MCQ Answer Key

1	**2**	**3**	**4**
B	C	C	A

1 for sinusoidal alternating current: $I_{rms} = \dfrac{V_{rms}}{R} = \dfrac{V_0}{\sqrt{2}R}$ and $\langle P \rangle = \dfrac{V_{rms}^2}{R} = \dfrac{V_0^2}{2R}$

if V_0 is doubled, I_{rms} doubles, and $\langle P \rangle$ increases by four times

2 $\langle P \rangle = I_{rms}^2 R = \dfrac{I_0^2}{2} R = \dfrac{5.0^2}{2}(10) = 125 \text{ W}$

3 half-wave sinusoidal rectified current:

$I_{rms} = \dfrac{I_0}{2} = \dfrac{7.6}{2} = 3.8 \text{ A}$

$\langle P \rangle = I_{rms}^2 R = (3.8)^2 (9.4) = 135 \text{ W} = 140 \text{ W (to 2 s.f.)}$

4 full-wave sinusoidal rectified voltage:

$V_{rms} = \dfrac{V_0}{\sqrt{2}} = \dfrac{224}{\sqrt{2}} = 158.39 \text{ V}$

$\Rightarrow I_{rms} = \dfrac{V_{rms}}{R} = \dfrac{158.39 \text{ V}}{70.0\ \Omega} = 2.26 \text{ A}$

and $\langle P \rangle = I_{rms}^2 R = (2.263)^2 (70.0) = 358 \text{ W}$

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5 A sinusoidal current I through a 10.0 Ω resistor varies with time t according to the equation $I = 1.2 \sin 100\pi t$. Determine the current and power dissipated at $t = 0.018$ s.

$I = 1.2 \sin(100\pi \times 0.018) = -0.705 \text{ A}$

$P = I^2 R = (-0.705)^2 \times 10 = 4.98 \text{ W}$

6 A steady current I dissipates a certain power in a variable resistor. The resistance has to be halved to obtain the same power when a sinusoidal alternating current is used.
What is the r.m.s. value of the alternating current?

$P_{dc} = I^2 R$ and $\langle P \rangle_{ac} = I_{rms}^2 \left(\dfrac{R}{2}\right)$

Since $P_{dc} = \langle P \rangle_{ac}$

$I^2 R = I_{rms}^2 \left(\dfrac{R}{2}\right)$

$I_{rms} = \left(\sqrt{2}\right) I$

7 Determine the r.m.s. current in each case.

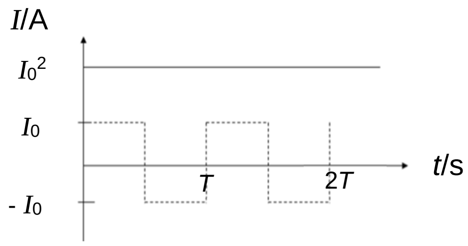
(a) A sinusoidal current of peak value 2.0 A.

For a sinusoidal current, $I_{rms} = \dfrac{I_o}{\sqrt{2}} = \dfrac{2}{\sqrt{2}} = 1.41 \text{ A}$

(b) A full-wave rectified sinusoidal current of peak value 3.0 A.

$I_{rms} = \dfrac{I_o}{\sqrt{2}} = \dfrac{3.0}{\sqrt{2}} = 2.12 \text{ A}$

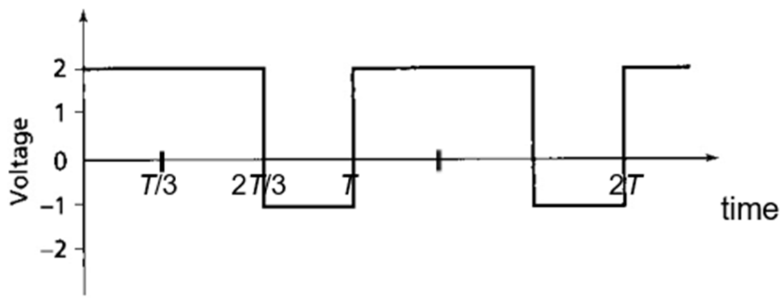
(c) A square wave current with a frequency of 1.0 Hz and has a value of 0.10 A for one half cycle and –0.10 A for the next half cycle.

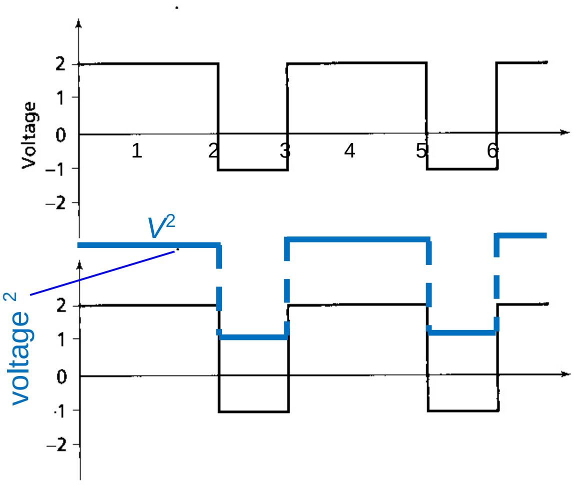


I^2 would yield a constant value of 0.010 A^2. Hence $\langle I^2 \rangle$ = 0.010 A^2 and I_{rms} = 0.10 A.

$I_{rms} = I_o = 0.10$ A

(d) An uneven square wave voltage as shown below.

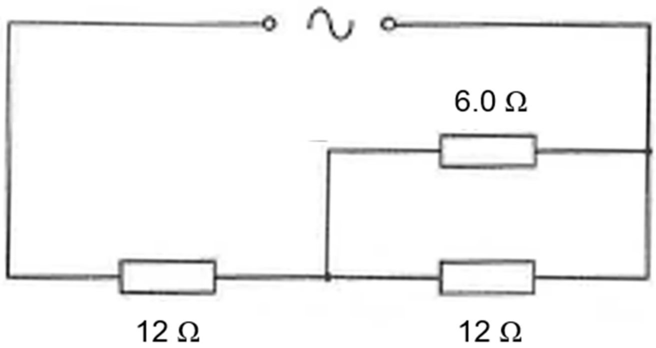




$$\langle V^2 \rangle = \frac{\int_0^T V^2 dt}{T} = \frac{4\left(\frac{2}{3}T\right) + 1\left(\frac{1}{3}T\right)}{T} = 3.0 \text{ V}^2 \Rightarrow V_{rms} = \sqrt{\langle V^2 \rangle} = 1.73 \text{ V}$$

$$\Rightarrow I_{rms} = \frac{1.73}{R} \text{ A} \quad \text{where } R \text{ (in } \Omega\text{) is the resistance in the a.c. circuit}$$

8 An a.c. power supply is connected to three resistors as shown.



The variation with time *t* of the voltage *V* of the power suply is given by the expression

$$V = 9.0 \sin 120\pi t$$

(a) For the power supply, determine

(i) the frequency *f*,

$\omega = 2\pi f = 120\pi$

$\Rightarrow f = 60 \text{ Hz}$

(ii) the root-mean-square (r.m.s.) voltage [60 Hz, 6.4 V]

$V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}} = \dfrac{9.0}{\sqrt{2}} = 6.4 \text{ V}$

(b) Calculate the peak current from the power supply. [0.56 A]

effective resistance of external circuit, $R = 12 + \dfrac{6.0 \times 12}{6.0 + 12} = 12 + 4.0 = 16.0\ \Omega$

peak current, $I_0 = \dfrac{V_0}{R} = \dfrac{9.0}{16.0} = 0.56 \text{ A}$

(c) Calculate the mean power dissipated in the resistor of resistance 6.0 Ω. [0.42 W]

Using potential divider principle,

peak voltage across the 6.0 Ω resistor $= \dfrac{4.0}{16.0}(9.0) = 2.25 \text{ V}$

mean power dissipated in the 6.0 Ω resistor, $\langle P \rangle = \dfrac{V_{\text{rms}}^2}{R} = \dfrac{V_0^2}{2R} = \dfrac{(2.25)^2}{2 \times 6.0} = 0.42 \text{ W}$

9 **(a)** The r.m.s. value of an a.c. is the value of the steady direct current which would dissipate heat at the same average rate in a given resistor.

(b) **(i)** For a sinusoidal voltage, $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}} = \dfrac{170}{\sqrt{2}} = 120 \text{ V}$

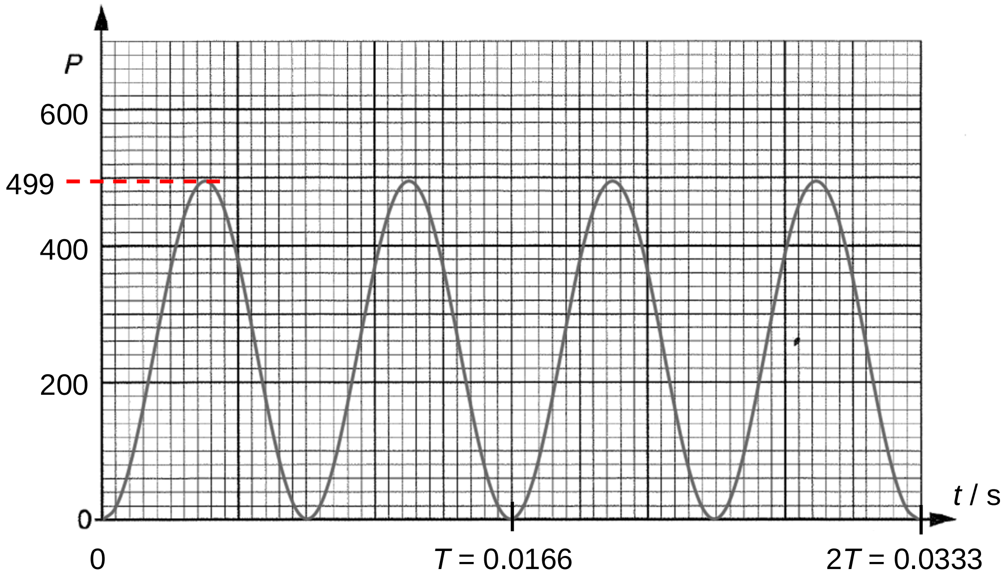
(ii) $f = \dfrac{\omega}{2\pi} = \dfrac{377}{2\pi} = 60 \text{ Hz}$

(iii) $\langle P \rangle = \dfrac{1}{2}\dfrac{V_0^2}{R} = \dfrac{1}{2}\dfrac{170^2}{58} = 249 \text{ W}$

(c) $T = \dfrac{1}{f} = \dfrac{1}{60} = 0.017 \text{ s}$

$$P = \frac{V^2}{R} = 499\ \sin^2 \omega t$$

A graph of P vs t shows a positive sine square curve with a time equal to two periods of the alternating potential difference:



MCQ Answer Key

10	11	12
B	D	B

10 $$\frac{(V_0)_2}{(V_0)_1} = \frac{1}{16} \Rightarrow (V_0)_2 = \frac{(V_0)_1}{16} = \frac{180}{16} = 11.25\text{ V}$$

$$\langle P \rangle = \frac{V_{rms}^2}{R} = \frac{V_0^2}{2R} \Rightarrow R = \frac{V_0^2}{2\langle P \rangle} = \frac{11.25^2}{2(32)} = 1.98\ \Omega = 2.0\ \Omega \text{ (to 2 s.f.)}$$

11 from turn ratio $= \frac{N_2}{N_1} = \frac{V_{\text{rms, 2}}}{V_{\text{rms, 1}}} = \frac{I_{\text{rms, 1}}}{I_{\text{rms, 2}}}$,

we have $\frac{600}{N_1} = \frac{9.0}{V_{\text{rms, 1}}} = \frac{250}{750} = \frac{1}{3}$

$\Rightarrow N_1 = 3 \times 600 = 1800$ and $V_{\text{rms, 1}} = 3 \times 9.0 = 27\text{ V}$

12 from turn ratio $= \frac{N_2}{N_1} = \frac{V_{\text{rms, 2}}}{V_{\text{rms, 1}}} = \frac{I_{\text{rms, 1}}}{I_{\text{rms, 2}}}$,

if N_2 is doubled and N_1 stays the same, then the new turn ratio $= 2 = \frac{V_s}{V_p} = \frac{I_p}{I_s}$

$\Rightarrow \frac{V_p}{V_s} = \frac{1}{2}$ (halves) and $\frac{I_p}{I_s} = 2$ (doubles)

13

(a) Use Faraday's law to explain why an alternating current in the primary coil gives rise to an alternating e.m.f. in the secondary coil. [4]

When a current flows through the primary coil, it produces a magnetic field.

[B1]

If the current is alternating (due to an alternating e.m.f. source), the magnetic flux linkage Φ_P through the primary coil also alternates continuously.

[B1]

The iron core serves to strengthen the magnetic flux and ensure efficient linkage of the flux from the primary coil to the secondary coil.

[B1]

In the secondary coil, the alternating magnetic flux linkage induces an alternating e.m.f., in accordance with Faraday's Law, which states that the induced e.m.f. is proportional to the rate of change of magnetic flux linkage.

[B1]

(b) In practice, the core of some transformer is made of laminated soft iron.

(i) State two reasons why soft iron, which is easily magnetized and demagnetized, is used as the core. [2]

Soft iron has **high magnetic permeability**, which greatly increases the magnetic flux density in the core. This amplifies the changes in magnetic flux linkage, resulting in a stronger induced e.m.f. in the secondary coil. Consequently, it enhances the efficiency of the transformer by improving the transfer of magnetic flux between the primary and secondary coils.

[B1]

Soft iron has **low hysteresis loss** because it can be easily magnetized and demagnetized by the alternating magnetic field caused by the current in the primary coil. This minimizes energy loss as heat in the core, which occurs when the energy required to magnetize the core is not entirely recovered during demagnetization.

[B1]

(ii) Explain how the lamination of the core reduces energy losses. [2]

Alternating magnetic flux in the core induces eddy currents, which are circulating currents in the core material. These eddy currents cause resistive heating, leading to energy losses.

[B1]

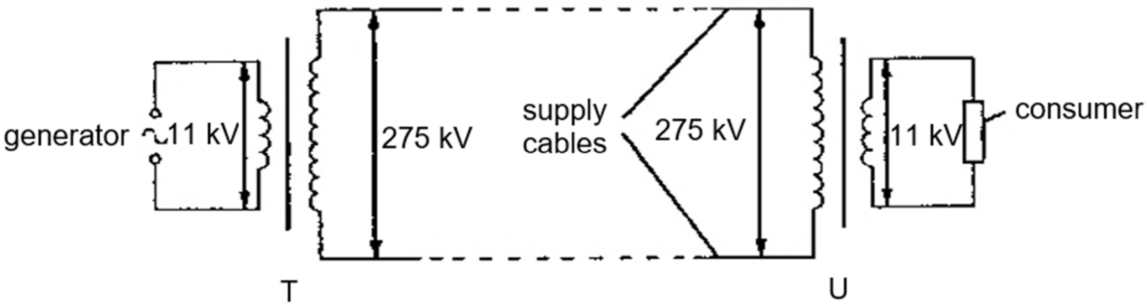
Lamination of the core involves using thin sheets of iron separated by an insulating varnish, which significantly increases the electrical resistance of each lamina's surface. This confines the eddy currents to individual laminae, narrowing their possible paths. The increased resistance of these paths **reduces the size** of the eddy currents, thereby **minimizing their heating effects and energy losses**.

[B1]

[Refer to Lecture Notes Annex D on Page 18-19.]

14 Jun98/II/5

Electrical power of 4400 kW is supplied to an industrial consumer at a considerable distance from a generating station. This is represented below.



In order to do this, the electricity supply company makes use of a circuit containing two transformers T and U. The transformers can be considered to be ideal and the supply cables are said to have negligible resistance.

(a) The power is generated at 11 kV r.m.s. and is supplied to the consumer at 11 kV r.m.s. Calculate the r.m.s. current supplied to the consumer.

$$I_{\text{rms}} = \frac{\langle P \rangle}{V_{\text{rms}}} = \frac{4400 \text{ kW}}{11 \text{ kV}} = 400 \text{ A}$$

(b) There is a potential difference of 275 kV r.m.s. between the supply cables. Calculate

1. the ratio $\frac{N_s}{N_p}$ for each transformer

For transformer T, $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{275}{11} = 25$

For transformer U, $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{11}{275} = \frac{1}{25}$

2. the current in the supply cables

$$I_{\text{rms}} = \frac{\langle P \rangle}{V_{\text{rms}}} = \frac{4400 \text{ kW}}{275 \text{ kV}} = 16 \text{ A}$$

(c) Explain why, when the resistance of the supply cables cannot be neglected, this arrangement is preferable to a system which generates and transmits the power at the same voltage of 11 kV r.m.s.

If there is resistance R in the supply cables, there would be power loss ($I_{\text{rms}}^2 R$) when transmitting electrical energy across the cables. Without a step-up and step-down transformer, the electrical energy would be transmitted with a current of 400 A, and would result in a much larger power loss in the supply cables.

The power loss in the supply cables would be larger by a factor $\left(\dfrac{400}{16}\right)^2 = 625$.

In transformers, the voltage ratio V_s/V_p is equal to the turns ratio N_s/N_p. Thus if the transformer's secondary has more turns than the primary, then the secondary voltage will be higher than the primary. By connecting the power generator to the primary coil of a transformer, the transmitted voltage can be stepped up to a high value for transmission, with an aim to reduce the power loss in the supply cables.

(d) Find the peak value of the current in (a).

For a sinusoidal current, $I_o = \sqrt{2} I_{\text{rms}} = \sqrt{2}(400) = 566$ A

- End -