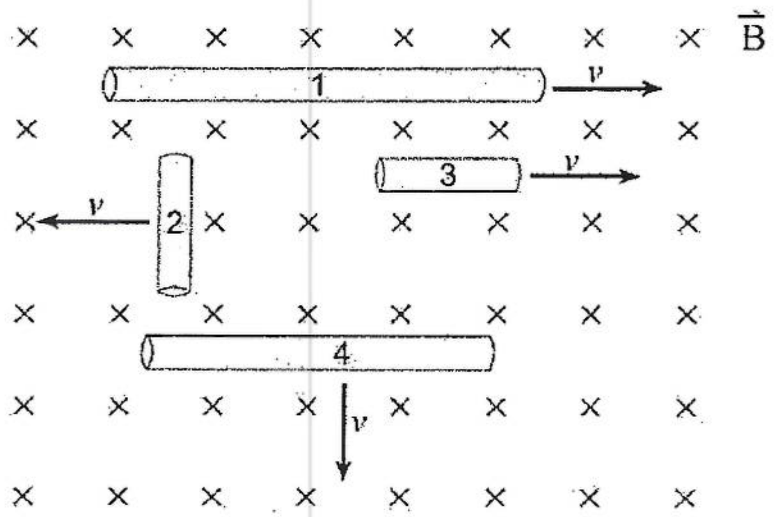
Year 12	*ATAR* Physics Unit 3	2018
TASK 7	***Electromagnetism 2 & Electromagnetic Induction*** *5.0%*	
NAME:	PHYSICS Teacher	
Data:	See Data Sheet Approx. marks shown.	
MARK:	/ 76	

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.

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



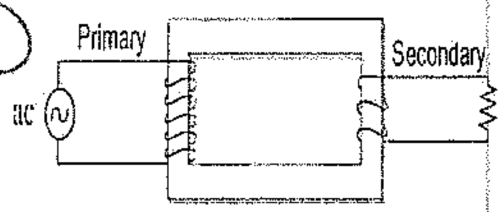
A) 1 B) 2 C) 3 D) 4 ✓

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?

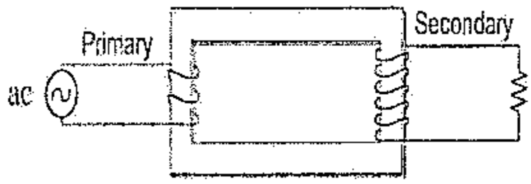
	SECONDARY TURNS	SECONDARY VOLTAGE
A.	40	9.6 V ac
B.	40	1 500 V ac
C.	2 000	30 V ac
D.	2 000	480 V ac

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

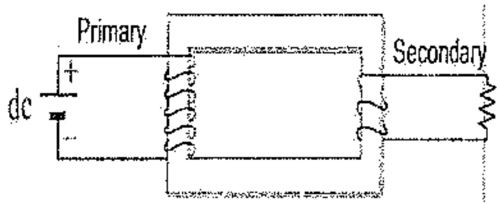
A.



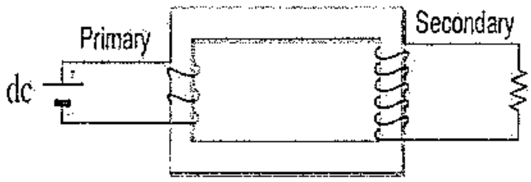
C.



B.

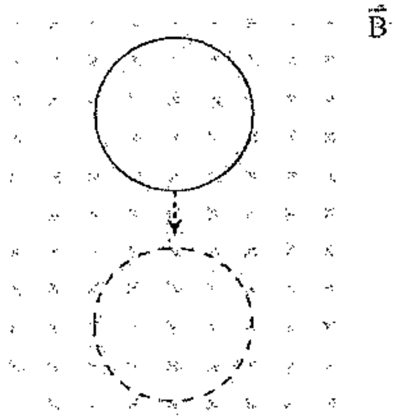


D.



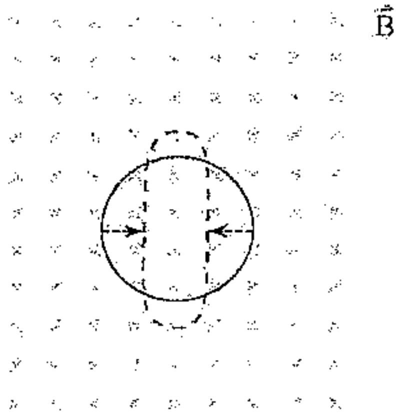
4. In which of the following situations would the greatest emf be induced in the coil? All changes occur in the same time interval.

A.



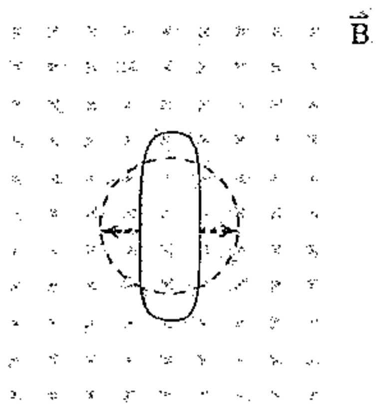
coil moves

B.



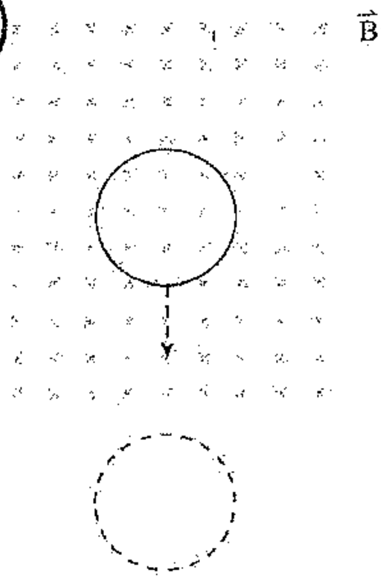
coil changes shape

C.



coil changes shape

D.

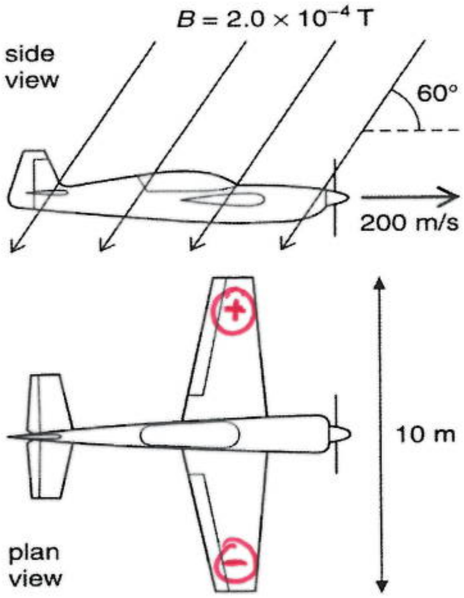


coil moves

Short structured questions

1. 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 2.0×10^{-4} T, at an angle of 60° to the horizontal.

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



Emf induced

$= B_{\perp} v l$

$= 2.0\times10^{-4} \sin 60^{\circ} \times 200 \times 10.0$

$= 0.346$ V

correct polarity

2. 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)

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

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

$= \frac{360 \times 12}{240} = 18$

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

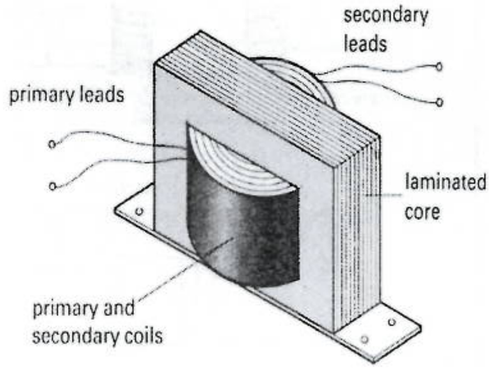
$\frac{V_p}{V_s} = \frac{I_s}{I_p}$

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

$= \frac{720\times10^{-3} \times 12}{240}$

$= 36$ mA or 0.036 A

2c) Carefully explain why the core of a transformer consists of many thin laminated sheets bonded together instead of a single solid soft iron cast. (2 marks)

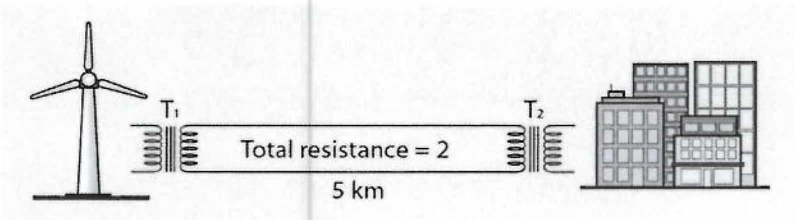


Large eddy currents induced in core. ✓

These dissipate heat energy ($P = I^2R$), can cause damage.

laminations greatly reduces the effect of eddy currents combining into a larger resultant current ✓

3. 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)

$P_{turbine} = 150 \times 10^3 W$

$V_{T1} = 10 \times 10^3 V$

$I_{T1} = \frac{P}{V_{T1}} = \frac{150 \times 10^3}{10 \times 10^3} = 15.0 A$ ✓

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

$\Delta V = 15(2) = RI$
$= 30 V$ ✓

$V_{T2} = V_{T1} - \Delta V$
$= 10000 - 30$ ✓
$= 9.97 \times 10^3 V$ ✓

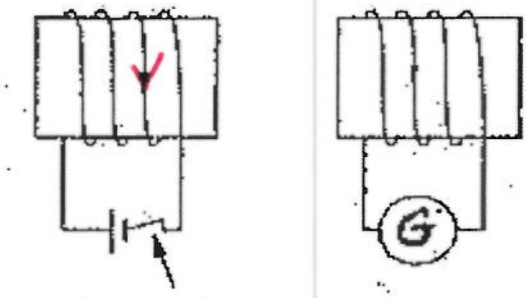
c) how much power is lost in the power line? Is this a significant problem? (2 marks)

$P_{loss} = I^2R = 15^2 2$
$= 4.50 \times 10^2 W$ ✓

Not significantly large ✓

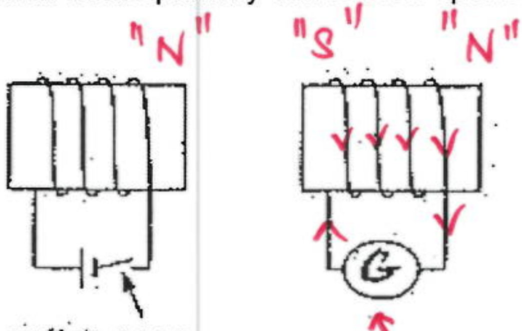
4. a) Two coils are placed side by side so that the magnetic field produced by one of the coils passes through the other. **Indicate the direction of the induced current through the galvanometer G in the secondary coil if any.**

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



No current ✓
(no rate of change of magnetic flux linkage)

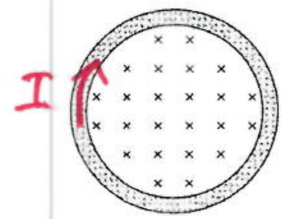
(ii) If the switch in the primary coil is then opened (1 mark)



momentary left deflection ✓

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

I (clockwise)

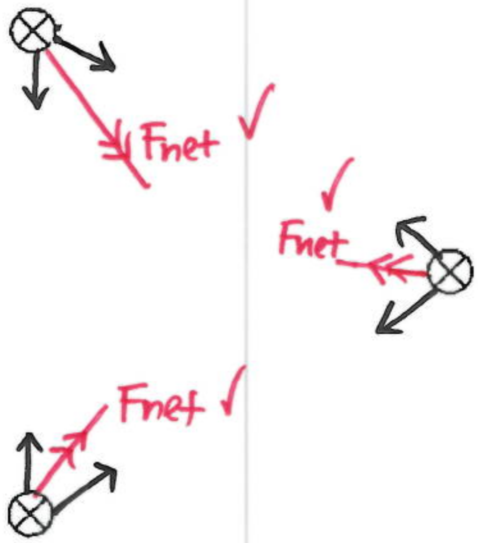


(i) On the figure above show the direction of the current in the loop. (1 mark)

(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)

Lower surface of page ✓
The North pole is the end from which the magnetic field emerges ✓

4 c) **Three current carrying wires are perpendicular to the page shown below.**



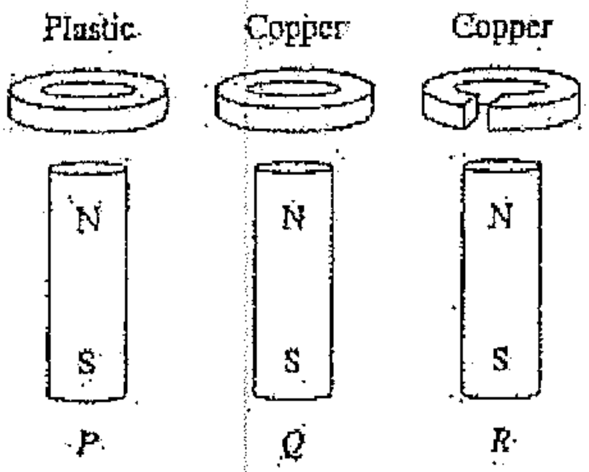
(i) Construct a force vector diagram on each wire to determine the direction of the net force on each wire. (3 marks)

(ii) Can three charges be placed in a triangular pattern so that their force diagram looks like this? If so, draw it. If no, explain why not. (2 marks)

No. ✓

Charges must be unlike to ✓
exert attractive forces on each other.
There are not 3 different unlike charges to be able
to acheive the force diagram above

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



a) Describes the order in which the rings P, Q and R (simultaneously or otherwise) reach the bottom of the magnets. (2 marks)

Rings P and R arrive simultaneously, followed by Q

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

Plastic, being an electical insulator, has no current flows in it. √½

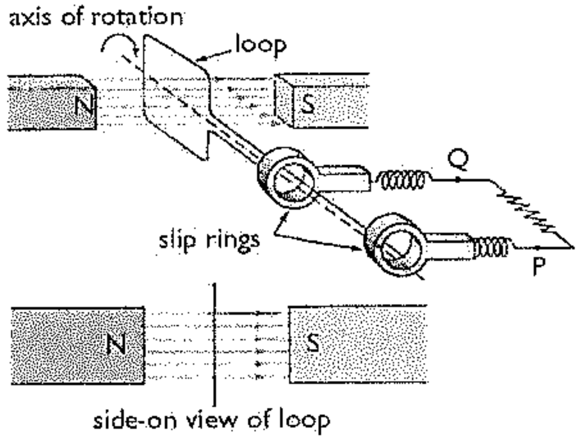
Ring R is not a complete ring. No current flow since it is not a closed circuit. √½

The strength of the magnetic field inside the ring increases. By <u>Lenz's law</u>, an emf & current is induced in the ring in order to produce a magnetic field to oppose this change, resulting in a force to slow down the ring Q √ √

6. The diagram below shows a simple AC electric generator. [15 marks]

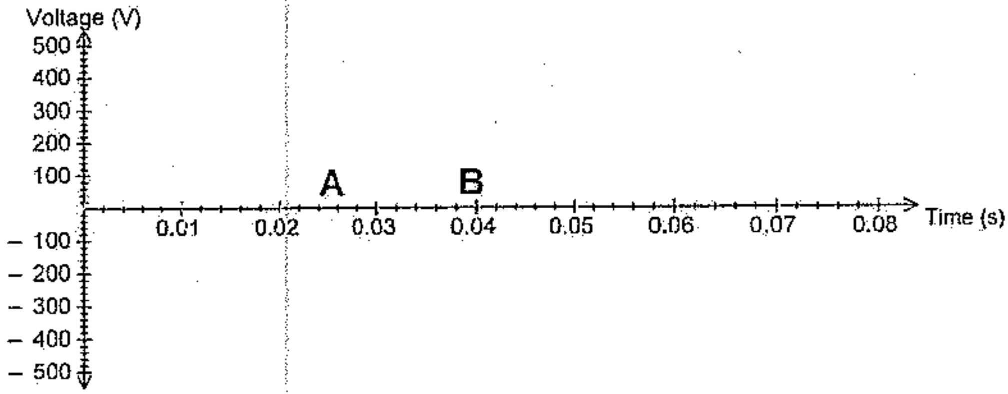
As the loop is rotated in the magnetic field, an emf is induced.

The graph below shows how the induced emf varies with time.



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

(1 mark)



b) With what ~~speed, in revolutions per second~~ frequency, is the generator turning?

$$f = \frac{1}{0.02} = 50 \text{ Hz}$$

(1mark)

$emf_{max} \approx 500$ V

c) In a typical single phase AC generator, the average emf induced is 350 V and its rotating coil consists of 500 turns. Find the magnetic flux (Φ) in the generator.

(4marks)

$$emf_{max} = NAB\,2\pi f$$

$$\sqrt{2} \times 350 = 500\,\Phi\,2\pi f$$

$$\Phi = \frac{350\sqrt{2}}{500(2\pi)50} = 3.15 \times 10^{-3} \text{ Wb}$$

Question 6 (continued)

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?

(3marks)

Adv: stronger B field possible $\Rightarrow$ greater induced emf

don't "wear out" like permanent magnets ✓ ✓

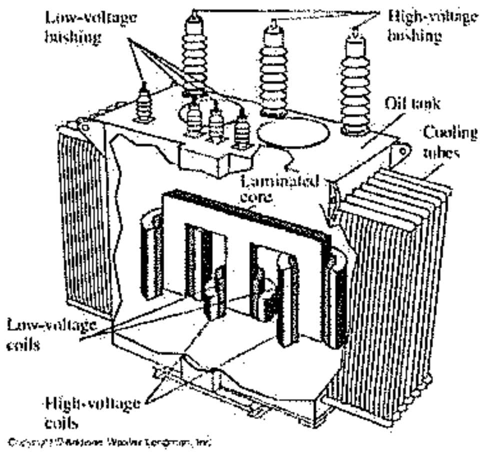
Disadv: "cold start" not possible without an external power supply to excite stator windings ✓

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? (2marks)

Large eddy currents produce heat ($P_{loss} = I^2R$) ✓

can cause damage and effect efficiency ✓



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

Higher voltage lowers the current for same power transmitted; ✓

P_{loss} in transmission lines due to I^2R is reduced ✓

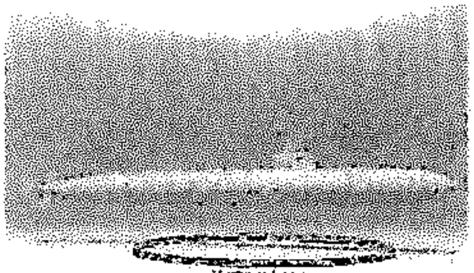
g) Why is electrical energy transmitted from generator to consumers using an alternating current? (2marks)

AC provides a $\Delta\Phi$ needed for use in transformers which don't work for DC ✓

if DC used, advantages of reducing power loss in cables/lines would not be possible! ✓

7. During the Second World War, it was common to guard harbours using a 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.



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

As sub moves over loop, there is a rate of change in magnetic flux linkage with the loop ✓
There will be less flux within area of loop
By Faraday's Law ✓ $\mathcal{E}_{induced} = \frac{N\Delta\Phi}{t}$ ✓
hence rate of change of flux induces an emf in loop

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? (3 marks)

$N = 50$ $\quad \frac{\Delta\phi}{\Delta t} = 8\times10^{-3}\ Wb\,s^{-1}$ ✓

$\mathcal{E} = N\frac{\Delta\phi}{\Delta t} = 50\times 8\times10^{-3}$ ✓

$= 0.400V$
$= 400\ mV$ ✓

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)

$\frac{\Delta B}{\Delta t} = \frac{100}{1}\times 3\times10^{-10} = 3\times10^{-8}\ Ts^{-1}$

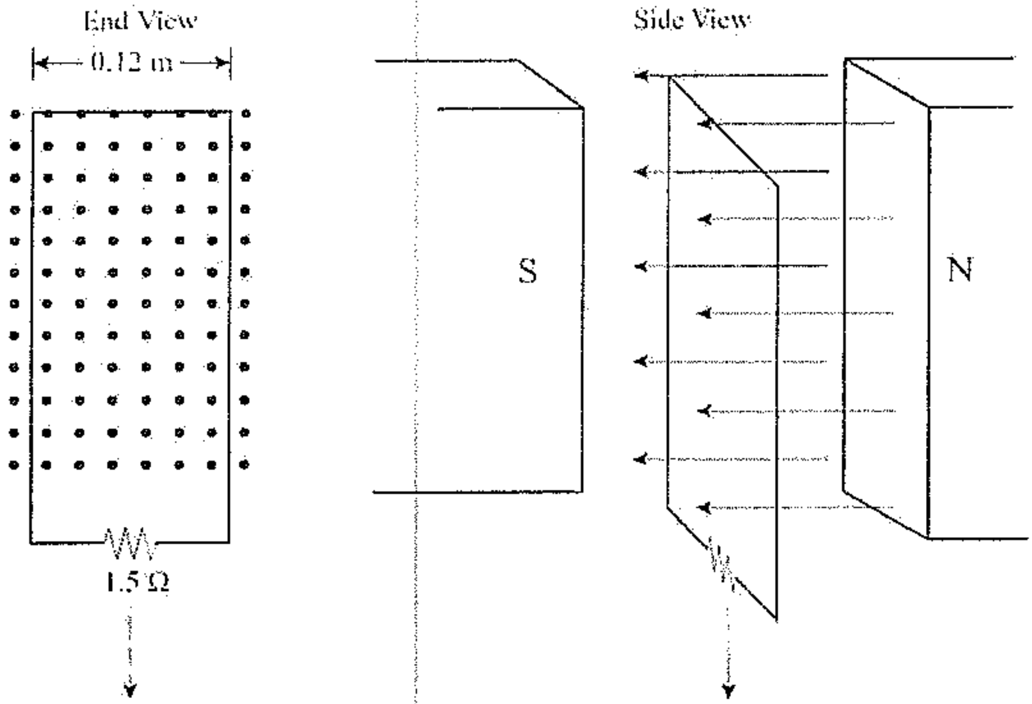
$\Phi = BA$

$\frac{\Delta\Phi}{\Delta t} = \frac{\Delta B\cdot A}{t}$

$A = \frac{\Delta\Phi}{\Delta B} = \frac{8\times10^{-3}}{3\times10^{-8}}$ ✓ ✓

$= 2.67\times10^{5}\ m^2$ ✓

8. A rectangular conducting loop of mass 4.50 x 10^{-2} kg and resistance 1.5 Ω is dropped in the direction shown through a uniform horizontal magnetic field of 1.8 T.



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

$a = 0$

$F_{net} = 0$ from $F_g = F_B$ ✓

$mg = BIl$ ✓

$I = \frac{mg}{lB}$ ✓

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

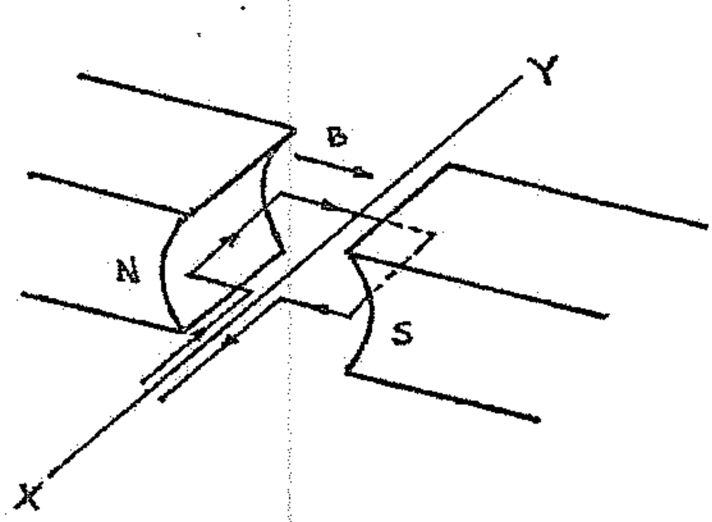
$= 2.04\,A$ ✓

$IR = Blv$

$\mathcal{E}_{induced} = Blv$ } ✓

$v = \frac{\mathcal{E}_{induced}}{Bl} = \frac{2.04\times1.5}{(1.8)\times0.12}$ ✓ $= 14.2\ ms^{-1}$ ✓

9. In a dc motor, the coil consists of rectangular loops of wire mounted on an axle rotating in a magnetic field of 0.45 T. The current in the wire is 5.6 A.



a) What force acts on each centimeter length of the wire? (4 marks)

$F = BIL$ ✓

$= 0{\cdot}45 \times 5{\cdot}6 \times 1 \times 10^{-2}$ ✓ ✓

$= 2{\cdot}52 \times 10^{-2}$ N ✓

b) The coil is made of 420 turns, each 225 mm long and 120 mm wide. The axle is mounted parallel to the long axis of the turns. Calculate the torque produced by this motor? (4 marks)

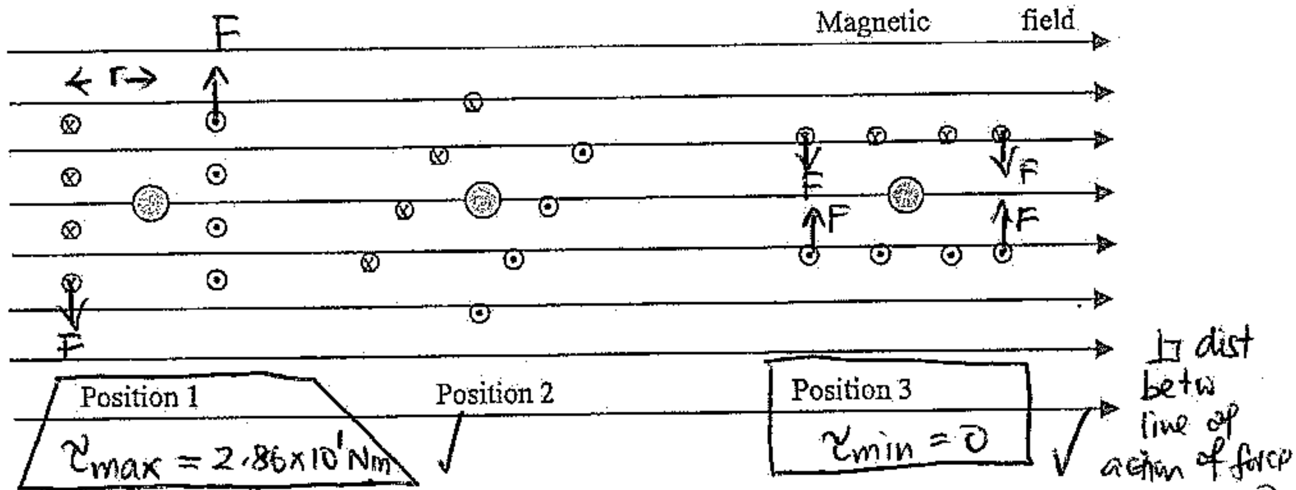
$\tau_{total} = BIAN$ ✓

$= 0{\cdot}45 \times 5{\cdot}6 \times 225 \times 10^{-3} \times 120 \times 10^{-3} \times 420$ ✓

$= 2{\cdot}86 \times 10^{1}$ Nm ACW ✓ ✓

c) The coil is viewed along the axis of motor (line XY shown in 9a).

The axis of rotation is a shaded circle



State clearly which of the diagram(s) the coil when its torque is a maximum and when its torque is a minimum. (2 marks)

Position 1 Maximum Torque

Position 3 Minimum/zero torque

END OF TEST