Western Australian Certificate of Education
ATAR course examination, 2018

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Test 5 - Induced EMF

Student Number: In figures

Mark: $\overline{\quad}$ 64

In words

Time allowed for this paper
Reading time before commencing work: five minutes
Working time for paper: seventy minutes

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens, (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short Answers	-	-	-		
Section Two: Problem-solving	12	12	70	64	100
Section Three: Comprehension	-	-	-	-	-
				Total	100

Instructions to candidates

1. The rules for the conduct of examinations at Holy Cross College are detailed in the College Examination Policy. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. Working or reasoning should be clearly shown when calculating or estimating answers.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

6. Answers to questions involving calculations should be ***evaluated and given in decimal form.*** It is suggested that you quote all answers to ***three significant figures***, with the exception of questions for which estimates are required. Despite an incorrect final result, credit may be obtained for method and working, providing these are ***clearly and legibly set out***.

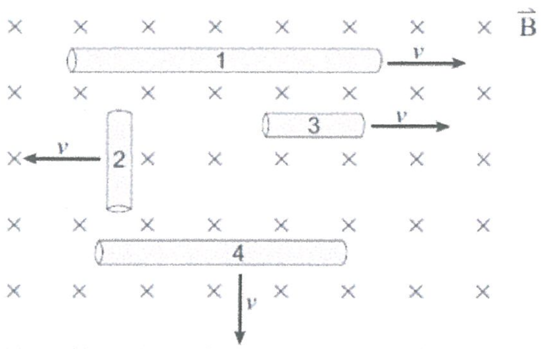
7. Questions containing the instruction "estimate" may give insufficient numerical data for their solution. Students should provide appropriate figures to enable an approximate solution to be obtained. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

8. Note that when an answer is a vector quantity, it must be given with magnitude and direction.

9. In all calculations, units must be consistent throughout your working.

The first 4 questions are multiple choice (1 mark each). Circle the 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?



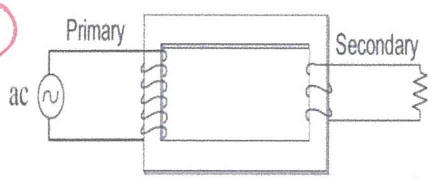
(a) 1 (b) 2 (c) 3 (d) 4

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?

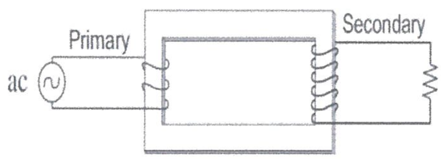
	SECONDARY TURNS	SECONDARY VOLTAGE
A.	40	9.6 V ac
B.	40	1 500 V ac
C.	2 000	30 V ac
D.	2 000	480 V ac

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

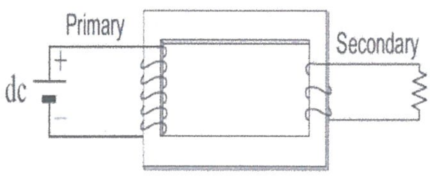
A.



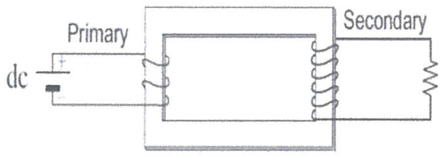
C.



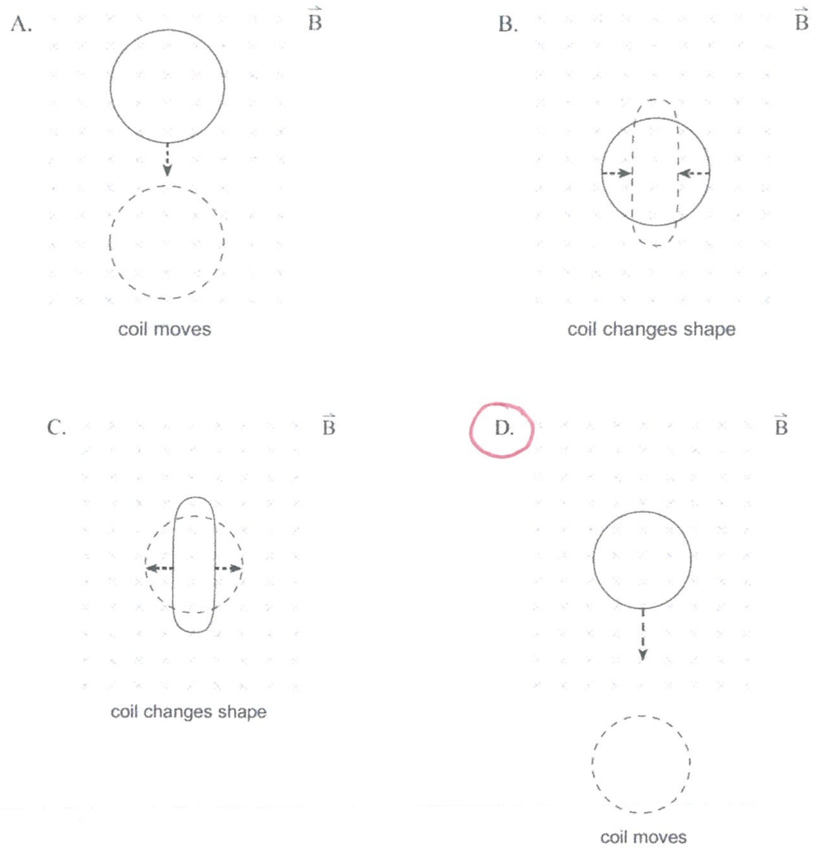
B.



D.

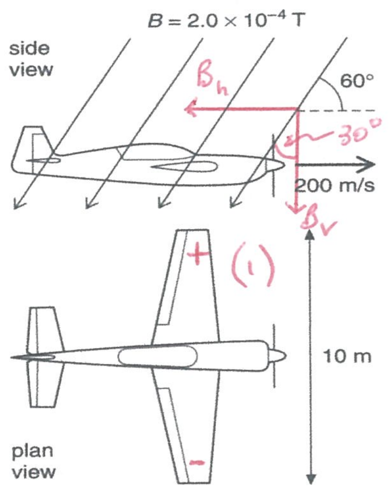


4. In which of the following situations would the greatest EMF be induced in the coil? All changes occur in the same time interval.



5. An aeroplane with a wingspan of 10.0 m is flying horizontally at a velocity of 2.00×10^2 ms^{-1}. In the region the plane is flying, the Earth's magnetic field is 2.00×10^{-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)



$$EMF = B\ell v \quad (1)$$

$$= (2.00 \times 10^{-4} \cos 30.0°)(10.0)(2.00 \times 10^{2}) \quad (1) \quad (1)$$

$$= \underline{0.346\text{ V}} \quad (1)$$

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 0.720 A 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)

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

$$\Rightarrow N_s = \frac{N_p V_s}{V_p} \quad (1)$$

$$= \frac{(360)(12.0)}{(240)}$$

$$= \underline{18} \quad (1)$$

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

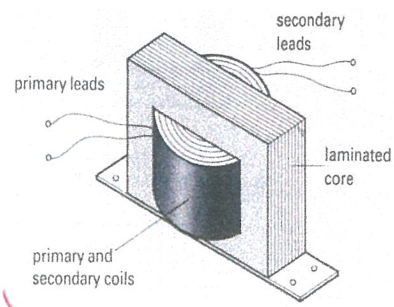
$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

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

$$= \frac{(12.0)(0.720)}{(240)} \quad (1)$$

$$= \underline{3.60 \times 10^{-2}\ A} \quad (1)$$

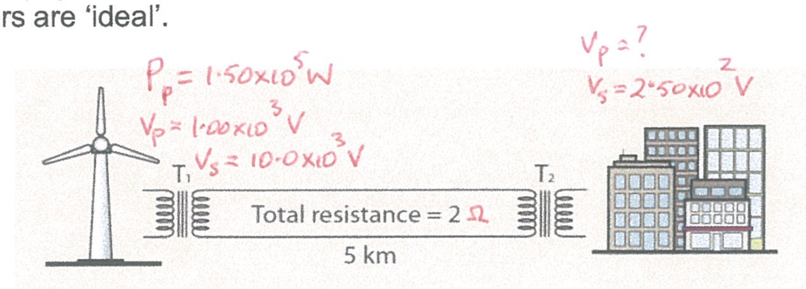
(c) Carefully explain why the core of a transformer consists of many thin laminated sheets bonded together instead of a single solid soft iron cast. (2 marks)



SINGLE CAST - large eddy current induced, creating lots of heat energy and power loss ($P_{loss} = I^2R$). (1)

LAMINATIONS - much smaller eddy currents so less power loss. (1)

7. The diagram shows a wind turbine that runs a 1.50×10^2 kW generator with an output voltage of 1.00 kV. The voltage is increased by transformer T_1 to 10.0 kV 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 2.50×10^2 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)

$$P_s = V_s I_s$$

$$\Rightarrow \quad I_s = \frac{1{\cdot}50 \times 10^5}{10{\cdot}0 \times 10^3}$$

$$= \underline{15{\cdot}0\,\text{A}} \quad (1)$$

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

$$V_{drop} = I_s R_s$$
$$= (15{\cdot}0)(2{\cdot}00)$$
$$= \underline{30{\cdot}0\,\text{V}} \quad (1)$$

$$V_p(T_2) = V_s - V_{drop}$$
$$= 10{\cdot}0 \times 10^3 - 30{\cdot}0$$
$$= \underline{9{\cdot}97 \times 10^3\,\text{V}} \quad (1)$$

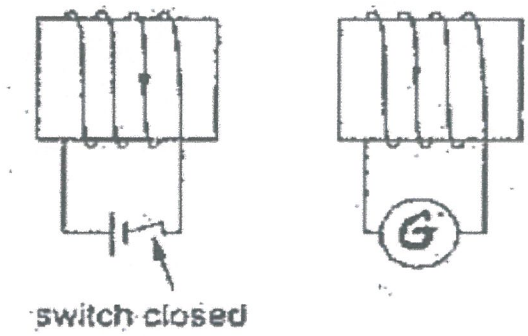
(c) how much power is lost in the power line? Is this a significant problem? (2 marks)

$$P_{loss} = I^2 R$$
$$= (15{\cdot}0)^2 (2{\cdot}00)$$
$$= 4{\cdot}50 \times 10^2\,\text{W} \quad (1)$$

$\therefore$ $\underline{P_{loss} \text{ is insignificant compared to } 1{\cdot}50 \times 10^5\,\text{W}}$ (1)

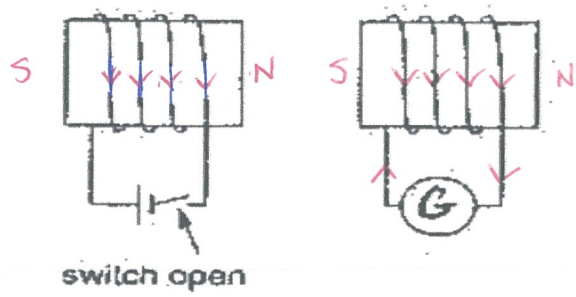
8. (a) Two coils are placed side-by-side so that the magnetic field produced by one of the coils passes through the other. ***Indicate the direction of the induced current through the galvanometer G in the secondary coil, if any.***

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



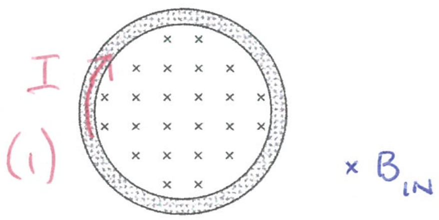
No current (1)

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



Galvanometer needle deflects left. (1)

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

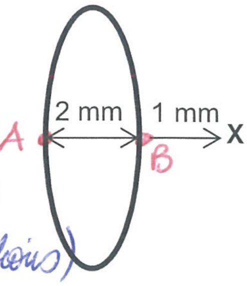


(i) On the figure above, show the direction of the current in the loop. (1 mark)

(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. (1)
- Magnetic field emerges from the N pole. (1)

(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 between the wires.



What is the magnetic field strength at point X, which is 1.00 mm to the right of the centre of the wire loop? (4 marks)

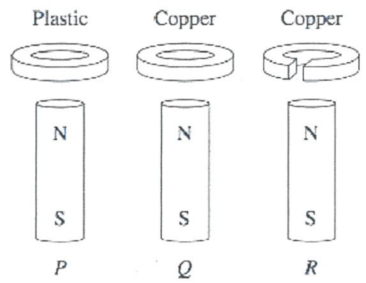
$B_x = B_B - B_A$ (since currents are opposite directions)

$= \frac{\mu_0 I_B}{2\pi d_B} - \frac{\mu_0 I_A}{2\pi d_A}$ (1)

$= \frac{(4\pi \times 10^{-7})(20.0)}{2\pi (1.00 \times 10^{-3})} - \frac{(4\pi \times 10^{-7})(20.0)}{2\pi (3.00 \times 10^{-7})}$ (1)

$= \underline{2.67 \times 10^{-3}\ T \text{ out of the page}}$
(1) (1)

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 reach the bottom of the magnets? Circle your answer. (2 marks)

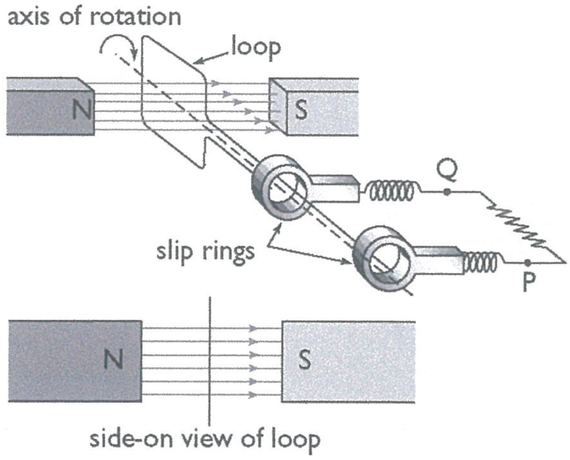
(i) They arrive in the order P, Q and R.
(ii) They arrive in the order P, R and Q.
(1) (iii) Rings P and R arrive simultaneously, followed by Q.
(iv) Rings Q and R arrive simultaneously, followed by P.

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

- Plastic is an insulator so no induced current flows. ($\frac{1}{2}$)
- R is not complete so no induced current flows. ($\frac{1}{2}$)
- Q is complete so an induced current flows. (1)
- This generates a magnetic field that interacts with the external field to generate an opposing force that slows Q. (1)

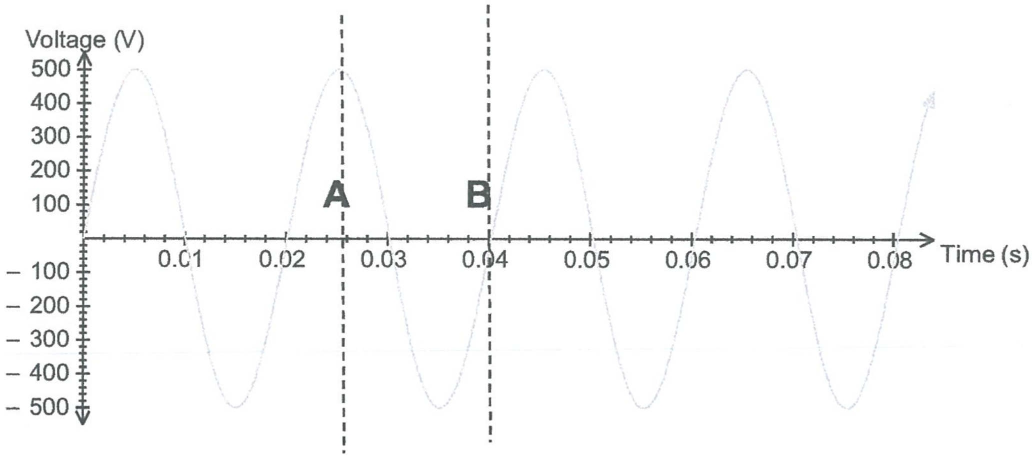
10. The diagram below shows a simple AC electric generator. [15 marks]

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,** in the graph could possibly correspond to the point of rotation shown in the diagram right?

B (1) (1 mark)



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

$$f = \frac{1}{T}$$

$$= \frac{1}{0 \cdot 02}$$

$$= \underline{50\ Hz} \quad (1)$$

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

$$EMF_{rms} = \frac{EMF_{max}}{\sqrt{2}}$$

$$\Rightarrow EMF_{max} = 350\sqrt{2}$$

$$= 495\ V \quad (1)$$

$$EMF_{max} = NBA2\pi f$$

Since $\phi = BA$:

$$\Rightarrow EMF_{max} = N\phi 2\pi f \quad (1)$$

$$\Rightarrow \phi = \frac{EMF_{max}}{N2\pi f}$$

$$= \frac{495}{(500)2\pi(50)} \quad (1)$$

$$= \underline{3 \cdot 15 \times 10^{-3}\ Wb} \quad (1)$$

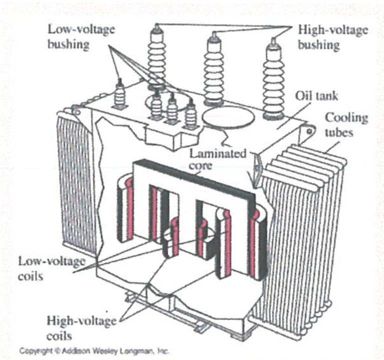
(d) In a commercial power station, the generators have electromagnets to provide the magnetic field. What are some of the advantages and disadvantages of this design principle? (3 marks)

ADVANTAGES
- Stronger magnetic field possible ⇒ greater induced EMF. (1)
- Won't "wear out" like permanent magnets, which lose their field over time. (1)

DISADVANTAGE
- "Cold start" not possible without an external power supply to energise the stator windings. (1)

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)



- Large eddy currents form in the core. (1)
- Power loss occurs ($P_{loss} = I^2R$), producing the heat.
- Large length of wire in the coils generates heat. (1)

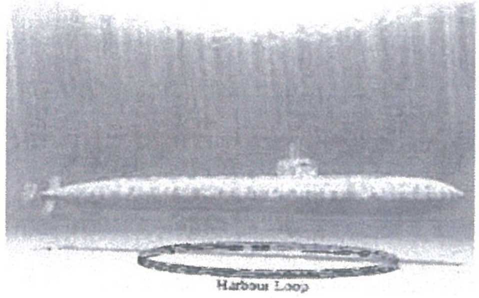
(f) Why is it necessary to step up the voltage before it is transmitted? (2 marks)

- Higher voltage lowers the current for the same power transmitted (1)
- This reduces the power loss across the transmission lines ($P_{loss} = I^2R$). (1)

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

- AC produces a changing magnetic field required in transformers to step up the voltage for transmission to reduce power loss. (1)
- DC does not allow transformers to work and power loss would be significant. (1)

11. 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 the submarine moves over the loop, there is a change in the flux threading it. (1)
- $\frac{\Delta\phi}{\Delta t}$ will reduce. (1)
- As $EMF = \frac{-N\Delta\phi}{\Delta t}$, a current is induced in the loop. (1)

(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)

$$EMF = \frac{-N\Delta\phi}{\Delta t} \quad (1)$$

$$= -\frac{(50)(8.00\times10^{-3})}{(1.00)} \quad (1)$$

$$= \underline{-0.400\ V} \quad (1)$$

(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 1.00% of that induced by the submarine? (3 marks)

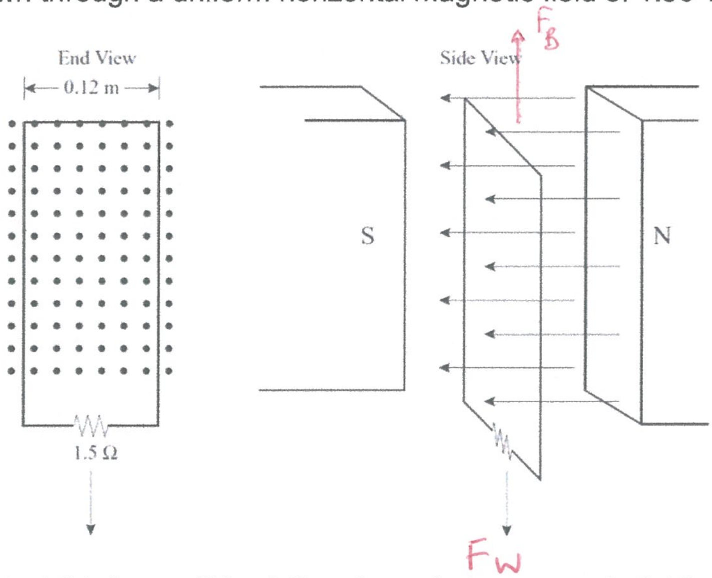
$$EMF = \frac{-N\Delta\phi}{\Delta t} = \frac{-N\Delta B A}{\Delta t}$$

$$\Rightarrow A = \frac{EMF\,\Delta t}{-N\Delta B} \quad (1)$$

$$= \frac{(-0.400)(\frac{1}{100})(1.00)}{-(50)(3.00\times10^{-10})} \quad (1)$$

$$= \underline{2.67\times10^{5}\ m^2} \quad (1)$$

12. A rectangular conducting loop of mass 4.50 x 10^{-2} kg and resistance 1.50 Ω is dropped in the direction shown 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)

$\Sigma F = 0 \Rightarrow F_W = F_B$ (1)

$\Rightarrow mg = IlB$ (1)

$\Rightarrow I = \frac{mg}{lB}$

$= \frac{(4.50 \times 10^{-2})(9.80)}{(0.12)(1.80)}$ (1)

$= 2.04\ A.$ (1)

$EMF = Blv = IR$ (1)

$\Rightarrow v = \frac{IR}{Bl}$

$= \frac{(2.04)(1.5)}{(1.80)(0.12)}$ (1)

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