring approaches the magnet the B field passing through the ring increases. By Lenz's Law a current will be induced in the ring to oppose its motion & so slows the ring down. Hence it lands last.

11. The diagram below shows a simple AC electric generator

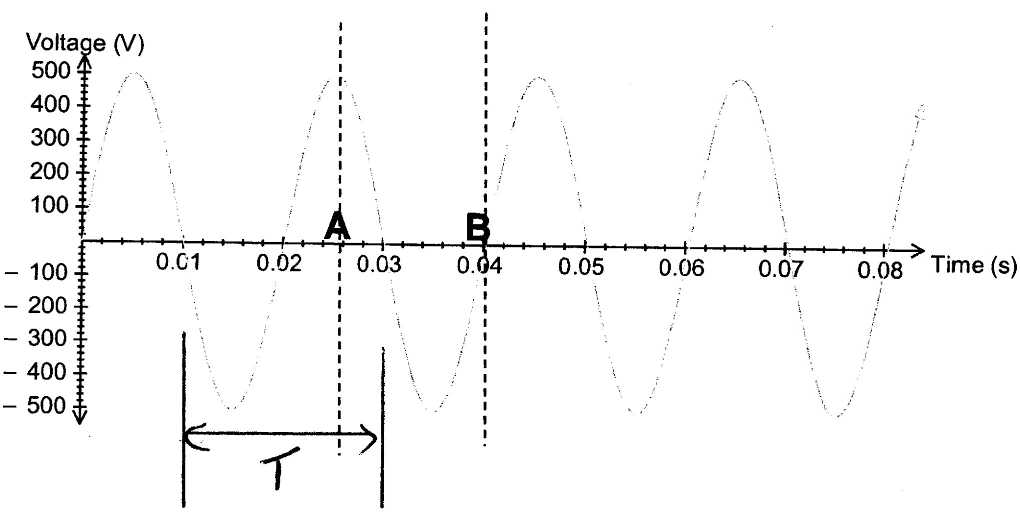
As the loop is rotated in the magnetic field, an emf is induced. The graph below shows how the induced emf varies with time.



(a) Which point, **A** or **B,** in the graph could possibly correspond to the point of rotation shown in the diagram right? B

(1 mark)

(max B ⇒ min EMF)



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(b) With what frequency is the generator turning? (1 mark)

$f = \frac{1}{T}$ $T = 0.2s$ $\therefore f = \frac{1}{0.2} = \underline{50.0\,Hz}$

(c) In a typical single phase AC generator, the emf_{rms} induced is 350 V and its rotating coil consists of 500 turns. Find the magnetic flux ϕ in the generator. (4 marks)

$$Emf_{rms} = \frac{Emf_{peak}}{\sqrt{2}}$$

$$\therefore Emf_{peak} = \sqrt{2} \times 350 = 494.975\,V.$$

$$Emf_{peak} = 2\pi BANf \quad \text{and} \quad \phi = BA$$

$$494.975 = 2\pi \phi\, 500 \times 50$$

$$\underline{\phi = 0.00315\,Wb = 3.15 \times 10^{-3}\,Wb.}$$

(3sf)

(d) In a commercial power station, the generators have electromagnets to provide the magnetic field.

What are some of the advantages and disadvantages of this design principle? (3 marks)

Advantages: 1. Electromagnets can produce very strong B fields $\therefore$ greater EMF can be induced.
2. Electromagnets provide a constant B field whereas the B field from permanent magnets reduce over time.
Disadv: Electromagnets required a power supply & so a "cold start" not possible if power supply fails.

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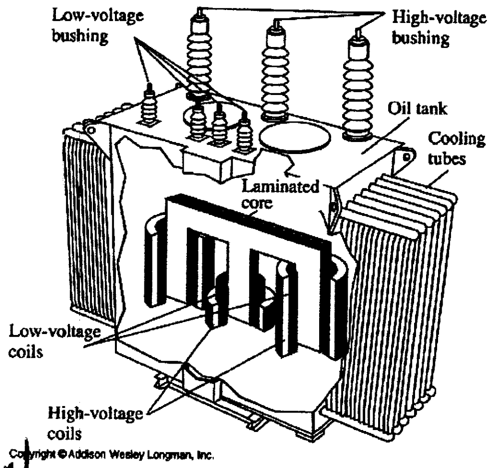
At Pinjar power station, the electricity is produced at 350 V and then stepped up to 132 kV before it is transmitted to the city.

(e) The transformer has an extensive cooling system to remove the large quantities of heat produced.

Why does the transformer produce this heat? (2 marks)



Joule heating ($H = I^2Rt$) occurs in the large length of wire in the coils. (This is minimized by having thicker wires in the coil with most current). Some heating also occurs due to eddy currents in the Fe core but this is reduced by using laminations.

(f) Why is it necessary to step up the voltage before it is transmitted? (2 marks)

In a transformer, stepping up (increasing) the voltage reduces the current. The current on the transmission cables needs to be as low as possible to reduce power loss on the transmission line ($P = I^2R$)

(g) Why is electrical energy transmitted from generator to consumers using an alternating current? (2 marks)

Transformers require AC to operate since a $\Delta\phi$ is needed to induce the emf in secondary coil. Transformers do not operate on continuous DC.

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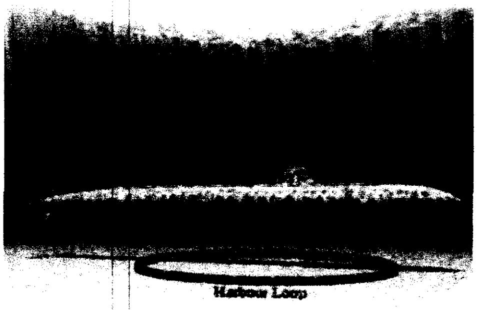
12. During the Second World War, it was common to guard harbours using a copper coil of very large area laid across the entrance to the harbor.

This device was intended to detect the presence of a submarine by the voltage induced as the submarine passed over the harbour loop.

The loop could be considered as an air-cored transformer and a submarine is made from steel.



(a) Carefully explain how such a voltage might be induced. (3 marks)

The steel of the submarine concentrates the Earth's lines of magnetic flux. This produces a change in flux as the submarine enters the loop. By Faraday's Law $EMF_{ind} = n\frac{\Delta\phi}{t}$ & so the rate of change of flux induces an emf in the loop that is measured.

(b) If, as a submarine passes, the flux passing perpendicularly through a 50 turn loop changes at a rate of 8.00 x 10^{-3} weber per second, what emf would be induced in the loop? (2 marks)

$$EMF_{ind} = -n\frac{\Delta\phi}{t}$$
$$= 50 \times 8 \times 10^{-3}$$
$$= 0.400\ V$$
$$(= 400\ mV)$$

(c) At the site of this harbour, natural variations in the vertical component of the Earth's magnetic field might occur at the rate of 3.00 x 10 $^{-10}$ tesla per second.

What is the maximum area the harbour loop must have if the naturally induced voltage is to remain below 1% of that induced by the submarine? (3 marks)

$$\frac{\Delta\phi}{t} = \frac{\Delta(B\,A)}{t} = A\frac{\Delta B}{t}$$
$$0.01 \times 8 \times 10^{-3} = A \times 3 \times 10^{-10}$$
$$\therefore A = 2.67 \times 10^{5}\ m^2$$

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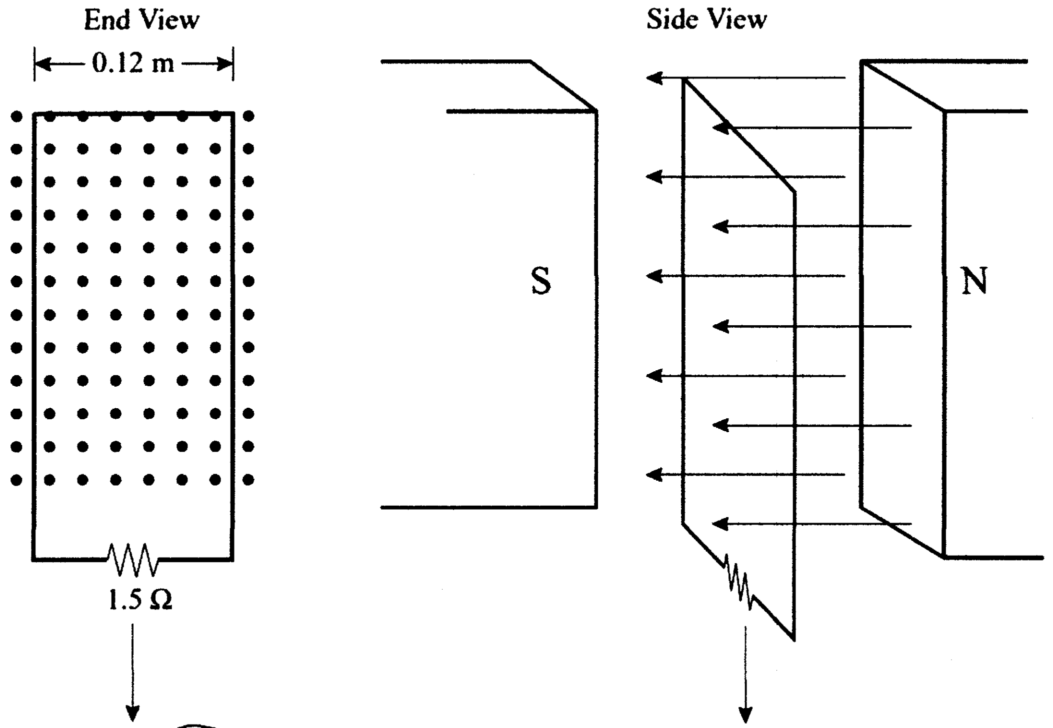
13. A rectangular conducting loop of mass 4.50 x 10^{-2} kg and resistance 1.50 Ω is dropped vertically through a uniform horizontal magnetic field of 1.80 T.



Determine the speed this loop will be falling through the magnetic field when it stops accelerating? (7 marks)

stops accelerating ⇒ terminal vel.

$\therefore F_{down} = F_{up} \qquad F_g = F_B$ ✓

$mg = BIl$ ✓

Now $I = \frac{V}{R} = \frac{emf}{R} = \frac{Bvl}{R}$ ✓

$\therefore mg = B\left(\frac{Bvl}{R}\right)l$

$\therefore mg = \frac{B^2 v l^2}{R}$ ✓ //

$\therefore V = \frac{mgR}{B^2 l^2} = \frac{4.50\times10^{-2} \times 9.8 \times 1.5}{1.80^2 + 0.12^2}$

$= 14.178\ ms^{-1}$

$= \underline{14.2\ ms^{-1}}$ ✓

$I = \frac{mg}{Bl}$

$= \frac{4.5\times10^{-2} \times 9.8}{1.8 \times 0.12}$

$= 2.04A$

Now

$emf = Bvl$

$\therefore IR = Bvl$

$\therefore v = \frac{IR}{Bl} = \frac{2.04 \times 1.5}{1.8 \times 0.12}$

$= \underline{14.2\ ms^{-1}}$

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