Page 435 Test yourself on prior knowledge

1 $f = \frac{1}{T}$

$= \frac{1}{0.004\ s}$

= 250 Hz

2 P = I^2R

= $(13\ A)^2 \times 14\ \Omega$

= 2.4 kW

3 ε = – NΔϕ/Δt = NΔ(BA)/Δt

and ε = IR

so:

$B = \frac{IRt}{NA}$

$= \frac{35 \times 10^{-3} \text{A} \times 50\Omega \times 0.2\ \text{s}}{10000 \times (1.5 \times 10^{-2} \text{m})^2}$

= 0.16 T

Page 438 Test yourself

1 The square root of the time average of the voltage squared, or peak voltage / √2.

2 **a)** $I_{rms} = V_{rms}/R$

= 6.0 V / 2.5 Ω

= 2.4 A

b) $P_{mean} = V_{rms}I_{rms}$

= 2.4 A × 6.0 V

= 14.4 W

c) $P_{peak} = 2\ P_{mean}$

= 2 × 14.4 W

= 28.8 W

3 **a)** P_{mean} = 15 kW

$I_{rms} = P_{mean}/V_{rms}$

= 15 000 W/ 120 V

= 125 A

b) $V_0 = V_{rms} \times \sqrt{2}$

$= 120\ V \times \sqrt{2}$

$= 170\ V$ (2 sf)

c) $P_{peak} = V_0 I_0$

$= 170\ V \times (125 A \times \sqrt{2})$

$= 30.1\ kW$

4 a) $P_{mean} = (P_{peak})/2$

$= 400\ W/2$

$= 200\ W$

b) UK mains (rms) voltage = 230 V

$I_{rms} = P_{mean} / V_{rms}$

$= 200\ W / 230\ V$

$= 0.87\ A$

Page 444 Test yourself

5 a) An emf is only induced if the magnetic flux changes, which does not happen if a dc supply is used: dc supplies a constant emf.

b) The laminations reduce the eddy currents generated in the core and improve the transformer's efficiency. Eddy currents reduce the value of the induced emf in the secondary coil and these large currents also heat the core and transfer energy to the surroundings.

c) A step-down transformer induces a lower voltage and larger current in the secondary coil. Power losses in the coil are given by I^2R, and using a thicker wire reduces R, which reduces losses in the secondary coil.

6 a) The turns ratio $N_s / N_p = V_s / V_p$

$= 132\ kV / 25\ kV$

$= 5.28 : 1$

b) Efficiency = 0.90 = power output / power input

Power input = $V_p I_p$

$= 25\ kV \times 40\ A = 1\ MW$

Power output = 1 MW × 0.90

= 900 kW

c) Current in the secondary, I_s = power output/V_s

= 900 kW / 132 kV

= 6.8 A

7 a) $N_s = V_s \times N_p / V_p$

$= 48\ V \times 200 / 12\ V$

$= 800$ turns on the secondary coil

b) Rearranging $V_p I_p = V_s I_s$ gives

$I_s = V_p I_p / V_s$

$= 12\ V \times 2.4\ A / 48\ V$

$= 0.6\ A$

8 Efficiency $= 0.95 = V_s I_s / V_p I_p$

$0.95 = 6\ V \times 4.8\ A / (230\ V \times I_p)$

$I_p = (6\ V \times 4.8\ A) / (230\ V \times 0.95)$

$I_p = 0.13\ A$

Pages 445–448 Practice questions

1 C

2 A

3 D

4 D

5 C

6 C

7 B

8 D

9 A

10 D

11 a) peak-to-peak voltage **=** 4 divisions × 3V per division = 12 V [1]

b) $V_{rms} = V_0/\sqrt{2}$ and $V_0 = 12\ V/2 = 6V$

$V_{rms} = 6\ V/\sqrt{2}$

$= 4.24\ V$ [1]

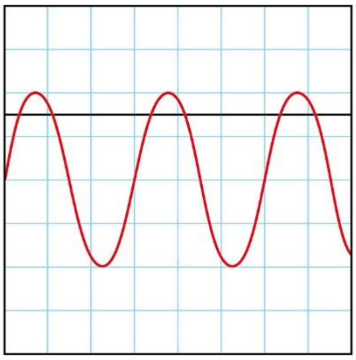
c) T = 3 divisions at 25 ms per division = 75 ms [1]

d) $f = 1/T$ [1]

$= 1/(75 \times 10^{-3}\ s)$

$= 13.3$ Hz (13 Hz to 2 sf) [1]

e) [1 mark for straight horizontal line; 1 mark for V = 4.24 V]



12 a) Maximum voltage of a waveform [1]

$V_{rms} = V_0/\sqrt{2}$ [1]

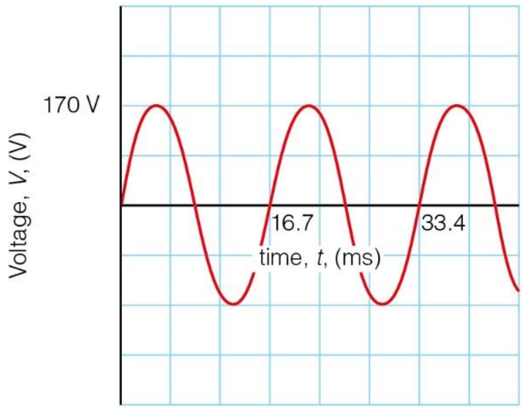
b) $V_{rms} = V_0/\sqrt{2}$ [1]

$= 170\ V/\sqrt{2} = 120\ V$ [1]

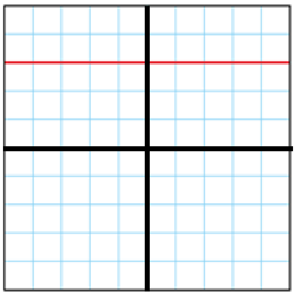
c) $P_{mean} = V_{rms}I_{rms}$

$= 120\ V \times 0.50\ A = 60\ W$ [1]

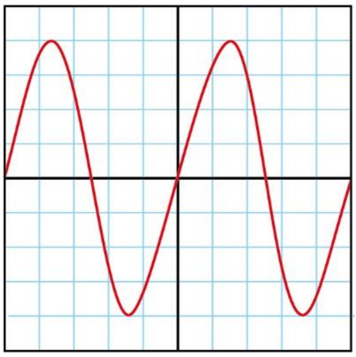
d) T = 1/f = 1/60 Hz = 16.7 ms [1]
Sinusoidal waveform of at least one cycle [1]
Peak voltage labelled [1]
At least one time value consistent with calculation of T [1]



13 a) i) Horizontal line 3 squares above axis [1 mark]



ii) Sinusoidal waveform of 4 squares amplitude [1]
Two complete cycles [1]
(because T = 1/50 Hz = 0.02 s, 0.02 s/4 × 10^{-3} s per division = 5 divisions)



b) $V_{rms} = V_0/\sqrt{2}$ [1]

$= 2 \text{ V}/\sqrt{2}$

$= 1.4$ V [1]

14 a) The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case. One mark per point clearly made. [6]

- Wind turbine and battery connected (separately) to oscilloscope input
- Timebase set to a value approx. 5 ms/div
- y gain adjusted to get as high an amplitude as possible
- Amplitudes used to find peak to peak voltage of wind turbine and battery voltage
- rms voltage of wind turbine found
- Use the timebase setting to find period
- Use period to find frequency
- Compare vales with stated values

b) P = VI

= 12 V × 2.5 A

= 30 W [1]

c) $P_{peak} = 2 \times P_{mean}$

= 2 × 30 W

= 60 W [1]

d) $V_0 = V_{rms} \times \sqrt{2}$

$= 12 \text{ V} \times \sqrt{2}$

= 17 V [1]

15 Any six points from those below: [6]

- The current in transmission cables causes [Joule] heating and energy losses, equal to I^2R
- Cables with a lower resistance are used as they have lower losses by heating (since I^2R is smaller)
- Reducing current in transmission cables reduces losses by heating (since I^2R is smaller)
- Power = VI, so reducing the current and increasing the voltage keeps the power transmitted constant
- The voltage generated by power stations is stepped up/increased using transformers at the power stations
- ac supply is used because transformers work using ac, not dc
- Stepping up the voltage reduces the current and hence the percentage of power lost during transmission

16 a) Turns ratio $= V_s/V_p$ [1]

$= 12\ \text{V}/230\ \text{V}$

$= 0.052$ [1]

Assuming the transformer is 100 % efficient [1]

b) P = VI

so $I_s = 60\ \text{W}/12\ \text{V}$

$= 5\ \text{A}$ [1]

Turns ratio $= I_p/ I_s$

The current in the supply lead is I_p = turns ratio $\times I_s$ [1]

$= 0.052 \times 5\ \text{A}$

$= 0.26\ \text{A}$ [1]

c) Efficiency $= V_sI_s/V_pI_p$ [1]

$= 100\% \times (11.8\ \text{V} \times 4.5\ \text{A})/(230\ \text{V} \times 0.26\ \text{A})$ [1]

$= 89\%$ [1]

17 a) $N_s = V_s \times N_p/V_p$ [1]

$= 415\ \text{V} \times 3000/11\,000\ \text{V}$ [1]

$= 113$ turns [1]

b) Efficiency $= P_{out}/P_{in} = V_sI_s/V_pI_p$ [1]

so $0.85 = 60\ \text{kW}/ V_pI_p$

$V_pI_p = 60\ \text{kW}/0.85$

$= 70.6\ \text{kW}$ [1]

$I_p = 70.6\ \text{kW}/11\ \text{kV}$

$= 6.4\ \text{A}$ [1]

c) Any two causes identified and explained for 2 marks each: [4]

- Eddy currents in the iron core cause heating/reduce the induced emf; eddy currents are reduced using a laminated core
- ac currents in the coils cause heating; heating is reduced by using low resistance wire in the coil
- hysteresis losses caused by repeated magnetization and demagnetization of the core; hysteresis is reduced using a soft magnetic material like iron
- leakage of magnetic flux/losses of magnetic flux from the primary coil; leakage is reduced by winding the coils close to each other

Page 448 Stretch and challenge

18 B

19 The voltage at any time, T, between 0 and t is:

$$V = \frac{V_0 T}{t}$$

So the power dissipated at any moment is:

$$P = \frac{1}{R}\left(\frac{V_0 T}{t}\right)^2$$

The energy dissipated between the times 0 and t is:

$$E = \frac{V_0^2}{Rt^2}\int_0^t T^2\, dT$$

$$= \frac{V_0^2}{Rt^2} \times \frac{t^3}{3}$$

$$= \frac{V_0^2 t}{3R}$$

Since the average power = $\frac{E}{t}$

$$P = \frac{V_0^2}{3R}$$

Which is the same power as would be dissipated by a constant dc voltage where

$$P = \frac{V_0^2}{3R} = \frac{V_{dc}^2}{R}$$

so $V_{dc} = \frac{V_0}{\sqrt{3}}$