Physics 3AB

Electricity and Magnetism Test 2013

Name: Solutions

Mark: / 54

= %

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(4 marks)**

A proton moves at a speed of 5.00 x 10^6 ms^{-1} at an angle of 30.0° relative to a magnetic field. It experiences a force of 4.80 x 10^{-13} N. What is the strength of the magnetic field?

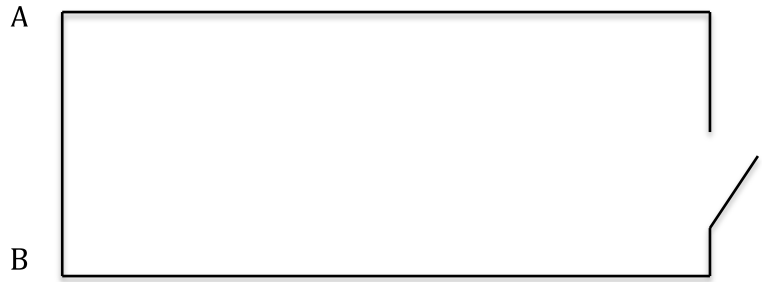
$F = qvB$ (1)

$4.80\times10^{-13} = (1.6\times10^{-19})(5\times10^{6})(B\sin 30)$ (1)

$B = 1.20\ T$ (1)

Question 2 **(4 marks)**

A rectangular loop of wire, as shown in the diagram below, is located in a magnetic field of 4.00 mT, which is directed into the page. The side AB is 6.00 cm long.



(a) If the loop is moved to the right at 2.00 ms^{-1}, with the switch open, determine the magnitude of the induced emf across AB

(3 marks)

$\varepsilon = v\ell B$ (1)

$= (2)(0.06)(4\times10^{-3})$ (1)

$= 4.80\times10^{-4}\ V$ (1)

(b) Which end of the wire (A or B) will be at the higher potential?

(1 mark)

A

Question 3 **(4 marks)**

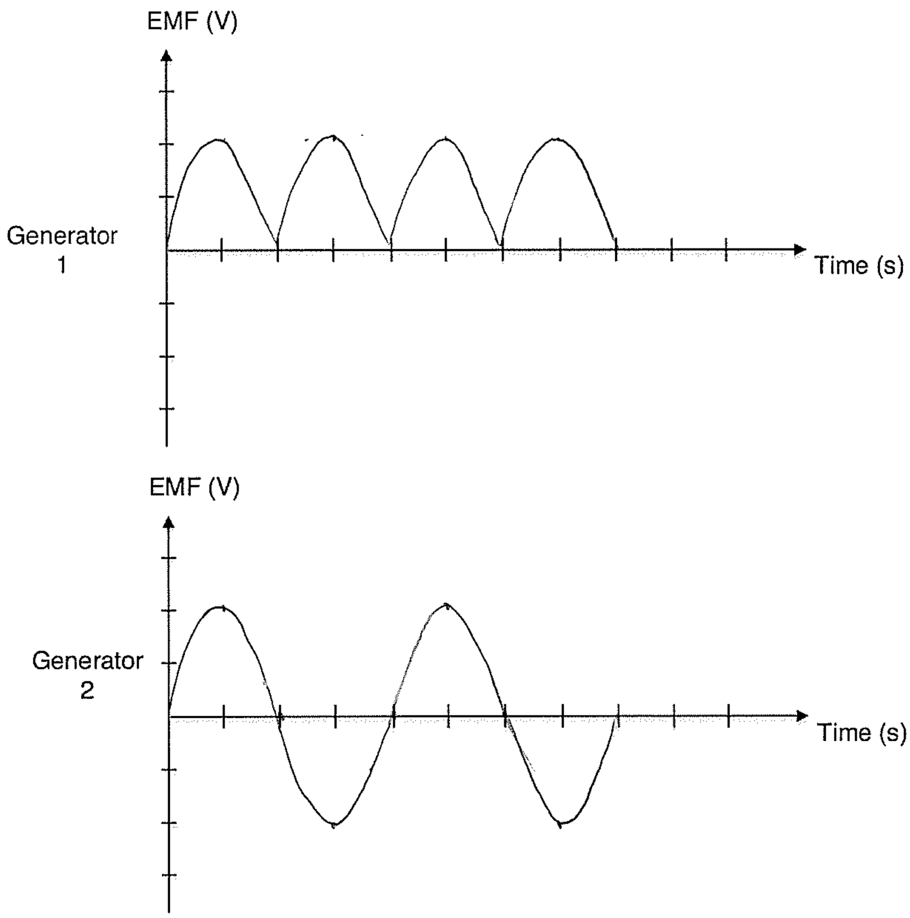
The diagram below shows two different types of generator (1 and 2) spinning at the same number of revolutions per minute. The only difference between the two generators is the way they are connected to the external circuits.

On the axes below, sketch a graph of **induced emf** vs **time** for each generator over **2** complete cycles from the position shown in the diagram.

-0.5 marks per graph
incorrect shape (i.e. not a curved sine shape)
not over 2 complete cycles
graphs not starting at the origin

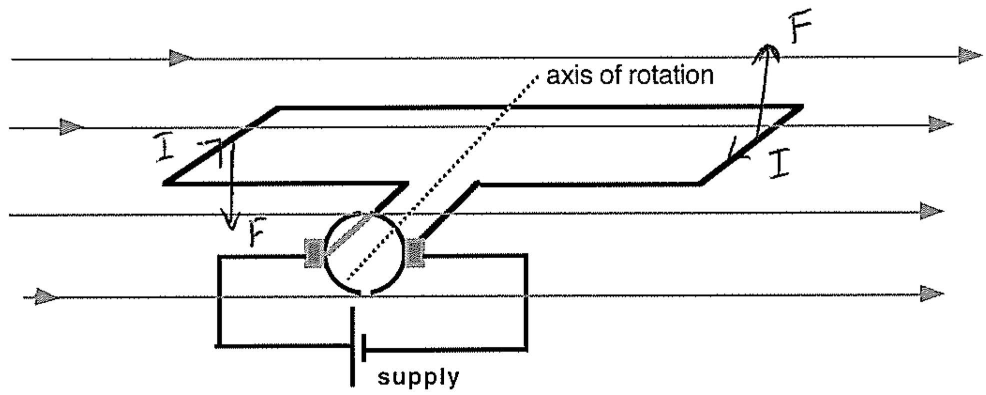
-1 mark per graph
incorrect graph (i.e. showing AC not DC output or vice versa)

-1 mark total
if the maximum emf on graphs is not the same
if the period (time for one cycle) of the graphs is not the same.



Question 4 **(15 marks)**

A simple DC electric motor, as shown in the diagram below, consists of a 10.0 cm x 10.0 cm square plane coil of 200 turns and resistance 0.300 Ω which can rotate in a radial field of magnetic flux density 0.400 Wbm^{-2}. The coil is wound on a core and connected to a 12.0 V battery.



(a) What is the starting current in the coil?

(3 marks)

$V = IR$ (1)

$12 = (I)(0.3)$ (1)

$I = 40.0\ A$ (1)

(b) Draw arrows to show the direction of the current in the sides of the coil and to show the forces on all the sides of the coil.

(2 marks)

(c) Explain why the coil rotates in the external magnetic field, when an electric current flows through it.

(3 marks)

- The current that is flowing the coil will have a magnetic field associated with it.
- This magnetic field will interact with the external magnetic field, producing a force on the side of the coil.
- As there are two forces of equal magnitude at an equal distance from the pivot, there will be a net torque on the motor causing it to rotate.

(c) Determine the torque of the coil when the motor has just started.

(4 marks)

$F = I\ell B$ (0.5)

$= (40)(0.10)(0.4)$ (0.5)

$= 1.60\ N$

$\tau = rF$ (0.5)

$= 200 \times 2 \times (0.05)(1.6)$ (0.5)

$= 32.0\ Nm$ (1)

Anticlockwise (1)

Or can use τ = BANI

(d) As the motor continues to spin, would the magnitude of the torque increase, decrease or remain the same? Explain your reasoning.

(6 marks)

- Magnitude of torque would decrease.
- As the motor continues to spin (and spin faster), the rate of change of the magnetic flux through the coil will change.
- Faraday's Law says that an emf will be induced that is proportional to the rate of change of the magnetic flux.
- Lenz's Law states that the direction of the induced emf will be such as to oppose the change that induced it.
- The induced emf will be in the opposite direction to the applied emf and so the net emf will be reduced, less current will flow through the coil
- and hence the torque, which is proportional to the amount of current will decrease.

Need to explain fully – not just state there is back emf present

Question 5 **(10 marks)**

An electricity substation delivers a current of 10.0 A at a voltage of 6.00 kV to an office building. The building uses a transformer to provide a current of 230 A at a voltage of 240 V.

(a) Determine the turns ratio of the transformer

(3 marks)

$$\frac{N_S}{N_P} = \frac{I_P}{I_S} \quad (1)$$

$$\frac{1}{N_p} = \frac{10}{230} \quad (1)$$

$$N_p = 23$$

$$23:1 \quad (1)$$

If all correct but have used the ratio of voltages instead if current -1 mark

(b) Calculate the energy lost by the transformer in eight hours

(4 marks)

$$P_S = VI \quad (0.5)$$

$$= (230)(240)$$

$$= 55200\ W$$

$$P_P = (6000)(10) = 60000\ W$$

$$P_f - P_i = 60000 - 55200 \quad (0.5)$$

$$= 4800\ W \quad (1)$$

$$P = \frac{E}{t} \quad (0.5)$$

$$4800 = \frac{E}{(8 \times 60 \times 60)} \quad (0.5)$$

$$E = 138\ MJ \quad (1)$$

(c) State **one** cause of energy loss in a transformer and explain how the effect can be reduced.

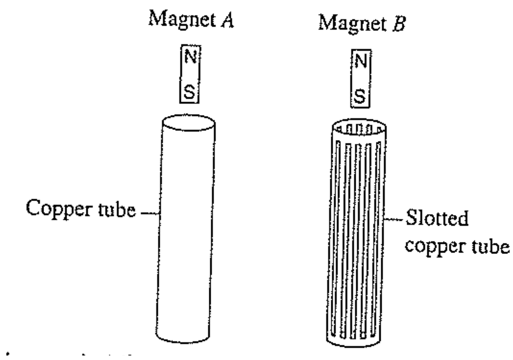
(3 marks)

Main example (others may be appropriate e.g. resistive heating in the coils, hysteresis losses).

- Resistive heating due to eddy currents in the soft iron core.
- Cut the iron into thin pieces and laminate.
- Reduces the amount of bulk metal in which the eddy currents can be formed, reducing the magnitude of the power loss

Question 6 **(6 marks)**

Identical magnets, A and B, are suspended above vertical copper tubes as shown in the diagram below.



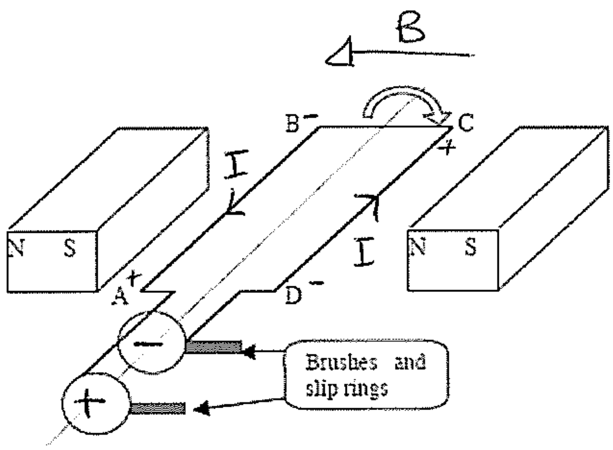
The magnets are dropped at the same time. Each magnet falls straight through its tube without touching the tube walls.

Which magnet leaves its tube first? Explain your reasoning.

- Magnet B
- As the magnets fall through the tubes, the magnetic flux through any one section of the tube will be changing.
- Faraday's law states that there will be an emf induced that is proportional to the rate of change of magnetic flux - this will produce eddy currents in the bulk metal.
- Lenz's law states that the direction of the induced emf will be in such a direction as to oppose the change that induced it.
- The induced emf will act in an opposite direction to the force due to gravity.
- As the slotted tube has less bulk mass, the eddy currents that are produced will be smaller in magnitude, hence the retarding force will be less and magnet B will fall through first.

Question 7 **(11 marks)**

The diagram below shows an electric generator. The coil has 100 turns and is being turned with a speed of 15.0 ms^{-1}. Sides AB and CD are of length 20.0 cm. The coils are located in an area with a magnetic flux density of 0.500 T.



(a) On the diagram, indicate the direction of the induced current in the coil.

(1 mark)

(b) Determine the maximum emf induced in the generator.

(3 marks)

$\varepsilon = 2Nv\ell B$ (1)

$= (2)(100)(15)(0.2)(0.5)$ (1)

$= 300\ V$ (1)

(c) What is the frequency of the generator?

(3 marks)

$v = 2\pi rf$ (1)

$15 = (2\pi)(0.05)(f)$ (1)

$f = 47.7\ Hz$ (1)

(d) If the current delivered by the generator is 10.0 A, what is the magnetic force on the side AB?

(4 marks)

$F = I\ell B$ (1)

$= 100 \times (10)(0.2)(0.5)$ (1)

$= 100 N$ (1)

(1) Down (no ecf on this from (a) – it should be known that the retarding force (due to the induced current) will be in the opposite direction to the applied force (making the generator turn)).