

11 Electro-magnetic induction review answers

Induced emf

1. A wire is moved left to right through a magnetic field going into page as shown.

State the direction of the induced electromotive force. **The electrons will move up the wire so the bottom of the wire will become positive meaning the emf is up the wire.**

- a. State the formula giving the size of this emf.

$\text{Emf} = Bvl = \text{Magnetic flux density} \times \text{velocity of wire} \times \text{length of wire}$

2. In the next diagram two coils of resistance wire of different diameters are in the same uniform magnetic field B. The magnitude of the magnetic field is increasing with time at a rate of 8T s^{-1} .

- a. State Lenz's law and use it to work out in which direction the current will flow.

The direction of the induced current will be such as to oppose the change in magnetic field. So current is anticlockwise

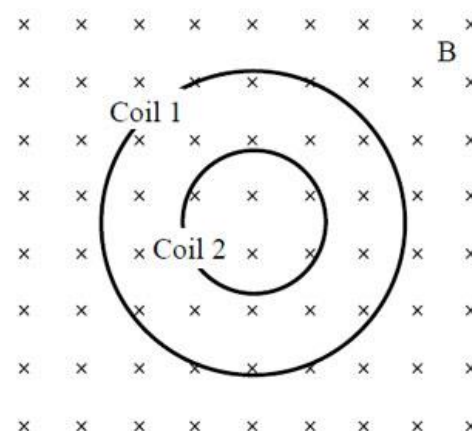
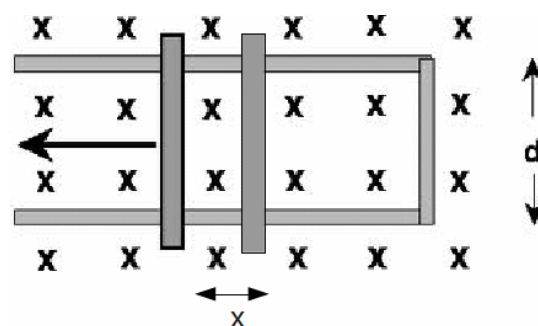
- b. Calculate the size of the induced emf ignoring the magnetic effect of the induced current.

$\text{Emf} = -N \times \text{rate of change of flux}$

$N = 1$ so $\text{emf} = -8\text{V}$

- c. State why the actual emf induced will be less than your answer in part b.

The current in the coil might increase quite fast which would result in an increasing magnetic field out of the paper which has the effect of reducing rate of change of flux



Alternating current

The trace opposite shows the induced emf of an AC generator peaking at 0.2V with a period of 64ms for a rotation.

1. State the approximate rms value of the voltage.

$0.2 \times \sqrt{2} = 0.28\text{V}$

2. Describe and quantify two differences in the trace if the generator was to rotate with a period of 32ms.

Frequency and emf amplitude both halved

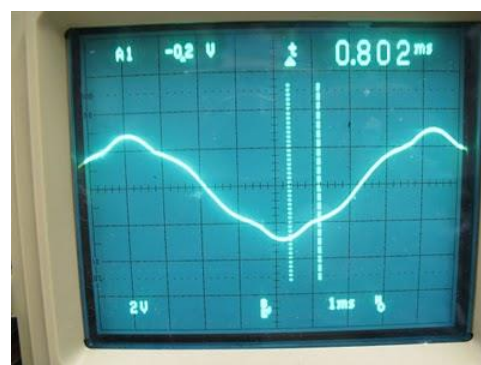
3. If the generator was connected to a 100 Ohmic resistor for this experiment calculate the power dissipated.

- a. At 64ms rotation period.

(must use rms values!) $P = V \times I = V^2/R = 0.28^2 / 100 = 0.00784 \text{ W} = 7.8 \text{ mW}$

- b. At 32ms rotation period.

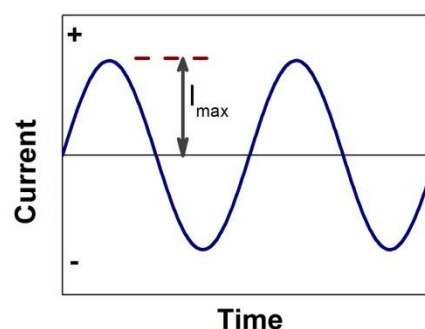
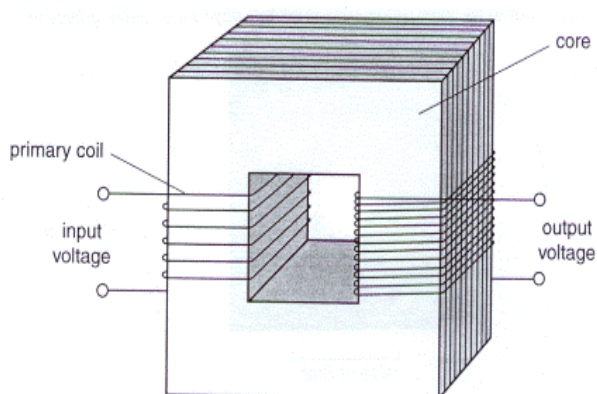
(rms) $P = V \times I = V^2/R = 0.14^2 / 100 = 0.00196 \text{ W} = 2.0 \text{ mW}$



4. Describe how alternating current in a primary coil induces emf in a secondary coil of a transformer. State at what point in current's variation the induced voltage will be at its maximum.

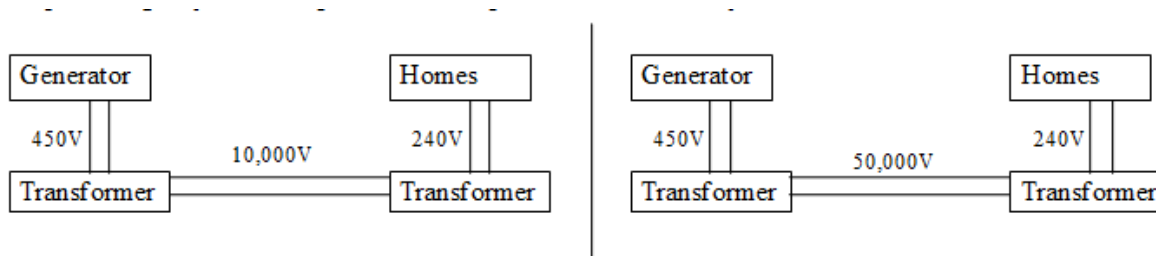
A transformer works by the primary coil setting up an alternating magnetic field in the core and the alternating magnetic field inducing a current in the secondary coil.

When the primary current is changing the most the maximum voltage will be induced in the secondary coil (Emf = - N x rate of change of flux). This occurs when the primary current is zero



Transmission of electrical power

1. This question gets you to compare these two power transmission systems:



The high voltage transmission lines in each system have a resistance of 1 Ohm. You can assume all other parts of the system to be "perfect". (in other words no power loss / 100% efficient).

- (i) If the "Homes" are using 100 kW of electrical power what current is being drawn on the 240V circuit ?

$$P = VI \text{ so } I = P/V = 100,000 \text{ W} / 240 \text{ V} = 417 \text{ A}$$

- (ii) What current is being drawn on (a) the 10,000V line and (b) the 50,000V line.

Same method as (i) there is 10A in the 10,000V line and 2A in the 50,000V line

- (iii) Given that the power loss is equal to I^2R for any circuit component calculate the power loss for

(a) The 10,000V line

(b) The 50,000V line

$$10^2 \times 1 = 100\text{W}$$

$$2^2 \times 1 = 4\text{W}$$

- (iv) What power must the generators provide (4 s.f.)

(a) For the 10,000V line

(b) For the 50,000V line

$$100.1 \text{ kW}$$

$$100.0 \text{ kW}$$

(v) What current must the two generators produce if their output voltage is 450V?

$$I = P / V = 100(.1) / 450 = 0.22A$$

(vi) Why are very high voltage lines used for long distance power distribution?

The higher the voltage the less current is required to deliver the power and so the less power losses.

2. Transformers are not “perfect”. An alternating supply delivers a current of 0.025 A at 12 V to the primary coil of a transformer. A 20 Ω resistor is connected to the secondary coil. The current in the secondary circuit is 0.110 A.

a. Calculate the power input.

$$P = VI = 12 \times 0.025 = 0.30 \text{ W}$$

b. Calculate the power output.

$$P = I^2R = 0.11^2 \times 20 = 0.24 \text{ W}$$

c. Calculate the efficiency.

$$0.242/0.3 = 0.81 \text{ (81\%)}$$

3. For the same transformer as in question 2 the frequency of the supply is increased. The power input is kept constant. The current in the secondary coil falls to 0.105 A. Calculate the new efficiency of the transformer.

$$P = I^2R = 0.105^2 \times 20 = 0.22 \text{ W}$$

$$0.2205/0.3 = 0.34 \text{ (74\%)}$$

Outline why many people do not wish to live near to electricity sub-stations and power lines.

== Not on syllabus but worth knowing. ==

There is some evidence to suggest the radiation given out by substation and power lines (electro-magnetic radiation at 50Hz – very low frequency - causes health problems similar to problems caused by stress / poor sleep.

== Metal grids in the walls / micro metal grids in the windows can reduce it ==

Capacitance

1. Define a dielectric material and explain why they are useful in a capacitor.

A dielectric material is an insulator that can be polarised by an electric field. It is useful in a capacitor as it prevents charge flowing between the two plates whilst allowing a large build-up of charge for an applied potential difference. (i.e. a larger capacitance)

2. A capacitor of coiled plates can be approximated to a parallel plate capacitor. A 16 μ F capacitor has a plate area of 6500 mm² and a plate separation of 0.20 μ m. Calculate the permittivity of the dielectric material in between the plates.

$$C = \epsilon A/d \text{ so } \epsilon = Cd/A \rightarrow \epsilon = 16 \times 10^{-6} \times 0.2 \times 10^{-6} / 6500 \times 10^{-6} = 4.9 \times 10^{-10} \text{ F}$$

3. The graph shows the charge stored on a capacitor for varying applied potential differences:

- a. Calculate the capacitance of the capacitor

Using value from graph at 8V:

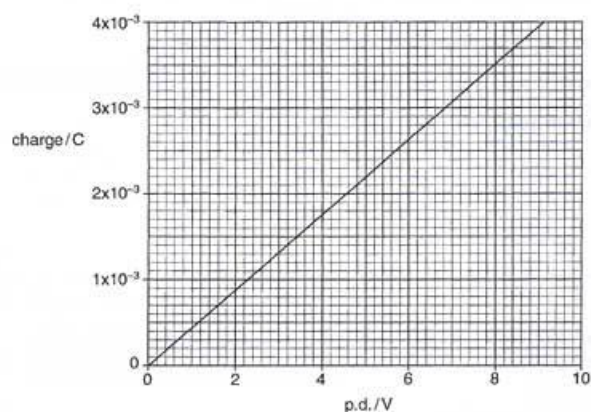
$$C = q/V = 3.5 \times 10^{-3} / 8 = 4.4 \times 10^{-4} \text{ F}$$

- b. Calculate the energy stored on the capacitor when a potential difference of 8V is applied across it.

$$E = \frac{1}{2} CV^2 = 0.5 \times 4.4 \times 10^{-4} \times 8^2 \\ = 1.4 \times 10^{-2} \text{ J}$$

- c. State the effect on the energy storage if two such capacitors are connected

- i. In series **The energy stored would halve**
 ii. In parallel **The energy stored would double**



4. The graph below shows the potential difference across a capacitor as it charges from a 9.0V battery via a 14.3kΩ resistor. The potential difference on a charging capacitor at time t is:

$$V = V_0(1 - e^{-(t/\tau)}) \text{ where } V_0 \text{ is the final potential difference and } \tau \text{ is the time constant.}$$

- a. Using the graph show that a time constant of 10s^{-1} is correct for this circuit.

The graph shows the after

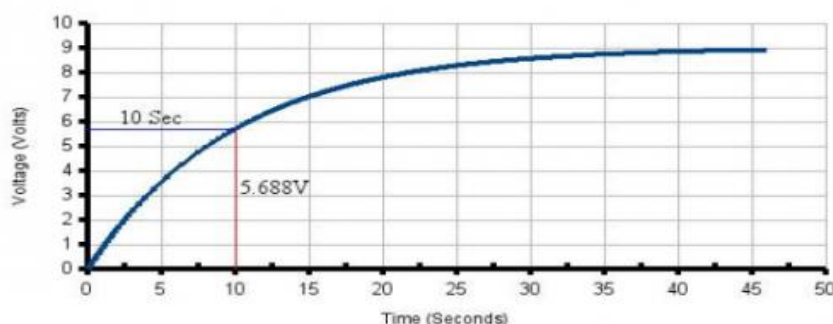
10s the pd. is 5.7V

$$9(1 - e^{-(10/10)}) =$$

$$9(1 - 0.368) = 5.7$$

Hence calculate.

Capacitor Charging



- b. The capacitance of the capacitor.

$$T = RC \text{ so } C = T/R = 10/14.3 \times 10^3 = 7.0 \times 10^{-4} \text{ F}$$

- c. The final amount of charge stored.

$$q = CV = 7.0 \times 10^{-4} \text{ F} \times 9 \text{ V} = 6.3 \text{ mC}$$

- d. The amount of charge stored at time t=10s

$$q = CV = 7.0 \times 10^{-4} \text{ F} \times 5.688 \text{ V} = 4.0 \text{ mC}$$

- e. The final amount of energy stored.

$$E = \frac{1}{2} CV^2 = 0.5 \times 7.0 \times 10^{-4} \times 9^2 = 2.8 \times 10^{-2} \text{ J}$$

- f. The rate of transfer of energy at t=5s

$E/t = P = VI$ – then use exponential equations to get V and I from V_0 and I_0

$V = V_0 e^{-(t/T)}$ is the equation for discharging for charging $V = V_0(1 - e^{-(t/T)})$

$$V = 9(1 - e^{-(5/7)}) = 4.59 \text{ V};$$

$$I_0 = V_0/R = 9/14 \times 10^3 = 0.643 \text{ mA}$$

$$I = I_0(1 - e^{-(t/T)}) = 0.643(1 - e^{-(5/7)}) = 0.328 \text{ mA}$$

$$P = VI = 4.59 \times 0.328 = 4.59 \text{ mW}$$