2018 Physics ATAR

Electromagnetism II

DC/AC motors

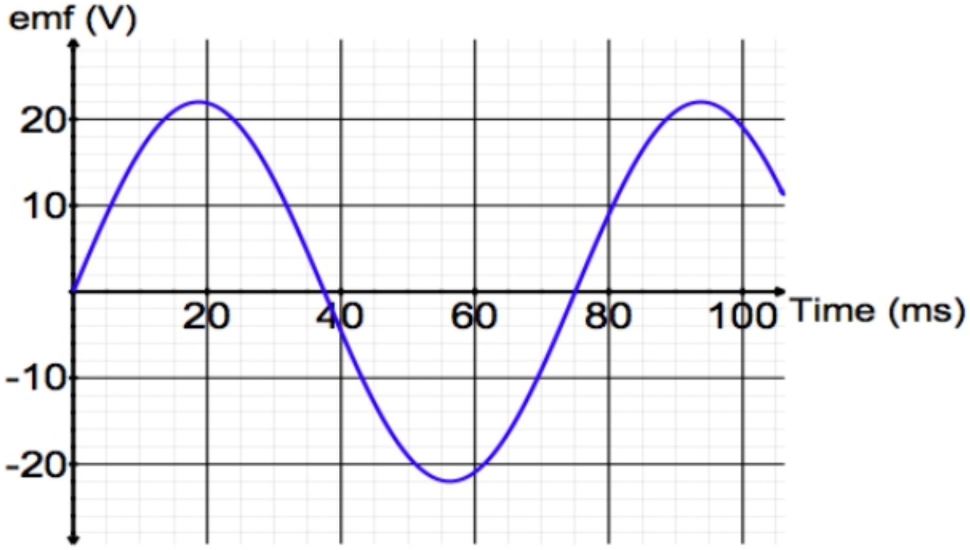
AC generators

Induced EMF

Transformers

Faraday/Lenz Law

The emf output of an AC generator is shown on the graph below.



Determine the RMS voltage of this AC generator. Show how you obtained your data from the graph.

(2)

Diagram 1 shows an AC generator. A rectangular coil is being rotated anticlockwise (as viewed from the slip rings) between the magnetic poles. A uniform magnetic field of flux density 0.162 T exists between the magnetic poles. The dimensions of the coil are 18.0 cm by 8.00 cm. The coil has 800 turns of wire and is rotated uniformly at 1440 rpm.

Diagram 1 – AC generator

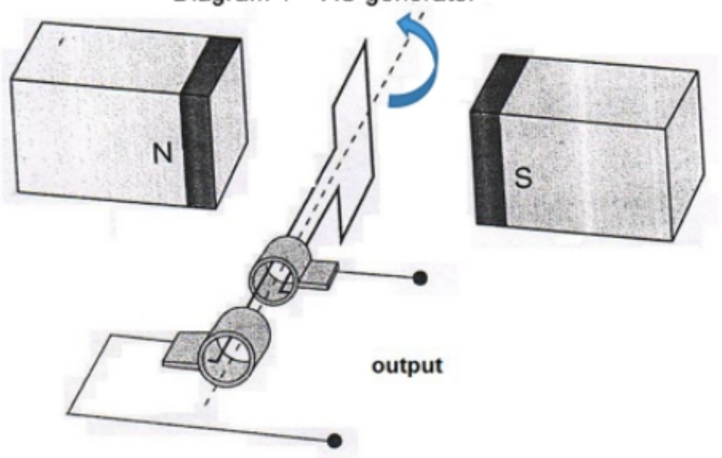
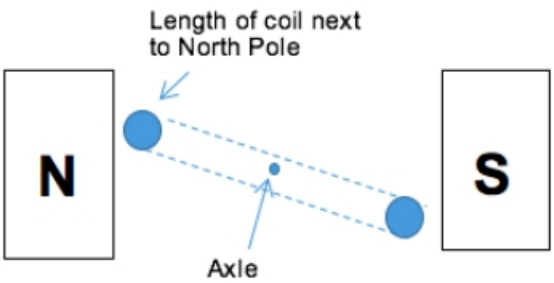


Diagram 2 – The AC generator viewed from the front (location of the slip rings) after the coil has been rotated anticlockwise by 70° from the position shown in Diagram 1.



a) Consider Diagram 2. What is direction of current in the length of wire next to the North magnetic pole? Circle a response. (1)

Into the page   Out of the page   Impossible to determine

b) Briefly describe how you arrived at your answer for the previous question (1)

c) At the instant shown in diagram 2, the magnitude of emf is: (circle a response) (1)

Increasing   Zero   Decreasing   Staying Constant

d) Explain your response to the previous question. (2)

e) As the coil continues to rotate from the position shown in Diagram 2, the direction of emf will reverse at a certain point. Determine how many degrees from the position shown that this will occur next. (1)

f) Calculate the maximum emf (V_{max}) for the AC generator shown in Diagrams 1 and 2. (3)

Diagram 3 shows a simple DC motor. It rotates clockwise as viewed from the commutator when the switch is turned on. A uniform magnetic field exists between the magnetic poles. Conducting coil JKLM is connected to the external battery via the split ring commutator.

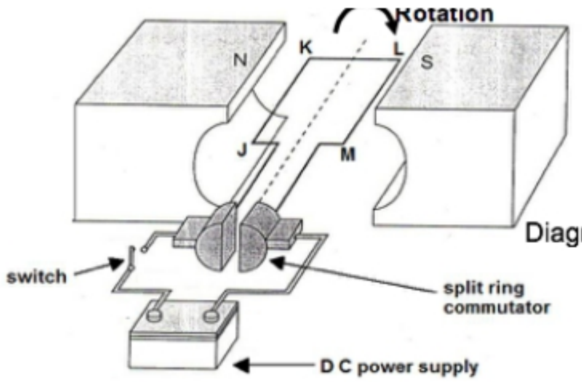


Diagram 3

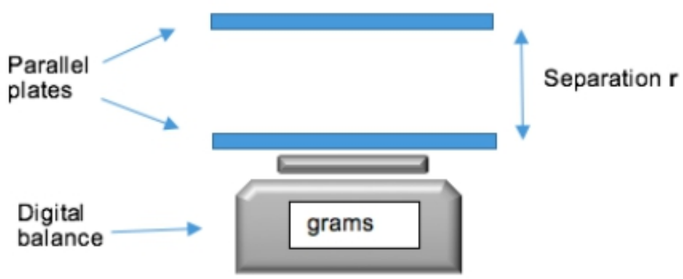
g) Explain briefly why the torque output of the motor is not constant.

(2)

h) Explain briefly why the net current flowing through the coil decreases as the motor speed increases.

(2)

A group of physics students devised an investigation to determine the value of Permittivity in free space – the electric constant $\boldsymbol{\varepsilon_0}$. They set up the equipment shown in the diagram. Two flat parallel aluminium plates could be separately stripped of electrons to give a charge of 2.20 x 10^{-7} C on each plate. The bottom plate was placed on a digital balance that read in grams. The balance was tared (set to zero) before the plates were charged. When the plates were charged the balance reading could be converted to the electrostatic force of repulsion experienced by the bottom plate. The top plate was clamped firmly in a plastic stand. The separation **r** between the plates was set with a Vernier gauge.



The students referred to the following equation and decided to linearise their data by plotting a graph of Force **F** on the y-axis versus $\frac{1}{r^2}$ on the x-axis. They determined the value of $\boldsymbol{\varepsilon_0}$ by referring to the gradient of the line of best fit.

$$F = \frac{1}{4\pi\,\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

The students decided to work with a relative uncertainty of ±10% for the mass readings. They converted this to an absolute uncertainty for the Force values.

Table of results

Separation r (m)	***1r2*** **(m^{-2})**	**Balance reading (grams)**	***Electrostatic Force*** **(N)**
0.065	234	10.51	0.103 ± 0.010
0.070		9.18	
0.080		6.94	
0.100		4.29	
0.120	69.4	3.16	0.031 ± 0.003

a) Complete the second column of the table for $\frac{1}{r^2}$. Two values have been done for you.

(1)

b) Complete the fourth column of the table for Electrostatic force and include the appropriate uncertainty range. Two values have been done for you.

(2)

c) Plot a graph of F versus $\frac{1}{r^2}$. You must include a line of best fit and error bars.

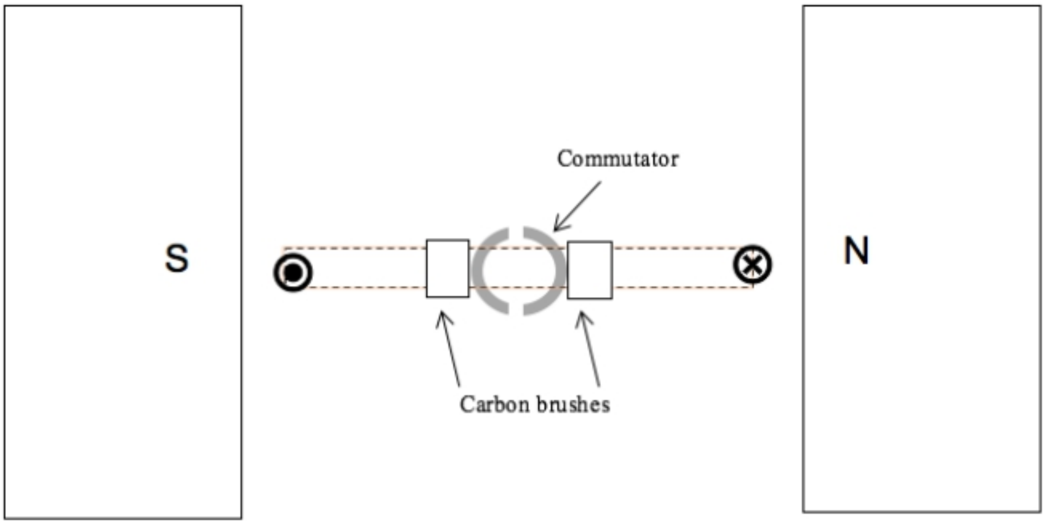
If you need to make a second attempt, spare graph paper is at the end of this question. Indicate clearly if you have used the second graph and cancel the working on the first graph.

(6)

d) Calculate the gradient of your line of best fit from your graph showing all working. (No units are required).

(3)

The diagram shows the side view of a DC electric motor. A square coil is placed flat in the uniform magnetic field between the North and South magnetic poles. Current direction in the coil is shown on the sides adjacent to the magnetic poles. The commutator and carbon brushes are also shown.



a) In which direction will the coil turn from this start position?

(1 mark)

b) Explain the function of the brushes and the function of the commutator.

(3 marks)

c) On the diagram above, use the symbols ⦿ and ⊗ to sketch the location of the coil sides adjacent to the magnetic poles after 30.0° of rotation from this start position. Put arrows on your symbols to indicate the direction of magnetic force acting on them.

(2 marks)

d) At this new position after 30.0° of rotation from the start position; determine the torque value of the motor as a percentage of maximum torque.

(2 marks)

e) A single 120 mm length of wire, adjacent to one of the magnetic poles, experiences a 0.0280 N magnitude of force when a current of 5.30 A is present. Calculate the magnetic flux density between the poles.

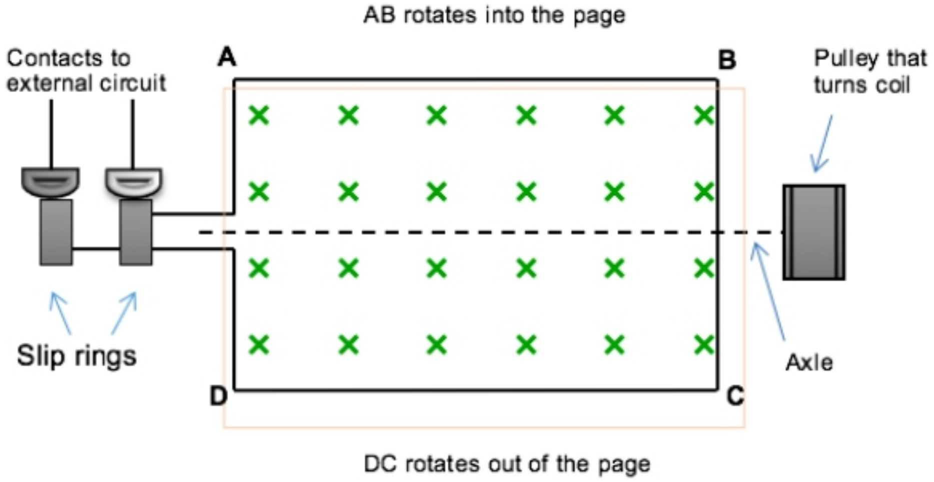
(2 marks)

f) After the motor is switched on its rate of rotation increases. As this happens the net current in the coil decreases. Clearly explain why this happens.

(3 marks)

The diagram shows the coil ABCD of an AC generator placed between magnetic poles.

- The uniform magnetic field of flux density 0.204 T is indicated.
- The dimensions of the coil are: AB = DC = 16.0 cm and AD = BC = 10.0 cm
- The coil rotates about the axle as indicated as a torque is applied to the pulley.
- The coil has 350 turns of wire and is rotated at 750 rpm.



a) Calculate the flux contained within the coil ABCD at the instant shown.

(2 marks)

b) Draw on the diagram the direction of induced current along AB and DC as the coil rotates from the position shown and explain briefly how you arrived at your answer.

(2 marks)

c) To get the coil to turn a torque is applied on the pulley. Explain why a counter-torque is also applied to the pulley as this happens.

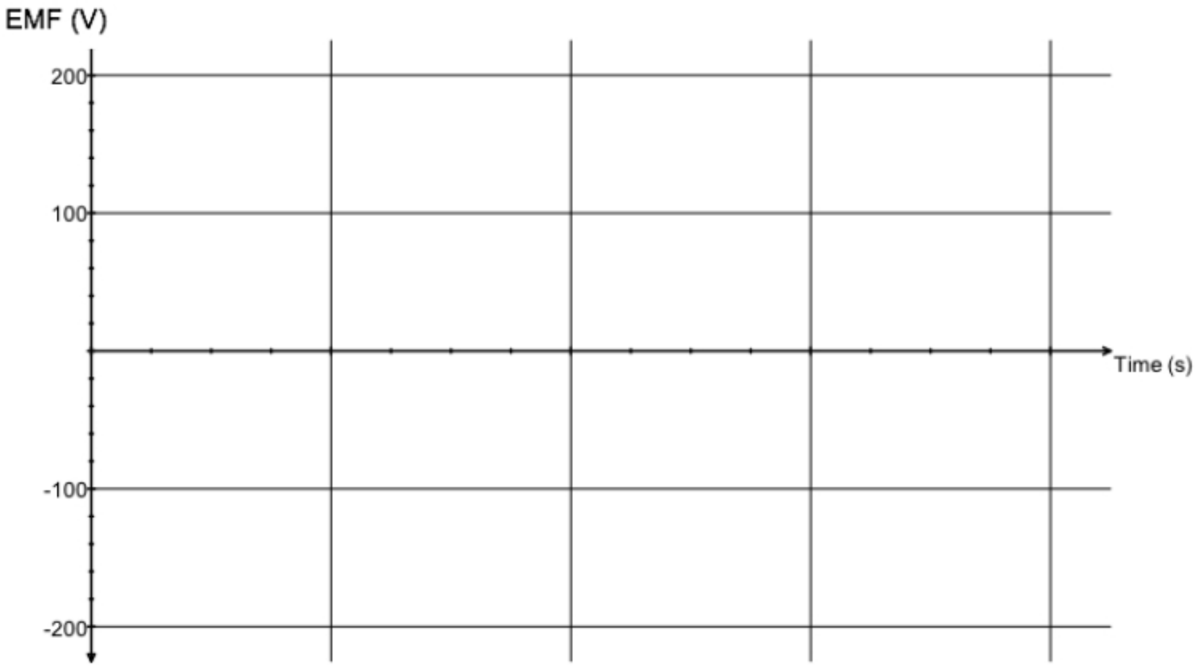
(2 marks)

d) Calculate the magnitude of the maximum emf from the AC generator.

(3 marks)

e) On the axes shown below, sketch the shape of the emf output for this generator as it rotates one full turn from the initial position shown. Add a suitable numerical time scale on the time axis and label your curve '750 rpm'.

(3)



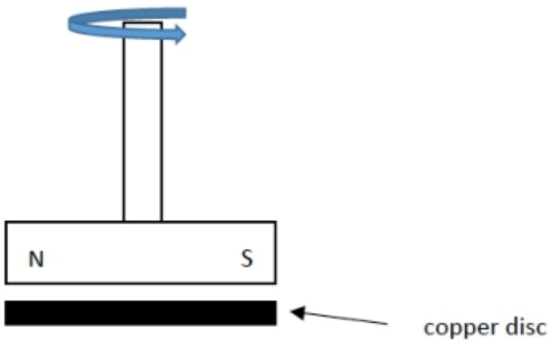
f) Sketch a second shape of the emf output for a rate of rotation of 1500 rpm and label this curve '1500 rpm'.

(2)

A current-carrying straight conductor is placed in a magnetic field and experiences a magnetic force equal to 75% of the maximum value this force could be in this field. Calculate the size of the angle 'θ' between the conductor and the magnetic field. Show working.

(3 marks)

A simple analogue car speedometer utilises magnetic properties in its operation. Its main components consist of a rotating bar magnet placed above a circular copper disc (see the diagram below).



As the bar magnet rotates in the manner shown, the copper disc follows it by rotating in the same direction. Explain why.

(4 marks)

Khai has a study lamp that uses a 35 W globe that operates at 24 V_{RMS}. The lamp plugs into the house mains 240 V_{RMS} power supply; consequently, it has a transformer placed in its base that allows the lamp to transform the voltage to the required value. The transformer can be assumed to be ideal. The secondary coil has 30 turns.

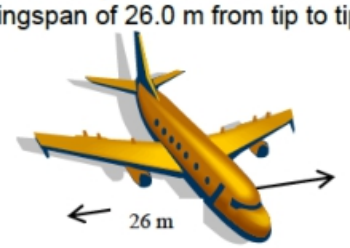
a) Calculate the number of turns on the primary coil.

(2 marks)

b) Calculate the RMS current flowing in the primary coil of the lamp when it is operating if the transformer is 84% efficient at transferring energy from the primary coil to the secondary coil.

(3 marks)

1. An aluminium plane maintains a constant altitude and is flying due West near Darwin where the Earth's magnetic field has a flux density of 5.50×10^{-5} T at an angle of dip of 54.0° to the horizontal. The plane has a wingspan of 26.0 m from tip to tip.



a) Calculate the magnitude of the flux density component that is being cut by the horizontal wings of the plane.

(2)

b) The jet's safety equipment detects a potential difference of 75.2 mV between each wing tip. Determine the speed of the plane.

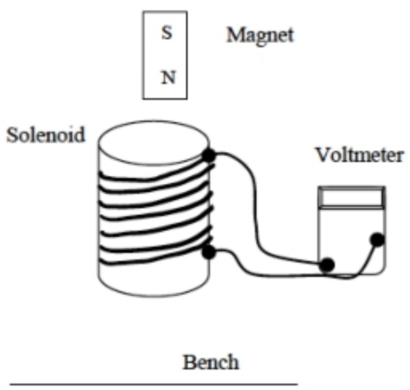
(2)

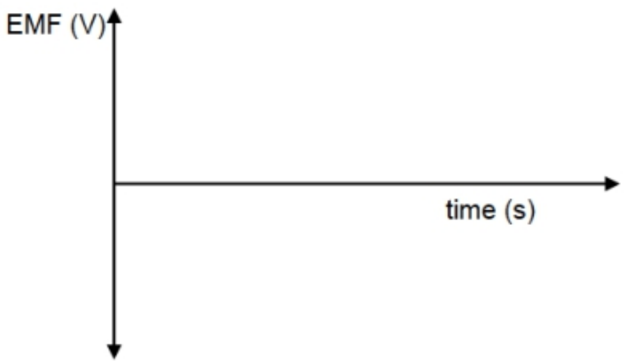
c) On which wing tip (North or South) would there be a positive charge? Explain briefly.

(2)

3. A permanent magnet is dropped through a hollow core solenoid which is connected to a voltmeter. Sketch the shape of an emf graph for this situation.

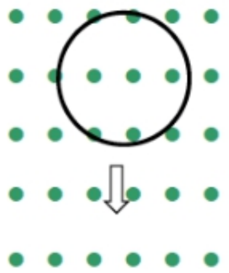
(2)



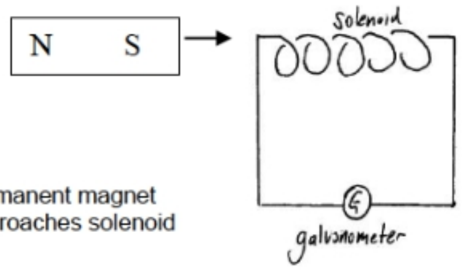


For the following situations *briefly* explain what happens in terms of Lenz's Law and show on the diagrams the direction of the induced current when the changes indicated are made.

(4)



a) Conducting loop moved down within a uniform magnetic field.



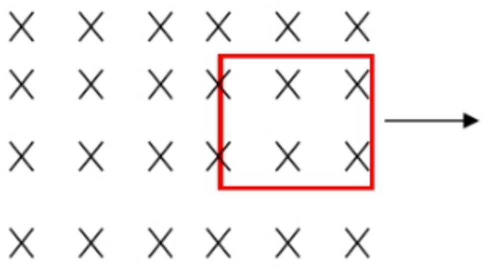
b) Permanent magnet approaches solenoid

An aluminium bar of length 2.20 m is dropping in a magnetic field of flux density of 5.50 mT
A potential difference of 7.60×10^{-2} V is established across the ends of the bar.

Determine the speed of the aluminium bar at the instant shown.

(2)

A square coil made of five (5) loops of copper wire is moving at a speed of 4.00 m s^{-1} right and has just reached the edge of a uniform magnetic field of flux density 84.0 mT. The square coil has a size of 25 cm by 25 cm.



a) Show by calculation that the coil will be fully removed from the field in a time of 6.25×10^{-2} s (2)

b) Indicate on the diagram the direction of induced current in the coil as it is removed and explain how you arrived at your response. (2)

c) Calculate the magnitude of induced emf as the coil is removed from the field. (3)