AQA

A Level

A Level Physics

Electromagnetism 3 (Answers)

Name:

MME
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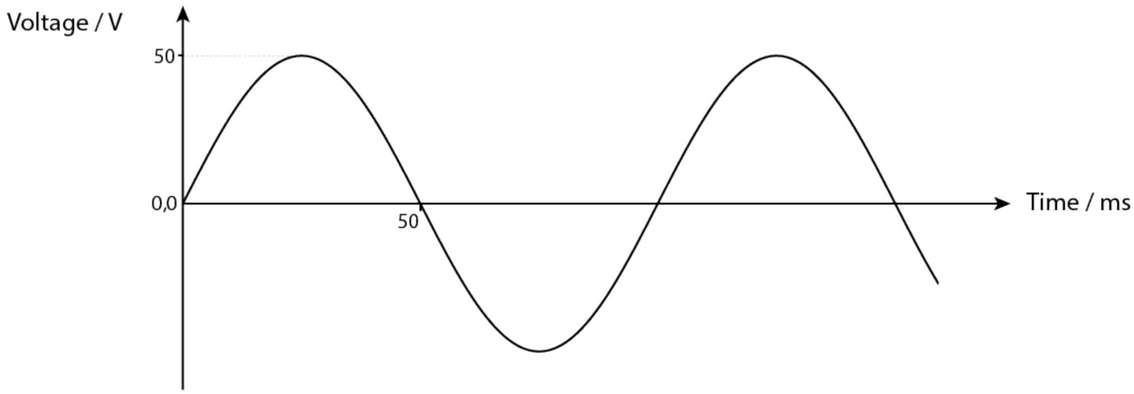
Total Marks: /30

1. The graph below shows how the voltage varies sinusoidally as a square coil is rotated in a uniform magnetic field of flux density 0.8 T. The coil measures 5 cm along each side and has 500 turns.

Total for Question 1: 17



(a) The variation of voltage with time can be modelled by the equation $V = V_{max} \sin \omega t$, where V_{max} and ω are the peak voltage and the angular frequency, respectively. By considering the power dissipated through an ohmic resistor, show that the average power dissipated is given by $\frac{V_{max}^2}{2R}$. [3]

Solution: $P = V^2/R = \frac{V_{max}^2 \sin^2 \omega t}{R}$
Average value of $\sin^2$ function is 0.5.
Rearranging gives $P = \frac{V_{max}^2}{2R}$

(b) This will be the same as the power dissipated by a direct current source running through a resistor. Express V_{DC} in terms of V_{max}. [2]

> **Solution:** $V_{DC} = V_{max}/\sqrt{2}$

(c) In the UK, the peak voltage of mains electricity is about 325 V. Why, then, is mains electricity frequently referred to as having a voltage of 230 V? Support your answer using simple calculations. [3]

> **Solution:** The voltage and current both vary sinusoidally for an AC power supply. The power supplied by a $V_{peak} = 325$ V AC source will not be the same as that supplied by a 325 V DC source. For comparison purposes, it is useful to know the nominal DC-equivalent voltage of a AC supply. This is the RMS voltage, which for a sinusoidal variation is $V_{peak}/\sqrt{2}325/\sqrt{2} = 230$ V.

(d) The AC supply above is used to power a circuit with a resistance of 40.0 Ω. Calculate the following:

i. The angular frequency of the supply. [2]

> **Solution:** 20π rad s^{-1}

ii. The peak current in the circuit. [2]

> **Solution:** 1.25 A

iii. The time taken to dissipate 800 J of energy in the circuit. [2]

> **Solution:** 25.6 s

iv. The emf induced in the coil after 25 ms of operation. [3]

> **Solution:** 1.7 V

2. Power in the national grid is transmitted at very high voltages. Transformers are used to reduce the transmission voltages to safer domestic voltages. A country's national grid depends on approximately 12000 km of power transmission cables operating at about 400 kV.

Total for Question 2: 13

(a) If the secondary coil of one of the step-down transformers is to continually have a non-zero current, why must the primary coil's supply have an alternating current? [3]

> **Solution:** If it were DC, when initially switched on the primary coil would produce a magnetic field. This flux is linked to the secondary coil so we would see a sudden increase in the voltage of the secondary coil. However, once the magnetic field stabilises there will no longer be any change in the flux linkage and so, by Faraday's law, there will be no induced emf in the secondary coil.
> In contrast, as the AC current varies, so too will the induced magnetic field. Therefore, the flux linkage will be constantly changing and a constantly varying, non-zero emf will be induced in the secondary coil.

(b) Why is it important that electricity is transmitted at high voltages and through cables with low resistivities? [2]

> **Solution:** High voltage implies low current. Since $P = I^2R$, this reduces losses.
> Low resistivity (an intrinsic property) will yield low resistance for a cable of a given length, again reducing dissipation.

(c) Given that the current in the grid is approximately 1000 A, calculate the resistance of the network expressing your answer in units of $\Omega\ \text{km}^{-1}$. [3]

> **Solution:** 0.03

(d) A typical power station provides an average of 80 MW to the grid. Calculate the power supplied by the grid, assuming that 100 stations like these feed it. [3]

> **Solution:** 7.6 GW

(e) Using your answer to the previous part, calculate the efficiency of the grid. [2]

> **Solution:** 95 %