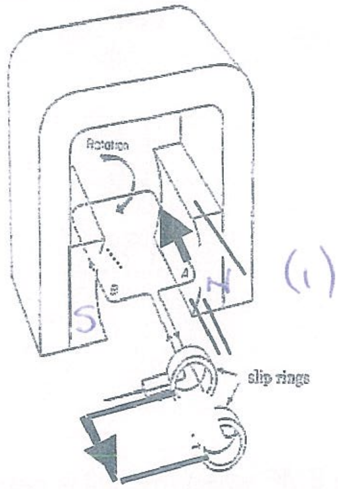
W-16

12 PHYSICS ATAR
TEST 3 - INDUCED EMF

NAME: SOLUTIONS MARK: —/48

When calculating numerical answers, show your working or reasoning clearly. Give final answers to three significant figures and include appropriate units where applicable.

1. The following diagram represents a generator with a coil of 35 loops, 15.0 cm wide by 28.0 cm long. The field strength between the poles is 0.0125 T and the coil is spinning clockwise at a rate of 1380 cycles per minute. The arrows show the direction of induced current in the circuit.



(a) Label the poles of the magnet shown in the diagram. (1 mark)

(b) Calculate the maximum flux passing through the coil as it spins (3 marks)

$\phi = BA$ (1)

$= (0.0125)(0.150)(0.280)$ (1)

$= 5.25 \times 10^{-4}$ Wb (1)

(c) This type of generator is also known as an alternator. Explain why is it called an alternator. (1 mark)

- It generates an alternating current (1)

(d) Calculate the peak (maximum) EMF generated. (4 marks)

$f = \frac{1380}{60}$

$= 23.0\ Hz$ (1)

$EMF_{max} = -2\pi NBAf$ (1)

$= -2\pi(35)(0.0125)(0.150)(0.280)(23.0)$ (1)

$= -2.66\ V$

$\therefore \underline{EMF_{max}} = \underline{2.66\ V}$ (1)

(e) Calculate the effective (root mean square) voltage produced by the generator. (2 marks)

$EMF_{rms} = \frac{EMF_{max}}{\sqrt{2}}$

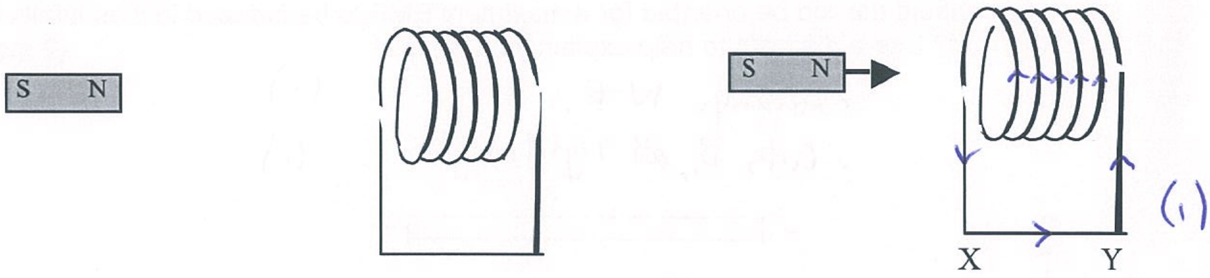
$= \frac{2.66}{\sqrt{2}}$ (1)

$= \underline{1.88\ V}$ (1)

(f) What is the value of the EMF when the coil is perpendicular to the magnetic field (B)? Use your knowledge of electromagnetic theory to explain your answer. (4 marks)

- Zero (1)
- The long side of the coil is moving parallel to the field. (1)
- No flux lines are being cut. (1)
- No EMF is induced in the conductor. (1)

2. A magnet is moved towards a coil of diameter 7.60 cm and consisting of 6 loops. The resistance of the coil wire is 0.222 Ohms. During this time the magnetic field strength passing through the coil increases from 2.00×10^{-3} T to 9.00×10^{-3} T generating an induced current 0.0345 Amps.



(a) Draw an arrow on the wire XY to show the direction of the induced current as the magnet is moved towards the coil. (1 mark)

(b) How long was the magnet moving toward the coil? (4 marks)

$$EMF = V = IR$$
$$= (0.0345)(0.222)$$
$$= 7.66 \times 10^{-3}\ V \quad (1)$$

$$EMF = -\frac{N\Delta\phi}{\Delta t} = \frac{-N\Delta B A}{\Delta t} = -\frac{N\Delta B \pi r^2}{\Delta t}$$

$$\Rightarrow \Delta t = -\frac{N\Delta B \pi r^2}{EMF} \quad (1)$$

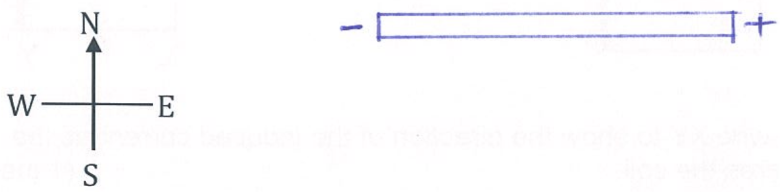
$$= -\frac{(6)(7.00\times10^{-3})\pi(0.0380)^2}{-7.66\times10^{-3}} \quad (1)$$

$$= \underline{2.49 \times 10^{-2}\ s} \quad (1)$$

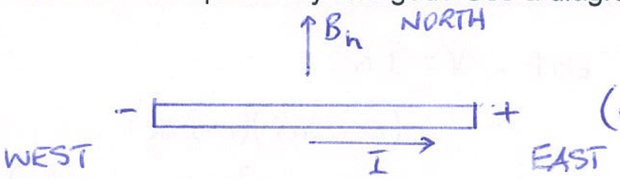
3. A steel rod of length 2.00 m and diameter 15.0 cm falls vertically from the top of a roof. Half way down it is travelling at 5.00 ms^{-1}. The horizontal (S → N) component of the Earth's magnetic field at this location is 2.88×10^{-5} T.

(a) How should the rod be oriented for a maximum EMF to be induced in it as it falls from the roof? Use a diagram to help explain your answer. (2 marks)

- Arrange W-E. (1)
- Cuts B_h at rightangles (1)



(b) Which end of the rod will be positively charged? Use a diagram to help show your answer. (1 mark)



(1)

(c) Calculate the maximum EMF that would be induced in the steel rod as it falls with a speed of 5.00 ms^{-1}. (3 marks)

$$EMF = B l v \quad (1)$$

$$= (2.88 \times 10^{-5})(2.00)(5.00) \quad (1)$$

$$= \underline{2.88 \times 10^{-4} \text{ V}} \quad (1)$$

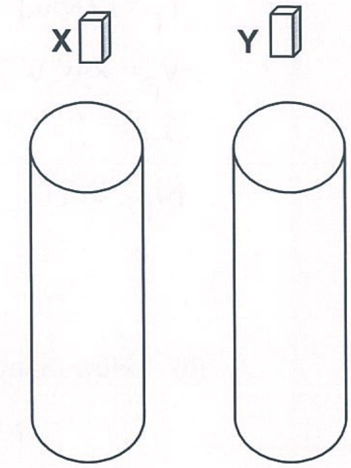
4. Energy consumption in our homes is measured in kilowatt-hours (kWh). Show that one kilowatt-hour is equal to 3.60 x 10^6 Joules. (3 marks)

$$E = Pt \quad (1)$$

$$= (1.00 \times 10^3)(60.0)(60.0) \quad (1)$$

$$= \underline{3.60 \times 10^6 \text{ J.}} \quad (1)$$

5. One bar magnet (X) is dropped through an aluminium cylinder. An identical magnet (Y) is dropped through a plastic cylinder.



(a) Which magnet will fall through its cylinder first (X or Y)?

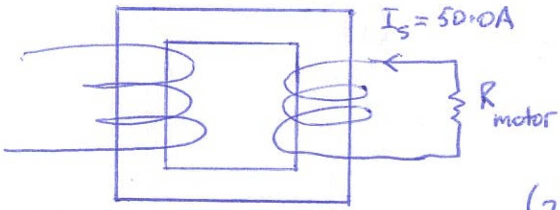
<u>Y</u> (1 mark)

(b) Using your knowledge of electromagnetic theory, explain your answer. (2 marks)

- Magnet X introduces a changing magnetic field to the Al cylinder.
- An eddy current is set up around the cylinder. (1)
- This produces an opposing magnetic field that slows the magnet.
- No eddy current exists in the plastic cylinder, hence it falls faster. (1)

6. The maximum power through the primary coil of a 100% efficient transformer is 1200 W at a voltage of 240 V. The primary coil has 800 turns. The secondary current produced is 50.0 A and is used to operate an electric motor.

(a) What voltage is produced in the secondary coil? Draw a diagram to help explain your answer. (4 marks)



(2)

$P_s = V_s I_s$

$\Rightarrow V_s = \frac{1200}{50.0}$ (1)

$= \underline{24.0 V}$ (1)

$P_p = 1200W$ $\quad$ $P_s = 1200W$

$V_p = 240V$ $\quad$ $V_s = ?$

$I_p = ?$ $\quad$ $I_s = 50.0A$

$N_p = 800$ $\quad$ $N_s = ?$

(b) How many turns does the secondary coil contain? (2 marks)

$\frac{N_s}{N_p} = \frac{V_s}{V_p}$

$\Rightarrow N_s = \frac{(24.0)(800)}{240}$ (1)

$= \underline{80}$ (1)

(c) Most transformers are not 100% efficient.

(i) Identify one source of power loss in the transformer core. (1 mark)

- Eddy currents in iron core.
- Resistance in the coils.

[Either - 1 mark]

(ii) Using your knowledge of electromagnetic theory, explain why the answer you gave for (c)(i) causes a reduction of efficiency. (3 marks)

Eddy currents
- Large cross-section (1) produces large eddy currents. (1)
- Produces a large energy loss according to $P_{loss} = I^2R$. (1)

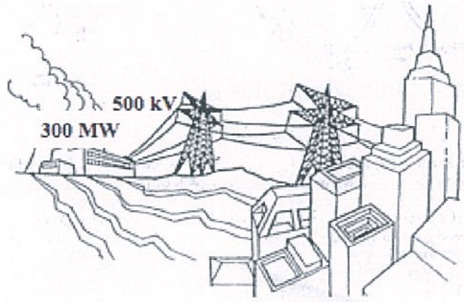
Resistance in coils
- $R = \frac{\rho l}{A}$ (1)
- $R \propto \frac{1}{A}$ (1) $\Rightarrow P_{loss}$ is greater for thin wires. (1)

(iii) Identify one way that transformer core power loss can be reduced. (1 mark)

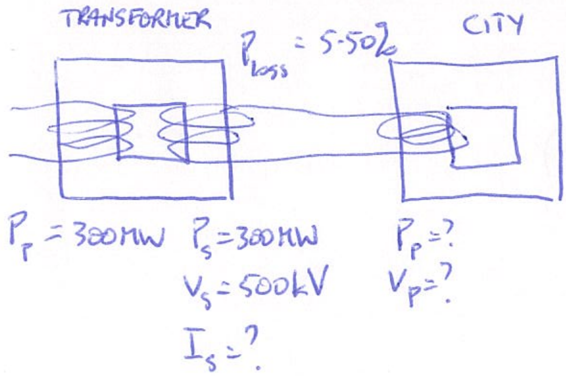
- Eddy currents - laminate the core to produce smaller currents.
- Resistance - coil with largest current must be thicker to reduce the resistance R.

[Either - 1 mark]

7. A power station produces 300 MW of electric power for a distant city. Just outside the power station, a 100% efficient transformer boosts the voltage to 500 kV. The power loss (and therefore also the voltage loss) occurring along the transmission wires is 5.50%.



(a) Calculate the power lost along the transmission wires. (2 marks)



$$P_{loss} = \frac{5.50}{100} \times \frac{300 \times 10^6}{1} \quad (1)$$

$$= 1.65 \times 10^7 \text{ W}$$

$$= \underline{16.5 \text{ MW}} \quad (1)$$

(b) Calculate the current flowing in the transmission wires. (2 marks)

$$P_s = V_s I_s$$

$$\Rightarrow I_s = \frac{300 \times 10^6}{500 \times 10^3} \quad (1)$$

$$= \underline{6.00 \times 10^2 \text{ A}}. \quad (1)$$

(c) Calculate the resistance of the transmission cables. (2 marks)

$$P_{loss} = I_s^2 R$$

$$\Rightarrow R = \frac{1.65 \times 10^7}{(6.00 \times 10^2)^2} \quad (1)$$

$$= \underline{45.8\ \Omega} \quad (1).$$

(d) Calculate the voltage available at the city. (2 marks)

$$V_{CITY} = V_{TRANS} - V_{DROP}$$

$$= 94.5\%\ V_{TRANS}$$

$$= \frac{94.5}{100} \times \frac{500 \times 10^3}{1} \quad (1)$$

$$= 4.72 \times 10^5\ V$$

$$= \underline{472\ kV} \quad (1)$$