Year 12 Electromagnet Test 2 sols

ALL SAINTS' COLLEGE

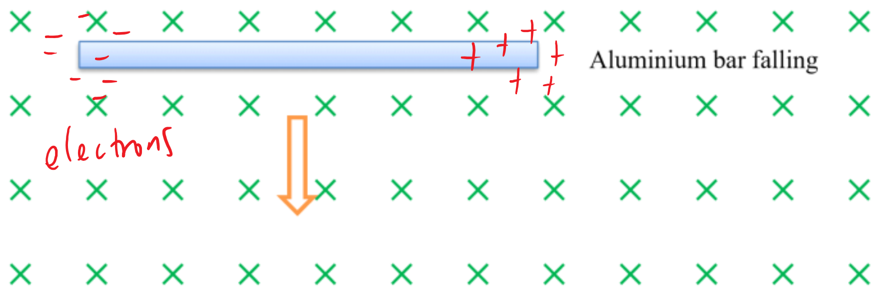
Ewing Avenue, Bull Creek, Western Australia

Year 12 Physics ATAR | Electromagnetism Test 2 | 2017

Time allowed: 50 minutes
Total marks available: 50
Show calculation answers to 3 significant figures

Student Name: Solutions

1. 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 x 10^{-2} V is established across the ends of the bar.



a) Determine the speed of the aluminium bar at the instant shown. (2)

$l = 2.20$ m $B = 5.50 \times 10^{-3}$ T $emf = 7.60 \times 10^{-2}$ V

$emf = vBl$ $v = \frac{emf}{Bl} = \frac{7.60 \times 10^{-2}}{5.50 \times 10^{-3} \times 2.2}$ ✓ $= 6.28$ m s^{-1} ✓

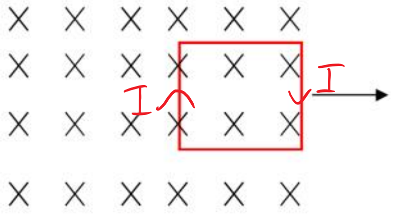
b) Indicate on the diagram where there is a build-up of electrons on the aluminium bar and briefly explain your response. (2)

At left hand side ✓

By left hand palm rule
(fingers = field, thumb = charge motion)
palm = force on electrons ✓

or similar

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 x 10^{-2} s (2)

$V_{av} = \frac{s}{t}$ $t = \frac{s}{V_{av}} = \frac{0.25}{4}$ ✓ $= 0.0625$ s ✓

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)

current = clockwise, by Lenz's Law ✓

replace lost field by current clockwise ✓

+ RH grip rule

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

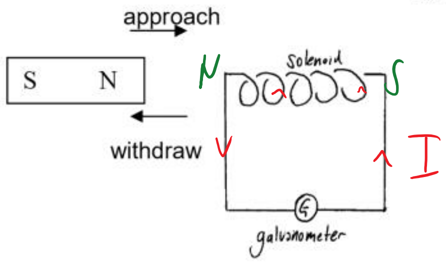
$$emf = -\frac{N(\Phi_2 - \Phi_1)}{t} = -\frac{5(0 - 5.25\times10^{-3})}{0.0625}$$ ✓

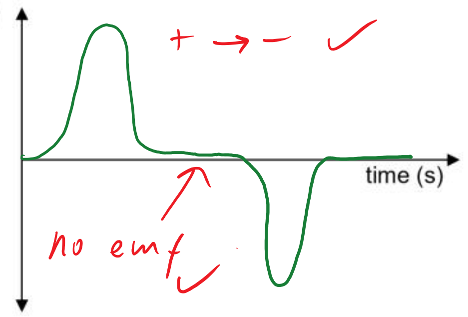
$\Phi_1 = B.A = 84\times10^{-3}\times0.25^2$ ✓

$\Phi_1 = 5.25\times10^{-3}$ Wb

emf = 0.420 V ✓

3. A permanent magnet approaches a solenoid, stops briefly, and is withdrawn again. Sketch the general shape of a graph of EMF versus time on the axes provided. (3)

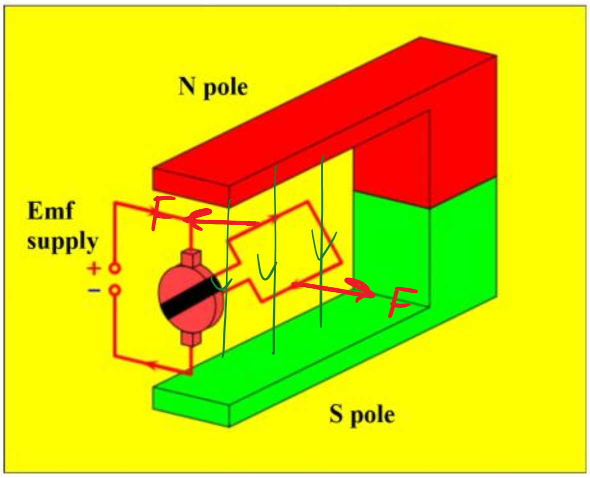




Indicate current direction in the solenoid circuit as the magnet approaches. Put an arrow on the diagram and label it current.

anticlockwise as above ✓

4. The diagram shows a DC electric motor. An external source of emf delivers a supply voltage to a coil that is free to rotate. The supply voltage introduces a current into the coil and its direction is shown on the diagram.



a) When the motor is turned on it starts to rotate anticlockwise (as viewed from the commutator). Explain why it rotates in this direction. (1)

($F_{mag} = B.I.l$ force) Direction from RH palm
For top length current - right, field - down ✓
palm = left (or similar)

b) Clearly explain how a back emf is established, the direction of back emf and what effect this has on the net current in the motor. (3)

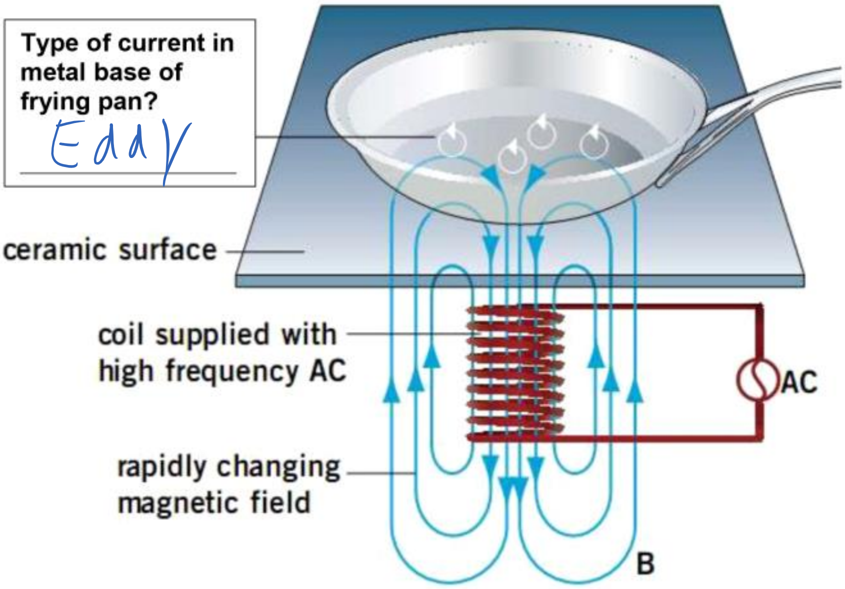
By Lenz's law as flux within Coil increases a current is induced that produces a a flux to oppose the change. (Or RH slap on q ✓
e.g q = left on top length. ✓
Direction = oppose emf current (acw)
Net current - decreases ✓

c) When the motor is doing work (e.g. used to turn a fan blade) the rate of rotation slows. Explain what effect this will have on the electrical power of the motor. You must refer to physics principles. (2)

Rotation rate decreases ∴ back emf decreases and net current increases. ✓

$P = V_{emf} \times I_{net}$ – increases ✓

5. The diagram shows the operating principles of an induction cooktop. A frying pan is placed on the ceramic cooking surface. A copper coil is mounted beneath the cooking surface. The coil is connected to a high frequency AC voltage. Heat is generated in the frying pan (i.e. its internal energy increases).



a) Name the type of current flowing in the metal base of the frying pan. Label this in the box on the diagram above.

(1)

Eddy ✓

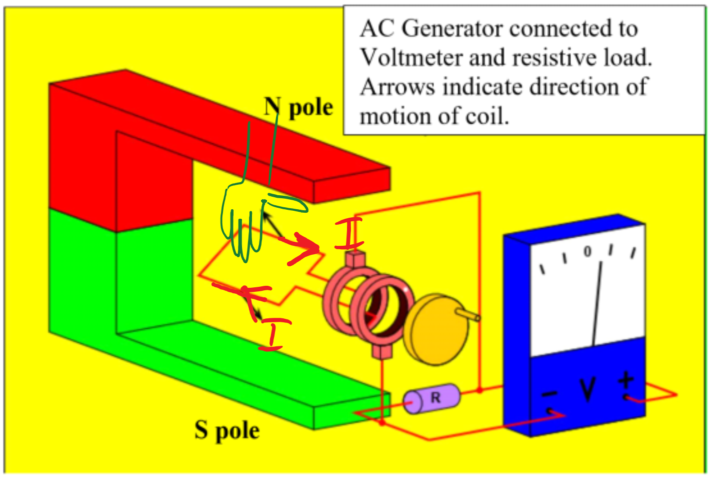
b) Explain how this design enables the temperature of the frying pan to increase. You must refer to physics principles in your response and demonstrate how the concepts are linked.

(3)

Current in coil establishes magnetic field which extends into metal pan. ✓ Eddy currents form which establish their own magnetic fields to oppose the change. AC so always changing. ✓ Energy conversion to heat at rate

$P = I_{eddy}^2 R_{pan}$ ✓

6. An AC generator is shown in the diagram. A rectangular conducting coil of 85 turns is situated in a uniform magnetic field of flux density 253 mT. The coil is provided with an anticlockwise driving torque (the arrows on the coil indicate direction of motion at this instant). The rate of rotation about an axis is 1500 r.p.m. The coil width = 15 cm and the coil length = 20 cm.



a) Calculate the maximum value of **flux** contained within the coil whilst it is turning. (2)

$\phi = B.A = 0.253 \times 0.15 \times 0.20 = 7.59\times10^{-3}$ Wb ✓ ✓

b) Calculate the magnitude of **maximum induced EMF** in the AC generator. (3)

$emf_{max} = NBA2\pi f$

$= 85\times(7.59\times10^{-3})\times2\pi\times\frac{1500}{60}$ ✓ ✓

$emf_{max} = 101.33 = 101$ Volts ✓

c) Indicate, on the coil length next to the South Pole in the diagram, the direction of current flow, as the coil rotates from this position. (1)

d) Briefly describe how you arrived at your answer for part c) (1)

Lenz's law replace lost field with current by RH grip.
Or force on charge moving left RH slap rule

e) Considering the position of the coil shown in the diagram above.

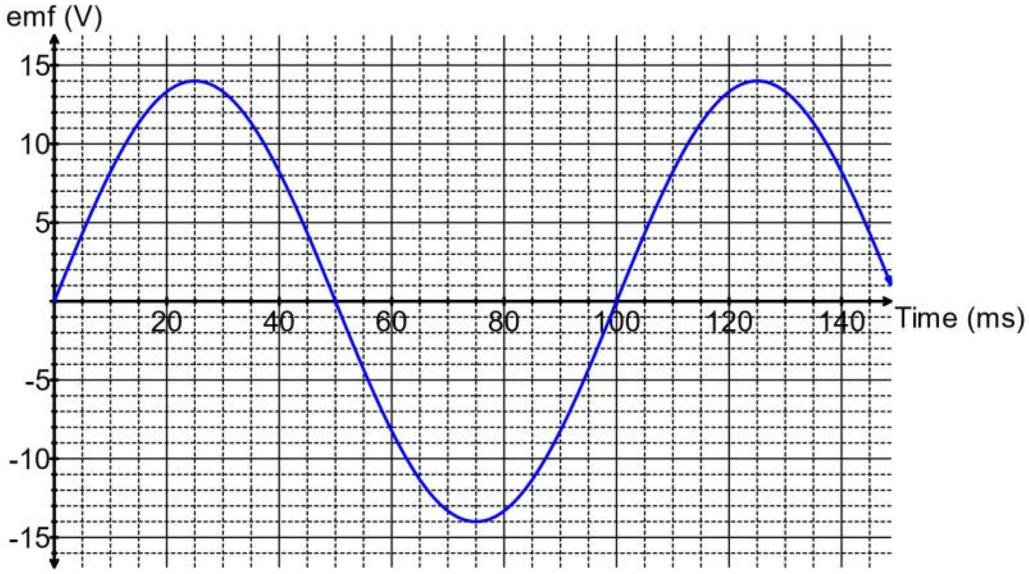
i) The magnitude of induced emf at this instant is: (circle a response) (2)

[✓ Increasing] Zero Decreasing Maximum

Explain how you arrived at your answer

Rate of change of flux is increasing as flux contained within Coil approaches zero.

The emf output of a **different** AC generator is shown on the graph below.



f) Determine the RMS voltage of this AC generator (2)

$V_{max} = 14\,V$ $V_{Rms} = \frac{V_{max}}{\sqrt{2}} = \frac{14}{\sqrt{2}}$ ✓

$V_{Rms} = 9.90\,V$ ✓

g) Determine the rate of rotation of the coil in r.p.m (revolutions per minute) from this graph. (3)

$T = 100\,ms = 0.1\,s$ ✓

$f = \frac{1}{T} = \frac{0}{0.1} = 10\,Hz$ ✓

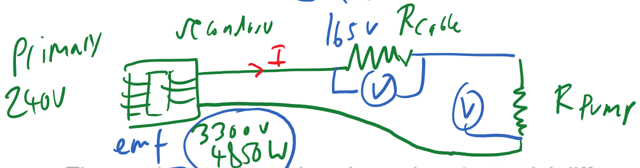
$rpm = 10 \times 60 = 600\,rpm$ ✓

7. A farmer needs to supply an AC electric pump with high voltage but only has a 240 V_{RMS} domestic supply available. He uses a transformer with 400 turns of wire on the primary stage to step up the voltage to 3.30 kV_{RMS}. Assume that the transformer is 100 % efficient in terms of flux linkage but only 89.0 % efficient in terms of power transfer.

a) Calculate the number of turns required on the secondary winding? (2)

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \qquad \frac{240}{3300} = \frac{400}{N_s} \quad ✓$$

$$N_s = \frac{400 \times 3300}{240} = 5500 \text{ turns} \quad ✓$$



$$emf = V_{cable} + V_{pump}$$

The maximum allowable voltage drop (potential difference) across the cables that connect the secondary coil of the transformer to the AC pump is 5% of the output voltage. The transformer has an electrical power output of 4.85 kW.

b) Calculate the maximum allowable resistance of the cables. (4)

$$V_d(max) = 5\% \times 3300 = 165 \text{ Volts} \quad ✓$$

$$I_{out} = \frac{P_{out}}{V_{emf}} = \frac{4850}{3300} = 1.47 \text{ A} \quad ✓$$

$$R = \frac{V_d}{I} = \frac{165}{1.47} \ ✓ = 112\,\Omega \quad ✓$$

c) Calculate how much current is drawn on the primary stage of the transformer. (3)

$$P_{secondary} = 89\% \times P_{primary}$$

$$P_{primary} = \frac{P_{secondary}}{0.89} = \frac{4850}{0.89} = 5449.4 \text{ W} \quad ✓$$

$$I_{primary} = \frac{P_{prim}}{V_{prim}} = \frac{5449.4}{240} \ ✓ = 22.7 \text{ A} \quad ✓$$

In a *non-ideal* transformer the electrical energy output is less than the electrical energy input.

d) Explain how a soft iron core made of laminations can increase efficiency. (2)

laminations block eddy currents ✓
eddy currents → I^2R power loss to heat
∴ less P_{loss} → heat ✓

e) Is copper a suitable material for the transformer core? Explain briefly. (1)

no, ✓ it must be ferromagnetic with domains to concentrate field lines. ✓

End of test