HOLY CROSS COLLEGE

Life to the Full

# Western Australian Certificate of Education
## ATAR course examination, 2019

### Question/Answer Booklet

# 12 PHYSICS

Name SOLUTIONS

## Test 4 - Induced EMF

Student Number: In figures

Mark: $\overline{\phantom{00}}$
41

In words

## Time allowed for this paper
Reading time before commencing work: five minutes
Working time for paper: fifty 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 | 7 | 7 | 20 | 21 | 51 |
| Section Two: Problem-solving | 3 | 3 | 30 | 20 | 49 |
| 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.

## Section A: Short Answer

Marks Allocated: 21 marks out of 41 total marks.
This section has 7 questions. Answer the questions in the spaces provided.

### Question 1

A metal aircraft with a wing span of 42.0 m flies horizontally with a speed of $1.00 \times 10^3$ kmh$^{-1}$ in a direction due east in a region where the vertical component of the flux density of the Earth's magnetic field is $4.50 \times 10^{-5}$ T.

(a) Calculate the flux cut per second by the wings of the aircraft. **(2 marks)**

$$\frac{\Delta\phi}{\Delta t} = EMF = B\ell v$$
$$= (4.50 \times 10^{-5})(42.0)(277.8) \quad (1)$$
$$= \underline{0.525 \text{ Wbs}^{-1}} \quad (1)$$

(b) What would be the change in the potential difference, if any, if the aircraft flew due west? **(1 mark)**

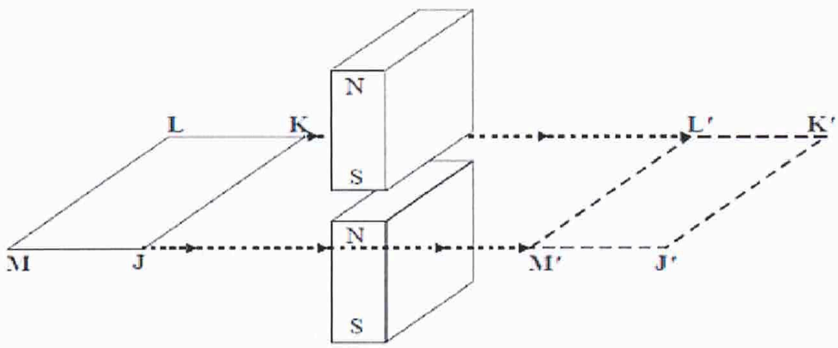
- Potential difference value remains the same.
- Positive end switches to the northern end of the wings.

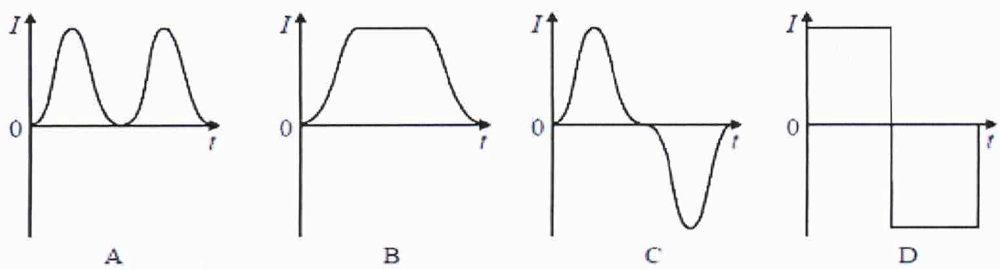
(1)

### Question 2

A rectangular conducting loop is pulled horizontally through the gap between two vertical magnets as shown in the diagram.

Which one of the graphs best represents the variation of loop current ***I*** with time ***t*** as the loop moves at a constant speed from **JKLM** to **J'K'L'M'**?

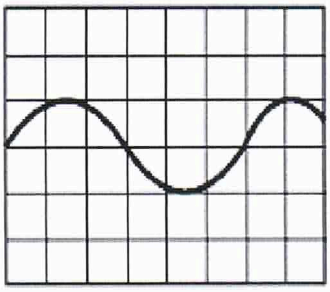


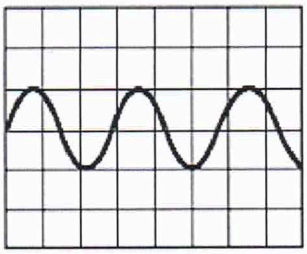

Answer: C (1) **(1 mark)**

## Question 3

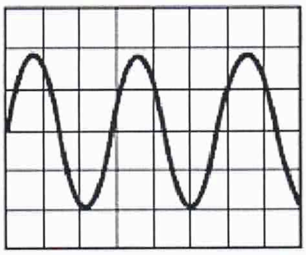
The diagram to the right shows the waveform obtained when the output of a generator is connected to a cathode ray oscilloscope.



Which one of the diagrams below best represents the output when the speed of rotation of the generator is ***doubled*** and no adjustment is made to the oscilloscope?



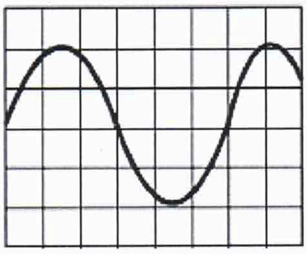
A



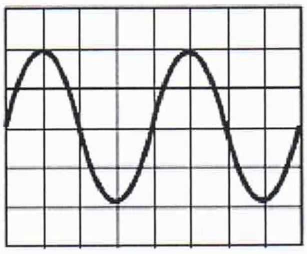
B

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

$$\Rightarrow EMF \propto \frac{1}{\Delta t}$$



C



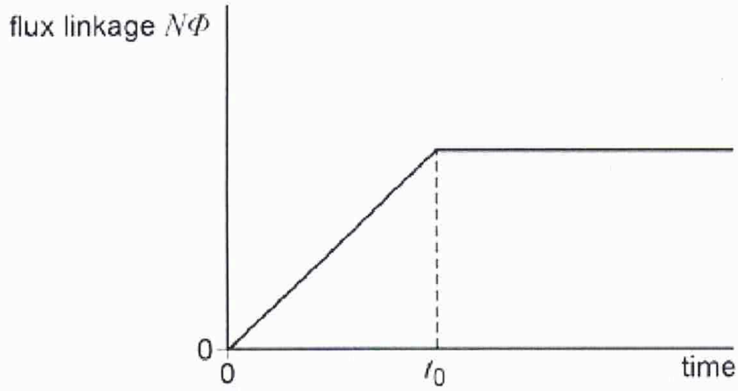
D

Answer: B (1)

**(1 mark)**

## Question 4

The graph shows how the flux linkage, $N\Phi$, through a coil changes when the coil is moved into a magnetic field.




(a) The emf induced in the coil: **(1 mark)**

**A** decreases, then becomes zero after time $t_0$.

**B** increases, then becomes constant after time $t_0$.

(1) **C** is constant, then becomes zero after time $t_0$.

**D** is zero, then increases after time $t_0$.

(b) Explain your choice. **(2 marks)**

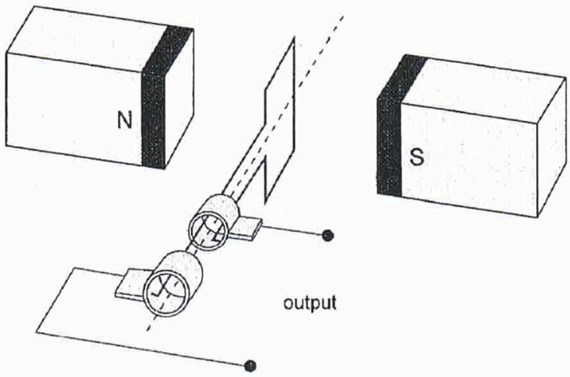
• $EMF = -\frac{N\Delta\phi}{\Delta t} \Rightarrow$ EMF is generated when $\phi$ changes.

• From $t=0$ to $t_0$, $\Delta\phi$ is constant so EMF is constant. (1)

• If $\phi$ is constant, EMF is zero. (1)

**Question 5**

The diagram below shows an AC generator consisting of a rectangular coil with sides 20.0 cm x 30.0 cm and 1000 turns rotating in a uniform magnetic field. The magnetic flux through the coil in the position shown is $3.00 \times 10^{-4}$ Wb.




(a) What is the magnitude of the magnetic field between the magnets? **(2 marks)**

$$B = \frac{\phi}{A}$$

$$= \frac{3.00 \times 10^{-4}}{(0.200)(0.300)} \quad (1)$$

$$= \underline{5.00 \times 10^{-3}\ T} \quad (1)$$

(b) The coil rotates at 50.0 Hz. Calculate the magnitude of the maximum induced EMF in the coil. **(2 marks)**

$$EMF(max) = NBA2\pi f$$

$$= (1000)(5.00 \times 10^{-3})(0.200)(0.300)2\pi(50.0) \quad (1)$$

$$= \underline{94.2\ V} \quad (1)$$

**Question 6**

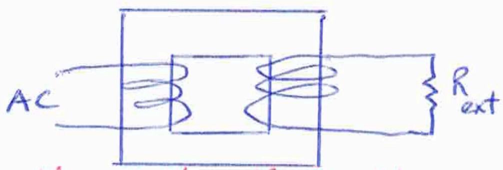
(a) Describe and explain ***two*** features of the core that improve the efficiency of a transformer. **(2 marks)**

- Made of soft iron – concentrates the magnetic field through the secondary coil.
  – reduces hysteresis losses by allowing B to change direction quickly.
- Laminated – reduces the size of eddy currents.

[Any 2 – 1 mark each]

(b) The primary coil of the transformer is connected to a 230 $V_{rms}$ ac supply. The current in the primary coil is 0.300 $A_{rms}$. The secondary coil has 300 turns and provides an output of 20.0 $V_{rms}$ and a power of 65.0 W.

(i) Calculate the number of turns on the primary coil. **(1 mark)**




$V_p = 230\text{V}$ $V_s = 20.0\text{V}$
$I_p = 0.300\text{A}$ $I_s = ?$
$N_p = ?$ $N_s = 300$
$P_p = ?$ $P_s = 65.0\text{W}$

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

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

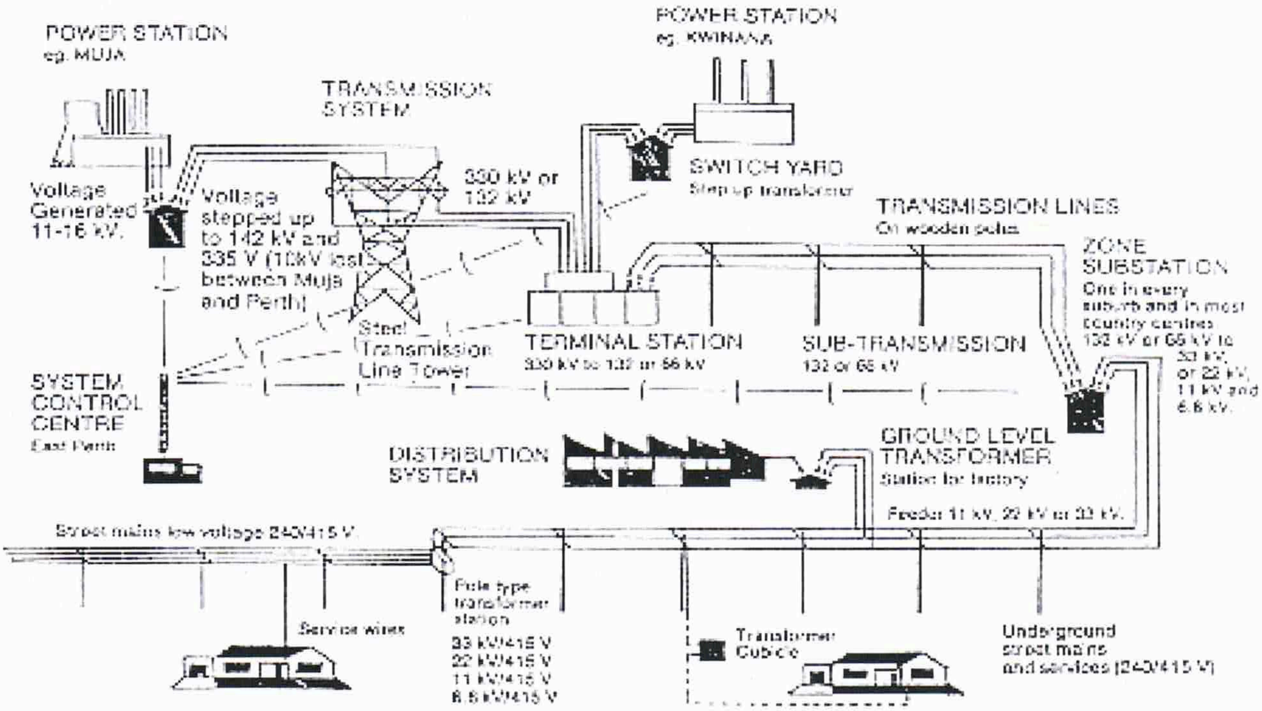
$$= \frac{(230)(300)}{(20.0)} = \underline{3.45 \times 10^3 \text{ turns}} \quad (1)$$

(ii) Calculate the efficiency of the transformer. **(2 marks)**

$$P_p = V_p I_p$$
$$= (230)(0.300)$$
$$= 69.0 \text{ W} \quad (1)$$

$$\%\text{ eff} = \frac{P_s}{P_p} \times \frac{100}{1}$$
$$= \frac{65.0}{69.0} \times \frac{100}{1}$$
$$= \underline{94.2\%} \quad (1)$$

## Question 7



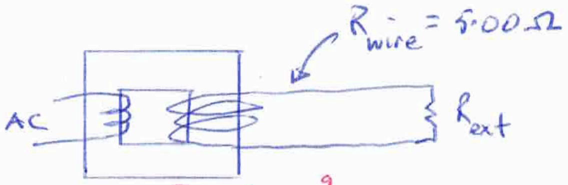

– *How electricity is transmitted from power stations to customers.*

The diagram above shows the power transmission grid for the Perth region. The power is generated at a voltage of 11.0 – 16.0 kV, transmitted at 132 kV and supplied to houses and industry at 240 V or 415 V.

The demand for power in Perth can reach 1.80 x $10^3$ MW during peak loadings.

Given that the resistance of the power lines from Muja to Perth (2.50 x $10^2$ km away) is 5.00 Ω, calculate the ***percentage power loss,*** assuming it is transmitted at 330 kV.

**(4 marks)**




$P_s = 1.80 \times 10^9$ W
$V_s = 3.30 \times 10^5$ V
$I_s = ?$

$P_s = V_s I_s$

$\Rightarrow I_s = \dfrac{1.80 \times 10^9}{3.30 \times 10^5}$ (1)

$= 5.45 \times 10^3$ A (1)

$P_{loss} = I^2 R$

$= (5.45 \times 10^3)^2 (5.00)$

$= 1.49 \times 10^8$ W (1)

$\% \text{ loss} = \dfrac{1.49 \times 10^8}{1.80 \times 10^9} \times \dfrac{100}{1}$

$= 8.28\,\%$ (1)

**Section B: Problem Solving**
Marks Allocated: 20 marks out of 41 total marks
This section has 3 questions. Answer the questions in the spaces provided.

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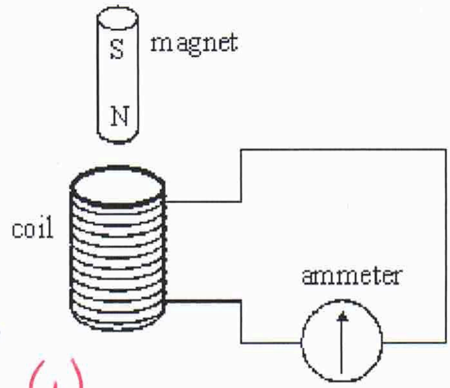
**Question 8**




A coil is connected to a centre zero ammeter, as shown. A student drops a magnet so that it falls vertically and completely through the coil.

(a) Describe what the student would observe on the ammeter as the magnet falls through the coil. **(2 marks)**

• Needle would move to the right as the magnet enters the coil. (1)

• The needle will deflect left to a larger value as the magnet leaves the coil. (1)

(b) If the coil were not present, the magnet would accelerate downwards at the acceleration due to gravity. State and explain how its acceleration in the student's experiment would be affected, if at all, ***as it left the coil***. **(2 marks)**

• Acceleration is $< 9.80\ ms^{-2}$. (1)

• The induced current in the coil tries to attract the magnet upwards, reducing the acceleration. (1)

(c) Suppose the student forgot to connect the ammeter to the coil, therefore leaving the circuit incomplete, before carrying out the experiment. Describe and explain what difference this would make to your conclusions in part (b). **(3 marks)**

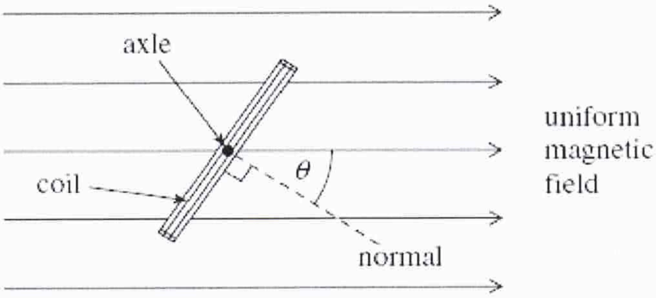
• There is an incomplete circuit ~~so~~ no induced current can flow. (1)

• No opposing magnetic field can be induced. (1)

• The magnet accelerates at $9.80\ ms^{-2}$. (1)

**Question 9**

The figure below shows an end-view of a simple electrical generator. A rectangular coil is rotated in a uniform magnetic field with the axle at right angles to the field direction. When in the position shown in the figure below, the angle between the direction of the magnetic field and the normal to the plane of the coil is $\theta$.



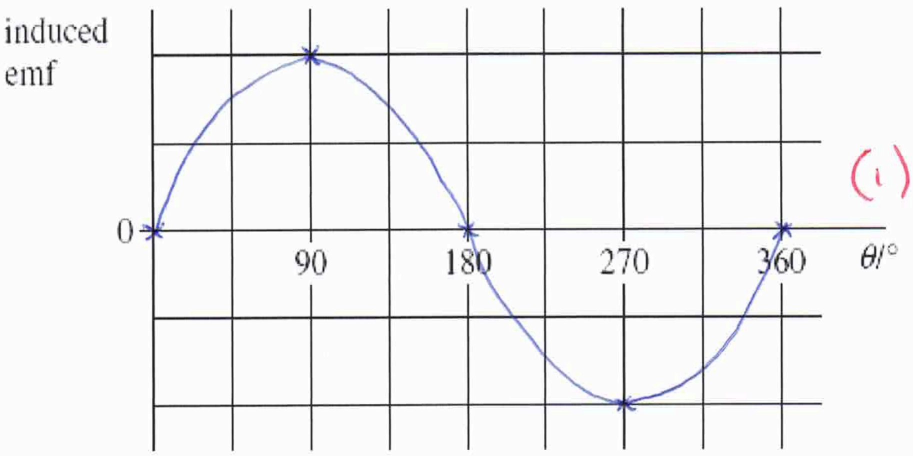

(a) The coil has 50 turns and an area of $1.9 \times 10^{-3}$ m$^2$. The flux density of the magnetic field is $2.8 \times 10^{-2}$ T. Calculate the ***flux linkage*** for the coil when $\theta$ is 35°, expressing your answer to an appropriate number of significant figures. **(3 marks)**

$$\phi = NBA$$
$$= (50)(2.8 \times 10^{-2} \cos 35°)(1.9 \times 10^{-3}) \quad (1)$$
$$= \underline{2.2 \times 10^{-3} \text{ Wb}} \quad (1)$$

[Must be 2 sig. fig - 1 mark]

(b) The coil is rotated at constant speed, causing an EMF to be induced.

(i) Sketch a graph on the outline axes to show how the induced EMF varies with angle $\theta$ during one complete rotation of the coil, starting when $\theta = 0$. Values are not required on the EMF axis of the graph. **(1 mark)**



(ii) Give the value of the flux threading the coil at the positions where the EMF has its greatest value. **(1 mark)**

- zero (1)

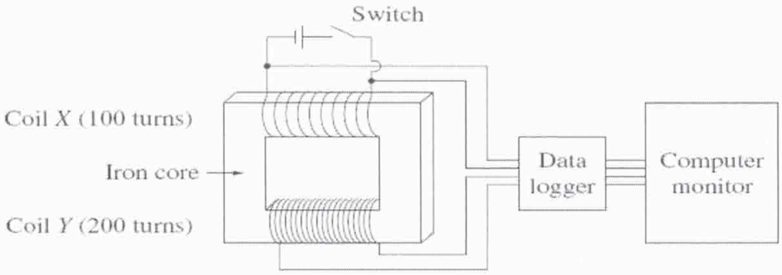
(iii) Explain why the magnitude of the EMF is greatest at the values of $\theta$ shown in your answer to part (b)(i). **(3 marks)**

- When $\theta = 90°$, the side of the coil is moving at right angles to B. (1)
- It is cutting the maximum number of flux lines. (1)
- Max EMF occurs when a conductor moves at right angles to B at $\theta = 90°$ and $270°$. (1)

**Question 10**

In a school experiment, students are constructing a transformer.

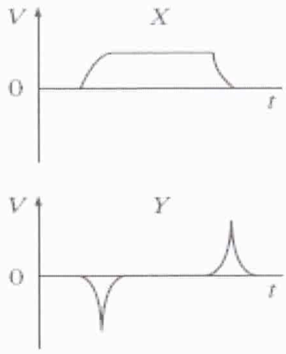
They set up the apparatus as shown in the diagram.



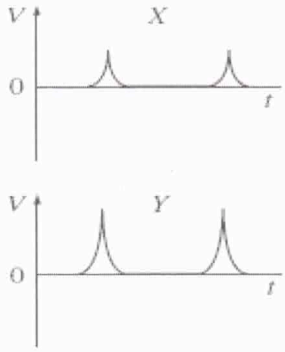

(a) While using the set up as shown in the diagram above, a student closes the switch for a short time, and then re-opens it. The data logger records the values for the voltage of both coil X and coil Y and displays it as voltage-time graphs.

Which of the following pairs of graphs best depicts the student's results? **(1 mark)**

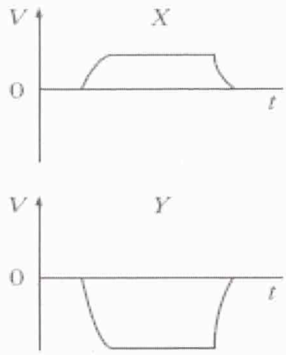
(1) (A)



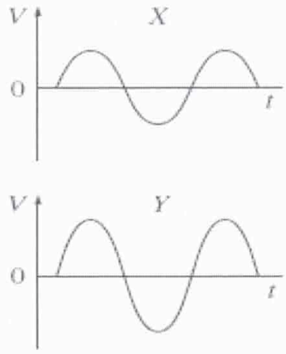

(B)




(C)




(D)




(b) The students realise that their 'transformer' is plugged into a DC power source and does not function correctly. The students change the input to an AC source and the transformer functions correctly. Explain why AC is necessary as an input current source for transformers. **(3 marks)**

- The current in the primary coil needs to alternate direction to produce a changing magnetic field. (1)
- The core concentrates the changing magnetic field through the secondary coil, which induces an alternating current. (1)
- A direct current will rise to a maximum and remain constant, so B does not change and no current is induced. (1)