Physics ATAR - Year 12

Electricity and Magnetism
Unit Test
2018

Name: SOLUTIONS

Mark:	/ 55
=	%

Time Allowed: 50 Minutes

Notes to Students:

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

Question 1 **(3 marks)**

Two point electric charges are separated by a certain distance and experience a repulsive force of magnitude, F. If the distance between them is reduced to one third of its previous value, and one of the charges is now doubled, calculate the magnitude of the new force.

$$F_1 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 \cdot q_2}{r^2}$$ (1)

$$F_2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2q_1 \cdot q_2}{(^1/_3 r)^2}$$

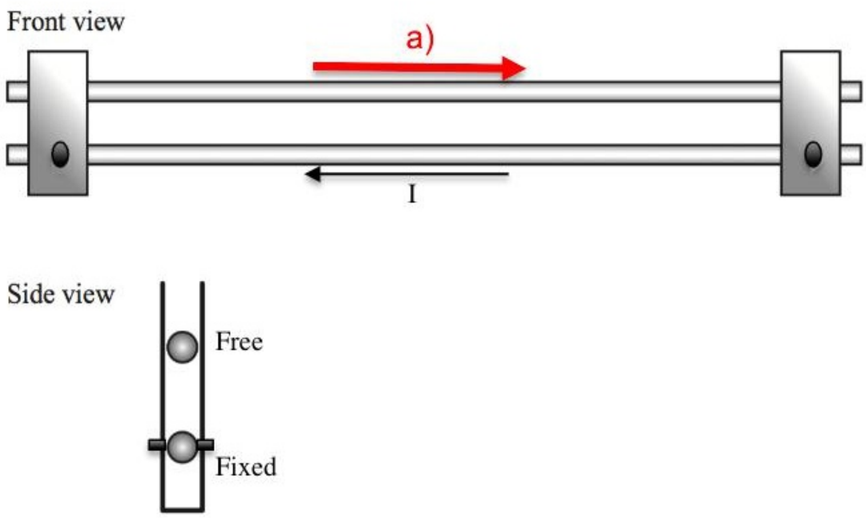
$$= \frac{2}{^1/_9}\cdot\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 \cdot q_2}{r^2}$$ (1)

$$= 18\ F_1$$ (1)

Question 2 **(8 marks)**

Two 2.00 m conductor rods are placed one above the other as shown.

The bottom conductor is held in place by the brackets and the top is free to move up and down. Each conductor has a mass of 0.0100 kg, and a current of 20.0 A moves through the bottom conductor from right to left as shown in the front view above.



(a) On the Front view diagram, sketch the direction of current that must flow in order for the top rod to levitate (remain in static equilibrium).

(1 mark)

(b) Calculate the strength of the magnetic field (produced by the bottom rod) a distance of 4.00 mm above the bottom rod.

(3 marks)

$B = \frac{\mu_0}{2\pi} \cdot \frac{I}{r}$ (1)

$= \frac{1.26\times10^{-6}}{2\pi} \cdot \frac{20}{4\times10^{-3}}$ (1)

$= 1.00 \times 10^{-3}$ T (1)

(c) Calculate the current flowing in the top rod that is necessary to suspend it 4.00 mm above the bottom rod.

(4 marks)

$\Sigma F_y = 0 = F_B + W$ (1)

BIL = - mg (1)

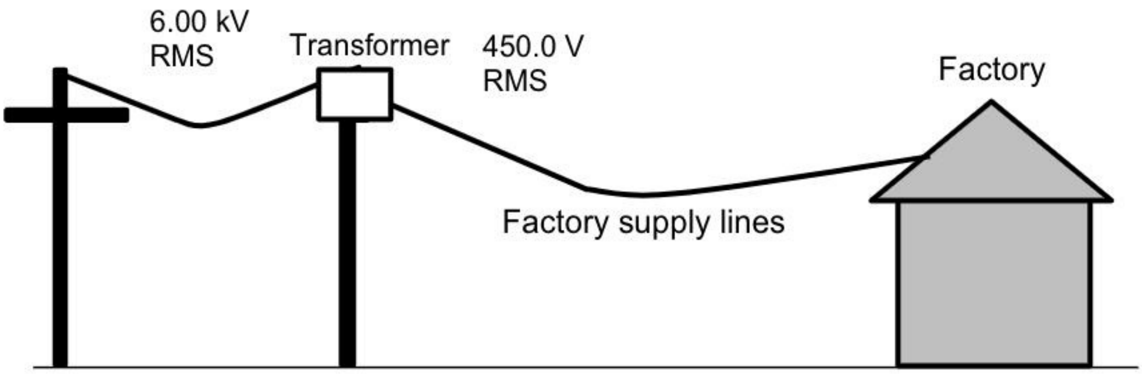
$I = \frac{-mg}{BL}$

$= \frac{-(0.01)(-9.80)}{1.00\times10^{-3}(2)}$ (1)

= 49.0 A (1)

Question 3 **(11 marks)**

The diagram below shows a single-phase AC voltage being supplied to a small factory. The main transmission lines supply electric power to a step-down transformer at 6.00 kV RMS. The transformer then steps this down to 4.50×10^2 V RMS. The wires connecting the factory to the step-down transformer have a combined resistance of 0.500 Ω. A total of 24.0 kW of electric power is being drawn from the output terminals of the transformer.



(a) Calculate the power loss in the factory supply lines.

(3 marks)

P = IV $I = \frac{P}{V}$ ½

$= \frac{24 \times 10^3}{450}$

= 53.3 A 1

$P_{Loss} = I^2R$ ½

$= (53.3^2)(0.5)$

= 1420 W 1

(b) Calculate the voltage delivered to the factory.

(3 marks)

$V_{drop} = IR$ ½

= (53.3)(0.5)

= 26.7 V 1

$V_{factory} = V_S - V_{drop}$ ½

= 450 – 26.7

= 423 V 1

(c) Calculate the ratio of primary windings to secondary windings in the transformer.

(2 marks)

$\frac{Np}{Ns} = \frac{Vp}{Vs} = \frac{6000}{450}$ = 13.3 :1 1

½ ½

Or 40:3 (accept either)

(d) State and explain one feature of the transformer that aims to maximise the efficiency of the voltage transformation.

(3 marks)

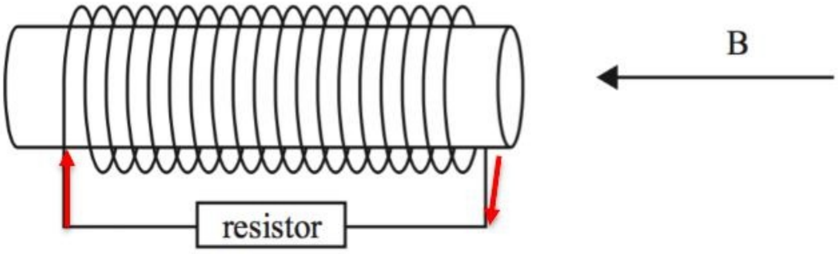
- Laminated core
- Reduces the magnitude/formation of eddy currents
- Resulting in less energy converted to heat, resulting in high efficiency

OR

- Soft iron
- Contains magnetic domains that align the presence of an external magnetic field
- Increasing the change in magnetic flux through the secondary coil, hence increasing the efficiency.

Question 4 **(6 marks)**

A coil is wound around a cardboard cylinder, as shown in the diagram. The cross-sectional area of the coil is 0.00600 m^2. There are 1000 turns in the coil (not all are shown in the diagram). The axis of the coil is immersed in a uniform external magnetic field of strength 0.00500 T and its direction is shown by the arrow labelled B in in the diagram.



(a) Calculate the magnitude of the flux through the first turn of the coil.

(2 marks)

$\phi = BA\cos\theta$ ½

= 0.005(0.006) ½

= 3.00 x10^{-5} Wb 1

The external magnetic field is now reduced to zero in a time of 15.5 x10^{-3} s.

(b) Calculate the magnitude of the induced emf in the coil.

(3 marks)

Emf = $\frac{-n\,\Delta\phi}{\Delta t}$ 1

= $\frac{-1000(0-3.00\times10^{-5})}{15.5\times10^{-3}}$ 1

= 1.94 V 1

(c) On the diagram, indicate the direction of the flow of induced current in the coil while the field is reducing to zero.

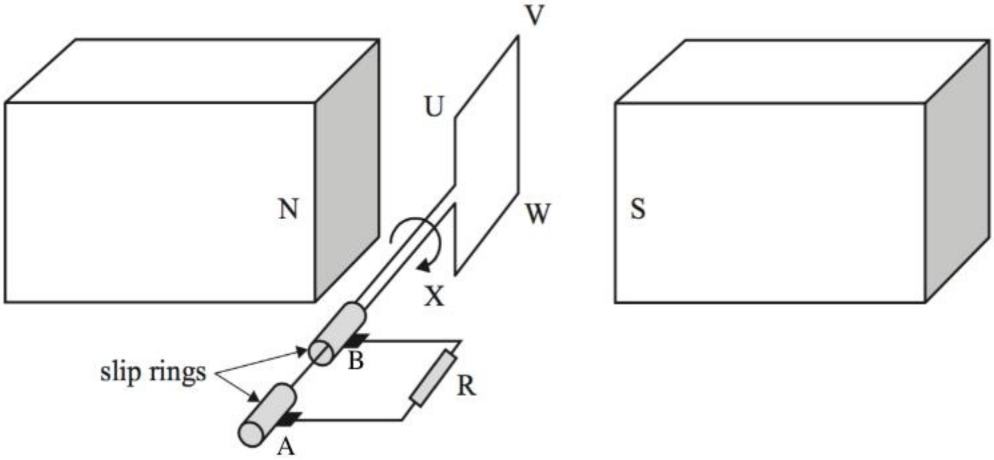
(1 mark)

As $\Delta\phi$ experience by the coil is right, induced emf must produce $\Delta\phi$ left (as per Lenz's Law)
This can be produced if current flows in direction on diagram

Question 5 **(7 marks)**

Roger and Mark construct a simple generator as shown.

When the single loop coil is rotating steadily, it rotates at 900.0 revolutions per minute and produces a peak emf of 0.350 V across terminals A and B. The coil has an area of 7.20×10^{-3} m^2.



(a) Calculate the period of one revolution.

(2 marks)

$f = 900 \frac{rev}{min} \times \frac{1}{60} = 15.0$ Hz (1)

$T = \frac{1}{f} = \frac{1}{15} = 0.0667$ s (1)

(b) Calculate the strength of the magnetic field that the coil is placed in.

(3 marks)

Emf = $2\pi BANf$ $B = \frac{emf}{2\pi ANf}$ (1)

$= \frac{0.350}{2\pi(7.20\times10^{-3})(1)(15)}$ (1)

= 0.516 T (1)

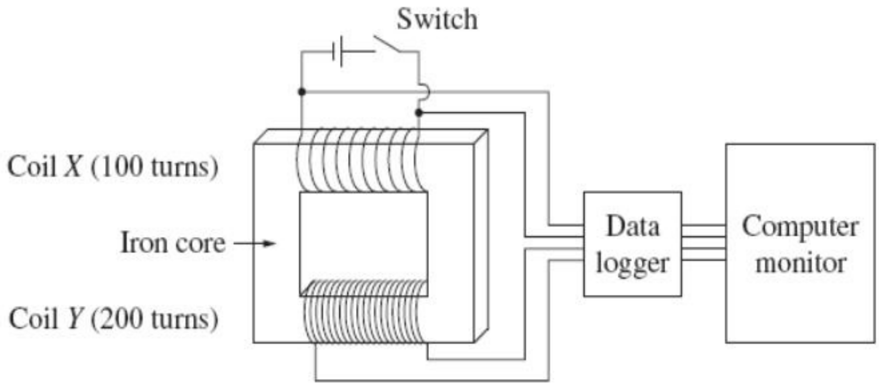
To increase the magnitude of the induced EMF produced by the generator, Mark suggests a number of modifications. His suggested changes are given in the table below.

(c) In the space provided, indicate the effect of each suggestion, including the relative change in the EMF produced. (2 marks)

Suggested modification	Effect on the EMF
Triple the number turns in the coil.	Triple emf
Increase the frequency to 1200 rpm	Increase by 1/3
Double the strength of the magnetic field	Double emf
Half the resistance of the resistor.	No effect

Question 6 **(6 marks)**

Students are constructing a transformer in class. They set up the apparatus as shown in the diagram below. The students' transformer is plugged into a DC power source and doesn't function correctly. The students change the input to a 50 Hz AC source and the transformer functions correctly.

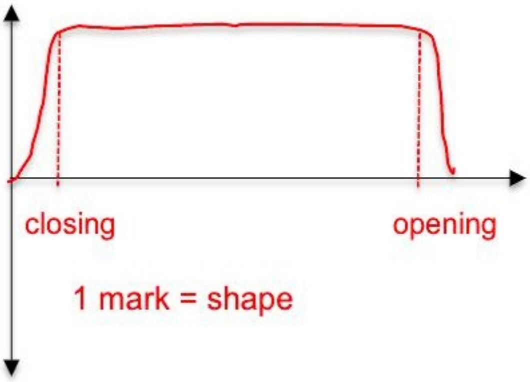


(a) Explain why AC is used and not DC as an input current source for transformers. (3 marks)

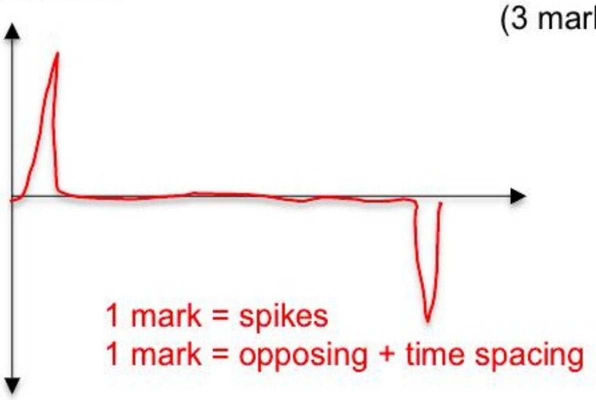
- According to Faraday's Law, an induced emf is proportional to the rate of change of magnetic flux with respect to time.
- DC current produces a steady magnetic flux, hence no change in magnetic flux to induce and emf in the secondary coil.
- AC current is constantly changing, hence the flux is changing and an emf can be induced in the secondary coil.

Returning to a DC source, 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.

(b) Sketch the Voltage time graphs for both coil X and coil Y that would be observed on the monitor. The time axis is to be common for both graphs. (3 marks)



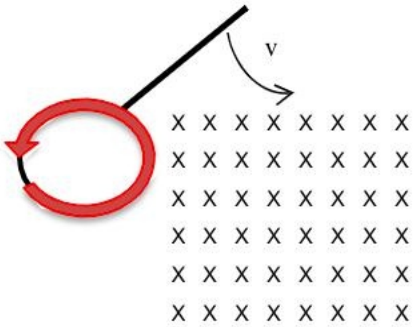
Coil X



Coil Y

Question 7 **(14 marks)**

A conducting metal ring of radius 2.00 cm, suspended using a non-conducting material is allowed to swing into a uniform magnetic field of 0.100 T as shown in the diagram below.



(a) Calculate the magnitude of the change in magnetic flux as the ring completely enters the magnetic field.

(2 marks)

$\phi = BA\cos\theta$ ½

$= 0.1\pi(2\text{x}10^{-2})^2$ ½

$= 1.26\ \text{x}10^{-4}$ Wb 1

(b) On the diagram, draw the direction of the induced current within the ring as it enters the magnetic field.

(1 mark)

(c) Describe and explain the motion of the ring as it swings into the magnetic field.

(4 marks)

- Ring will slow/retard as it crosses the boundary
- As the ring enters the boundary, according to Faraday's Law an emf will be produced proportional to the rate of change of magnetic flux.
- According the Lenz's Law, the direction of the induced emf will be in such a way as to oppose the change in flux that created it
- The magnetic field produced by the induced current will interact with the external magnetic field to produce a resistive/braking force

(d) State the direction of the current, if any, flowing within the ring for each of the following scenarios.

(i) The ring is entirely within the magnetic field.
zero (1 mark)

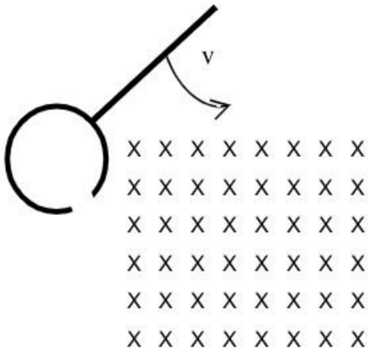
(ii) The ring is exiting the magnetic field.
Clockwise or opposite to (b) (1 mark)

(iii) The ring is entirely within the magnetic field and the field strength quickly increases.
Anticlockwise or same as (b) (1 mark)

(iv) The ring is entirely within the magnetic field and the field strength quickly changes to 0.100 T out of the page.
Clockwise or opposite to (b) (1 mark)

(e) The ring is now swapped for one of equal dimensions except that the new ring has a cut in it. Describe and explain the motion of the ring now.

(3 marks)



- Less of a braking force will be evident
  (more than no B field, but statement not required)

- as only smaller eddy currents will be able to form within the metal
- the magnitude of the induced emf will be lower

END OF TEST