ALTERNATING CURRENTS
WORKSHEET
A-Level Physics 9702

MJ24/41/Q7

1 A circuit contains a power supply that provides a sinusoidal alternating input voltage V_{IN}. There is an output voltage V_{OUT} across a load resistor R, as shown in Fig. 7.1.

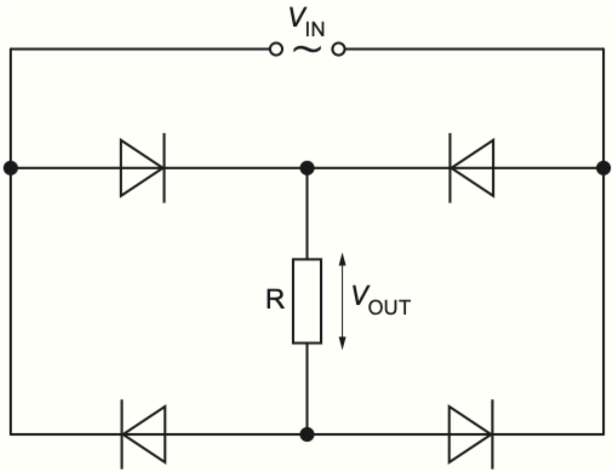

Fig. 7.1

(a) State the purpose of the circuit in Fig. 7.1.

....

....

.... [2]

(b) Fig. 7.2 shows the variation of V_{OUT} with time t.

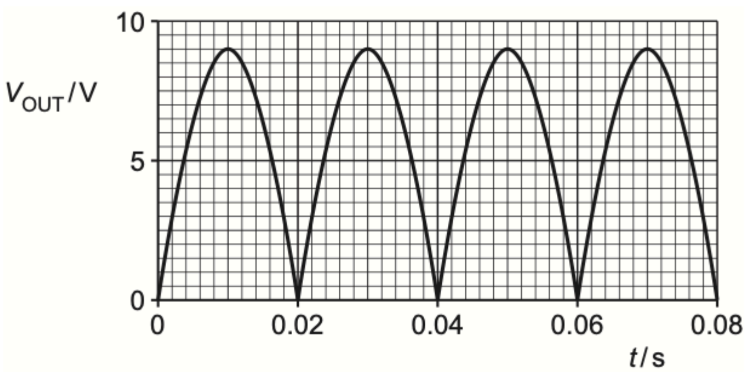

Fig. 7.2

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https://cyrus-physics.com

(i) The load resistor R has a resistance of 370 Ω.

Show that the maximum power dissipated in R is 0.22 W.

[2]

(ii) On Fig. 7.3, sketch the variation with *t* of the power *P* dissipated in R.

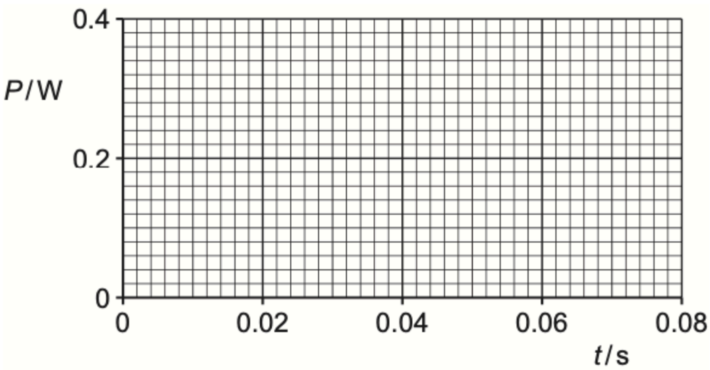

Fig. 7.3

[3]

(iii) Calculate the mean power dissipated in R.

mean power = ... W [1]

(c) The circuit of Fig. 7.1 is disconnected, and R is connected directly across the power supply.

Explain, without calculation, how the mean power now dissipated in R compares with the answer in **(b)(iii)**.

....

....

.... [2]

[Total: 10]

2 **(a)** Three capacitors are connected as shown in Fig. 4.1. **March24/42/Q4**

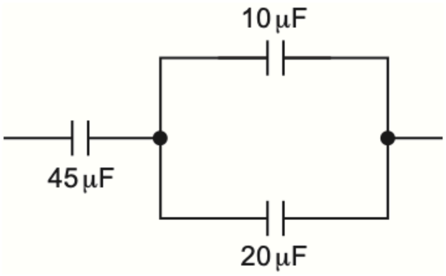

Fig. 4.1

Determine the total capacitance, in μF, of the network of three capacitors.

capacitance = ... μF [2]

(b) A capacitor of capacitance 45 μF is connected to a variable power supply initially set at 8.0 V. The output of the power supply increases so that the potential difference (p.d.) across the capacitor increases to 9.6 V.

Calculate the increase in energy ΔE stored in the capacitor.

ΔE = ... J [2]

(c) A sinusoidal a.c. power supply is connected to the input of a bridge rectifier. The output of the rectifier is connected to a load resistor.

(i) Complete the circuit in Fig. 4.2 by adding a capacitor to smooth the p.d. across the load resistor.

Fig. 4.2

[1]

(ii) The variation with time *t* of the p.d. *V* of the smoothed output is shown in Fig. 4.3.

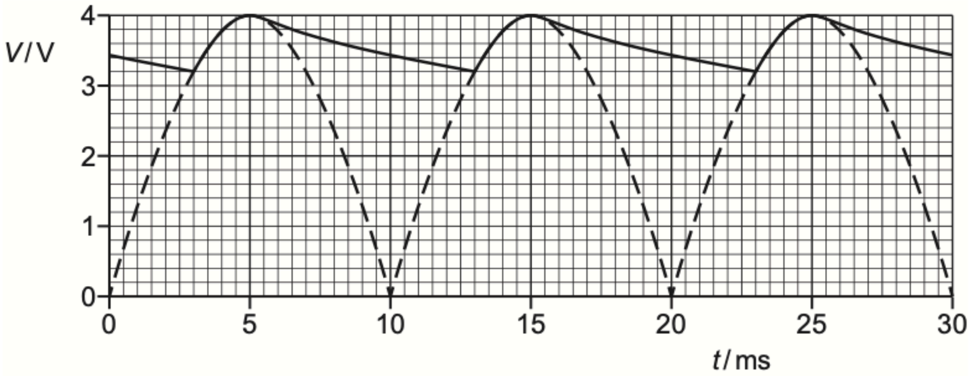

Fig. 4.3

Determine the time constant, in ms, of the smoothing circuit.

time constant = ... ms [3]

(d) A sinusoidal a.c. power supply has a maximum power of 16 W.

State the value of the mean power when the output of the power supply is:

(i) full-wave rectified

mean power = ... W [1]

(ii) half-wave rectified.

mean power = ... W [1]

[Total: 10]

3 A varying current I passes through a resistor of resistance R in the circuit shown in Fig. 7.1.

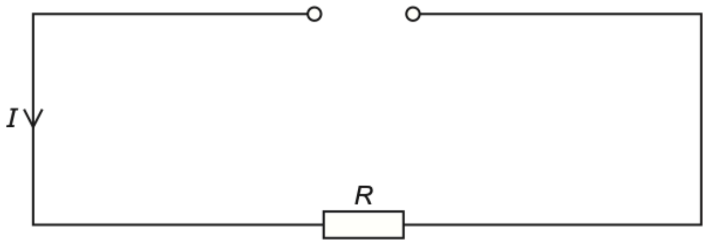

Fig. 7.1

Fig. 7.2 shows the variation with time t of I.

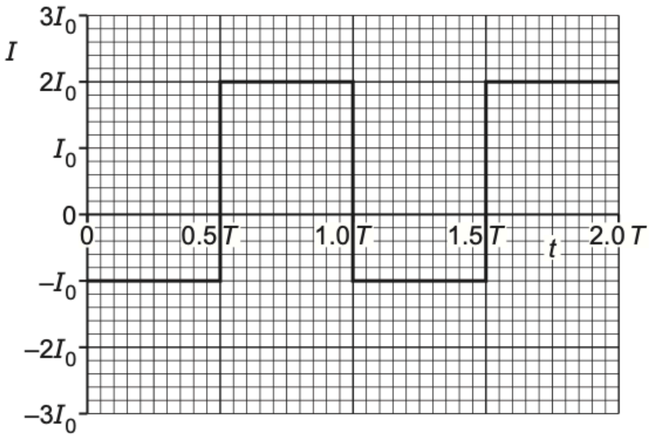

Fig. 7.2

The current has magnitude $2I_0$ when it is in the positive direction and I_0 when it is in the negative direction. The period of the variation of the current is T.

(a) Determine expressions, in terms of I_0 and R, for the power P dissipated in the resistor for the times when:

(i) the current is in the negative direction

P = ... [1]

(ii) the current is in the positive direction.

P = ... [1]

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(b) On Fig. 7.3, sketch the variation of P with t between t = 0 and t = 2.0T. Label the power axis with an appropriate scale.

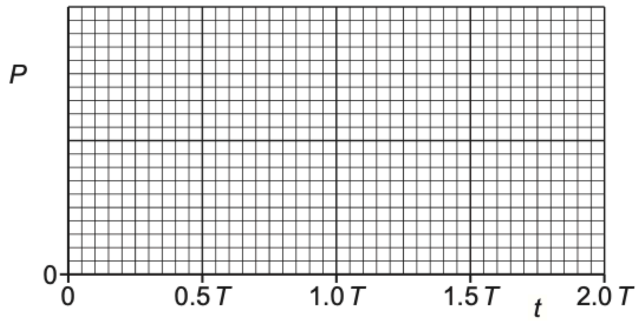


Fig. 7.3

[3]

(c) Use your answer in **(b)** to determine an expression, in terms of I_0 and R, for:

(i) the mean power $\langle P \rangle$ in the resistor

$\langle P \rangle$ = ... [1]

(ii) the root-mean-square (r.m.s.) current $I_{r.m.s.}$ in the resistor.

$I_{r.m.s.}$ = ... [2]

[Total: 8]

4 An electron in a metal rod moves randomly about a mean position. When an alternating voltage is applied to the ends of the rod, the mean position can be considered to oscillate with simple harmonic motion along the axis of the rod. Fig. 4.1 shows the variation with time t of the displacement x of the mean position from a fixed point on the axis of the rod.

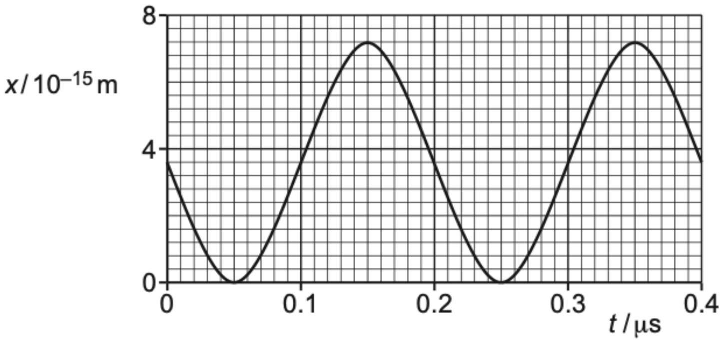


Fig. 4.1

(a) **(i)** Determine the amplitude of the oscillations.

amplitude = ... m [1]

(ii) Determine the angular frequency of the oscillations.

angular frequency = ... rad s^{-1} [1]

(iii) Use your answers in **(a)(i)** and **(a)(ii)** to show that the maximum drift speed v_0 of the electron is $1.1 \times 10^{-7}\,m\,s^{-1}$.

[2]

(b) The rod has a cross-sectional area of 4.3 cm^2 and contains a number density of conduction electrons (charge carriers) of 8.5×10^{28} m^{-3}.

All of the conduction electrons in the rod may be assumed to be oscillating in phase with, and with the same amplitude as, the oscillation shown in Fig. 4.1.

(i) Use the information in **(a)(iii)** to calculate the magnitude I_0 of the maximum current in the rod.

I_0 = ...A [2]

(ii) On Fig. 4.2, sketch the variation of the current I in the rod with time t between $t = 0$ and $t = 0.40\,\mu$s.

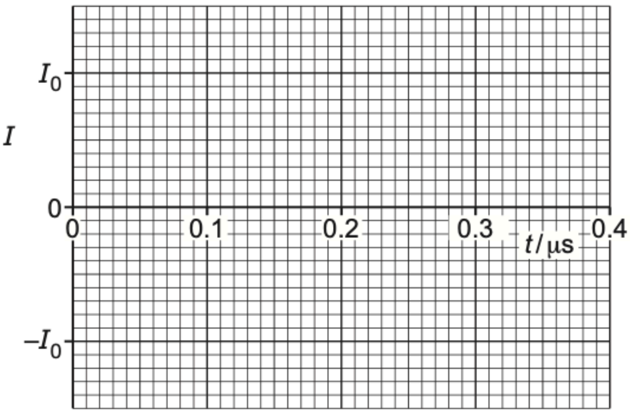


Fig. 4.2

[2]

(iii) Use your answers in **(a)(ii)** and **(b)(i)** to determine an expression for I in terms of t, where I is in A and t is in s.

I = ... [2]

(iv) Determine the root-mean-square (r.m.s.) current in the rod.

r.m.s. current = ...A [1]

[Total: 11]

5 Part of an electric circuit is shown in Fig. 5.1. **MJ23/41/Q5**

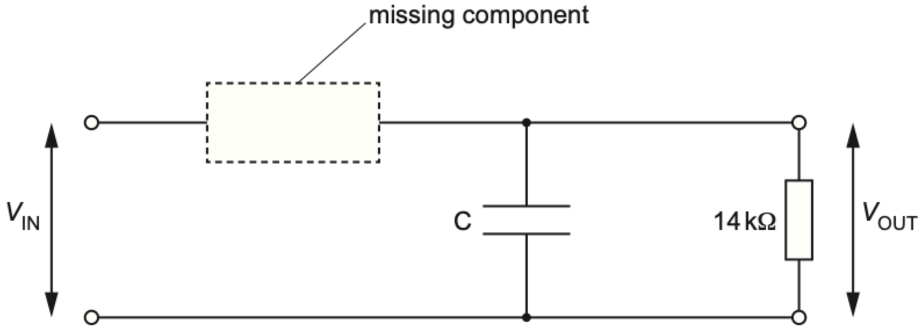


Fig. 5.1

The circuit is used to produce half-wave rectification of an alternating voltage of potential difference (p.d.) V_{IN}.

The output p.d. across the 14 kΩ resistor is V_{OUT}.

(a) (i) A component is missing from the circuit of Fig. 5.1.

Complete the circuit diagram in Fig. 5.1 by adding the circuit symbol for the missing component, correctly connected. [1]

(ii) A capacitor C is shown in the circuit of Fig. 5.1.

State the effect on V_{OUT} of including the capacitor in the circuit.

.... [1]

(b) Fig. 5.2 shows the variation with time t of V_{IN}.

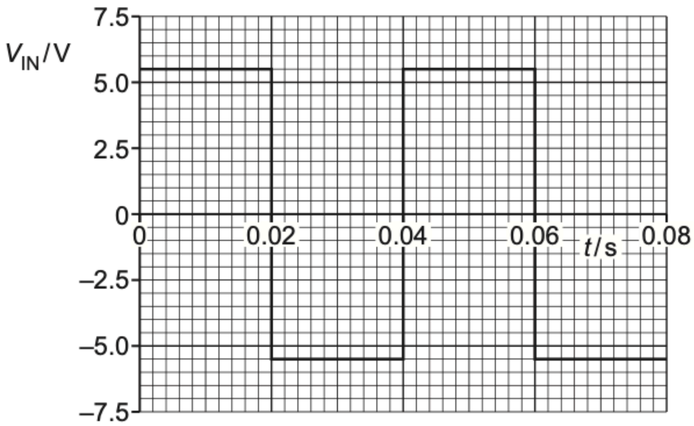


Fig. 5.2

Fig. 5.3 shows the variation with t of V_{OUT}.

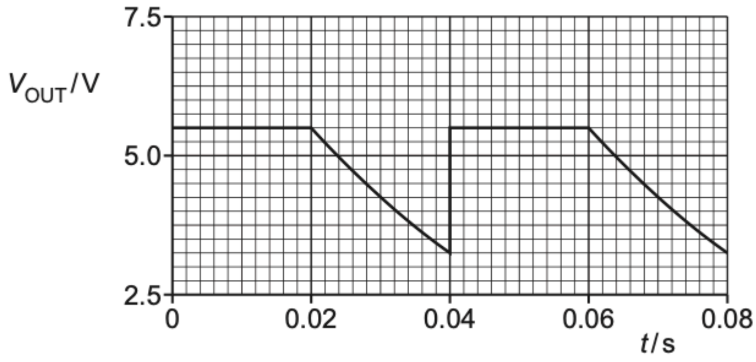


Fig. 5.3

(i) Determine the frequency of V_{IN}.

frequency = ... Hz [1]

(ii) Show that the time constant τ for the discharge of the capacitor through the resistor is 0.038 s.

[2]

(iii) Calculate the capacitance of C. Give a unit with your answer.

capacitance = ... unit .... [2]

(c) The circuit of Fig. 5.1 is modified so that it produces full-wave rectification of an input voltage.

Suggest, with a reason, how V_{OUT} now varies with time when V_{IN} is as shown in Fig. 5.2.

....

....

.... [2]

[Total: 9]

6 Four diodes are used in a bridge rectifier circuit to produce rectification of a sinusoidal a.c. input voltage V_{IN}.
Fig. 7.1 shows part of the circuit, but three of the diodes are missing.

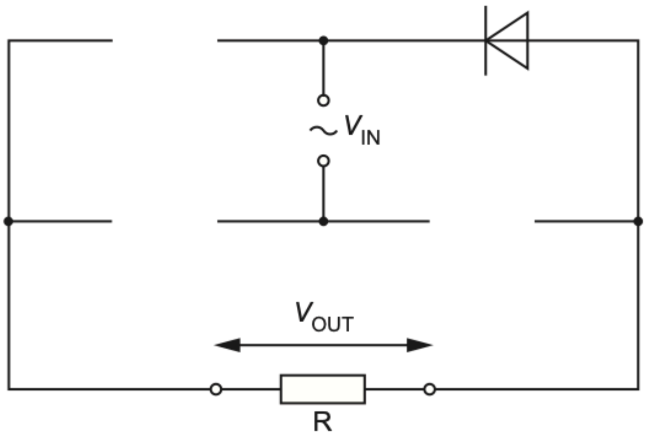


Fig. 7.1

The p.d. across the load resistor R is the output p.d. V_{OUT} of the bridge rectifier.

(a) **(i)** State the name of the type of rectification produced by a bridge rectifier.

.... [1]

(ii) Complete Fig. 7.1 by drawing the three missing diodes, correctly connected. [2]

(iii) On Fig. 7.1, draw an arrow to indicate the direction of the current in resistor R. [1]

(b) V_{IN} has amplitude V_0 and period T. Fig. 7.2 shows the variation with time t of V_{IN}.

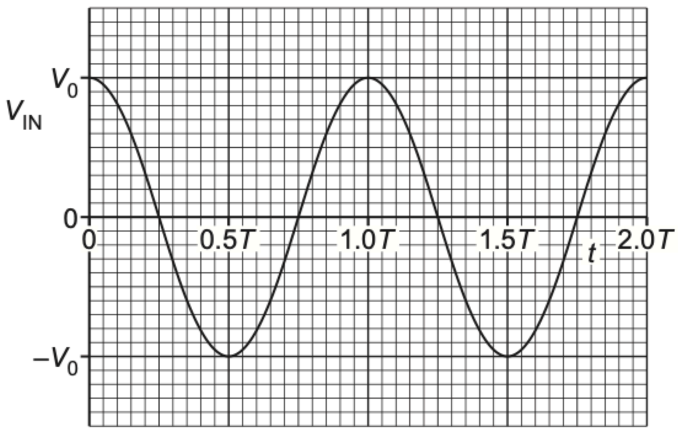


Fig. 7.2

(i) On Fig. 7.3, sketch the variation of V_{OUT} with t between $t = 0$ and $t = 2.0T$.

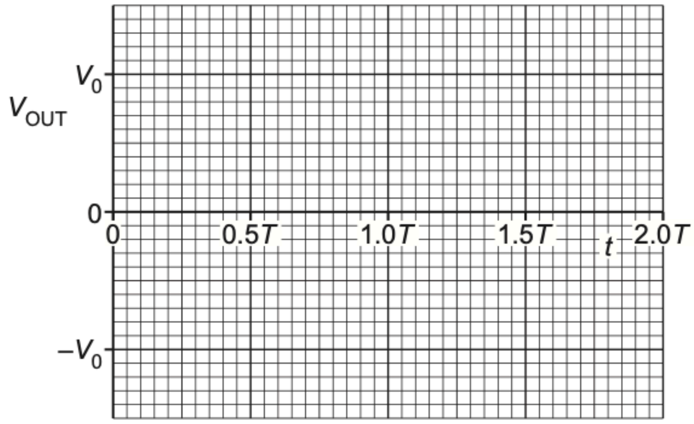


Fig. 7.3

[3]

(ii) The power dissipated in the resistor is P.

On Fig. 7.4, sketch the variation of P with t between $t = 0$ and $t = 2.0T$.

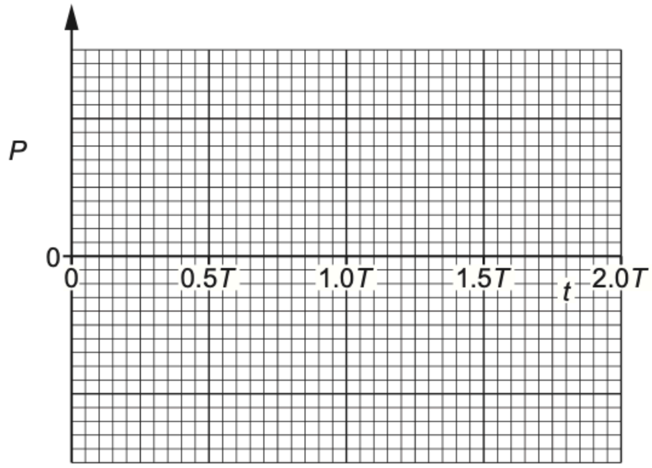


Fig. 7.4

[2]

(iii) Suggest, with a reason, how the root-mean-square (r.m.s.) value of V_{OUT} compares with the r.m.s. value of V_{IN}.

....

.... [1]

[Total: 10]

7 **(a)** A sinusoidal alternating voltage has a root-mean-square (r.m.s.) potential difference (p.d.) of 4.2 V and a frequency of 50 kHz.

(i) The alternating voltage is applied across a resistor of resistance 760 Ω.

By considering the peak voltage, show that the maximum power dissipated by the resistor is 46 mW.

[2]

(ii) On Fig. 7.1, draw a smooth curve to show how the power P dissipated in the resistor varies with time t between $t = 0$ and $t = 40\,\mu s$. Assume that $P = 0$ when $t = 0$.

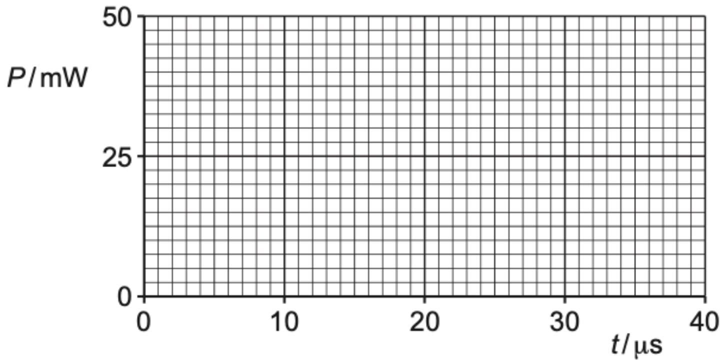


Fig. 7.1

[3]

(iii) Use your line in **(a)(ii)** to explain why the mean power dissipated in the resistor is 23 mW.

....

....

.... [1]

8 **(a)** State Lenz's law of electromagnetic induction. **ON22/42/Q8**

....

....

.... [2]

(b) Two coils of insulated wire are wound on an iron bar, as shown in Fig. 8.1.

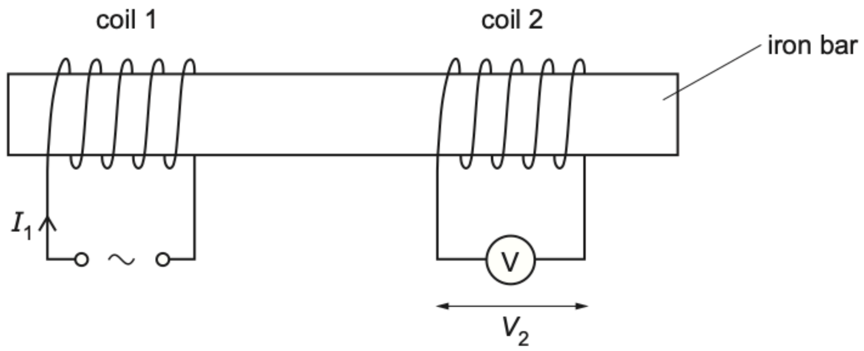


Fig. 8.1

There is a current I_1 in coil 1 that varies with time t as shown in Fig. 8.2.

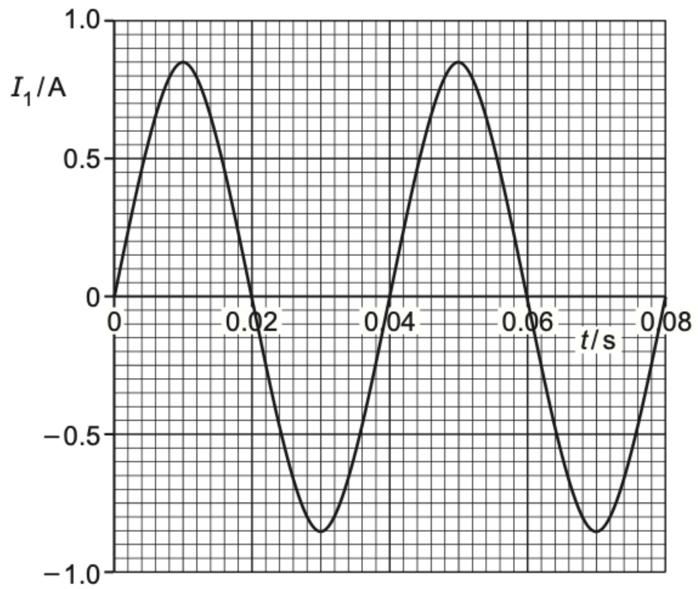


Fig. 8.2

(i) The variation with t of I_1 can be represented by the equation

$$I_1 = X \sin Yt$$

where X and Y are constants.

Use Fig. 8.2 to determine the values of X and Y. Give units with your answers.

X = ... unit ....

Y = ... unit ....
[3]

(ii) The current in coil 1 gives rise to a magnetic field in the iron bar.
Assume that the flux density of this magnetic field is proportional to I_1.

An alternating electromotive force (e.m.f.) is induced across coil 2. The p.d. across coil 2 is measured using the voltmeter and has a root-mean-square (r.m.s.) value of 4.6V.

On Fig. 8.3, sketch a line to show the variation with t of V_2 between t = 0 and t = 0.08s.

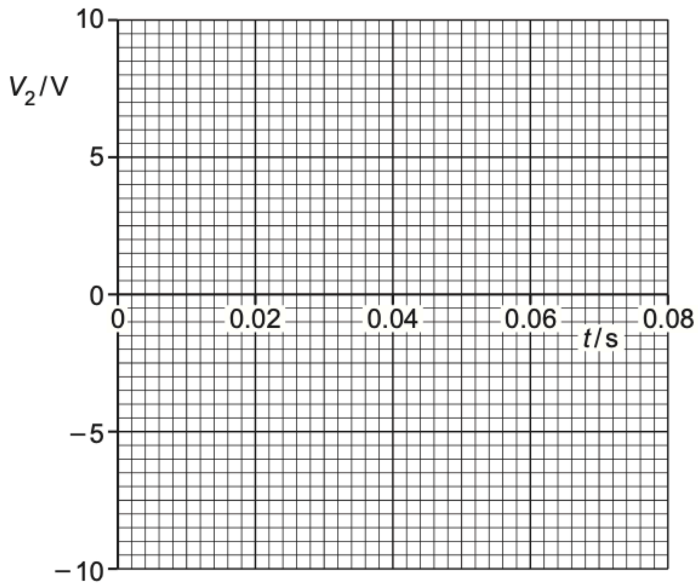


Fig. 8.3

[3]

(iii) Use the laws of electromagnetic induction to explain the shape of your line in **(b)(ii)**.

....

....

....

.... [3]

[Total: 11]

9 Fig. 5.1 shows four diodes and a load resistor of resistance 1.2 kΩ, connected in a circuit that is used to produce rectification of an alternating voltage.

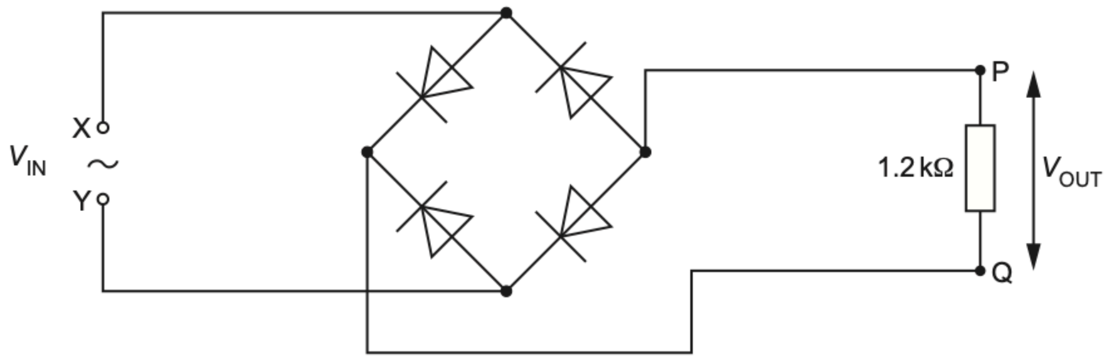


Fig. 5.1

(a) **(i)** State what is meant by rectification.

....

.... [1]

(ii) State the type of rectification produced by the circuit in Fig. 5.1.

.... [1]

(b) A sinusoidal alternating voltage V_{IN} is applied across the input terminals X and Y. The variation with time t of V_{IN} is given by the equation

$$V_{IN} = 6.0 \sin 25\pi t$$

where V_{IN} is in volts and t is in seconds.

(i) On Fig. 5.1, label the output terminals P and Q with the appropriate symbols to indicate the polarity of the output voltage V_{OUT}. [1]

(ii) The magnitude of the output voltage V_{OUT} varies with t as shown in Fig. 5.2.

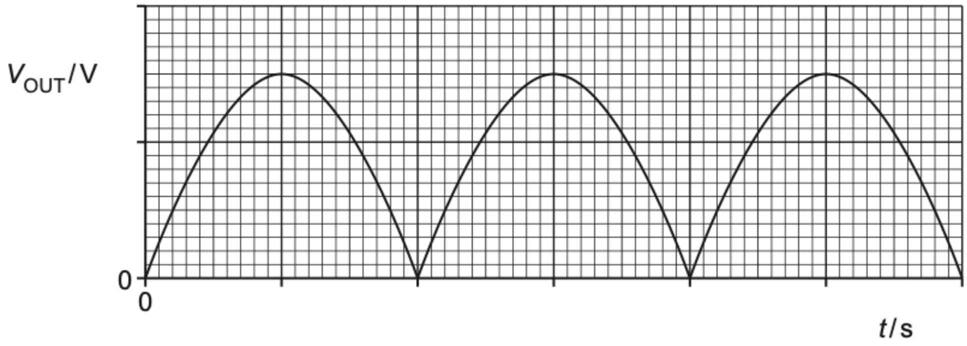


Fig. 5.2

On Fig. 5.2, label both of the axes with the correct scales. Use the space below for any working that you need.

[3]

(c) The output voltage in **(b)** is smoothed by adding a capacitor to the circuit in Fig. 5.1. The difference between the maximum and minimum values of the smoothed output voltage is 10% of the peak voltage.

(i) On Fig. 5.1, draw the circuit symbol for a capacitor showing the capacitor correctly connected into the circuit. [1]

(ii) On Fig. 5.2, sketch the variation with t of the smoothed output voltage. [2]

(iii) Calculate the capacitance C of the capacitor.

C = ... F [3]

[Total: 12]

10 **(a)** Alternating current (a.c.) is converted into direct current (d.c.) using a full-wave rectification circuit. Part of the diagram of this circuit is shown in Fig. 7.1.

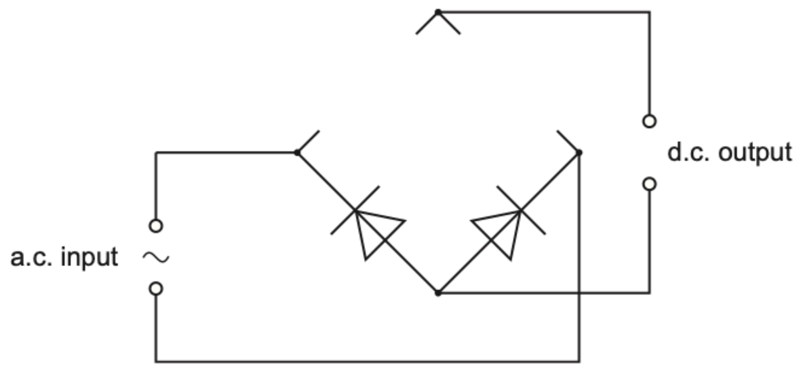


Fig. 7.1

(i) Complete the circuit in Fig. 7.1 by adding the necessary components in the gaps. [1]

(ii) On Fig. 7.1 mark with a + the positive output terminal of the rectifier. [1]

(b) The output voltage *V* of an a.c. power supply varies sinusoidally with time *t* as shown in Fig. 7.2.

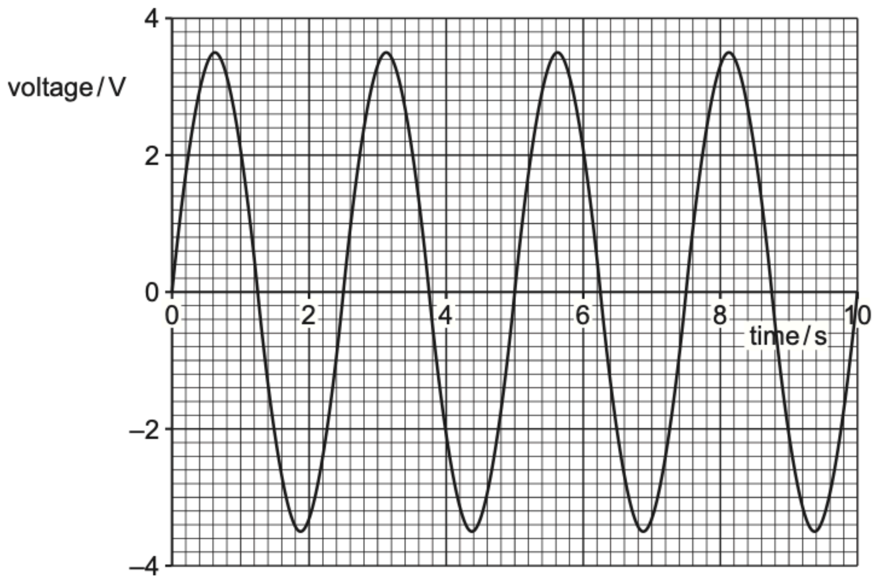


Fig. 7.2

(i) Determine the equation for *V* in terms of *t*, where *V* is in volts and *t* is in seconds.

V = ... [2]

(ii) The supply is connected to a 12 Ω resistor. Calculate the mean power dissipated in the resistor.

mean power = ... W [2]

[Total: 6]

ON21/41/Q9

11 **(a)** State, by reference to the power dissipated in a resistor, what is meant by the *root-mean-square* (*r.m.s.*) value of an alternating voltage.

....

....

....

.... [2]

(b) A coil is rotating freely, on frictionless bearings, at constant speed in a uniform magnetic field. This rotation causes an induced alternating electromotive force (e.m.f.) across the open terminals of the coil. The induced e.m.f. has r.m.s. value 12 V and frequency 50 Hz.

The speed of rotation of the coil is now doubled.

(i) State and explain, with reference to the principles of electromagnetic induction, the effect of the increased speed of rotation on the r.m.s. value of the induced e.m.f.

....

....

....

.... [2]

(ii) On Fig. 9.1, sketch the variation with time t of the induced e.m.f. E across the terminals of the coil at the **increased** speed of rotation. Your line should extend from time t = 0 to time t = 20 ms. Assume that E = 0 when t = 0.

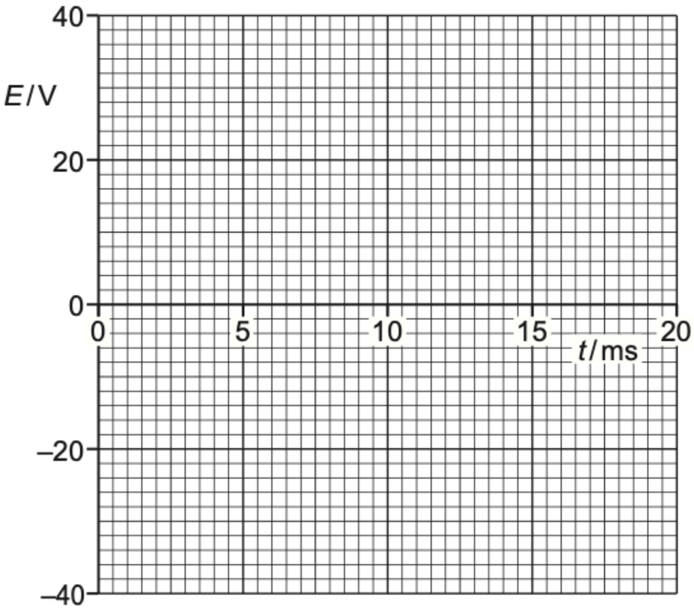


Fig. 9.1

[3]

(c) State and explain the effect on the motion of the coil in **(b)** of connecting a load resistor across its terminals.

....

....

....

.... [2]

[Total: 9]

12 **(a)** By reference to heating effect, explain what is meant by the *root-mean-square* (*r.m.s.*) value of an alternating current.

....

....

.... [2]

(b) The variations with time t of two currents I_1 and I_2 are shown in Fig. 10.1 and Fig. 10.2.

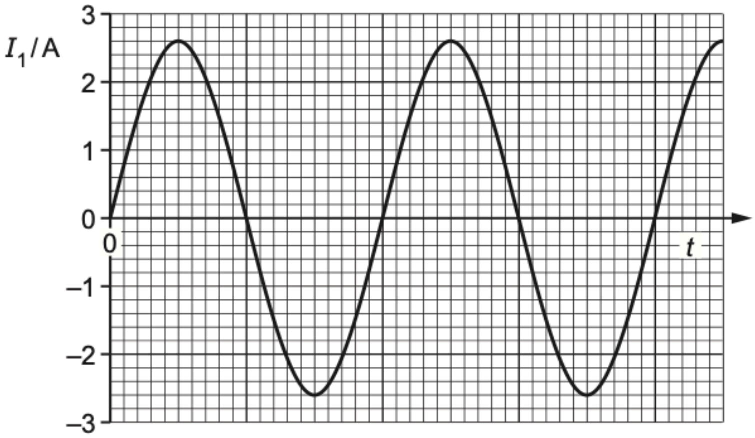


Fig. 10.1

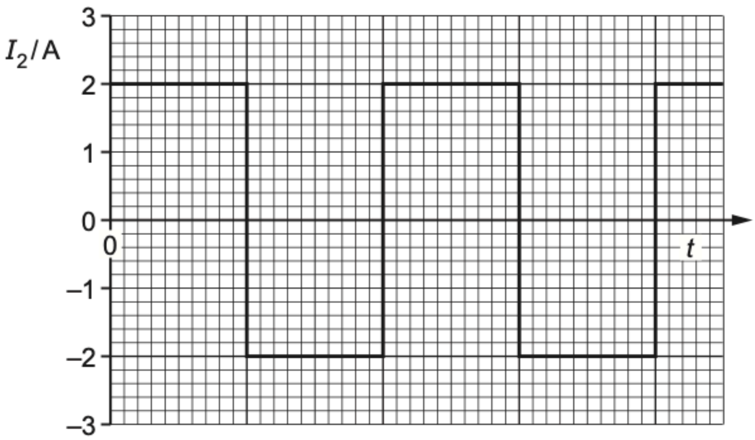


Fig. 10.2

(i) Use Fig. 10.1 to determine the peak value and the r.m.s. value of the current I_1.

peak value = ... A

r.m.s. value = ... A
[1]

(ii) Use Fig. 10.2 to determine the peak value and the r.m.s. value of the current I_2.

peak value = ... A

r.m.s. value = ... A
[1]

(c) The variation with time t of the supply voltage V to a house is given by the expression

$$V = 240 \sin kt$$

where V is in volts, t is in seconds and k is a constant with unit rad s^{-1}.

(i) The frequency of the supply voltage is 50 Hz.

Determine k to two significant figures.

k = ... rad s^{-1} [2]

(ii) The supply voltage is applied to a heater. The mean power of the heater is 3.2 kW.

Calculate the resistance of the heater.

resistance = ... Ω [2]

[Total: 8]

13 The output potential difference (p.d.) of an alternating power supply is represented by

$$V = 320\sin(100\pi t)$$

where V is the p.d. in volts and t is the time in seconds.

(a) Determine the root-mean-square (r.m.s.) p.d. of the power supply.

r.m.s. p.d. = ... V [1]

(b) Determine the period T of the output.

T = ... s [2]

(c) The power supply is connected to resistor R and a diode in the circuit shown in Fig. 10.1.

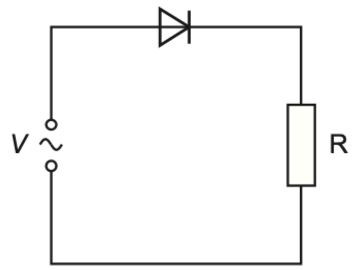


Fig. 10.1

(i) State the name of the type of rectification produced by the diode in Fig. 10.1.

.... [1]

(ii) On Fig. 10.2 sketch the variation with time t of the p.d. V_R across R from time $t = 0$ to time $t = 40$ ms.

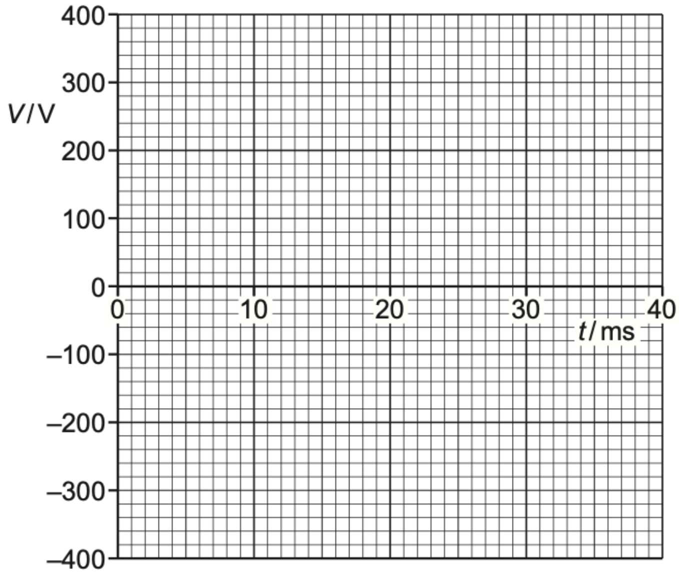


Fig. 10.2

[3]

(iii) On Fig. 10.1, draw the symbol for a component that may be connected to produce smoothing of V_R.

[1]

[Total: 8]

March20/42/Q9

14 **(a)** The output of a power supply is represented by:

$$V = 9.0 \sin 20t$$

where V is the potential difference in volts and t is the time in seconds.

Determine, for the output of the supply:

(i) the root-mean-square (r.m.s.) voltage, $V_{r.m.s.}$

$V_{r.m.s}$ = ...V [1]

(ii) the period T.

T = ... s [2]

(b) The variations with time *t* of the output potential difference *V* from two different power supplies are shown in Fig. 9.1 and Fig. 9.2.

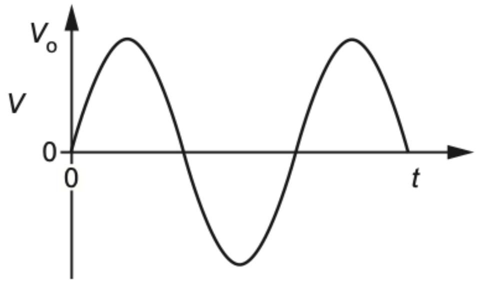


Fig. 9.1

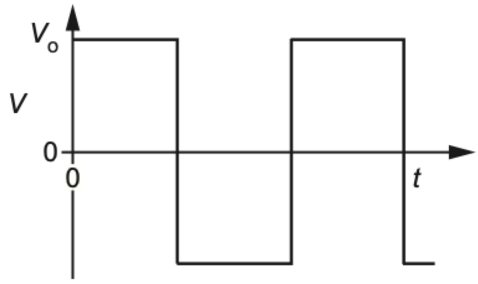


Fig. 9.2

The graphs are drawn to the same scale.

State and explain whether the same power would be dissipated in a 1.0 Ω resistor connected to each power supply.

....

....

.... [1]

(c) **(i)** The power supply in **(a)** is connected to a transformer. The input power to the transformer is 80 W.

The secondary coil is connected to a resistor. The r.m.s. voltage across the resistor is 120 V. The r.m.s. current in the secondary coil is 0.64 A.

Calculate the efficiency of the transformer.

efficiency = ... [3]

(ii) State **one** reason why the transformer is not 100% efficient.

....

.... [1]

[Total: 8]

15 A bridge rectifier using four ideal diodes is shown in Fig. 10.1.

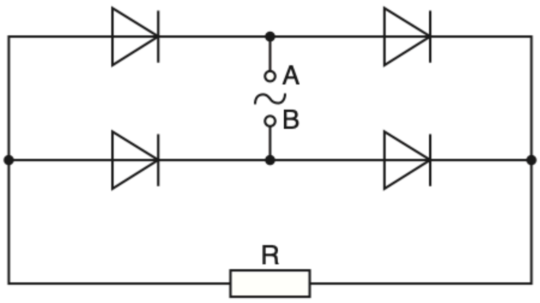


Fig. 10.1

The sinusoidal alternating electromotive force (e.m.f.) applied between points A and B has a root-mean-square (r.m.s.) value of 7.0 V.

(a) **(i)** On Fig. 10.1, circle the diodes that conduct when point B is positive with respect to point A. [1]

(ii) Calculate the maximum potential difference V_{MAX} across resistor R.

V_{MAX} = ... V [1]

(b) A capacitor is connected into the circuit to produce smoothing of the potential difference across resistor R.

The variation with time *t* of the potential difference *V* across resistor R is shown in Fig. 10.2.

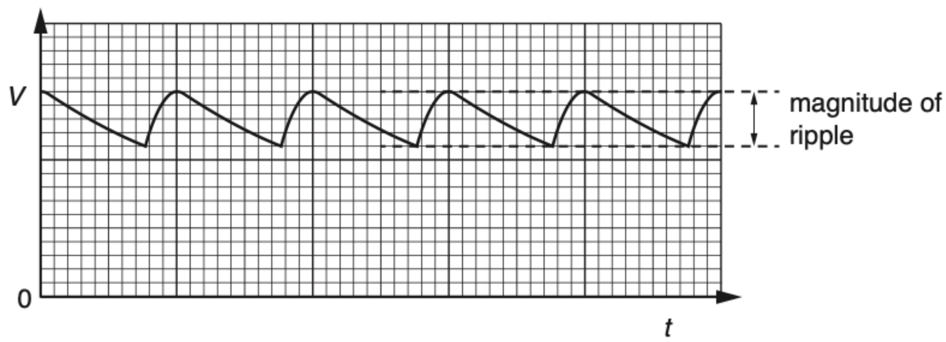


Fig. 10.2

(i) On Fig. 10.1, draw the symbol for a capacitor, connected so as to produce smoothing. [1]

(ii) State the effect, if any, on the magnitude of the ripple on V when, separately:

1. a capacitor of larger capacitance is used

....

2. the resistor R has a smaller resistance.

....
[2]

[Total: 5]

MJ19/41/Q10

16 A bridge rectifier contains four diodes. The output of the rectifier is connected to a resistor R, as shown in Fig. 10.1.

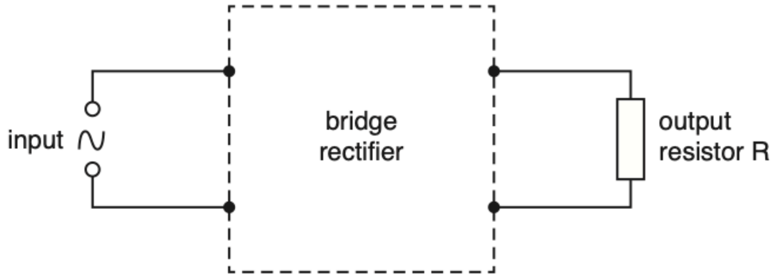


Fig. 10.1

The variation with time t of the input e.m.f. E to the rectifier is given by the expression

$$E = 15\cos(210t)$$

where t is measured in seconds and E in volts.

The variation with time t of the potential difference V across resistor R is shown in Fig. 10.2.

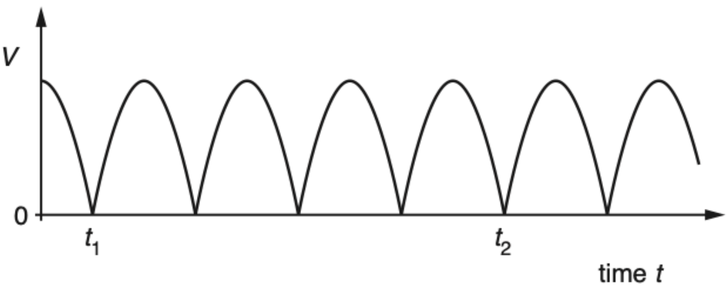


Fig. 10.2

Determine:

(a) the maximum potential difference V_{MAX} across resistor R

V_{MAX} = ...V [1]

(b) the time interval, to two significant figures, between time t_1 and time t_2.

time = ... s [3]

[Total: 4]

March19/42/Q8

17 A horseshoe magnet is placed on a top pan balance. A rigid copper wire is fixed between the poles of the magnet, as illustrated in Fig. 8.1.

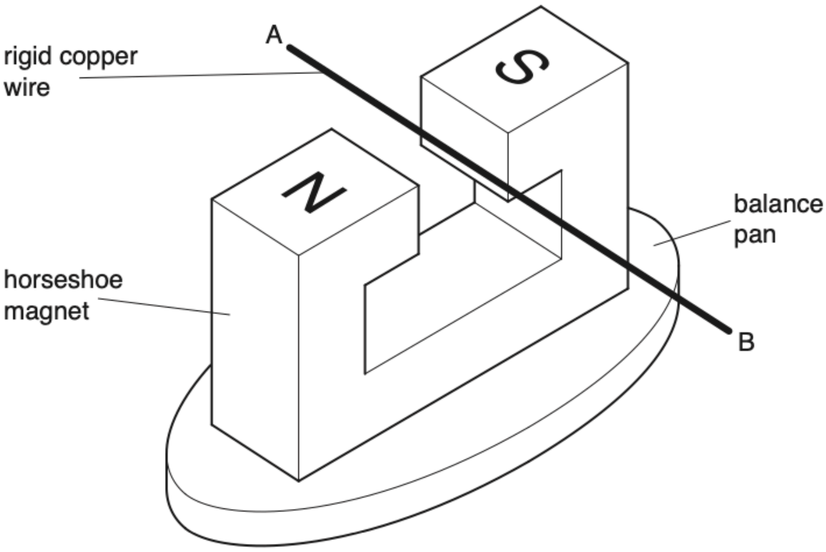


Fig. 8.1

The wire is clamped at ends A and B.

(a) When a direct current is switched on in the wire, the reading on the balance is seen to **decrease**.

State and explain the direction of:

(i) the force acting on the wire

....

....

....

.... [3]

(ii) the current in the wire.

....

....

.... [2]

(b) A direct current of 4.6A in the wire causes the reading on the balance to change by 4.5×10^{-3} N.

The direct current is now replaced by an alternating current of frequency 40 Hz and root-mean-square (r.m.s.) value 4.6 A.

On the axes of Fig. 8.2, sketch a graph to show the change in balance reading over a time of 50 ms.

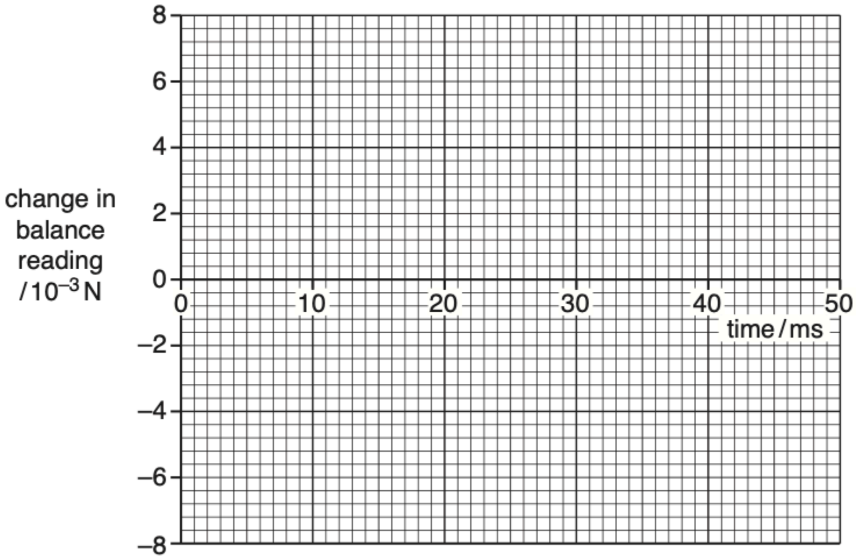


Fig. 8.2

[3]

[Total: 8]

ON18/42/Q10

18 **(a)** The root-mean-square (r.m.s.) value of the voltage of a sinusoidal alternating supply is 9.9 V. The frequency of the supply is 50 Hz.

Derive an expression for the variation with time *t* (in second) of the potential difference *V* (in volt) of the supply.

V = ... [2]

ON17/42/Q11

19 The circuit for a full-wave rectifier using four ideal diodes is shown in Fig. 11.1.

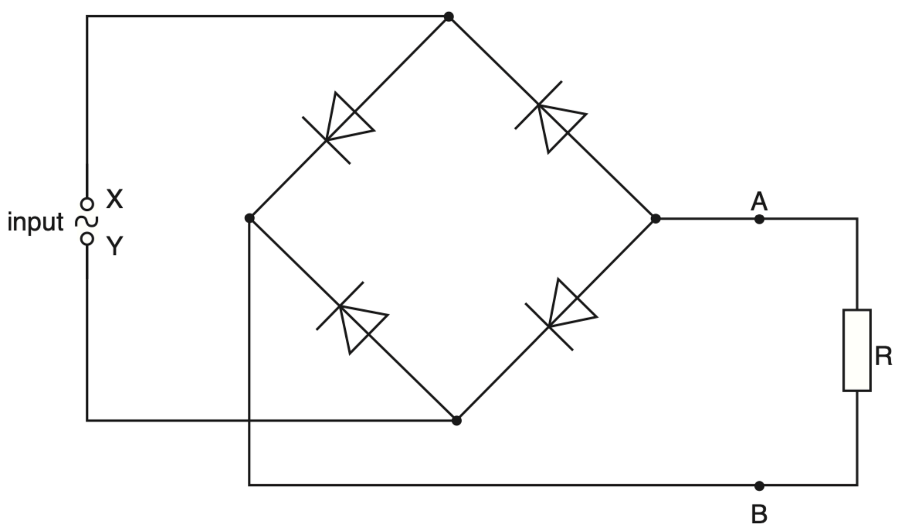


Fig. 11.1

A resistor R is connected across the output AB of the rectifier.

(a) On Fig. 11.1,

(i) draw a circle around any diodes that conduct when the terminal X of the input is positive with respect to terminal Y, [1]

(ii) label the positive (+) and the negative (–) terminals of the output AB. [1]

(b) The variation with time t of the potential difference V across the input XY is given by the expression

$$V = 5.6 \sin 380t$$

where V is measured in volts and t is measured in seconds.

The variation with time t of the rectified potential difference across the resistor R is shown in Fig. 11.2.

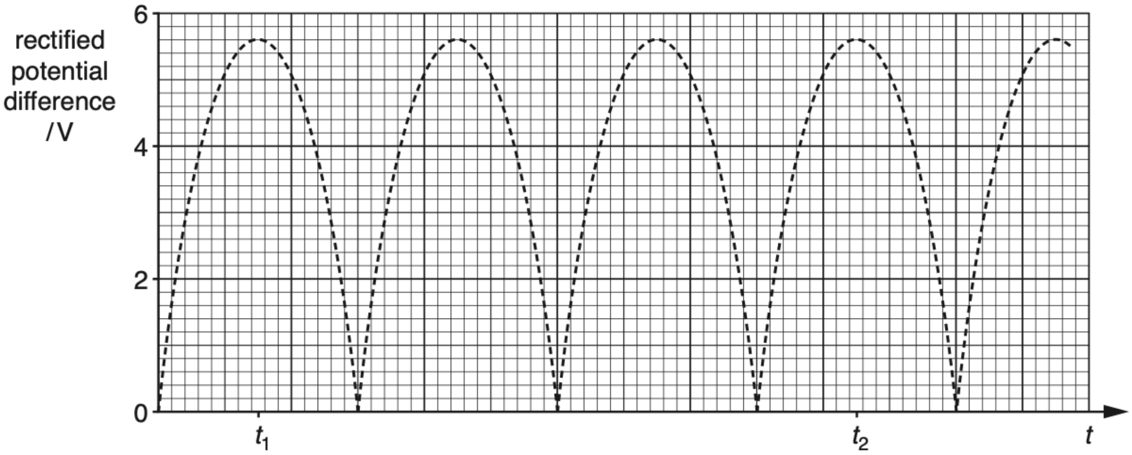


Fig. 11.2

Use the expression for the input potential difference V, or otherwise, to determine

(i) the root-mean-square (r.m.s.) potential difference $V_{r.m.s.}$ of the input,

$V_{r.m.s.}$ = ... V [1]

(ii) the number of times per second that the rectified potential difference at the output reaches a peak value.

number = ... [2]

(c) A capacitor is now connected between the terminals AB of the output.
The capacitor reduces the variation (the ripple) in the output to 1.6 V.

(i) On Fig. 11.2, sketch the variation with time t of the smoothed output voltage for time $t = t_1$ to time $t = t_2$. [4]

(ii) Suggest and explain the effect, if any, on the mean power dissipation in resistor R when the capacitor is connected between terminals AB.

....

....

....[2]

[Total: 11]

20 The variation with time t of the sinusoidal current I in a resistor of resistance 450 Ω is shown in Fig. 11.1.

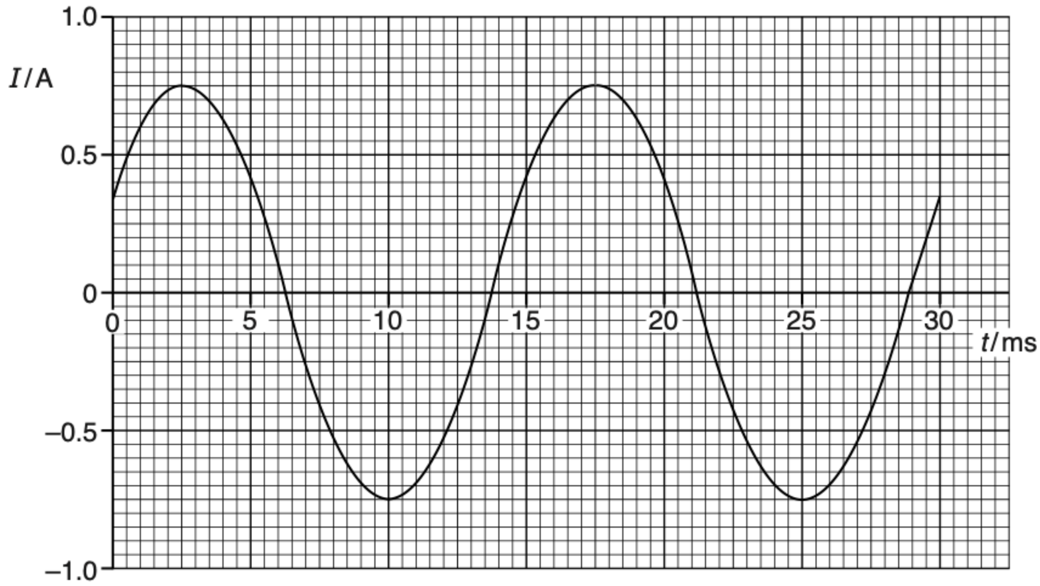


Fig. 11.1

Use data from Fig. 11.1 to determine, for the time $t = 0$ to $t = 30$ ms,

(a) the frequency of the current,

frequency = ... Hz [2]

(b) the mean current,

mean current = ... A [1]

(c) the root-mean-square (r.m.s.) current,

r.m.s. current = ... A [2]

(d) the energy dissipated by the resistor.

energy = ... J [2]

[Total: 7]

21 A stiff wire is held horizontally between the poles of a magnet, as illustrated in Fig. 9.1.

ON16/42/Q9

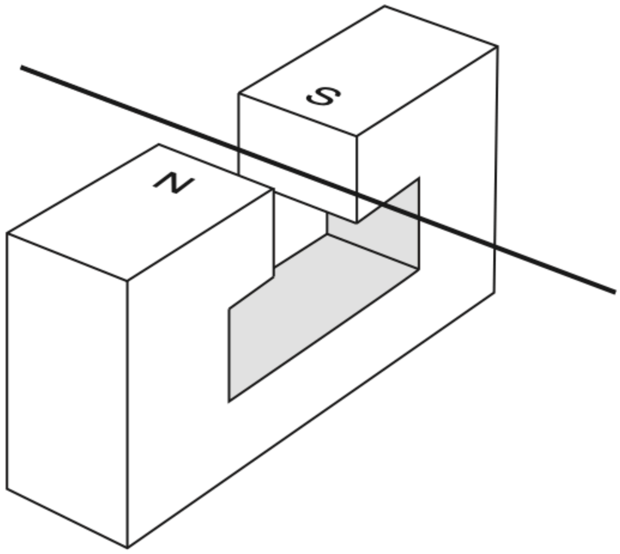


Fig. 9.1

When a constant current of 6.0A is passed through the wire, there is an additional downwards force on the magnet of 0.080N.

(a) On Fig. 9.1, draw an arrow on the wire to show the direction of the current in the wire. Explain your answer.

....

....

....

.... [3]

(b) The constant current of 6.0A is now replaced by a low-frequency sinusoidal current. The root-mean-square (r.m.s.) value of this current is 2.5A.

Calculate the difference between the maximum and the minimum forces now acting on the magnet.

difference = ... N [4]

[Total: 7]

1 (a)	rectification (of the input voltage)	**M1**
	full-wave	**A1**
7(b)(i)	$P = V^2 / R$ **or** maximum V = 9.0 V	**C1**
	$P_{MAX} = 9.0^2 / 370 = 0.22$ W	**A1**
7(b)(ii)	sinusoidal shape with minima sitting on the time axis	**B1**
	correct frequency and phase, with minima at 0, 0.02, 0.04, 0.06 and 0.08 s and maxima at 0.01, 0.03, 0.05 and 0.07 s	**B1**
	all maxima shown at 0.22 W	**B1**
7(b)(iii)	mean power = peak power / 2 = 0.22 / 2 = 0.11 W	**A1**
7(c)	power–time graph is identical	**B1**
	(so) mean powers are equal	**B1**

2 (a)	combined capacitance of parallel capacitors = 30 (μF)	**C1**
	total capacitance $= (1 / 45 + 1 / 30)^{-1}$ = 18 μF	**A1**
4(b)	$E = ½CV^2$	**C1**
	$\Delta E = ½ \times 45 \times 10^{-6} (9.6^2 - 8.0^2)$ $= 6.3 \times 10^{-4}$ J	**A1**
4(c)(i)	gaps in circuit closed and correct symbol for capacitor shown in parallel with load resistor	**B1**
4(c)(ii)	two correct pairs of values of t and V read off from within same discharge cycle, e.g. (5.0, 4.0) and (13.0, 3.2)	**C1**
	correct substitution of values of V, V_0 and Δt into $V = V_0 \exp(-\Delta t / \tau)$ e.g. $3.2 = 4.0 \exp(-8.0 / \tau)$	**C1**
	τ = 36 ms	**A1**
4(d)(i)	8.0 W	**A1**
4(d)(ii)	4.0 W	**A1**

3 a)(i)	$P = I_0^2R$	**A1**
7(a)(ii)	$P = 4I_0^2R$	**A1**
7(b)	sketch: square wave of period T, with P always non-zero	**B1**
	horizontal lines, from 0 to 0.5T and from 1.0T to 1.5T, all at the same level that the scale indicates to be I_0^2R	**B1**
	horizontal lines, from 0.5T to 1.0T and from 1.5T to 2.0T, at a level that is four times higher than the lower lines	**B1**
7(c)(i)	$\langle P \rangle = (5/2)I_0^2R$	**A1**
7(c)(ii)	$\langle P \rangle = I_{r.m.s.}^2R$	**C1**
	$I_{r.m.s.}^2R = (5/2)I_0^2R$ $I_{r.m.s.} = \sqrt{(5/2)}\, I_0$	**A1**

4 a)(i)	amplitude = ½ × 7.2 × 10^{-15} = 3.6 × 10^{-15} m	A1
4(a)(ii)	ω = 2π / (0.20 × 10^{-6}) = 3.1 × 10^{7} rad s^{-1}	A1
4(a)(iii)	$v_0 = \omega x_0$	C1
	v_0 = 3.1 × 10^7 × 3.6 × 10^{-15} = 1.1 × 10^{-7} m s^{-1}	A1
4(b)(i)	$I_0 = nAv_0e$ = 8.5 × 10^{28} × 4.3 × 10^{-4} × 1.1 × 10^{-7} × 1.60 × 10^{-19}	C1
	= 0.64 A	A1
4(b)(ii)	sketch: two cycles of sinusoidal curve of amplitude I_0 and period 0.20 μs	B1
	correct phase, with $I = +I_0$ at $t = 0$	B1
4(b)(iii)	equation of form $I = I_0 \cos \omega t$	M1
	value of I_0 used matches answer to **(b)(i)** and value of ω used matches answer to **(a)(ii)** [if **(a)(ii)** and **(b)(i)** correct then I = 0.64 cos (3.1 × 10^7 t)]	A1
4(b)(iv)	$I_{r.m.s.} = I_0 / \sqrt{2}$ = 0.64 / √2 = 0.45 A	A1

5 a)(i)	correct circuit symbol for a diode shown correctly connected in series with the wires leading into and out of the dotted box	B1
5(a)(ii)	smoothing / V_{OUT} is smoothed	B1
5(b)(i)	frequency = 1 / 0.04 = 25 Hz	A1
5(b)(ii)	$V = V_0 \exp(-t/RC)$ **and** $\tau = RC$ **or** $V = V_0 \exp(-t/\tau)$	C1
	3.25 = 5.50 exp (– 0.020 / τ) leading to τ = 0.038 s	A1
5(b)(iii)	$\tau = RC$	C1
	capacitance = 0.038 / 14000 = 2.7 × 10^{-6} F	A1
5(c)	V_{IN} has constant magnitude in both positive and negative directions	B1
	(so) V_{OUT} is (now) constant / V_{OUT} does not vary with time	B1

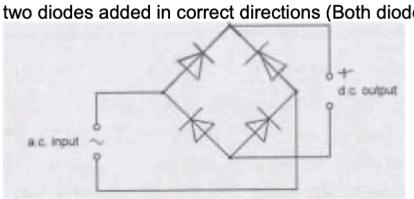
6 (a)(i)	full-wave (rectification)	B1
7(a)(ii)	lower left diode shown pointing left	B1
	lower right and upper left diodes shown pointing left	B1
7(a)(iii)	arrow indicating current direction in resistor to the right	B1
7(b)(i)	sketch: periodic line showing minimum V_{OUT} = 0 and maximum $V_{OUT} = +V_0$	B1
	line showing peak V_{OUT} at t = 0, 0.5T, 1.0T, 1.5T and 2.0T, with V_{OUT} going to zero half-way in between each peak	B1
	line showing correct modulated sine shape	B1
7(b)(ii)	sketch: sinusoidal curve with troughs sitting on the time axis	B1
	<u>peak</u> power at t = 0, 0.5T, 1.0T, 1.5T and 2.0T and zero power half-way in between each peak	B1
7(b)(iii)	same power-time graph with or without rectification, so same V_{rms} **or** V^2-time graph is same for both V_{OUT} and V_{IN}, so same V_{rms} **or** power does not depend on sign of V, so same V_{rms}	B1

7 a)(i)	peak voltage = $4.2 \times \sqrt{2}$ (= 5.9 V)	**B1**
	power = V^2 / R = $5.9^2 / 760$ = 0.046 W or 46 mW	**A1**
7(a)(ii)	sketch shows peak(s) in power at 46 mW	**B1**
	correct shape (sinusoidal wave sitting on *t*-axis)	**B1**
	four cycles of repeating pattern shown, with P = 0 at 0, 10, 20, 30, 40 μs	**B1**
7(a)(iii)	line is symmetrical about 23 mW	**B1**

8 a)	direction of induced e.m.f.	**M1**
	such as to (produce effects that) oppose the change that caused it	**A1**
8(b)(i)	X = 0.85 A	**A1**
	Y = $2\pi / 0.040$	**C1**
	= 160 rad s^{-1}	**A1**
8(b)(ii)	two cycles of a sinusoidal curve with a period of 0.040 s	**B1**
	correct phase (i.e. V_2 max / min at t = 0, 0.02, 0.04, 0.06 and 0.08 s, and V_2 zero at t = 0.01, 0.03, 0.05, 0.07 s)	**B1**
	maximum / minimum V_2 shown (consistently) at ± 6.5 V	**B1**
8(b)(iii)	(magnitude of) V_2 is proportional to rate of change of (magnetic) flux	**B1**
	• V_2 is proportional to <u>gradient</u> of I_1–t curve • V_2 has maximum magnitude when I_1–t curve is steepest • V_2 is zero when I_1–t curve is horizontal / a maximum or minimum • V_2 changes sign when sign of gradient of I_1–t curve changes *Any two points, 1 mark each*	**B2**

9 a)(i)	conversion (from a.c.) to d.c.	**B1**
5(a)(ii)	full-wave (rectification)	**B1**
5(b)(i)	P labelled – **and** Q labelled +	**B1**
5(b)(ii)	V_{OUT} scale labelled 4 and 8 on the 2 cm tick marks	**B1**
	T = $2\pi / \omega$ = $2\pi / 25\pi$ = 0.08 s	**C1**
	t scale labelled 0.02, 0.04, 0.06, 0.08, 0.10, 0.12 on the 2 cm tick marks	**A1**
5(c)(i)	correct symbol used for capacitor and capacitor connected in parallel with the 1.2 kΩ resistor.	**B1**
5(c)(ii)	straight lines or curves, with negative decreasing gradients, drawn between adjacent peaks, from top of first peak to meet line going up to next peak	**B1**
	lines, from one peak to the line going up to the next peak, show a drop in p.d. of 1½ small squares	**B1**
5(c)(iii)	V = 0.90 × 6.0 (= 5.4 V) **or** discharge time (for each cycle) = 0.034 s	**C1**
	$V = V_0 \exp(-t / RC)$ $5.4 = 6.0 \exp[-0.034 / (1.2 \times 10^3 \times C)]$	**C1**
	$C = 2.7 \times 10^{-4}$ F	**A1**

10

a)(i)	two diodes added in correct directions (Both diodes pointing inwards and upwards), correct symbols only 	**B1**
7(a)(ii)	'+' anywhere on upper output wire	**B1**
7(b)(i)	$\omega = 2\pi / T$ $= 2\pi / 2.5$ $= 0.80\ \pi$ or $4\pi / 5$ or 2.5	**C1**
	(V =) **3.5 sin (0.8π *t*)** or 3.5 sin ($4\pi\, t/5$) or 3.5 sin (2.5 t)	**A1**
7(b)(ii)	(P=) $\frac{V^2}{2R}$ or (P=) $\frac{V_{r.m.s.}{}^2}{R}$ $= \frac{3.5^2}{2\times 12}$ or $\frac{2.47^2}{12}$	**C1**
	= 0.51 W	**A1**

11

(a)	constant voltage	**M1**
	that produces/dissipates same power as (the mean power of) the alternating voltage	**A1**
9(b)(i)	(maximum) rate of cutting of (magnetic) flux doubles	**B1**
	(peak and hence) r.m.s. induced e.m.f. doubles	**B1**
9(b)(ii)	sketch: (sinusoidal) wave of period 10 ms	**B1**
	peak E shown as ± 34 V (*1 mark out of 2 awarded if peak E shown as* ± 17 V *or* ± 24 V)	**B2**
9(c)	current in the coil results in forces that oppose its rotation **or** current in the resistor dissipates the energy of rotation	**B1**
	coil stops rotating	**B1**

12

(a)	the steady current **or** the direct current	**M1**
	that produces the same heating effect (as the alternating current)	**A1**
10(b)(i)	peak current = 2.6 A **and** r.m.s. current = 1.8 A	**A1**
10(b)(ii)	peak current = 2.0 A **and** r.m.s. current = 2.0 A	**A1**
10(c)(i)	$k = 2\pi f$	**C1**
	$= 2\pi \times 50$ $= 310$ rad s^{-1}	**A1**
10(c)(ii)	power = $V_{RMS}{}^2 / R$ **or** power = $V_0{}^2 / 2R$	**C1**
	$R = (240/\sqrt{2})^2 / 3200$ **or** $R = 240^2 / (2 \times 3200)$ $R = 9.0\ \Omega$	**A1**

13 a)	**230** V	**A1**
10(b)	ω = 100π $T = \frac{2\pi}{\omega} = \frac{2\pi}{100\pi}$	**C1**
	= 0.020 s	**A1**
10(c)(i)	half-wave (rectification)	**B1**
10(c)(ii)	sinusoidal half waves in positive V only or negative V only, peak at 320 V	**B1**
	line at zero for second half of cycle	**B1**
	two time periods shown, each of 0.020 s	**B1**
10(c)(iii)	capacitor added in parallel with resistor	**B1**

14 (a)(i)	9.0 / √2 = **6.4** V	**A1**
9(a)(ii)	ω = 20 ω = 2π / T T = 2π / 20	**C1**
	T = **0.31** s	**A1**
9(b)	the r.m.s. voltages are different, so no	**B1**
9(c)(i)	$P = V_{r.m.s.} \times I_{r.m.s.}$	**C1**
	= 120 × 0.64 = 76.8 W	**C1**
	efficiency = (76.8 / 80) × 100 = **0.96** or **96** %	**A1**
9(c)(ii)	Any one from: • heat losses due to resistance of windings / coils • heat losses in magnetising and demagnetising core / hysteresis losses in core • heat losses due to eddy currents in (iron) core • loss of flux linkage	**B1**

15 a)(i)	lower right **and** upper left diodes circled	**B1**
10(a)(ii)	maximum = 7.0√2 = 9.9 V	**A1**
10(b)(i)	correct symbol for capacitor, shown connected in parallel with R	**B1**
10(b)(ii)	**1.** (ripple) decreases	**B1**
	2. (ripple) increases	**B1**

16 (a)	V_{MAX} = 15 V	**A1**
10(b)	210 = 2π / T	**C1**
	T = 0.0299 s	**C1**
	$(t_2 - t_1)$ = 0.060 s	**A1**

17 a)(i)	*Either* Newton's third law *or* equal and opposite forces	**B1**
	force on magnet is upwards	**B1**
	so force on wire downwards	**B1**
8(a)(ii)	using (Fleming's) left-hand rule	**M1**
	current from B to A	**A1**
8(b)	sinusoidal wave with at least 1 cycle	**B1**
	peaks at +6.4 mN and –6.4 mN	**B1**
	time period 25 ms	**B1**

18	(a)	$V_0 = \sqrt{2} \times V_{r.m.s.} = \sqrt{2} \times 9.9$ (= 14 V) **and** $\omega = 2\pi f = 2\pi \times 50$ (= 314 rad s^{-1})	**C1**
		$V = 14 \sin 314t$	**A1**

19 a)(i)	circles drawn only around the top left and bottom right diodes	**B1**
11(a)(ii)	B shown as (+)ve and A shown as (–)ve	**B1**
11(b)(i)	$V_{r.m.s.}$ (= 5.6 / √2) = 4.0 V	**A1**
11(b)(ii)	380 = $2\pi f$ **or** f = 60.5 Hz	**C1**
	number (= $2f$) = 120	**A1**
11(c)(i)	peak values (all) unchanged	**B1**
	(all) minima shown at 4.0 V	**B1**
	three lines from near peak showing concave curves after leaving dotted line not 'kinked' and not cutting the peak reaching candidate's minimum at the point where the decay meets the next dotted line	**B1**
	three lines drawn along the dotted lines showing rise in voltage from minima back to peak values	**B1**
11(c)(ii)	mean p.d. is higher **or** r.m.s. p.d. is higher **or** capacitor supplies energy to resistor	**M1**
	so (mean) power increases	**A1**

20 **(a)** period = 15 ms — C1

frequency (= 1 / T) = 67 Hz — A1 [2]

(b) zero — A1 [1]

(c) $I_{r.m.s.} = I_0 / \sqrt{2}$ — C1

= 0.53 A — A1 [2]

(d) energy = $I_{r.m.s.}^2 \times R \times t$ or $\frac{1}{2} I_0^2 \times R \times t$

or

power = $I_{r.m.s.}^2 \times R$ and energy = power × t — C1

energy = $0.53^2 \times 450 \times 30 \times 10^{-3}$

= 3.8 J — A1 [2]

21 **(a)** (by Newton's third law) force on wire is up(wards) — M1

by (Fleming's) left-hand rule/right-hand slap rule to give current — A1

in direction left to right shown on diagram — A1 [3]

(b) force ∝ current *or* $F = BIL$ *or* B (= 0.080 / 6.0L) = 1 / 75L — C1

maximum current = 2.5 × √2
= 3.54 A — C1

maximum force in one direction = (3.54 / 6.0) × 0.080
= 0.047 N — C1

difference (= 2 × 0.047) = 0.094 N

or

force varies from 0.047 N upwards to 0.047 N downwards — A1 [4]