CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 21: Alternating Currents

Past Papers 2021 – 2025

QUESTION PAPER 18 Questions

Prepared by

Waseem Ahmad

A Level Physics Teacher

Author of ***Practical Mastery: Cambridge 9702 Paper 3***

www.examspath.com

Question 1

(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 $t = 0$.

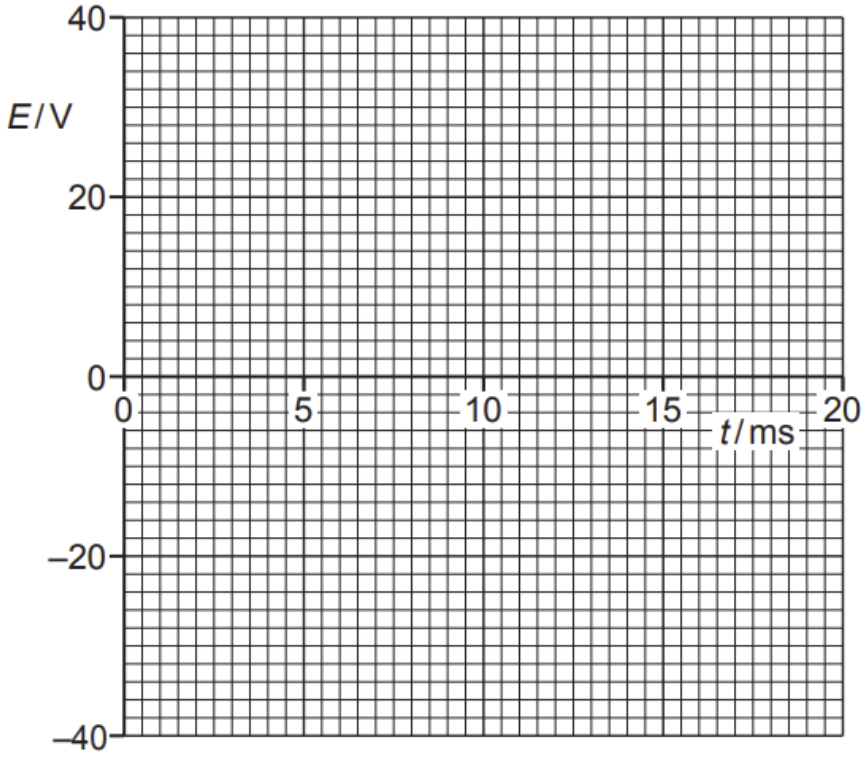


Fig. 9.1

[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]

Question 2

(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.

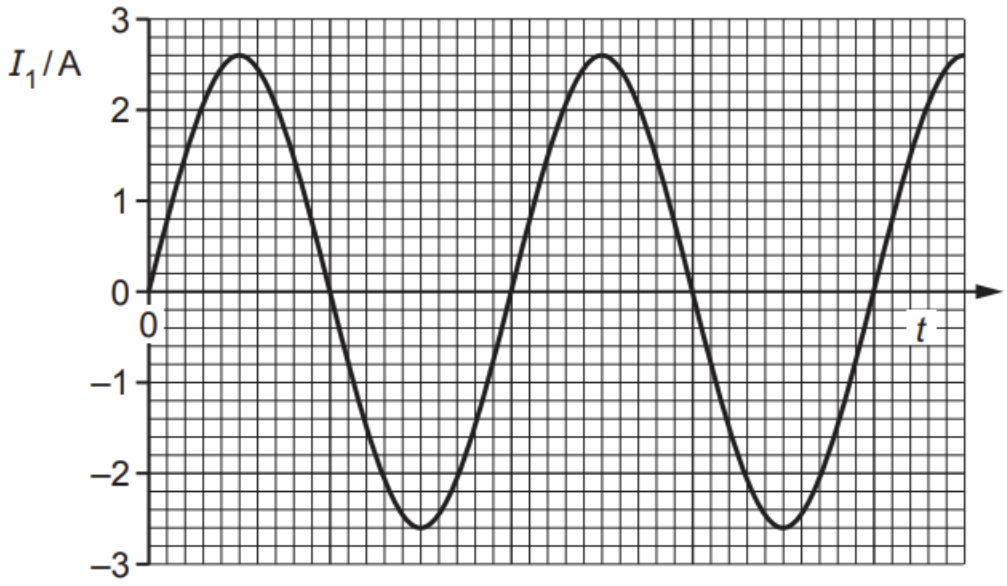


Fig. 10.1

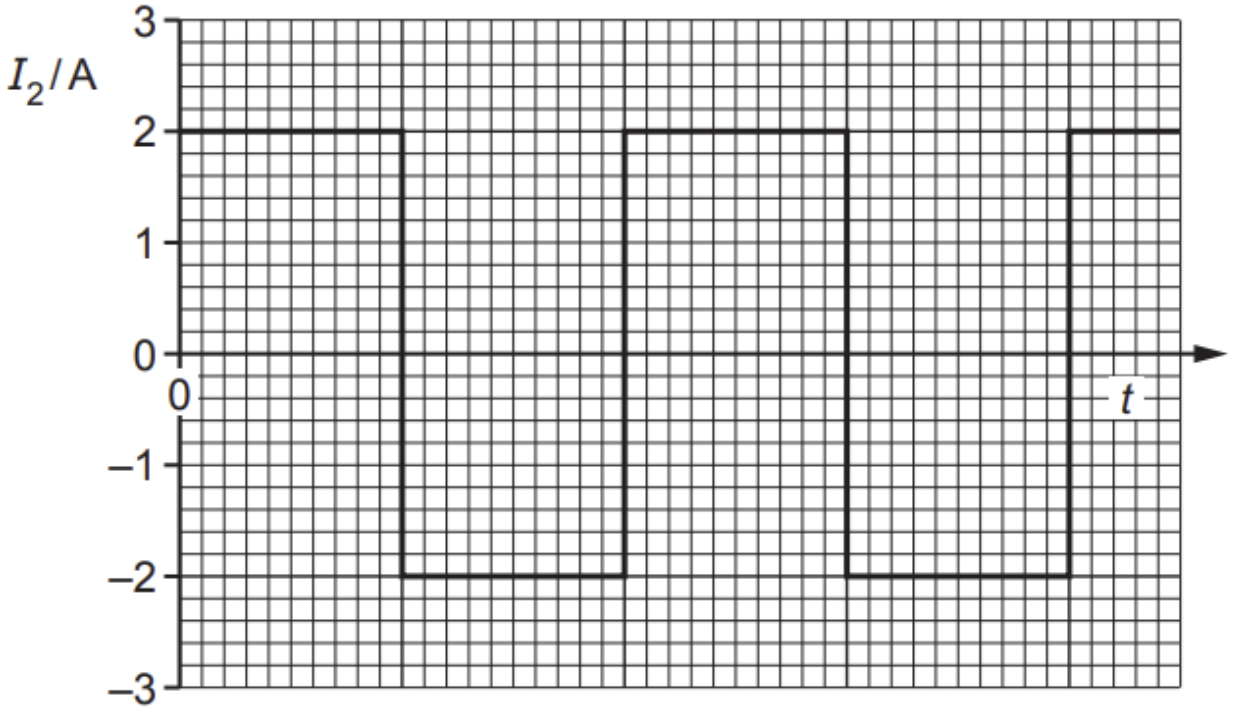


Fig. 10.2

(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]

Question 3

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.

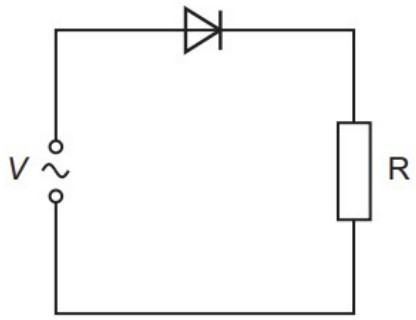


Fig. 10.1

(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.

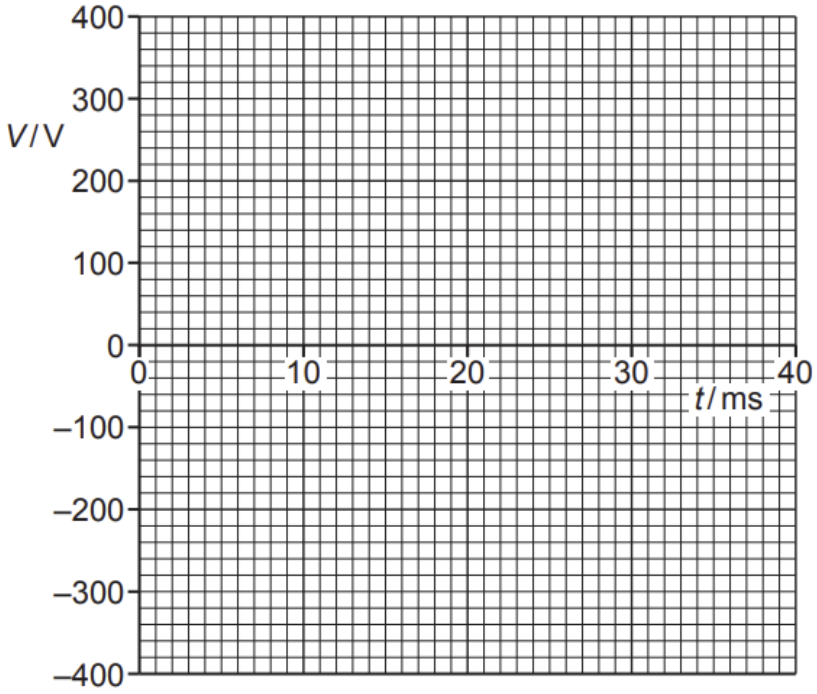


Fig. 10.2

[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]

Question 4

(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.

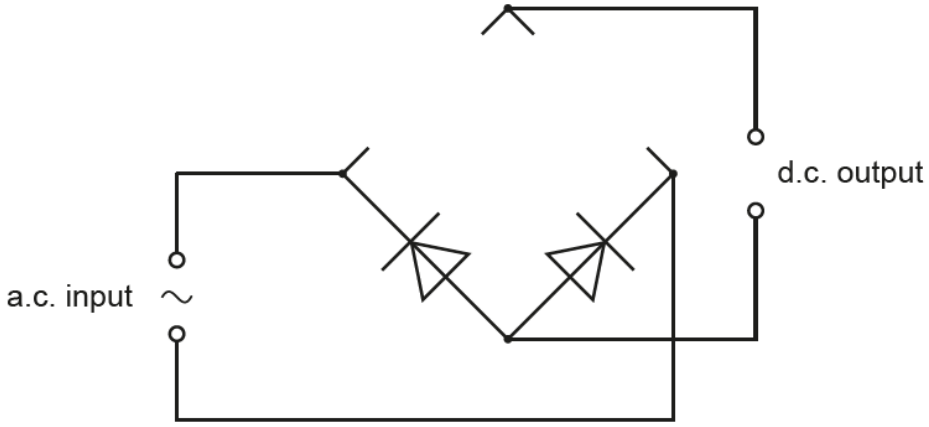


Fig. 7.1

(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.

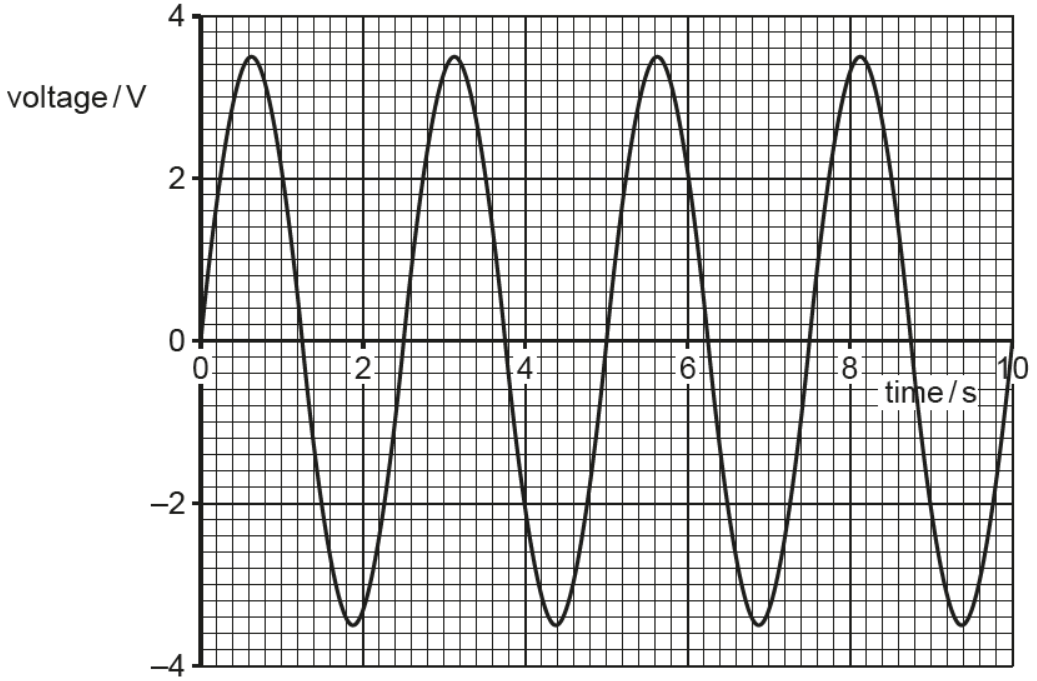


Fig. 7.2

(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]

Question 5

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.

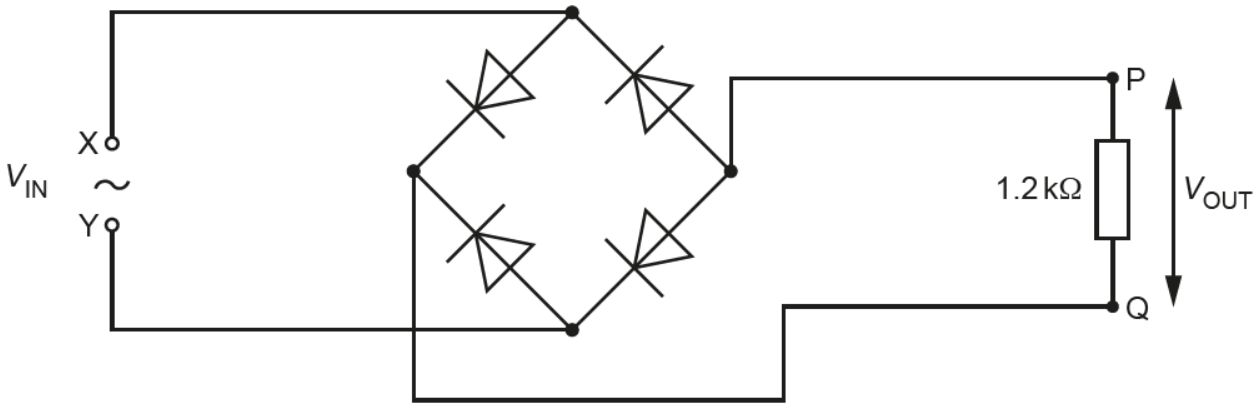


Fig. 5.1

(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.

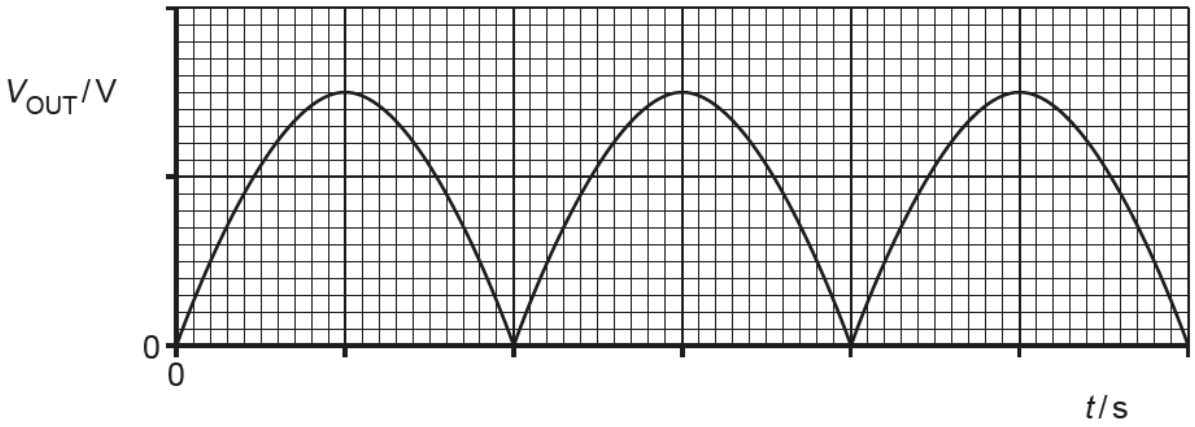


Fig. 5.2

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]

Question 6

(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 $t = 0$.

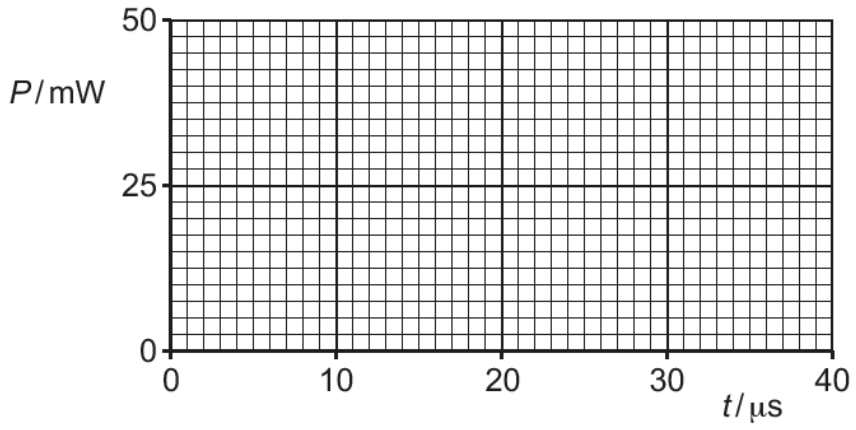


Fig. 7.1

[3]

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

.....

.....

..... [1]

(b) The alternating voltage in **(a)** is now applied to a piezoelectric crystal in air.

(i) Explain what happens to the air surrounding the crystal.

.....

.....

.....

..... [3]

(ii) A second piezoelectric crystal is placed in the air near to the first crystal.

Explain the effect of the surrounding air in **(b)(i)** on the second crystal.

..... [1]

[Total: 10]

Question 7

Part of an electric circuit is shown in Fig. 5.1.

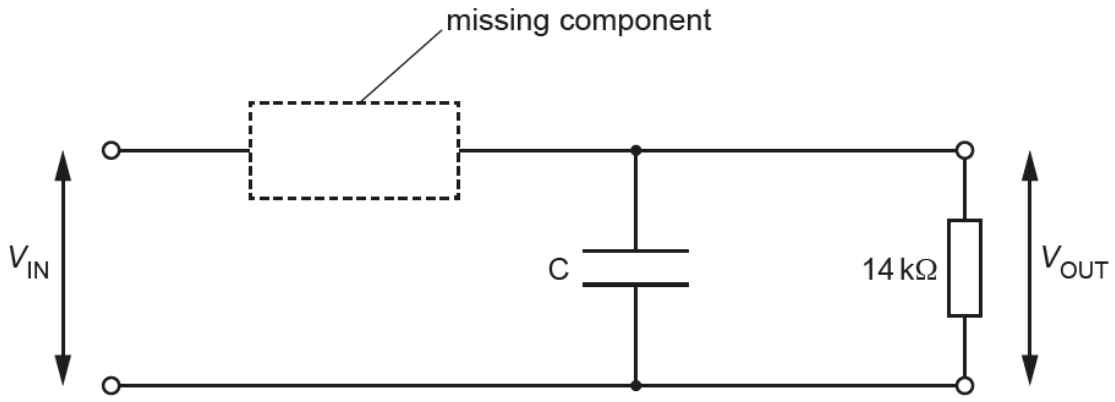


Fig. 5.1

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}.

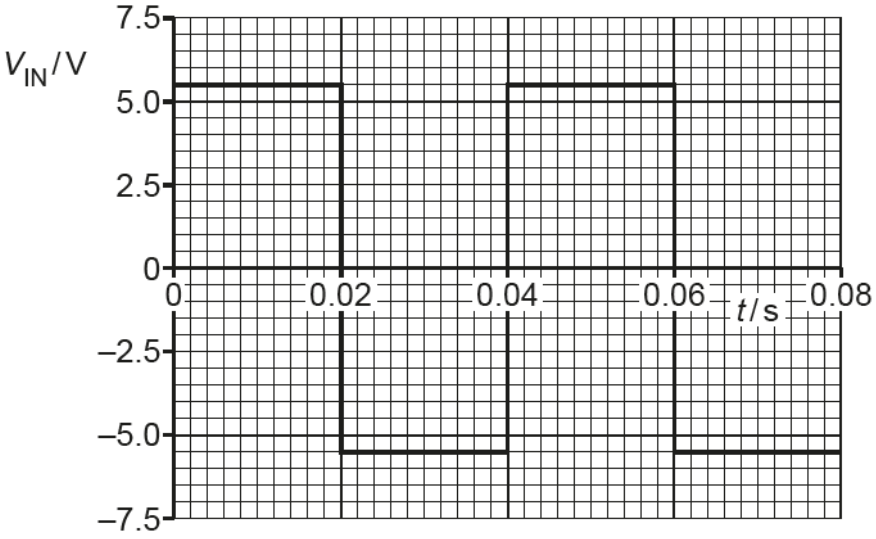


Fig. 5.2

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

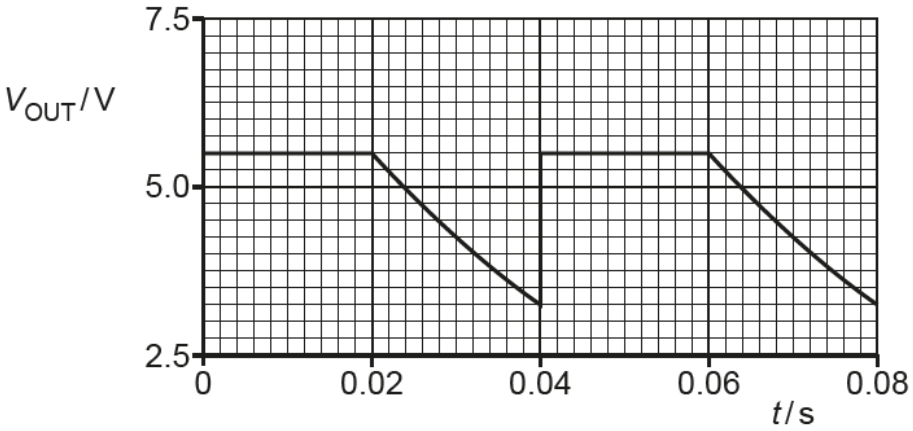


Fig. 5.3

(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]

Question 8

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.

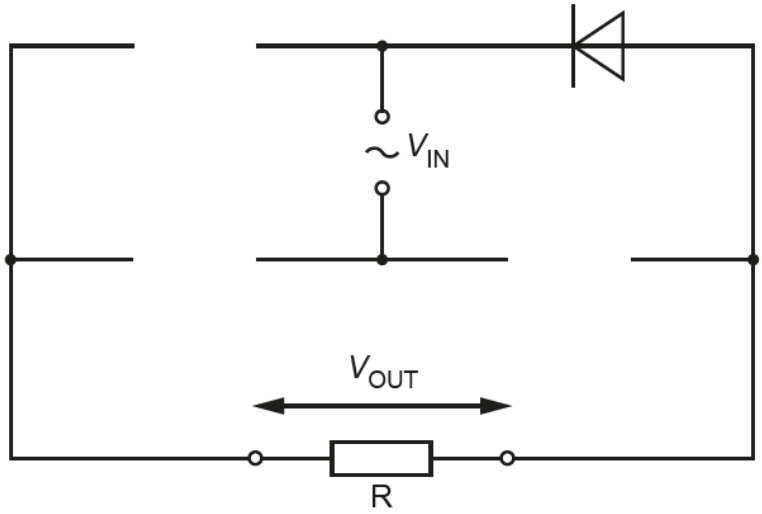


Fig. 7.1

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}.

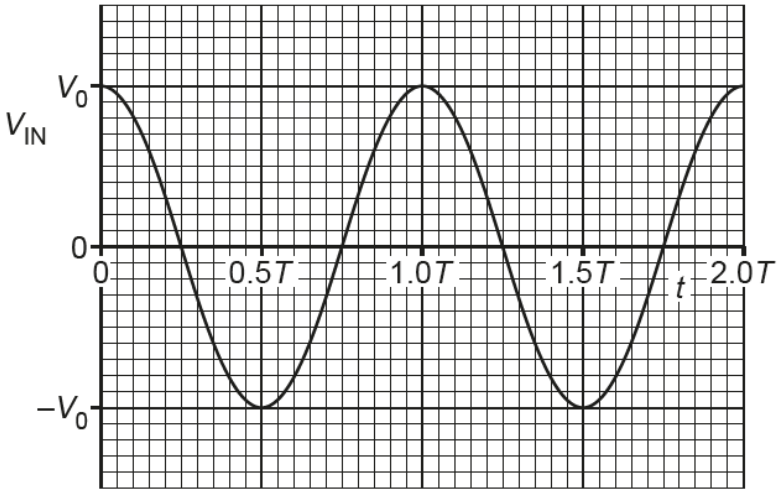


Fig. 7.2

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

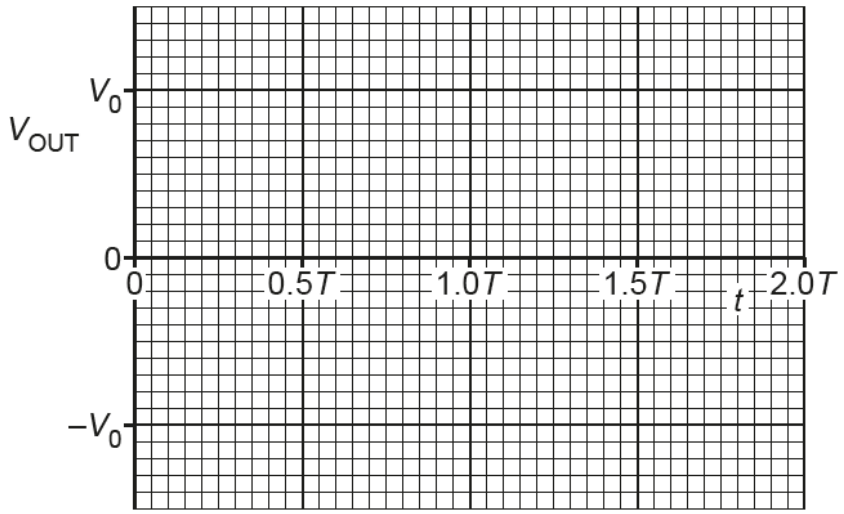


Fig. 7.3

[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 $t = 2.0T$.

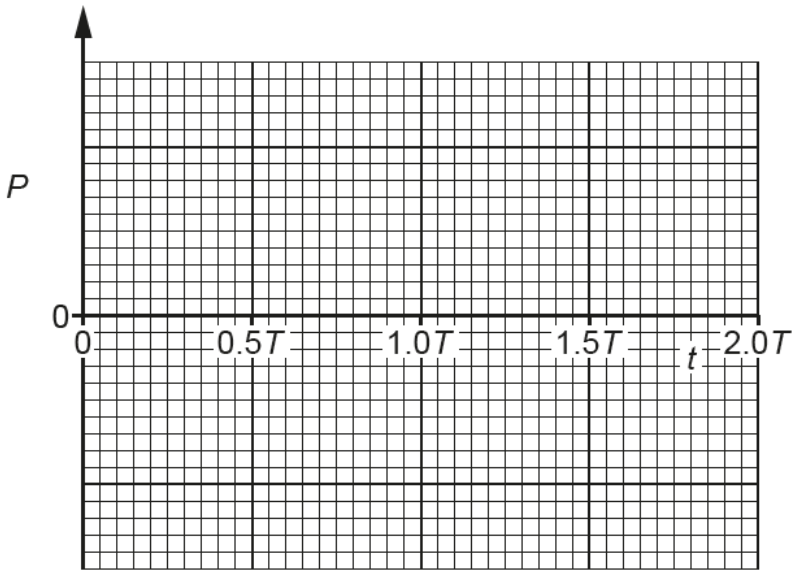


Fig. 7.4

[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]

Question 9

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

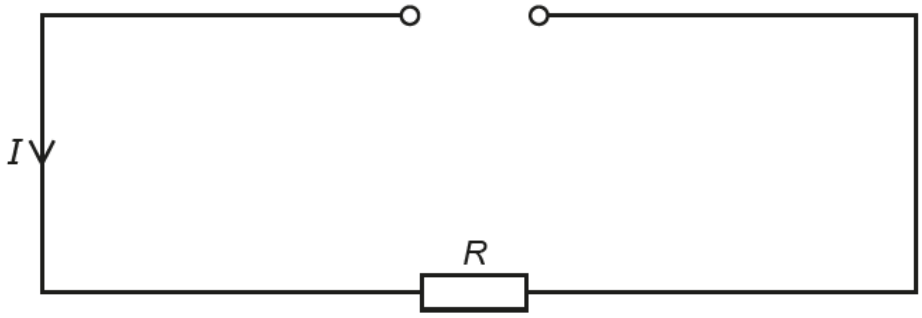


Fig. 7.1

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

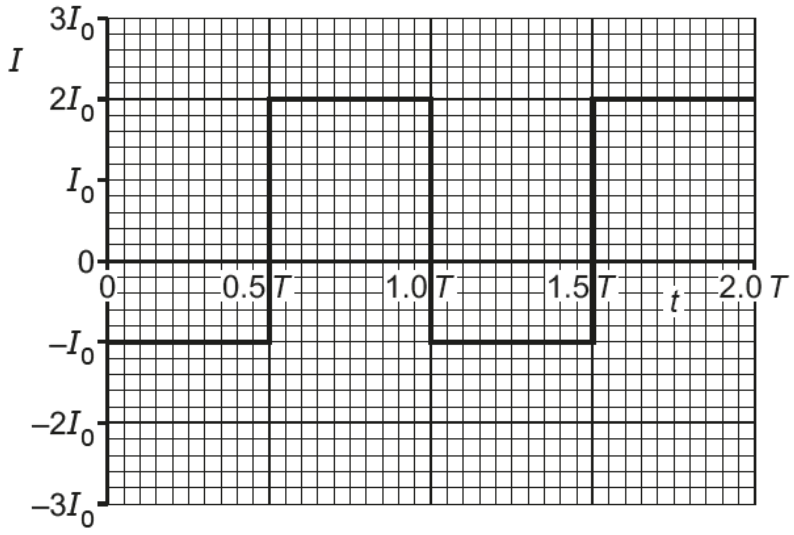


Fig. 7.2

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]

(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.

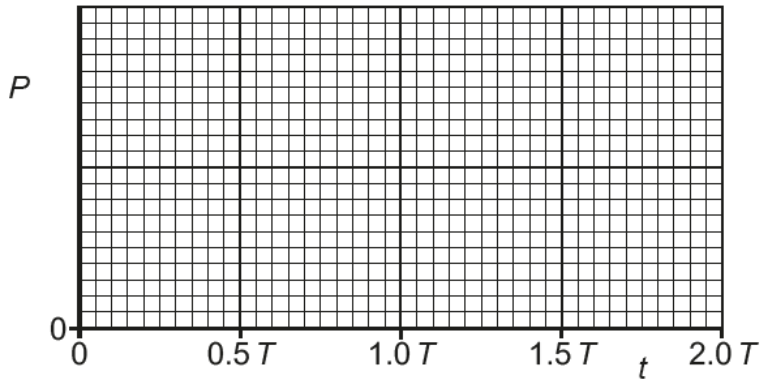


Fig. 7.3

[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]

Question 10

(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.

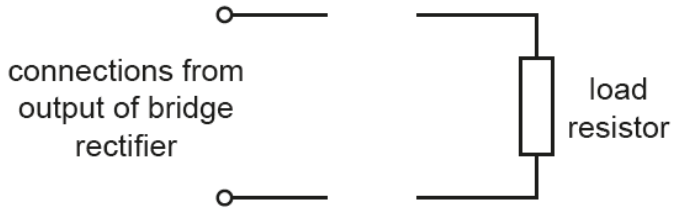


Fig. 4.2

[1]

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

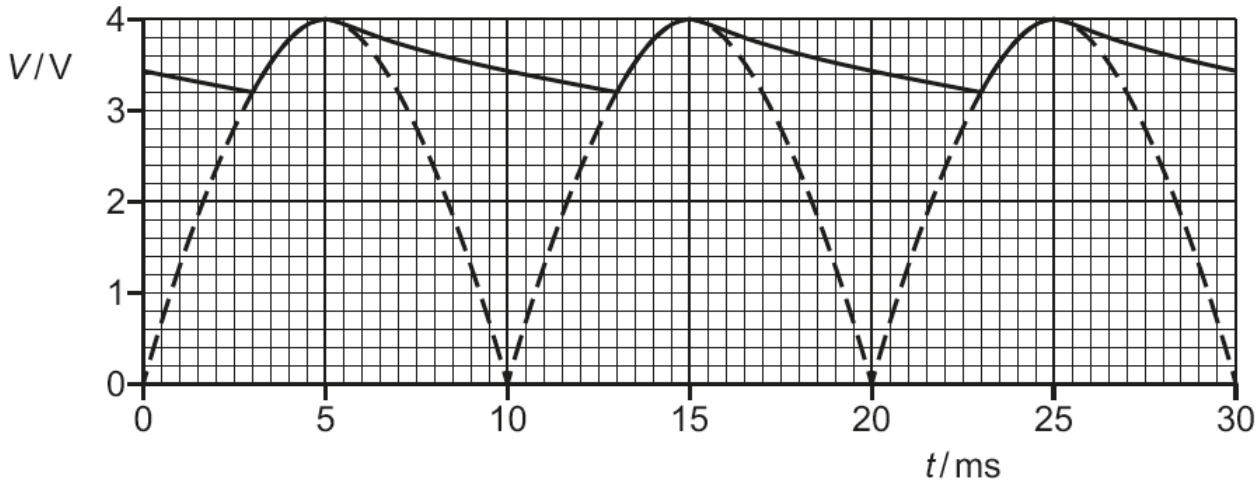


Fig. 4.3

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]

Question 11

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.

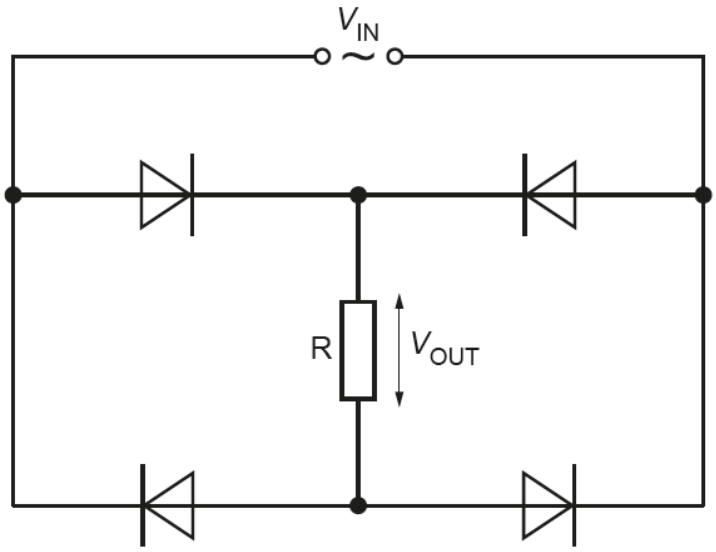


Fig. 7.1

(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.

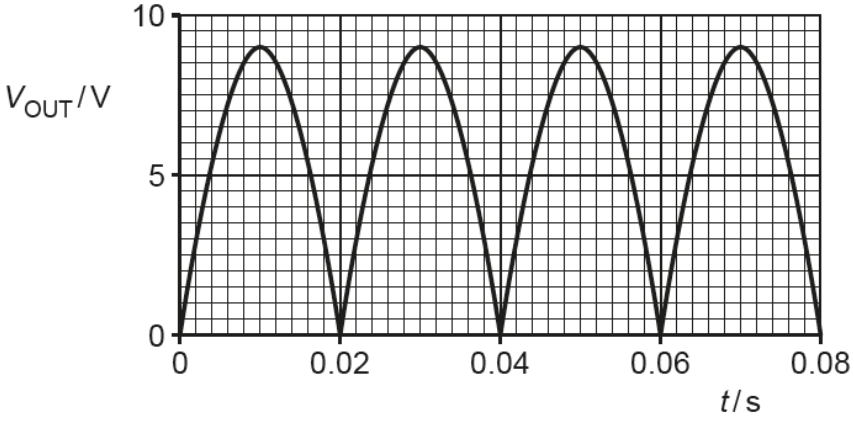


Fig. 7.2

(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.

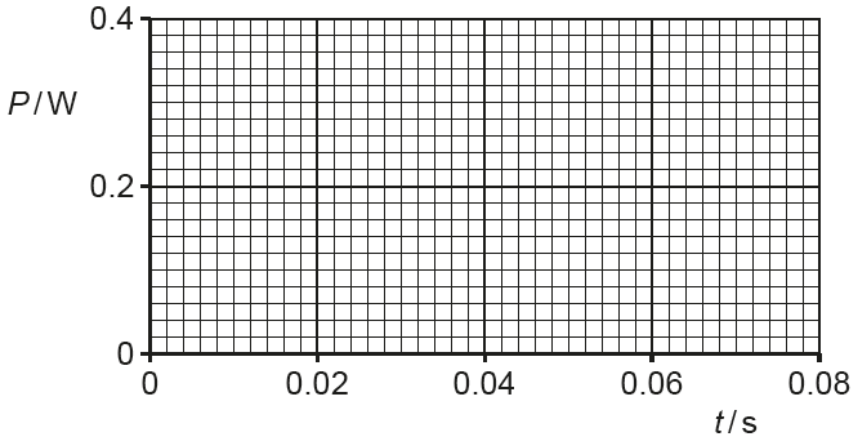


Fig. 7.3

[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]

Question 12

(a) (i) State what is meant by rectification of an alternating voltage.

.....

..... [1]

(ii) State the difference between half-wave rectification and full-wave rectification.

.....

.....

..... [2]

(b) (i) Complete Fig. 6.1 to show a circuit that produces half-wave rectification of an alternating input voltage V_{IN} to produce output voltage V_{OUT} across the resistor R.

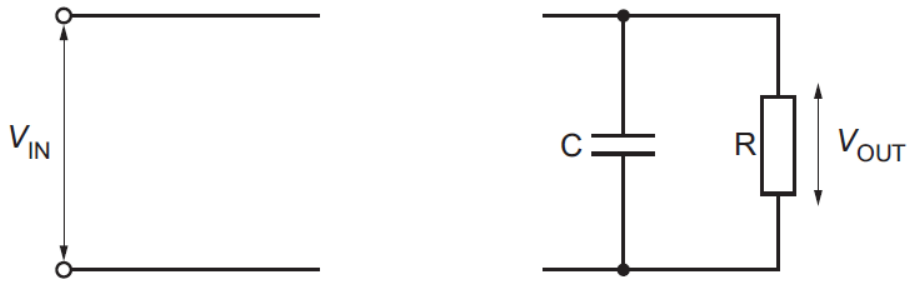


Fig. 6.1

[2]

(ii) State the purpose of the capacitor C in the circuit of Fig. 6.1.

.....

..... [1]

(c) The input voltage V_{IN} in Fig. 6.1 is a square wave. Fig. 6.2 shows the variation of V_{IN} with time t.

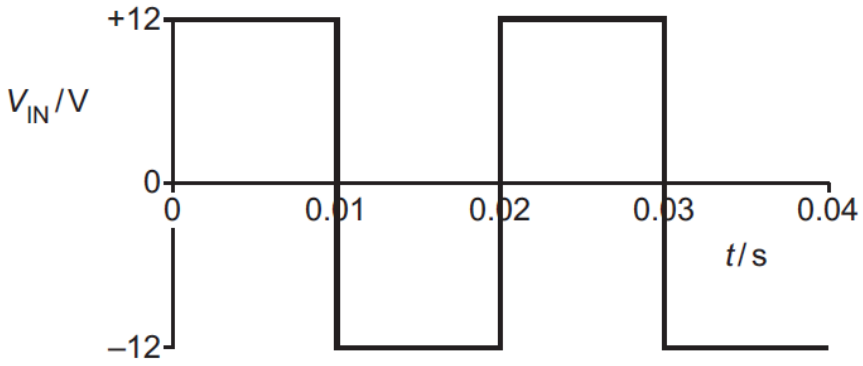


Fig. 6.2

Fig. 6.3 shows the variation of V_{OUT} with t.

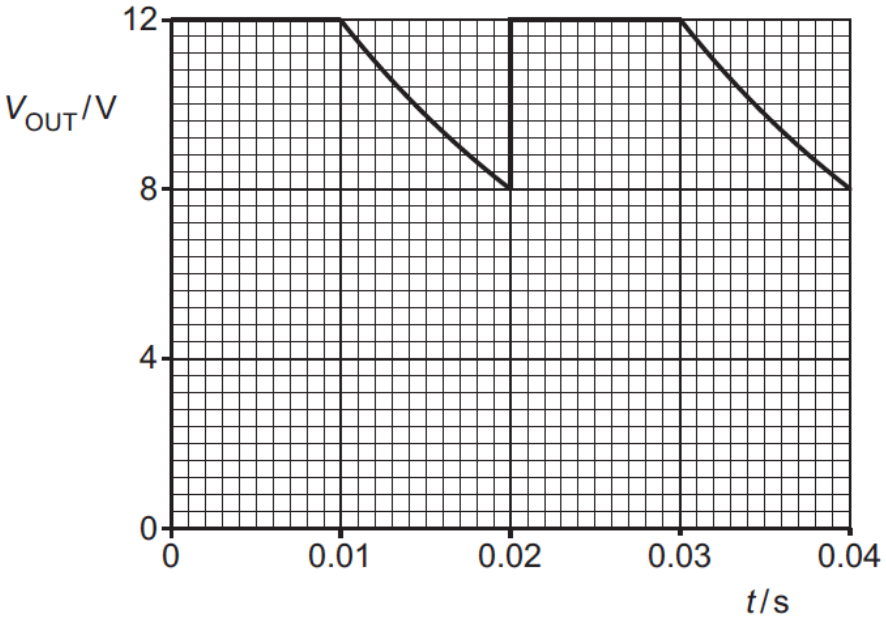


Fig. 6.3

The maximum energy stored in the capacitor is 0.041 J.

(i) Show that the capacitance of C is 570 μF.

[2]

(ii) Determine the resistance of R.

resistance = ... Ω [3]

[Total: 11]

Question 13

(a) State what is meant by the frequency of an alternating current.

.....

..... [1]

(b) An alternating current I in a resistor of resistance 680 Ω varies with time t according to

$$I = 3.5\sin(40\pi t)$$

where I is in A and t is in s.

(i) Show that the period of the alternating current is 50 ms.

[1]

(ii) On Fig. 8.1, sketch the variation of I with t between $t = 0$ and $t = 100$ ms.

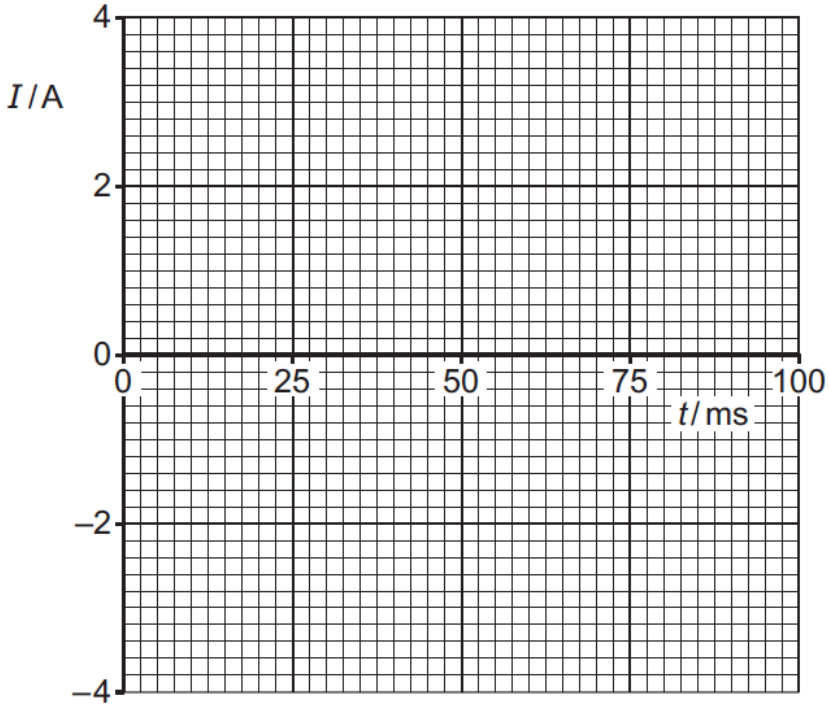


Fig. 8.1

[3]

(iii) Determine the root-mean-square (r.m.s.) current in the resistor.

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

(c) Use data from **(b)**, including your answer in **(b)(iii)**, to show by calculation that the mean power in the 680 Ω resistor is half of the peak power.

[3]

[Total: 9]

Question 14

Fig. 6.1 shows a circuit that rectifies an alternating input voltage V_{IN} and produces an output voltage V_{OUT} across a resistor R.

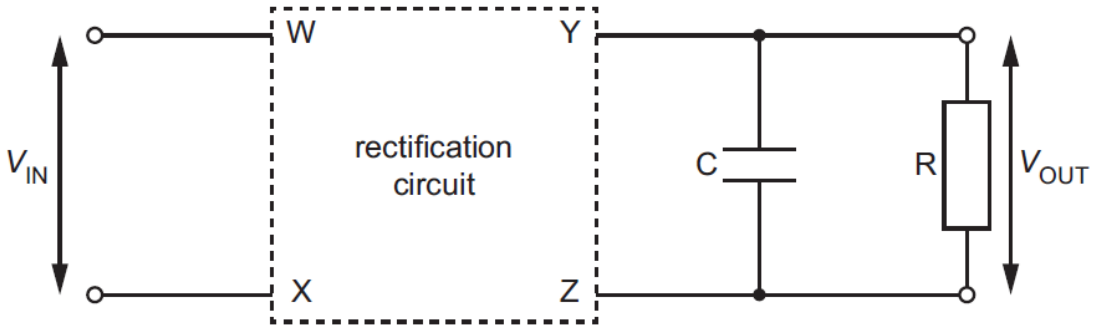


Fig. 6.1

The four terminals of the rectification circuit are labelled W, X, Y and Z.
A capacitor C is connected in parallel with resistor R.

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

.....

..... [1]

(ii) State the purpose of capacitor C.

.....

..... [1]

(b) Fig. 6.2 shows the variations with time t of the potential differences (p.d.s) V_{IN} and V_{OUT}.

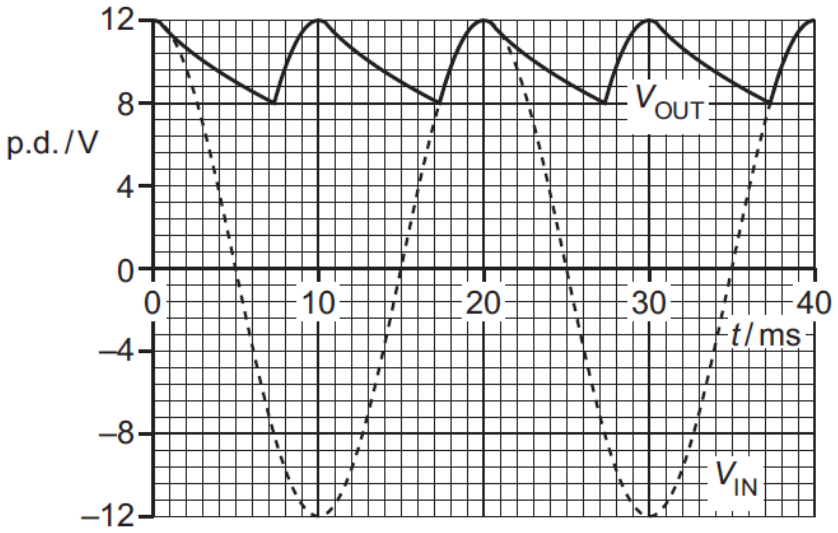


Fig. 6.2

(i) The variation of V_{IN} with t can be represented by

$$V_{IN} = A \cos Bt$$

where A and B are constants.

Determine the values of A and B. Give a unit with your answer for A.

A = ... unit .....

B = ... rad s^{-1}

[2]

(ii) Determine the type of rectification produced by the circuit in Fig. 6.1.

..... [1]

(iii) On Fig. 6.3, draw the circuit diagram for the components inside the rectification circuit.

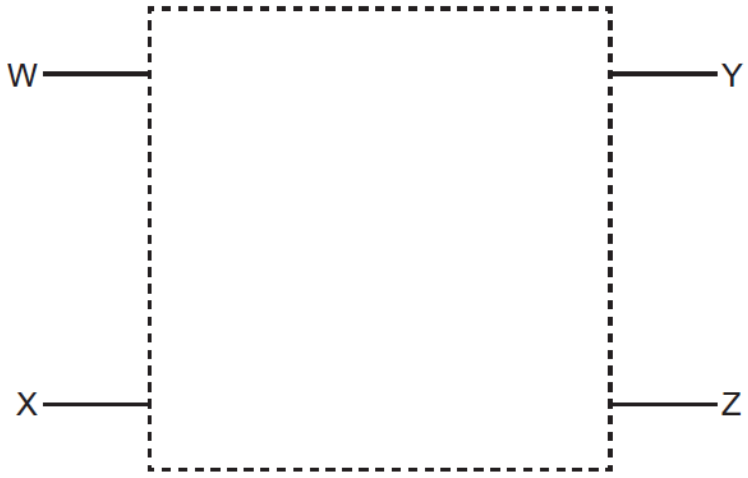


Fig. 6.3

[2]

(iv) Determine a value for the time constant for the discharge of the capacitor C through the resistor R in Fig. 6.1.

time constant = ... s [3]

(c) The capacitor C has a capacitance of 570 μF.

Use your answer in **(b)(iv)** to determine the resistance of resistor R.

resistance = ... Ω [2]

[Total: 12]

Question 15

Fig. 8.1 shows a circuit that produces rectification of an alternating input voltage.

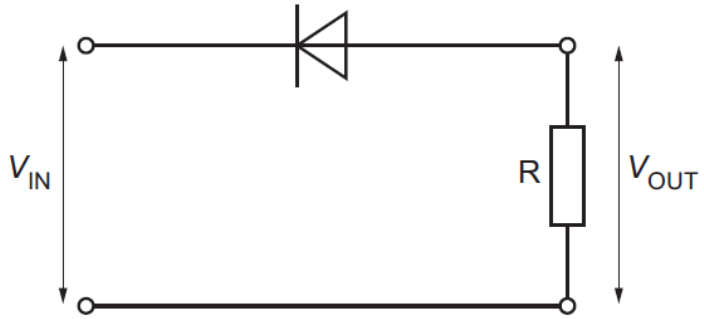


Fig. 8.1

The input voltage V_{IN} is sinusoidal. The rectified output voltage V_{OUT} is applied across resistor R.

The variation of V_{IN} with time t has amplitude V_0 and period T, as shown in Fig. 8.2.

The variation of V_{IN} with time t has amplitude V_0 and period T, as shown in Fig. 8.2.

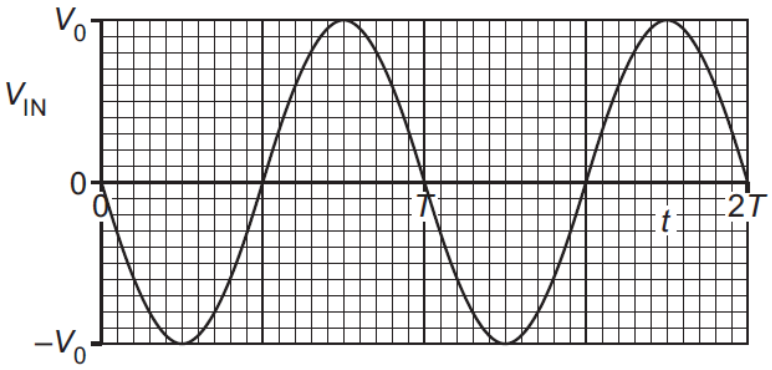


Fig. 8.2

The root-mean-square (r.m.s.) value of V_{IN} is 6.0 V.

(a) (i) State the type of rectification produced by the circuit of Fig. 8.1.

..... [1]

(ii) Calculate V_0.

V_0 = ... V [1]

(b) Resistor R has resistance 45 Ω.

Assume that there is no p.d. across the diode when it is conducting.

(i) Determine the peak power P_0 in the resistor.

P_0 = ... W [2]

(ii) On Fig. 8.3, sketch the variation of the power P in the resistor with t between $t = 0$ and $t = 2T$.

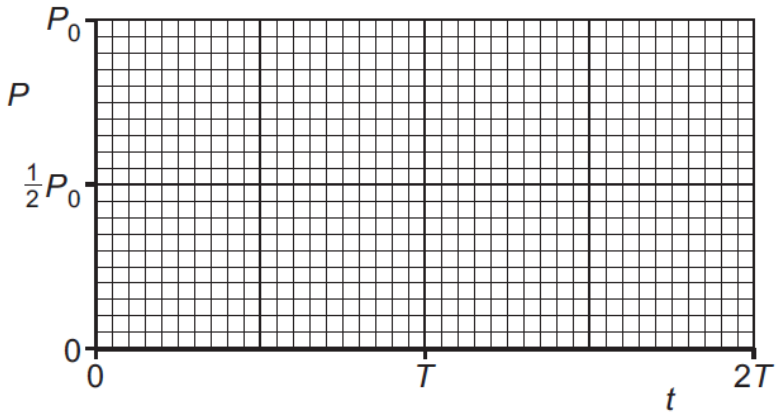


Fig. 8.3

[3]

(iii) Use the answer in **(b)(ii)** to explain why the mean power in the resistor is $\frac{1}{4}P_0$.

.....

.....

..... [2]

(iv) Use the information in **(b)(iii)** to determine the r.m.s. value of V_{OUT}.

r.m.s. voltage = ... V [1]

[Total: 10]

Question 16

An incomplete circuit diagram of a bridge rectifier is shown in Fig. 8.1.

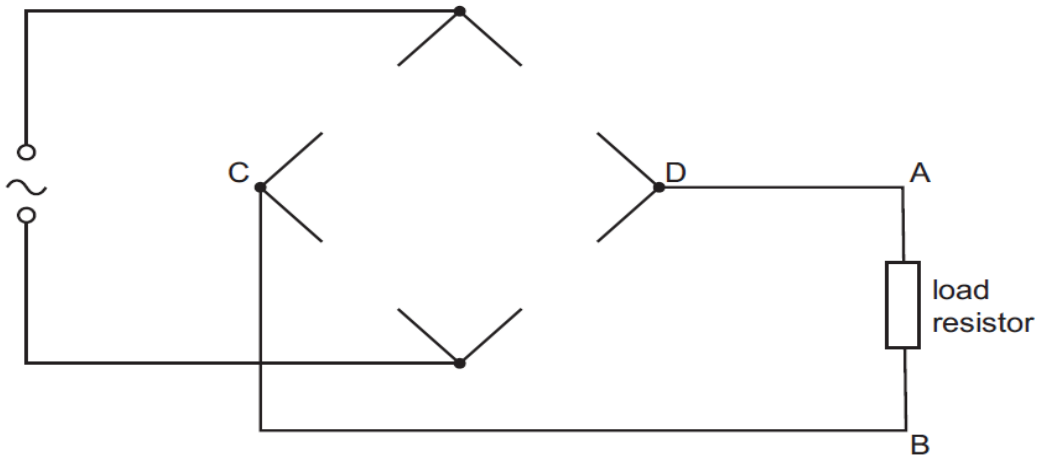


Fig. 8.1

(a) Complete Fig. 8.1 for the bridge rectifier such that the point A is at a positive potential with respect to point B. [2]

(a) Complete Fig. 8.1 for the bridge rectifier such that the point A is at a positive potential with respect to point B. [2]

(b) The variation with time t of the potential difference (p.d.) V across the load resistor is shown in Fig. 8.2.

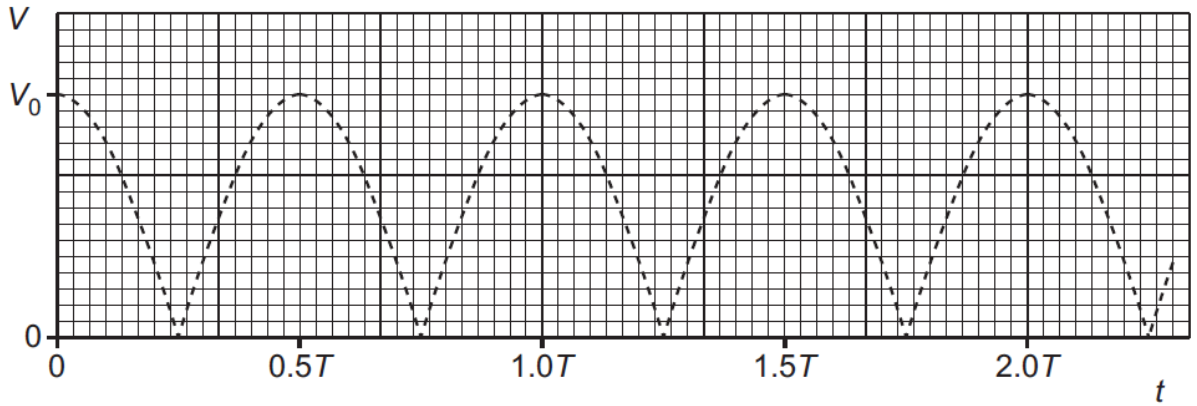


Fig. 8.2

A capacitor is now connected between points C and D of the bridge rectifier. This results in smoothing of the p.d. across the load resistor. The difference between the maximum and minimum values of the smoothed p.d. is 33% of the peak p.d. V_0.

(i) On Fig. 8.2, draw a line to show the variation of the potential difference V across the load resistor with time t. Your line should extend from $t = 0.5T$ to $t = 2.0T$. [3]

(ii) Use your line in **(b)(i)** to determine, in terms of T, the time constant of the smoothing circuit.

time constant = ... T [3]

(iii) The resistance of the load resistor is now increased. The capacitance of the capacitor is unchanged.

State and explain the effect of this change on the smoothed output p.d.

.....

.....

..... [2]

[Total: 10]

Question 17

An alternating voltage V varies with time t according to

$$V = 18\cos 40\pi t$$

where V is in V and t is in s.

(a) For the alternating voltage:

(i) show that the period is 0.050 s

[1]

(ii) determine the root-mean-square (r.m.s.) voltage.

r.m.s. voltage = ... V [1]

(b) On Fig. 7.1, sketch the variation of V with t for values of t from $t = 0$ to $t = 100$ ms.

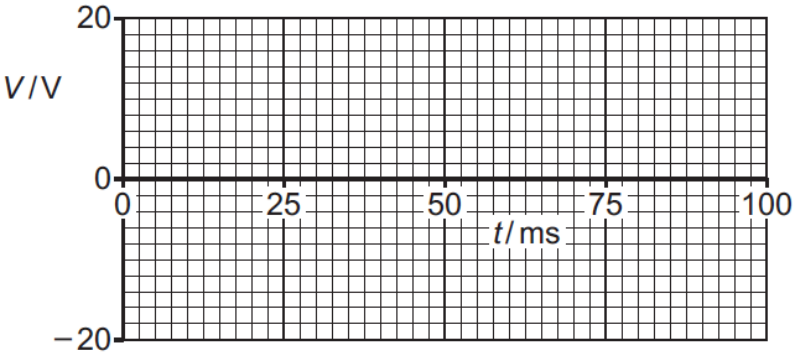


Fig. 7.1

[3]

(c) The alternating voltage is rectified to produce an output voltage across a load resistor R, as shown in Fig. 7.2.

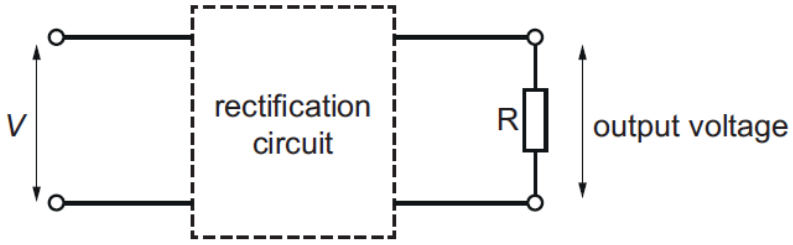


Fig. 7.2

Fig. 7.3 shows the variation with *t* of the power *P* in the load resistor.

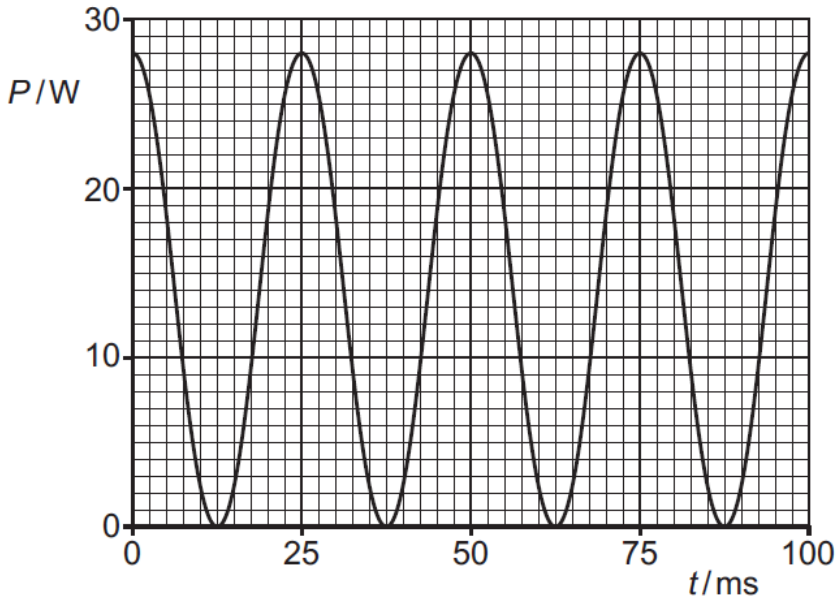


Fig. 7.3

State **three** conclusions that can be drawn from Fig. 7.3. The conclusions may be qualitative or quantitative. Use the space for any working.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

[Total: 8]

Question 18

Fig. 6.1 shows part of a bridge rectifier circuit that can be used for rectification of an alternating input voltage V_{IN}.

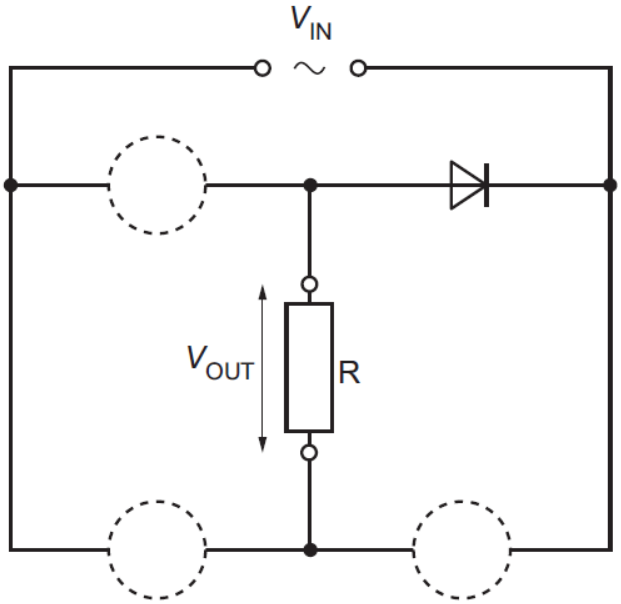


Fig. 6.1

The circuit contains four diodes, one of which is shown.
The rectified output voltage V_{OUT} is applied across load resistor R.

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

.....

..... [1]

(ii) State the name of the type of rectification produced by a bridge rectifier circuit.

..... [1]

(iii) Complete the circuit in Fig. 6.1 by drawing the three missing diodes inside the dashed circles. [2]

(b) The input voltage varies with time t according to the equation

$$V_{IN} = 34 \sin 18t$$

where V_{IN} is in V and t is in s.

(i) Show that the period of the input voltage is 0.35 s.

[2]

(ii) Calculate the root-mean-square (r.m.s.) input voltage.

r.m.s. voltage = ... V [1]

(iii) On Fig. 6.2, sketch the variation of V_{OUT} with t from $t = 0$ to $t = 0.35$ s.

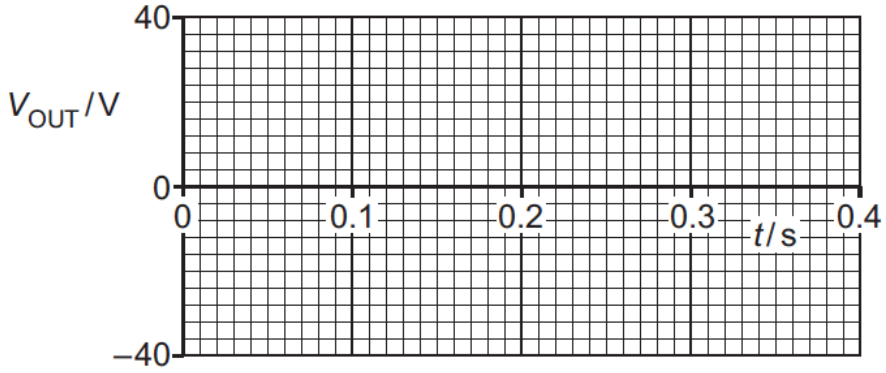


Fig. 6.2

[3]

(c) Resistor R has a resistance of 56 kΩ. A capacitor of capacitance 12 μF is connected into the circuit of Fig. 6.1 in order to smooth the output voltage.

(i) On Fig. 6.1, draw the capacitor correctly connected into the circuit. [1]

(ii) Calculate the time constant of the smoothing circuit.

time constant = ... s [2]

(iii) During each discharge cycle, the time for which the capacitor is discharging is 0.14 s.

Determine the minimum value of the smoothed output voltage.

minimum voltage = ... V [2]

[Total: 15]

End of Question Paper • Waseem Ahmad, A Level Physics Teacher • examspath.com