# 11.1 Electromagnetic Induction

## Question Paper

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|---|---|
| Course | DP IB Physics |
| Section | 11. Electromagnetic Induction (HL only) |
| Topic | 11.1 Electromagnetic Induction |
| Difficulty | Hard |

**Time allowed:** 60

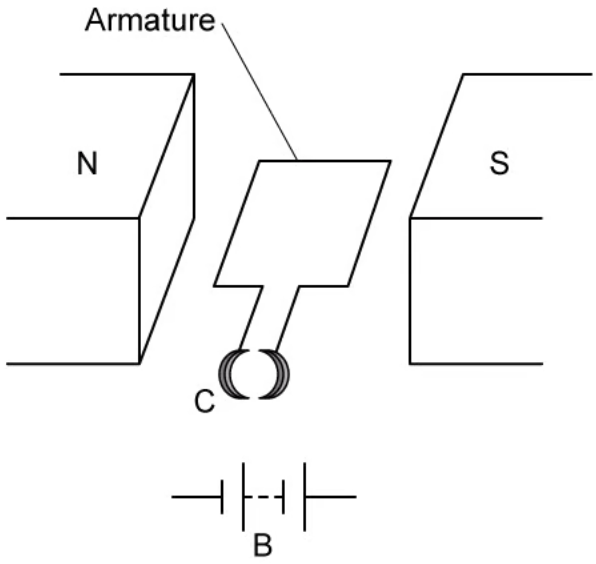
**Score:** /44

**Percentage:** /100

## Question 1a

The diagram below is a representation of a simple dc electric motor. The armature consists of a single rectangular coil and rotates between the poles of a permanent magnet.

The connections between the coil and battery B are not shown. The split ring is labelled C.




(a)
For this circuit

(i)
Complete the circuit by drawing the missing components onto the diagram.

[1]

(ii)
State the direction of the motion of the coil.

[1]

(iii)
Describe how the connections from battery B to the split ring enable the coil to rotate continuously in one direction.

[3]

**[5 marks]**

## Question 1b

An ac generator consists of a coil between two magnets. The coil starts in the vertical position and rotates.

(b)
State and explain the shape of the graph of emf generated by this configuration over time.

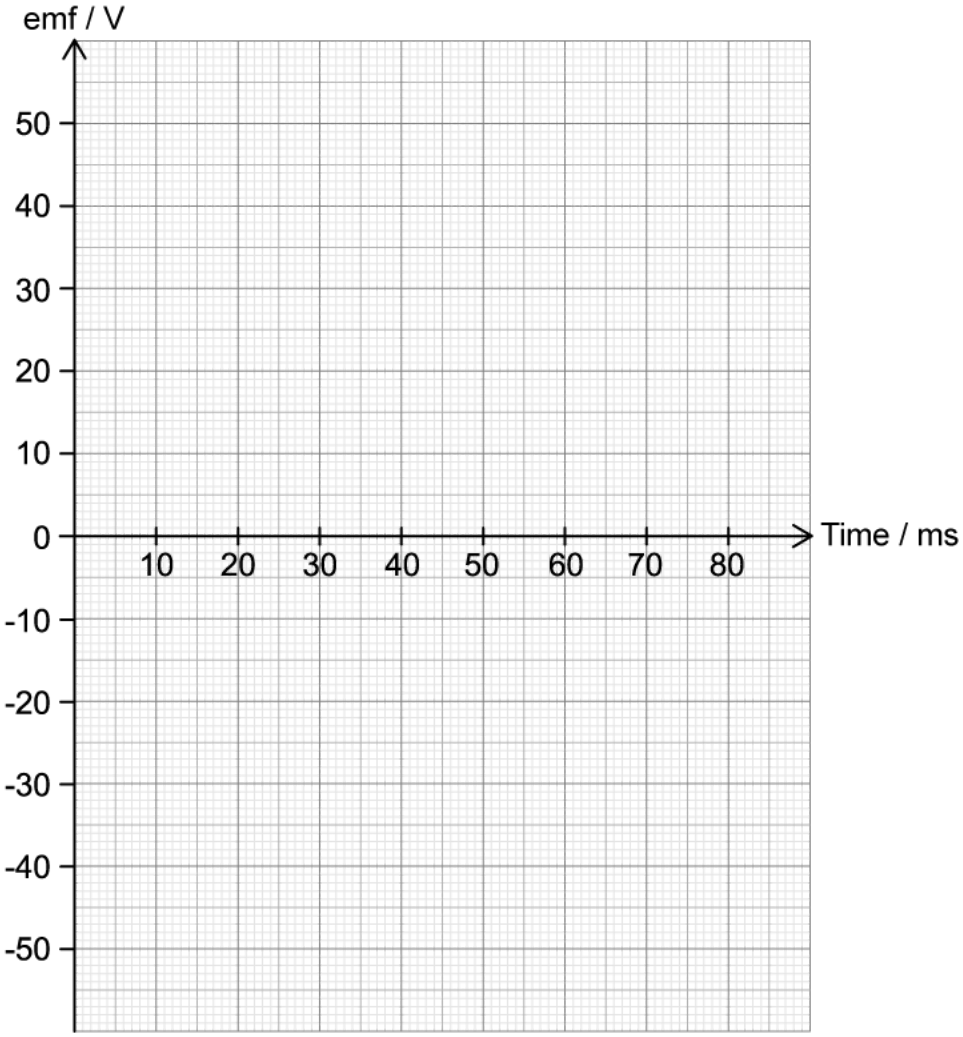
[2]

**[2 marks]**

## Question 1c

The coil starts in the vertical position and rotates with a frequency of 25 Hz. The root mean square value of the current is 0.71 mA and the wires have a resistance of 50 kΩ.

(c)
Sketch a graph to show the e.m.f generating in the coil.



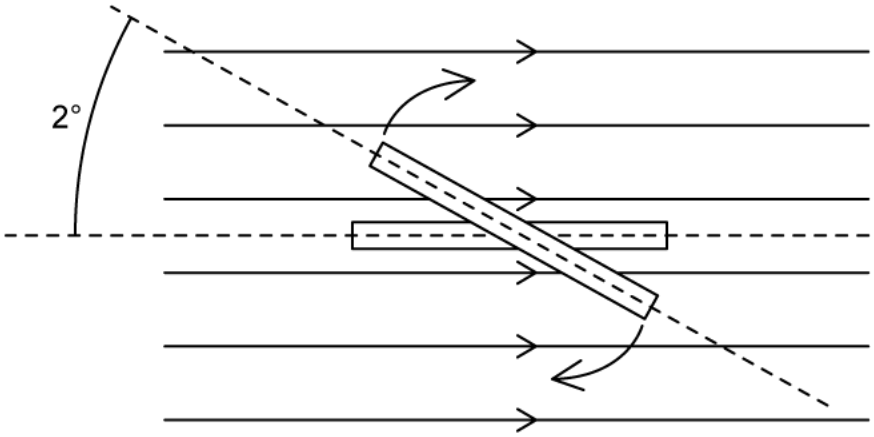

[3]

**[3 marks]**

## Question 1d

A different coil of length 4050 mm and 3700 mm width is now used in the same generator in a magnetic flux density of 0.98 T. The coil has 62 turns and rotates at the same frequency as the previous coil, 25 Hz.

(d)
Calculate the magnitude of the e.m.f. generated by the coil when it moves through an angle of 2.0° from an initially horizontal position.



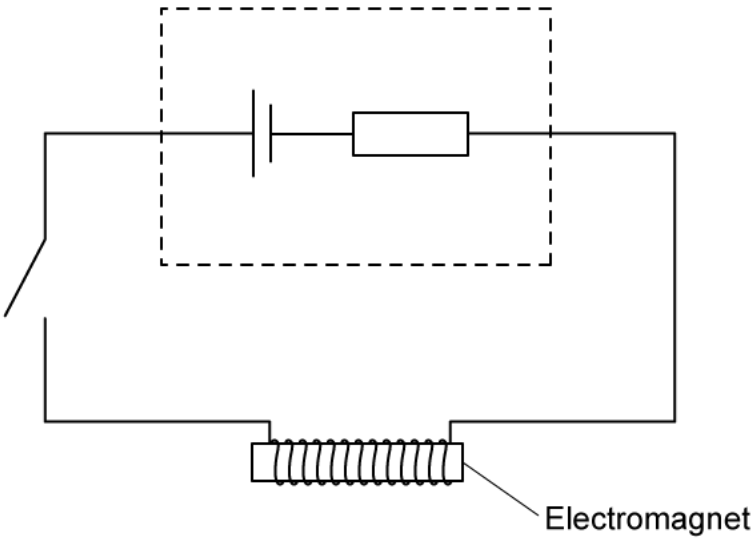

[3]

**[3 marks]**

## Question 2a

This question is about the motional e.m.f. which can be induced in different situations.

A circuit is set up as shown and then the switch is closed so that current can flow. Observations are made for the first 100 ms.




(a)
Explain the effects on the electromagnet of the switch being closed. The analysis should make reference to the expected changes in current, e.m.f. and energy.

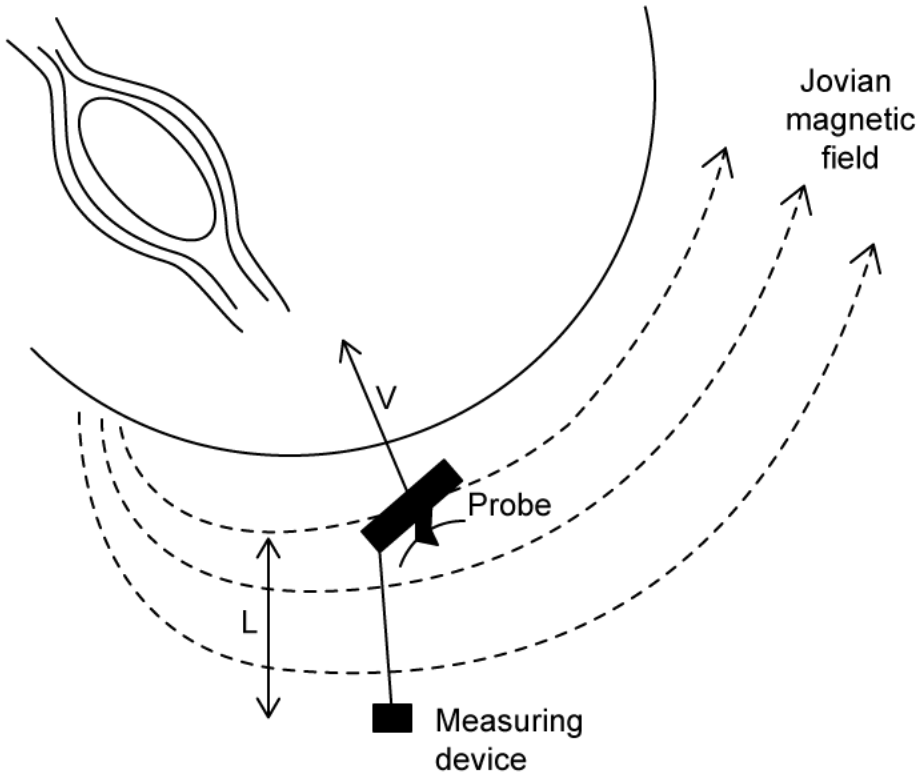
[6]

**[6 marks]**

## Question 2b

An unmanned probe is in orbit around Jupiter at right angles to the planet's magnetic field. The probe launches a remote measuring device which remains connected to it by a conducting cable.

When the probe and the device are at a distance *L* the cable is held in a straight line which is also perpendicular to Jupiter's magnetic field.




(b)
For the motion of the cable in the magnetic field

(i)
Sketch a labelled diagram to show the cable, field lines and direction of the force on the electrons within the cable.

[2]

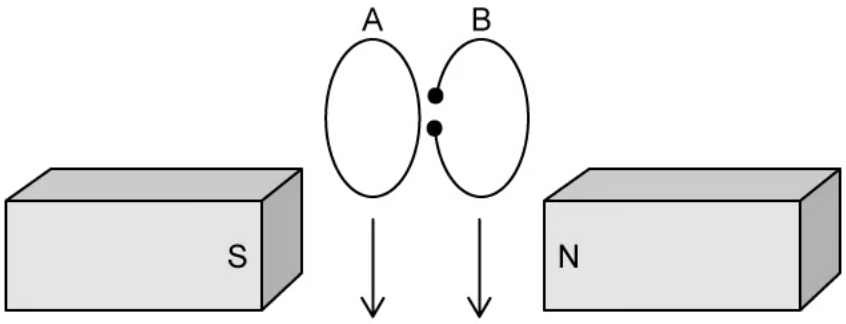
(ii)
The magnetic field vector *B* is at an angle $\theta$ to the field lines. Deduce an expression for the motional e.m.f. which is induced in the conducting wire.

[3]

**[5 marks]**

## Question 3a

In an experiment two metal rings A and B are dropped from the same height between two magnets. The rings are identical, apart from a small slit cut in B.

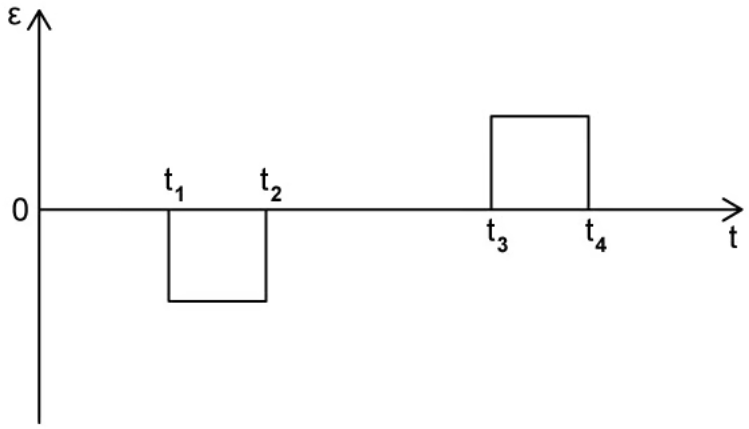



(a)
Describe and explain the motion of A and B as they fall between the magnets. The use of sketches to illustrate is encouraged.
[5]

**[5 marks]**

## Question 3b

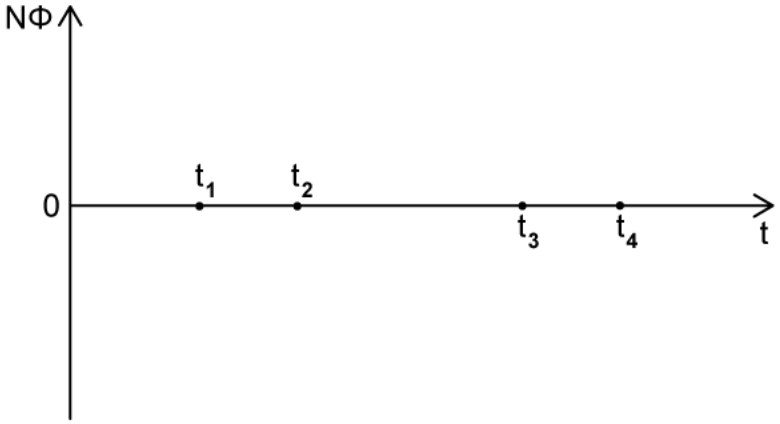
In a thought experiment the variation of induced e.m.f. $\varepsilon$ in a coil with time is considered.




Students are asked to discuss the properties of the graph shown above to determine how it might be reproduced.

(b)

Use the axes provided to sketch a graph of the magnetic flux linkage $N\Phi$ through the conductor between $t = 0$ to $t = t_4$.

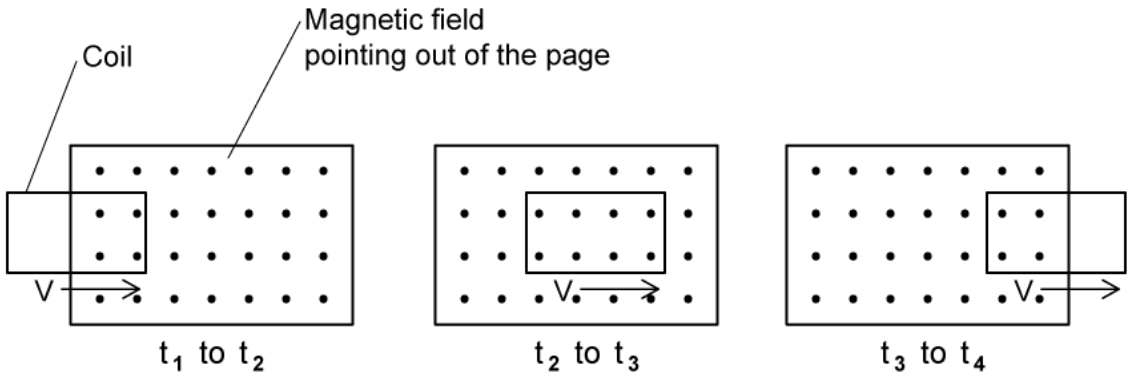



[5]

**[5 marks]**

## Question 3c

The graph in part (b) was produced using a coil moving at constant speed into and then out of a uniform magnetic field. The motion is represented in the diagram.




(c)

By analysing the stages of the motion explain why no induced e.m.f. is seen for the section $t_2$ to $t_3$ although the coil can be described as 'cutting magnetic field lines' at that time.

[2]

**[2 marks]**

## Question 3d

An experiment is designed to model an aeroplane flying parallel to the Earth's surface at a constant speed $v$.

The wingspan of the plane is modelled by a thin metallic rod of length $L = 75.0$ cm which is connected to a voltmeter. The Earth's magnetic field is at 70° to the vertical and has a flux density of $1.8 \times 10^{-4}$ T.

(d)

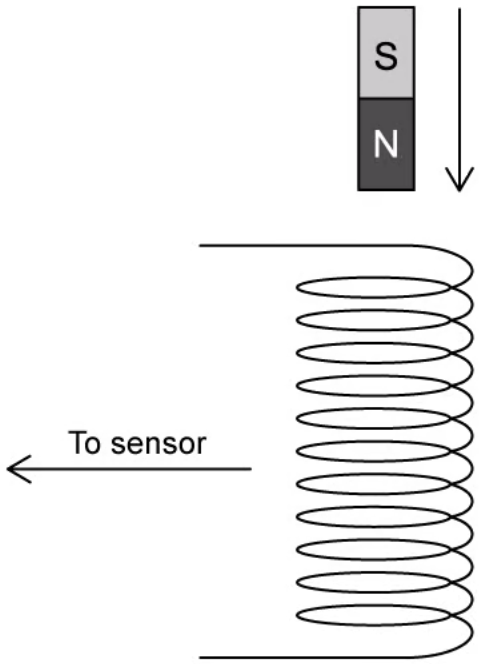
Determine the speed at which the metal rod would need to be propelled to generate an emf of 0.15 mV across the ends.

[2]

**[2 marks]**

## Question 4a

A magnet is dropped through a vertical solenoid.




(a)

On the axes provided sketch a graph of the expected e.m.f. as time progresses.

[3]


**[3 marks]**

## Question 4b

(b)
Explain the shape of the graph from part (a).

[3]

**[3 marks]**