Physics ATAR - Year 12

Electricity and Magnetism Unit Test 2017

Name: SOLUTIONS	Mark: / 59 = %

Time Allowed: 50 Minutes

Notes to Students:

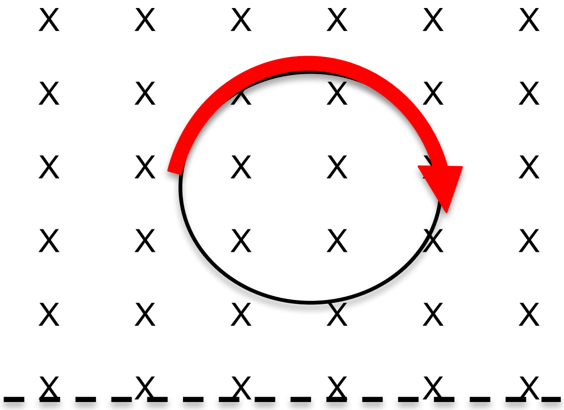
1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(12 marks)**

The diagram to the right shows a ring of wire of radius 2.00 cm, which is immersed in a uniform magnetic field of intensity 50.0 mT. A student pulls the ring downwards at a constant speed of 10.0 ms^{-1}.

(a) Indicate on the ring the direction of any induced current as it leaves the field.

(1 mark)



(b) Calculate the time taken for the ring to cross the magnetic boundary.

(2 marks)

t = s / v ½

= (2x 0.02) / 10 ½

= 4.00 x 10^{-3} s 1

(c) If the ring has a resistance of 3.00 mΩ, calculate the average current induced.

(4 marks)

$\mathcal{E} = -\frac{n\Delta\phi}{\Delta t}$ ½

$= \frac{-1(50\times10^{-3})(\pi\times0.02^2)}{0.004}$ ½

= 0.0157 V 1

I = V / R ½

= 0.0157 / 3x10^{-3} ½

= 5.23 A 1

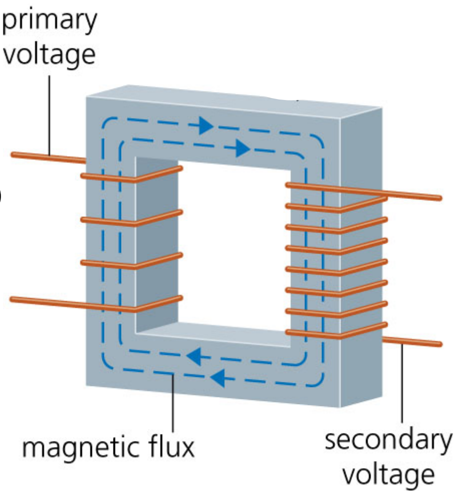
(d) State what effect the student would feel as he pulls the ring out of the field and explain why.

(5 marks)

- As the ring is pulled out of the field, there is a change in magnetic flux through the ring.
- Farday's law states that the emf induced will be proportional to the rate of change of flux with respect to time.
- Len's law states that the direction of the induced current will be such to oppose the change in flux that originally induced it.
- The current induced will have a magnetic field associated with it that will cause a magnetic attraction to the external field
- Hence, the student will fell a retarding force (upward force) to the motion of the ring.

Question 2 **(10 marks)**

The diagram to the right shows a simple step-up transformer.



(a) State two features of the transformer and explain how they enable it to operate efficiently.

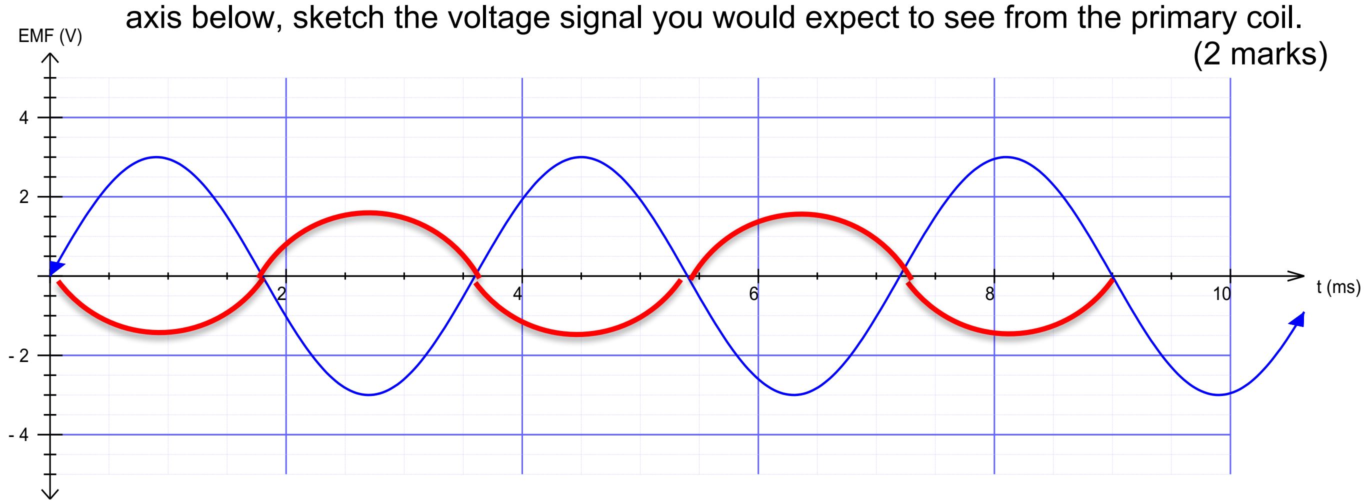
(4 marks)

- Laminations in iron core
- Reduces the bulk mass in which eddy currents can form which reduces the power loss due to resistive heating

- Use of soft iron core
- Directs magnetic flux through to secondary coil (or reduces flux leakage)

(b) A voltage probe is connected across the secondary coil of the simple transformer shown on the previous page and the voltage curve is displayed below. On the same axis below, sketch the voltage signal you would expect to see from the primary coil.

(2 marks)



(c) If the primary loops have a peak current of 2.55 A, calculate the RMS current in the secondary loop.

(4 marks)

$$\frac{N_S}{N_P} = \frac{V_S}{V_P} = \frac{I_P}{I_S}$$ ½

$$I_P = I_S . \frac{N_S}{N_P}$$

$= 2.55 \times \frac{4}{8}$ ½

$= 1.275$ A 1

$$I_{RMS} = \frac{I_{Peak}}{\sqrt{2}}$$ ½

$= \frac{1.275}{\sqrt{2}}$ ½

$= 0.902$ A 1

Question 3 **(6 marks)**

A 500-loop generator is rotated at 3.00 x 10^3 revolutions per minute. The loops have dimensions of 0.200 m by 0.300 m and are placed in a uniform magnetic field of 0.655 T. The armature of the generator is connected to a split-ring commutator.

(a) Calculate the maximum EMF produced.

(4 marks)

f = 3000 / 60 ½

= 50.0 Hz 1

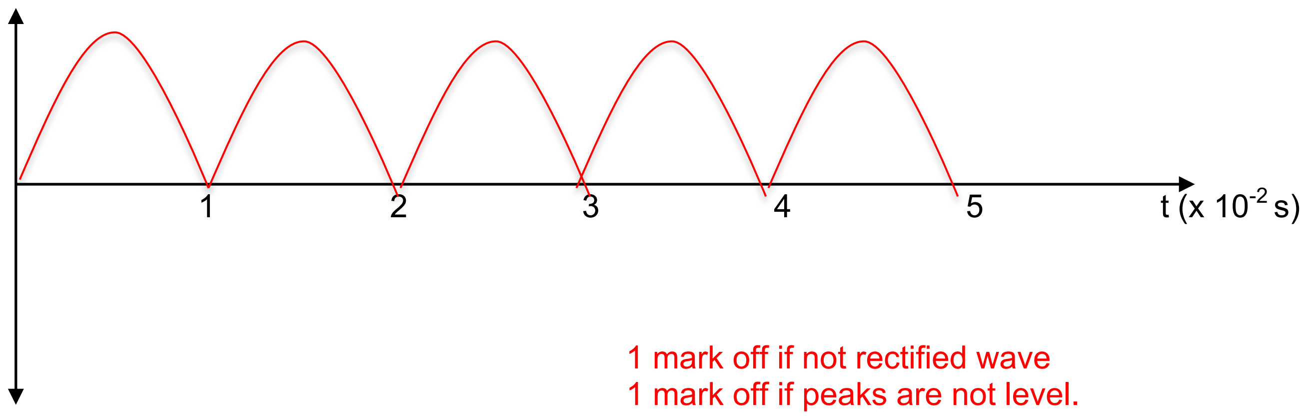
EMF $= 2\pi BAnf$ ½

$= 2\pi(0.655)(0.3 \times 0.2)(500)(50)$ 1

$= 6.17 \times 10^3$ V 1

(b) On the axis below, sketch the voltage sinal produced by the generator using the values provided and calculated in question (a).

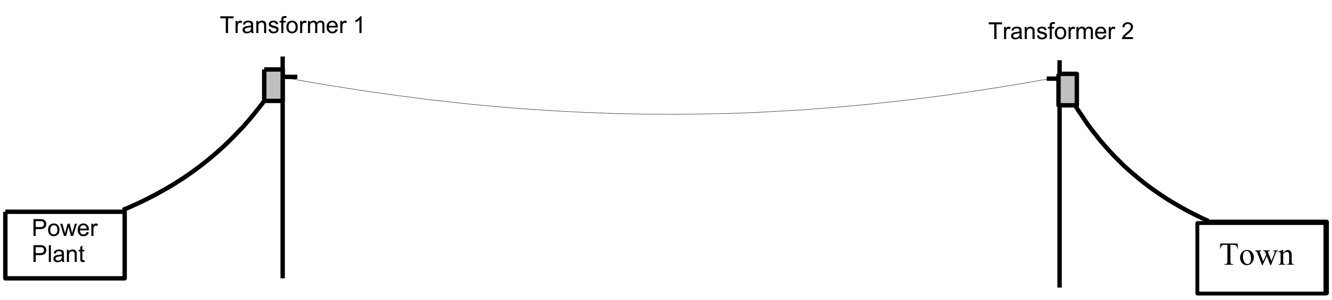
(2 marks)



1 mark off if not rectified wave
1 mark off if peaks are not level.

Question 4 **(11 marks)**

Consider the following system. A country town has a power plant that is 15.0 km from town. The power plant has a 455 kW generator producing an AC signal at a voltage of 1.00 kV. This is stepped up to 35.0 kV by a 96.0 % efficient transformer after the power plant in Transformer 1. The transmission wires have a total resistance of 73.5 Ω and are connected to Transformer 2 at the town which is 90.0% efficient.



(a) Calculate the power loss across the transmission wires.

(4 marks)

$P_s = P_p \times \frac{\varepsilon}{100}$

$= 455 \times 10^3 \times 0.96$

$= 437 \times 10^3$ W 1

If student does not factor in power loss In transformer -1 mark

$I_s = \frac{P_s}{V_s} = \frac{437 \times 10^3}{35000}$ ½

$= 12.5$ A 1

$P_L = I^2R$ ½

$= 12.5^2(73.5)$

$= 11.5 \times 10^3$ W 1

(b) Calculate the voltage supplied to Transformer 2.

(3 marks)

$V_{drop} = I_s R$ ½

= 12.5 (73.5)

= 917 V 1

$V_{T2} = V_s - V_{drop}$ ½

= 35,000 - 917

= 34,100 V 1

(c) Transformer 2 has 12,000 windings in the primary coil and 600 windings in the secondary coil. Calculate the current that flows from the transformer to the town.

(4 marks)

$P_p = I_p V_p$

= 12.5 (34,100)

= 426,000 W

$P_s = P_p \times \frac{\varepsilon}{100}$

$= 426 \times 10^3 \times 0.90$

$= 383 \times 10^3$ W

$V_S = \frac{V_P N_S}{N_P} = 1705$ V

$P_S = I_S V_S$

$I_S = 383{,}000 / 1705$

= 225 A

OR

$Ps = \frac{Eff}{100}.Pp$

$I_S V_S = \frac{Eff}{100} I_P V_P$ Since $\frac{N_S}{N_P} = \frac{V_S}{V_P}$

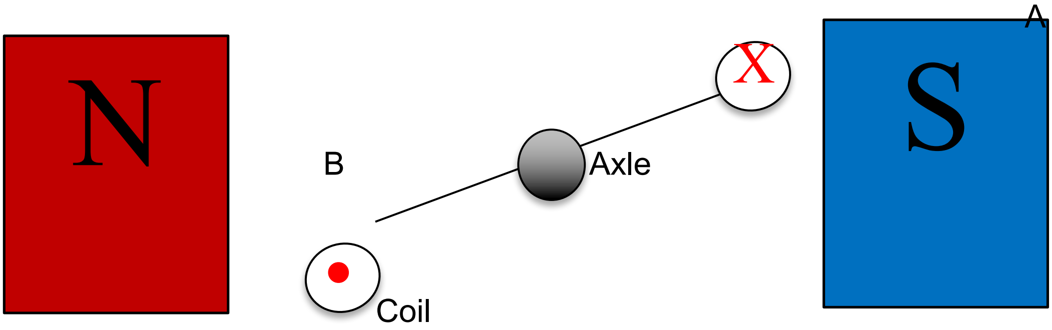
$Is = \frac{Eff}{100} . \frac{I_P N_P}{Ns}$

$= \frac{90}{100} . \frac{12.5(12000)}{600}$ = 225 A

If student does not factor in power loss in transformer -1 mark

Question 5 **(10 marks)**

A student made a DC motor from an electronics kit. He uses a square coil of side lengths 3.50 cm and 50.0 turns. A side (cross-section) view of the motor armature is shown below.



(a) If the coil is rotating clockwise as viewed, indicate, on the diagram, the direction of the current in the coil at points A and B.

(2 marks)

(b) If the maximum torque produced by the motor is 1.65 x 10 $^{-2}$ Nm and 1.55 A of current is flowing, calculate the magnetic field strength through the coil.

(4 marks)

F = BIL ½ τ = rF ½

τ = 2nrBIL 1

$$B = \frac{\tau}{2nrIL} = \frac{1.65 \times 10^{-3}}{2(50)(0.035/2)(1.55)(0.035)} = 0.174\ \text{T}$$ 1 1

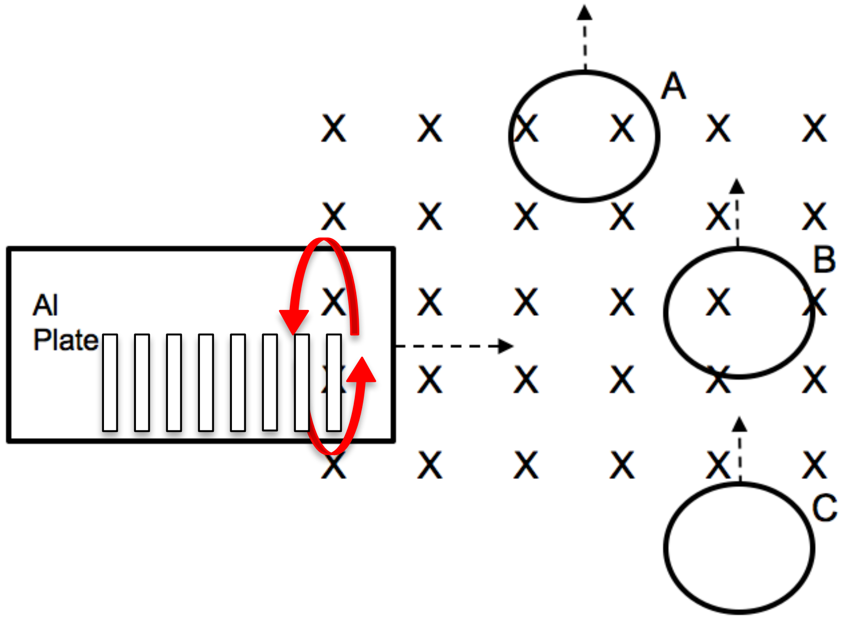
(c) While the DC motor is still operating, another student holds the armature and prevents it from turning. State the effect this will have on the DC motor and explain why.

(4 marks)

- Damage or burn out the motor/armature.
- As the armature turns, there is a changing magnetic flux through the coil. Faraday's law states that an emf will be generated proportional to the rate of change of magnetic flux.
- Lenz's law states that this emf will act in a direction so as to oppose the change that induced it. This will be a back emf, reducing the net emf (and current through)across the coil
- With no motion of the armature, there is no back emf, and a large current flowing leading to increased resistive heating.

Question 6 **(5 marks)**

Consider the following items travelling relative to a magnetic field shown below. The dashed arrows represent their direction of travel.



(a) State the direction of the induced conventional current for rings A, B and C.
(3 marks)

A Clockwise

B No Current

C Anti-Clockwise

(b) On the Aluminium plate, draw the eddy currents that are produced.
(1 mark)

(d) Sketch below how the Aluminium plate could be modified to reduce the eddy currents that are produced.
(1 mark)

Question 7 **(5 marks)**

A car roof rack (a horizontal metal bar mounted onto a car's roof) of length 1.60 m is placed on a car in Perth which travels at 115 kmh^{-1} north. The magnetic field strength at Perth is measured to be 0.585 μT at 66.4° above the horizontal.

(a) Calculate the EMF induced across the roof rack as the car travels at this velocity.

(4 marks)

$B_\perp = B\sin 66.4$

$= 0.585 \times 10^{-6} \sin(66.4)$

$= 0.536 \times 10^{-6}$ T 1

$v = 115 / 3.6$

$= 31.9$ 1

emf = $vB_\perp L$ ½

$= (31.9)(0.536 \times 10^{-6})(1.60)$ ½

$= 2.74 \times 10^{-5}$ V 1

(b) State which side of the roof rack generates a positive charge.

(1 mark)

East

END OF TEST