Week 47

A-Level Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

A-Level Physics Name: ______________ Score: ______

1. An alternating current:
   - ☐ reverses direction periodically
   - ☐ flows one way only
   - ☐ never changes
   - ☐ has no frequency
2. A diode conducts current:
   - ☐ in one direction only
   - ☐ in both directions
   - ☐ never
   - ☐ only at very high voltage
3. In $V = V_0 \sin(\omega t)$ the coefficient of t is the ______ frequency, equal to $2\pi f$.

   ____
4. Half-wave rectification uses ______ diode.

   ____
5. Mains supply is 50 Hz. What is its period?

   ________________ s
6. Where does a smoothing capacitor go?
   - ☐ in parallel with the load
   - ☐ in series with the load
   - ☐ in series with the diode
   - ☐ across the a.c. supply, before the diodes
7. On a CRO trace one complete cycle spans 4.0 divisions with the time-base at 5.0 ms per division. What is the frequency, in Hz?

   ____
8. How many diodes are in a bridge (full-wave) rectifier?

   ____
9. The average power of a.c. in a resistor is ______ the peak power.

☐ half

☐ equal to

☐ double

☐ a quarter of

10. A full-wave rectified output repeats at twice the frequency of the a.c. input.

☐ True ☐ False

A-Level Physics

1. **reverses direction periodically**

   a.c. keeps swapping direction — mains does so 50 (or 60) times a second.

2. **in one direction only**

   This one-way behaviour is what lets diodes rectify a.c. into d.c.

3. **angular**

   omega is 2*pi*f, so a supply written sin(100*pi*t) has f = 50 Hz, not 100*pi Hz. The angle is in radians, so a calculator left in degrees turns every such step into nonsense.

4. **one**

   A single diode passes the positive half-cycles and blocks the negative ones (leaving gaps).

5. **0.02 s**

   $T = \frac{1}{f} = \frac{1}{50} = 0.020$ s.

6. **in parallel with the load**

   It must discharge THROUGH the load between peaks, which needs it in parallel. In series it would block the d.c. entirely, which is the opposite of the point.

7. **50.0**

   T = 4.0 x 5.0 ms = 20 ms, so f = 1/0.020 = 50 Hz. Count divisions for a WHOLE cycle, not a half.

8. **4**

   Four diodes, arranged so the load current always flows the same way whichever input terminal is positive.

9. **half**

   The mean of $\sin^2$ over a cycle is $\frac{1}{2}$, so $\langle P \rangle = \frac{1}{2} P_{\text{peak}}$.

10. **True**

    Both half-cycles become positive humps, so the output ripples at double the input frequency.

A-LEVEL PHYSICS • EXERCISE SHEET

21.1 Characteristics of alternating currents

Name: ______________ Class: __________ Date: ____________ **Total: 22 marks**

KEY WORDS period 周期 • power 功率 • frequency 频率 • peak value 峰值 • current 电流

Objective

Build the skills to answer exam questions on **alternating currents** — peak, r.m.s. and mean power.

You must be able to:

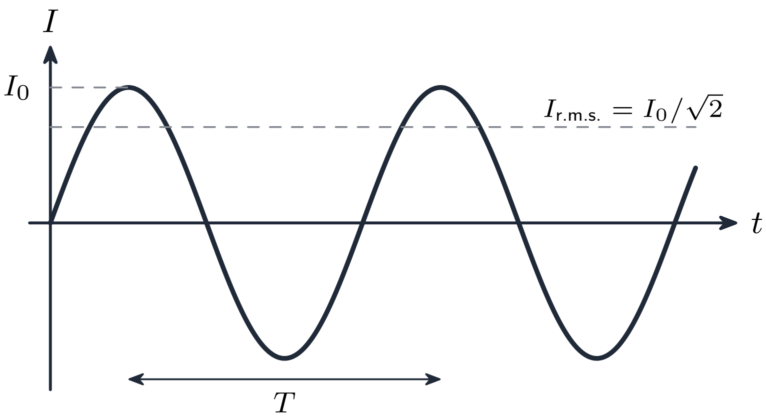
- use **period**, **frequency** and **peak value** for a.c.
- use $x = x_0 \sin \omega t$ and $I_{\text{r.m.s.}} = I_0/\sqrt{2}$
- use that the **mean power** is **half** the peak power

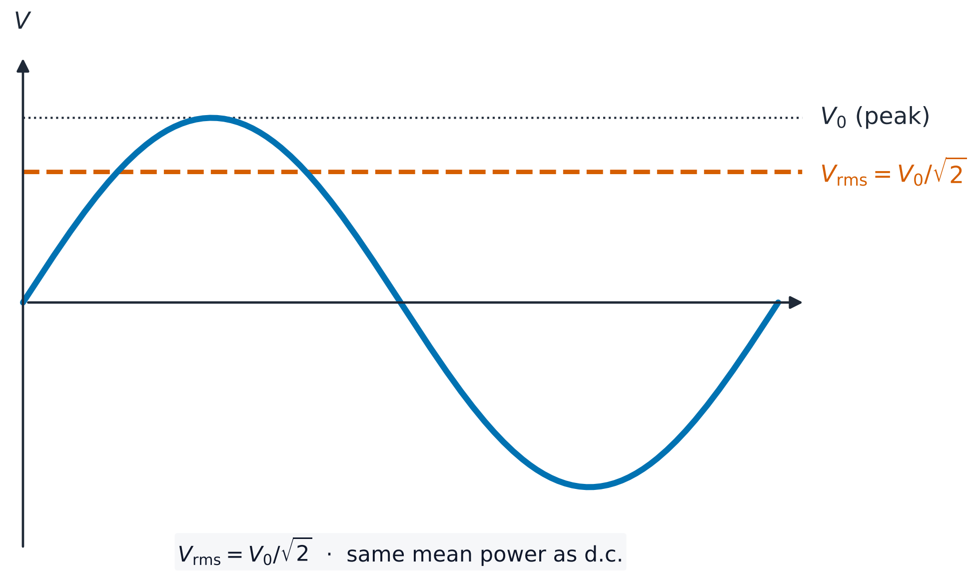
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Alternating current

An a.c. follows $I = I_0 \sin \omega t$:





RMS values of an alternating current

- **peak** I_0 (amplitude); **period** T; **frequency** $f = 1/T$; $\omega = 2\pi f$.

Reading the equation

Exam questions often **give** the a.c. as an equation, e.g. $V = 18\cos(40\pi t)$. Read off the **peak** ($V_0 = 18$ V) and the **angular frequency** ($\omega = 40\pi$ rad s^{-1}), then $T = \dfrac{2\pi}{\omega}$ and $f = \dfrac{1}{T}$.

Worked example. For $V = 18\cos(40\pi t)$: $\omega = 40\pi$, so $T = \dfrac{2\pi}{40\pi} = 0.050$ s and $f = 20$ Hz; $V_{\text{r.m.s.}} = 18/\sqrt{2} = 13$ V.

r.m.s. and mean power

$$I_{\text{r.m.s.}} = \frac{I_0}{\sqrt{2}}, \qquad V_{\text{r.m.s.}} = \frac{V_0}{\sqrt{2}}.$$

The **mean power** in a resistor is **half** the peak power; $\langle P \rangle = I_{\text{r.m.s.}} V_{\text{r.m.s.}} = \dfrac{V_{\text{r.m.s.}}^2}{R}$.

Worked example. $V_0 = 340$ V: $V_{\text{r.m.s.}} = 340/\sqrt{2} = 240$ V.

2 Practice

Now apply the methods above.

2.1 Define the **peak value** and the **period** of an alternating current. [2]

2.2 An a.c. has a peak current of 5.0 A. Find the **r.m.s.** current. [2]

2.3 State the relationship between the r.m.s. and peak **voltage**. [1]

2.4 Mains frequency is 50 Hz. Find the **period**. [1]

2.5 An a.c. voltage is $V = 18\cos(40\pi t)$. State the **peak voltage** and the **angular frequency**. [2]

3 Exam-style questions

3.1 The r.m.s. value of a sinusoidal a.c. of peak I_0 is: [1]

- **A** I_0
- **B** $I_0/2$
- **C** $I_0/\sqrt{2}$
- **D** $2I_0$

3.2 A sinusoidal supply has a peak voltage of 340 V. Calculate (a) the r.m.s. voltage, (b) the mean power delivered to a 100 Ω resistor. [4]

3.3 Explain why the **mean power** in a resistor is **half** the peak power for a sinusoidal a.c. [2]

3.4 An a.c. has a period of 0.020 s. Find the **angular frequency** ω. [2]

3.5 A mains voltage is $V = 340\sin(100\pi t)$, with V in volts and t in seconds.

(a) Show that the **period** is 0.020 s. [2]

(b) Calculate the **r.m.s. voltage** and the **mean power** delivered to a 60 Ω heater. [3]

Solutions

Each answer shows the steps, then the **result**.

2.1

- **peak value** — the maximum value in a cycle
- **period** — the time for one complete cycle

2.2

- $I_{\text{r.m.s.}} = I_0/\sqrt{2}$

$$I_{\text{r.m.s.}} = \frac{5.0\ \text{A}}{\sqrt{2}} = \mathbf{3.5}\ \text{A}$$

2.3

- $V_{\text{r.m.s.}} = V_0/\sqrt{2}$

2.4

- $T = 1/f = 1/(50\ \text{Hz}) = \mathbf{0.020}\ \text{s}$

2.5

- peak $V_0 = 18\ \text{V}$
- $\omega = 40\pi\ \text{rad s}^{-1}$ ($\approx 126\ \text{rad s}^{-1}$)

3.1 C

- $I_{\text{r.m.s.}} = I_0/\sqrt{2}$

3.2

(a) $V_{\text{r.m.s.}} = V_0/\sqrt{2}$

$$V_{\text{r.m.s.}} = \frac{340\ \text{V}}{\sqrt{2}} = \mathbf{240}\ \text{V}$$

(b) $P = V_{\text{r.m.s.}}^2/R$

$$P = \frac{(240\ \text{V})^2}{100\ \Omega} = \mathbf{576}\ \text{W}$$

3.3

- the power $P = I^2R$ varies as $\sin^2$, whose **average over a cycle is** $\frac{1}{2}$
- so the mean power is half the peak power I_0^2R

3.4

- $\omega = 2\pi/T$

$$\omega = \frac{2\pi}{0.020\ \text{s}} = \mathbf{3.1 \times 10^2}\ \text{rad s}^{-1}$$

3.5

(a) $\omega = 100\pi$ rad s^{-1}

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{100\pi \text{ rad s}^{-1}} = \mathbf{0.020} \text{ s}$$

(b) $V_{\text{r.m.s.}} = 340 \text{ V}/\sqrt{2} = 240$ V

$$\langle P \rangle = \frac{V_{\text{r.m.s.}}^2}{R} = \frac{(240 \text{ V})^2}{60\ \Omega} = \mathbf{9.6 \times 10^2} \text{ W}$$

7 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.

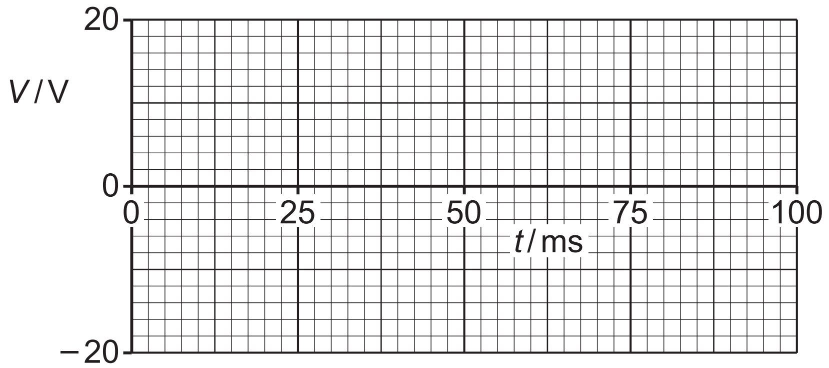


Fig. 7.1

[3]

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

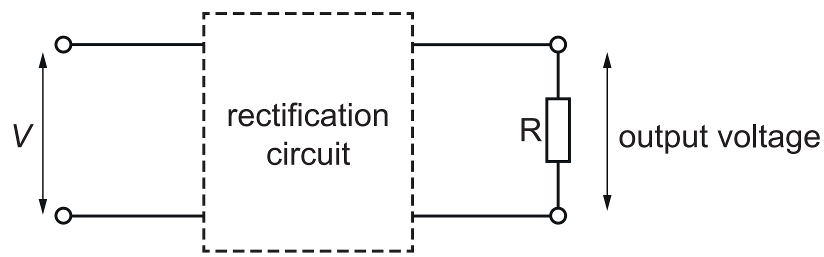


Fig. 7.2

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

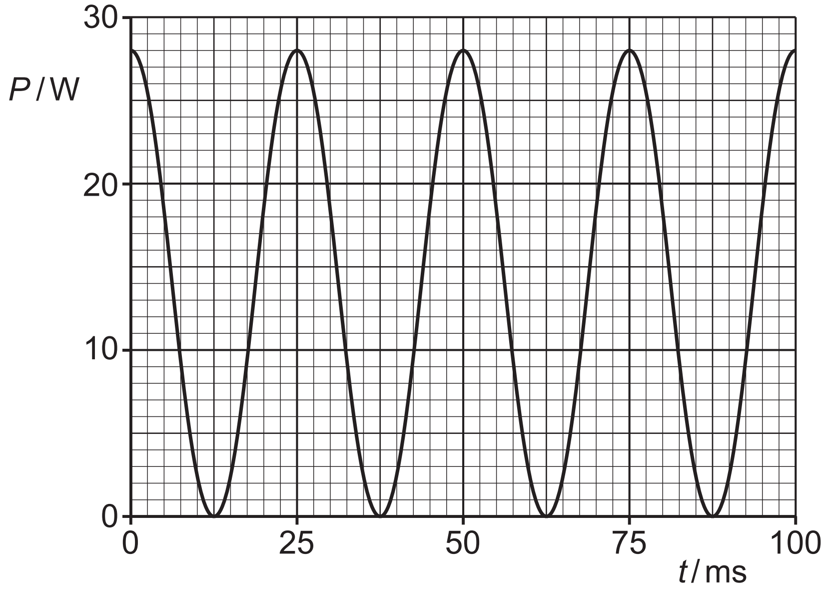


Fig. 7.3

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]

7 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.

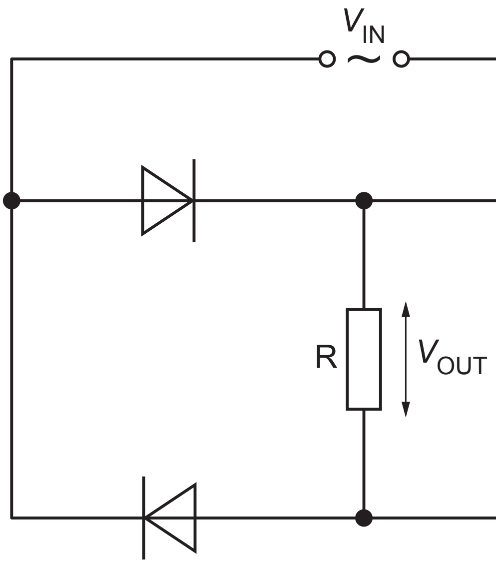


Fig. 7.1

(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.

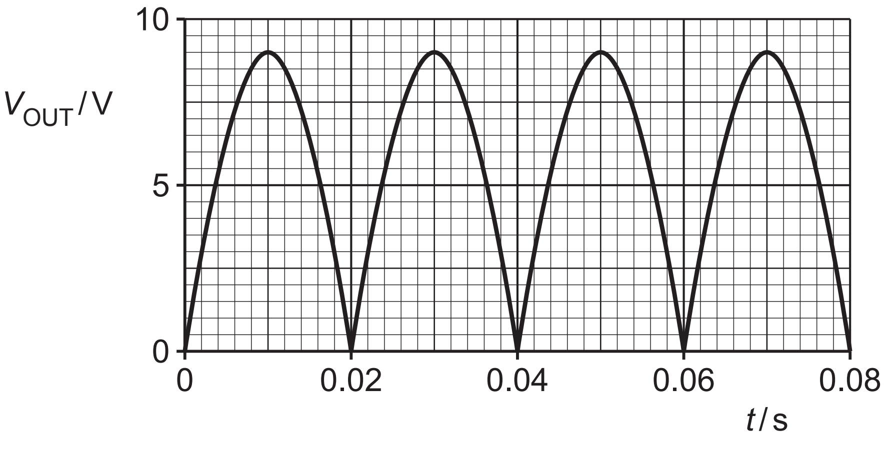


Fig. 7.2

(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.

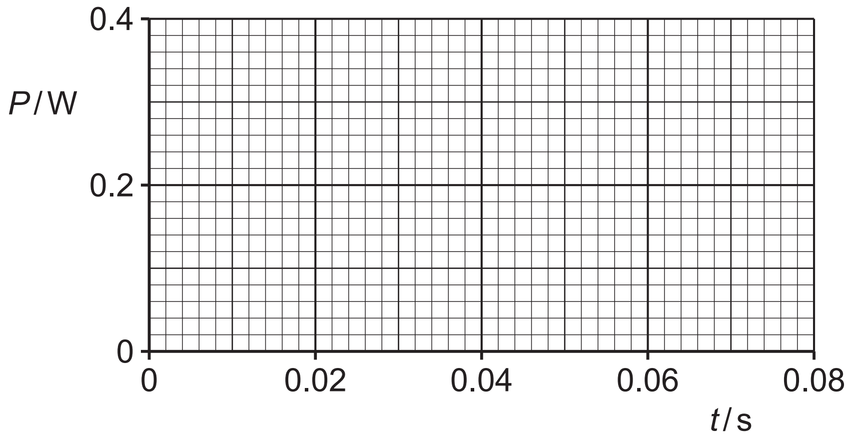


Fig. 7.3

[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]

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.

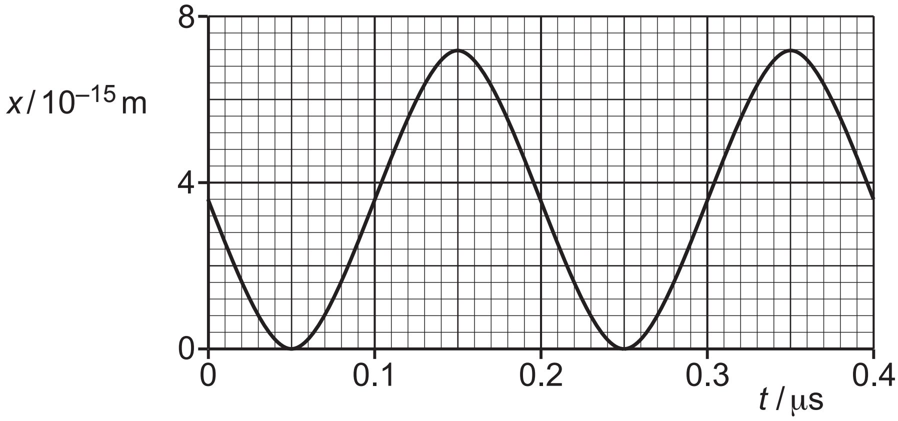


Fig. 4.1

(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 1.1×10^{-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 $8.5 \times 10^{28}\,m^{-3}$.

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 $t = 0.40\,\mu s$.

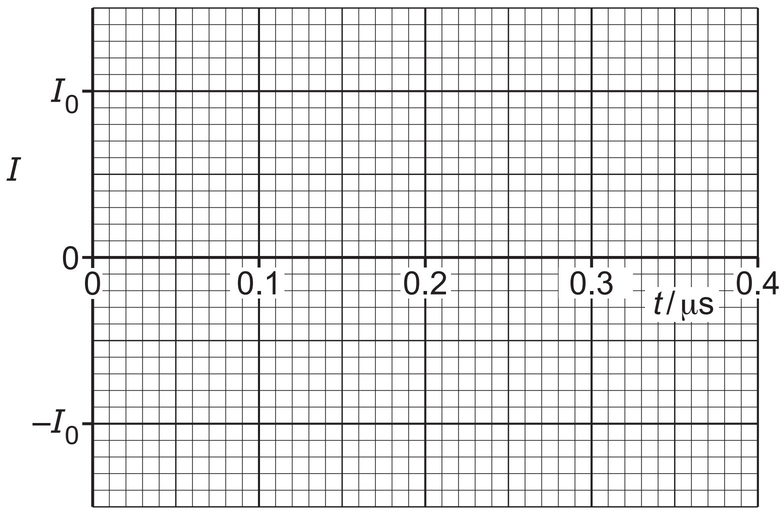


Fig. 4.2

[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]

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

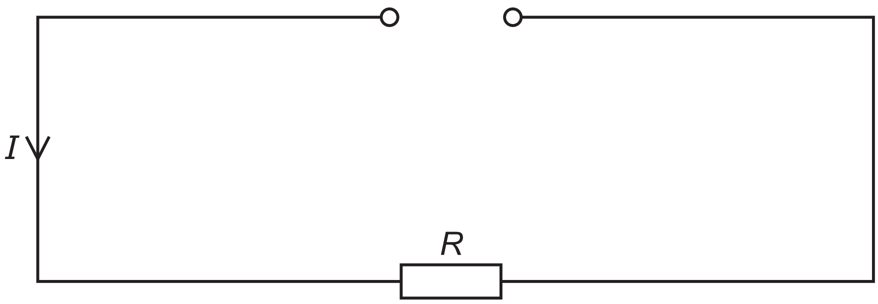


Fig. 7.1

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

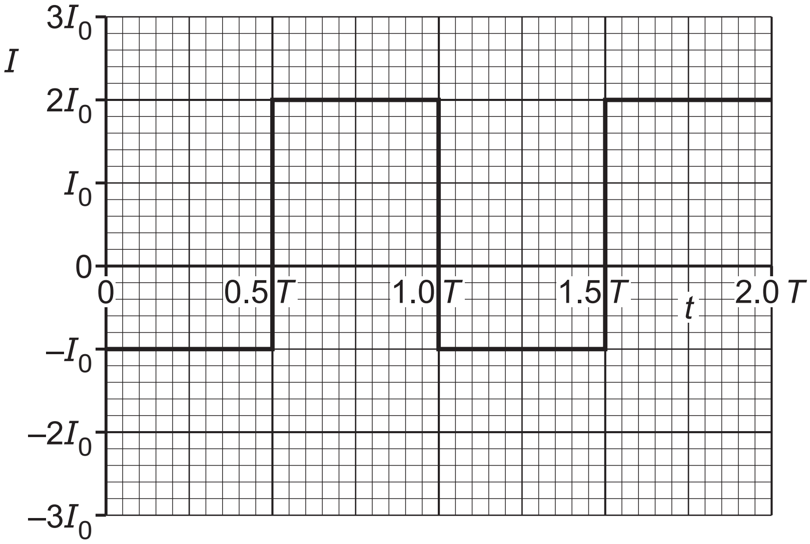


Fig. 7.2

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.

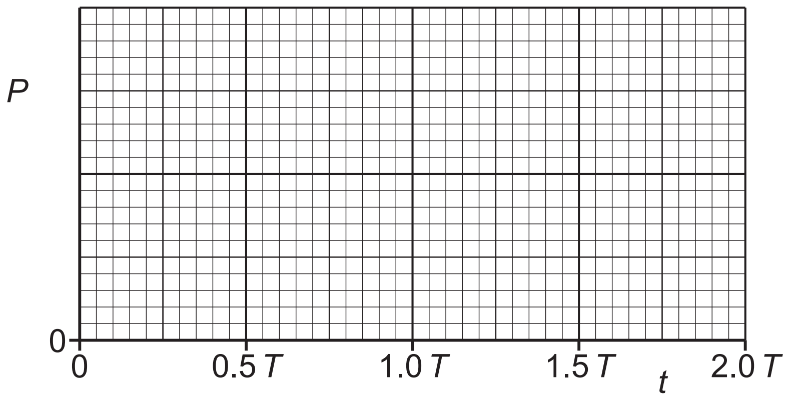


Fig. 7.3

[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 $I_{\text{r.m.s.}}$ in the resistor.

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

[Total: 8]

21.2 Rectification and smoothing

Name: ____________ Class: ________ Date: __________ **Total: 27 marks**

KEY WORDS rectification 整流 • bridge rectifier 桥式整流器 • diode 二极管 • smoothing 平滑 • half-wave rectification 半波整流

Objective

Build the skills to answer exam questions on **rectification** and **smoothing**.

You must be able to:

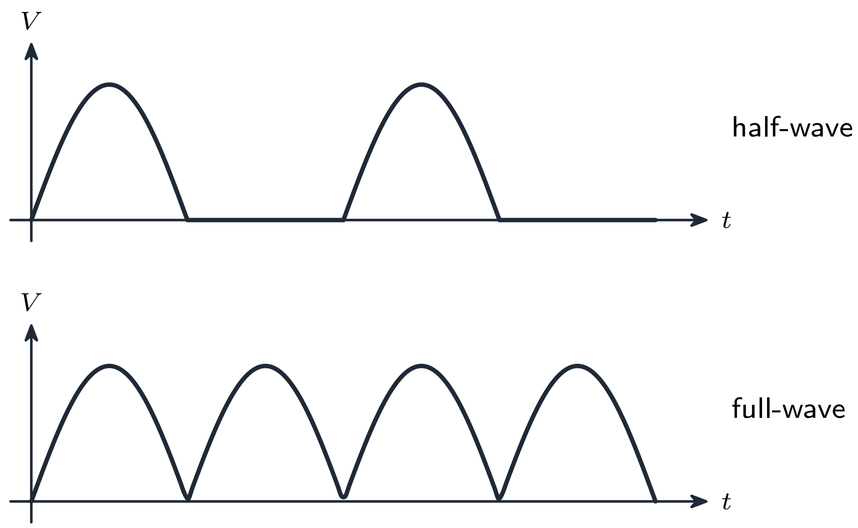
- distinguish **half-wave** and **full-wave** rectification
- explain the **single diode** and the **bridge rectifier**
- explain capacitor **smoothing**

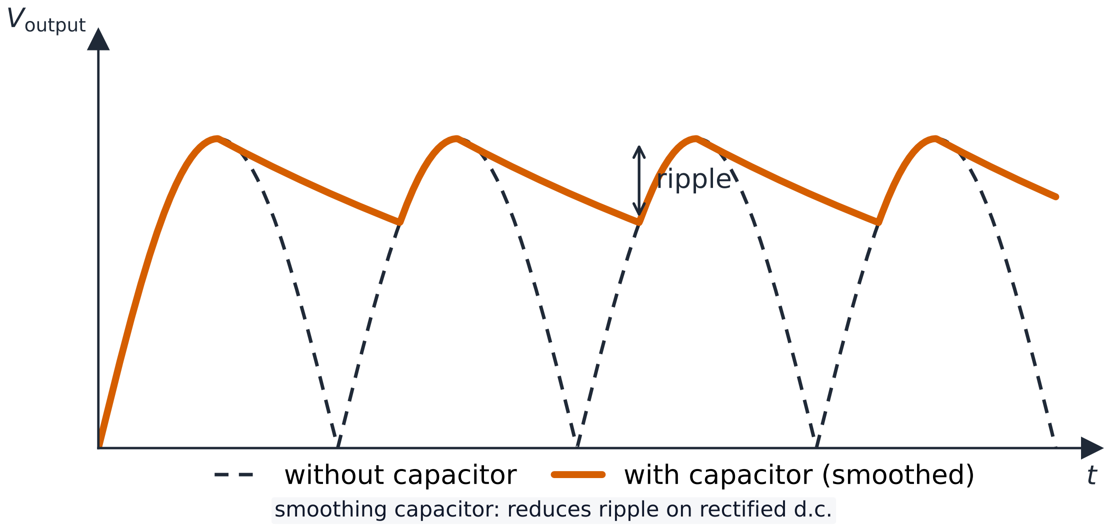
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Rectification

Rectification turns a.c. into one-direction (d.c.-like) voltage using **diodes**:





A smoothing capacitor after rectification

- **half-wave** (single diode): passes only positive half-cycles — half the input wasted;
- **full-wave** (4-diode **bridge rectifier**): uses every half-cycle, giving continuous humps at **twice** the frequency.

■ **Smoothing**

A **capacitor** across the load charges on each peak and discharges through the load in the gaps, reducing the **ripple**. A **larger** capacitance (or larger load resistance) gives **smoother** output (larger time constant RC).

2 Practice

Now apply the methods above.

2.1 State what **rectification** does. [1]

2.2 State how many **diodes** a bridge rectifier uses. [1]

2.3 State the difference between **half-wave** and **full-wave** output. [2]

2.4 State the purpose of a **smoothing capacitor**. [1]

3 Exam-style questions

3.1 A **single diode** in series with a load produces: [1]

- **A** full-wave rectification
- **B** half-wave rectification
- **C** smoothed d.c.
- **D** alternating current

3.2 Explain how a single diode produces **half-wave** rectification. [2]

3.3 Describe how a **bridge rectifier** (four diodes) achieves **full-wave** rectification. [3]

3.4 Explain how a **capacitor** smooths the output, and what happens to the smoothing if the **capacitance is increased**. [3]

3.5 A bridge rectifier is built from four diodes and supplied with a sinusoidal input of peak voltage 12 V. The input completes 8 cycles in 2.8 s.

(a) **State** what is meant by **rectification**, and name the type produced by a bridge rectifier. [2]

(b) **Show that** the period of the input is 0.35 s. [1]

(c) **Calculate** the root-mean-square input voltage. [2]

(d) In the space below, **sketch** the output voltage V_{OUT} across the load against time, from $t = 0$ to $t = 0.35$ s. **Label** both axes with values. [3]

(e) A large capacitor is now connected **across the load**. On the same sketch, **draw** the new output and **explain** its shape. [3]

(f) **State and explain** the effect on the smoothed output of (i) using a larger capacitance, and (ii) connecting a smaller load resistance. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- turns an **alternating** voltage/current into a **one-direction** (d.c.-like) one

2.2

- **four**

2.3

- half-wave keeps **only the positive half-cycles** (with gaps)
- full-wave **inverts the negative half-cycles** too, giving a continuous run of positive humps at twice the frequency

2.4

- to **smooth** the output — reduce the ripple, giving a steadier d.c.

3.1 B

- a single diode gives **half-wave rectification**

3.2

- the diode conducts only when **forward-biased** (positive half-cycle)
- on the negative half-cycle it is **reverse-biased** and blocks the current, so only positive humps pass

3.3

- four diodes are arranged so that on **each** half-cycle a **different pair** conducts
- whichever a.c. terminal is positive, the current through the load flows the **same way**
- so every half-cycle is used, giving full-wave output

3.4

- the capacitor **charges** to the peak and **discharges** slowly through the load during the dips, filling the gaps and reducing the ripple
- a **larger** capacitance increases the time constant RC
- so it discharges more slowly and the output is **smoother** (smaller ripple)

3.5

(a) rectification is the conversion of **alternating** current into **direct** (one-directional) current

- a bridge rectifier gives **full-wave** rectification

(b) $T = 2.8\ \mathrm{s}/8 = \mathbf{0.35}\ \mathrm{s}$

(c) $V_{\text{r.m.s.}} = V_0/\sqrt{2}$

$$V_{\text{r.m.s.}} = \frac{12\text{ V}}{\sqrt{2}} = \mathbf{8.5}\text{ V}$$

(d) all humps **above** the axis — the negative half-cycles are flipped up

- **two** humps in 0.35 s, so the output period is 0.175 s
- peak value 12 V, axes labelled

(e) the output becomes a **smoothed** line that rises with each hump to 12 V and then decays gently until the next hump catches it

- the capacitor **charges** to the peak, then **discharges** through the load while the rectified voltage falls
- so the output never drops to zero and the remaining variation is the **ripple**

(f) (i) a larger capacitance stores more charge and discharges more slowly ($\tau = RC$ is longer), so the ripple is **smaller**

(ii) a smaller load resistance draws more current and shortens τ, so the capacitor discharges further between humps and the ripple is **larger**

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

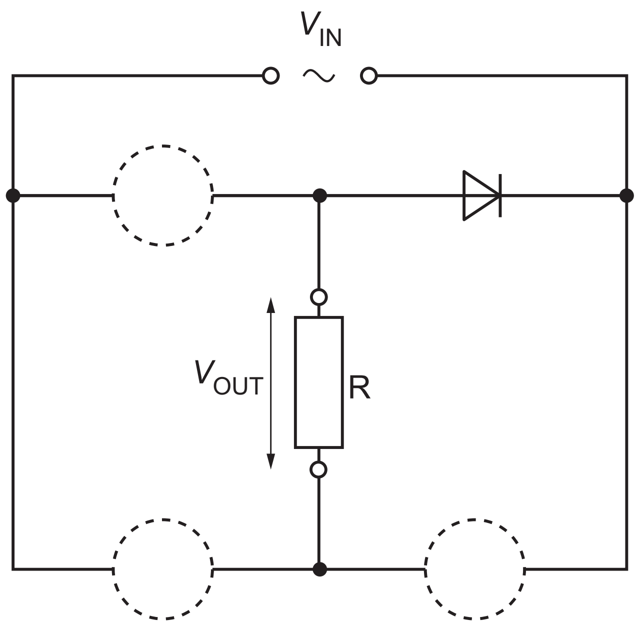


Fig. 6.1

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.

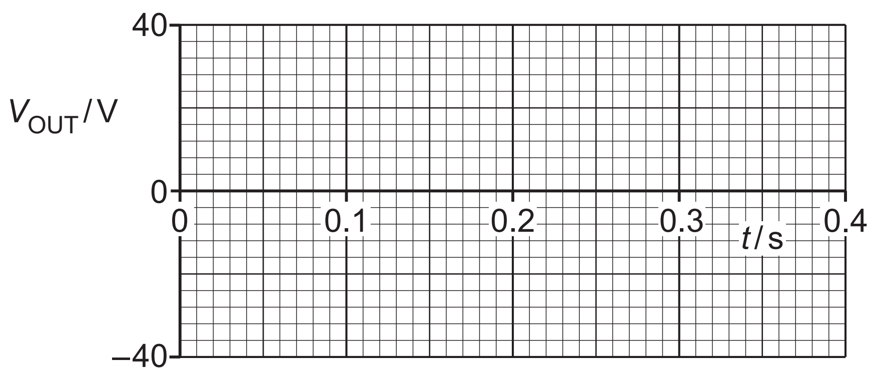


Fig. 6.2

[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]

6 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.

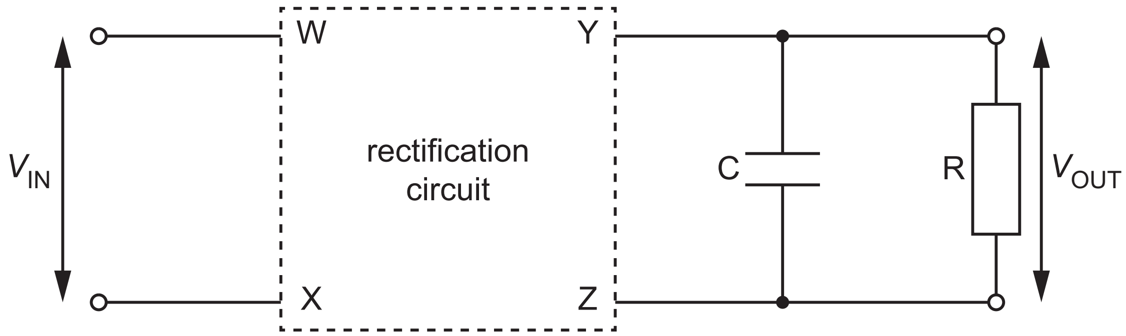


Fig. 6.1

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}.

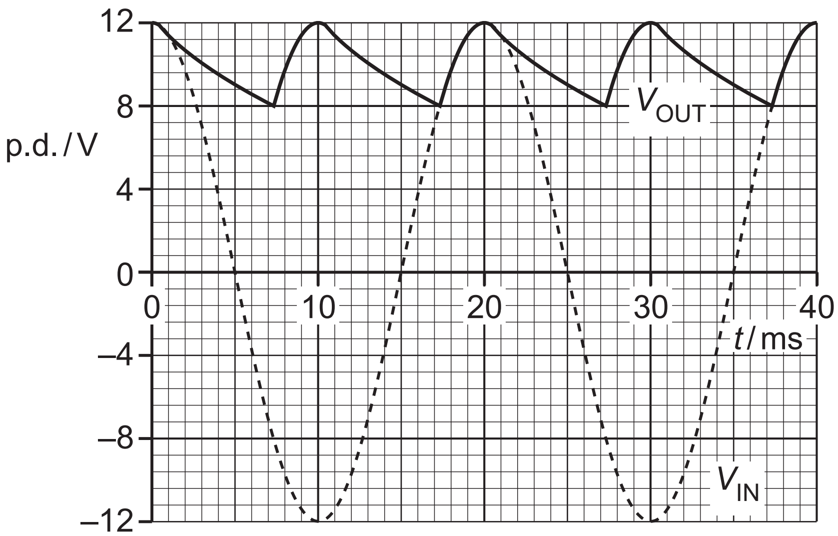


Fig. 6.2

(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.

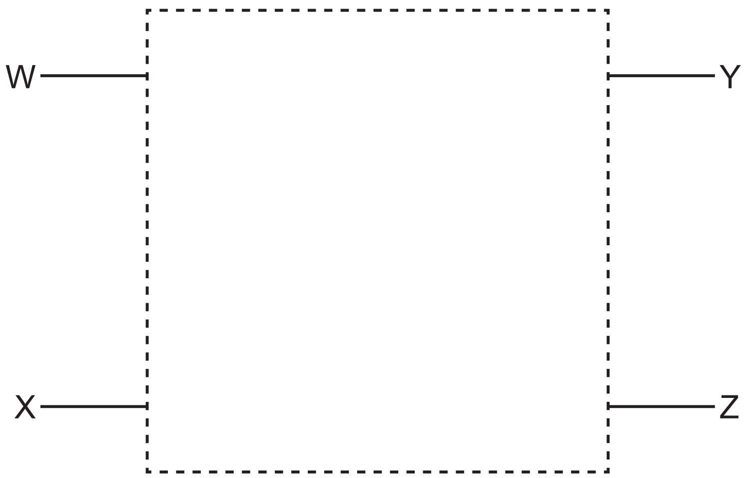


Fig. 6.3

[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]

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

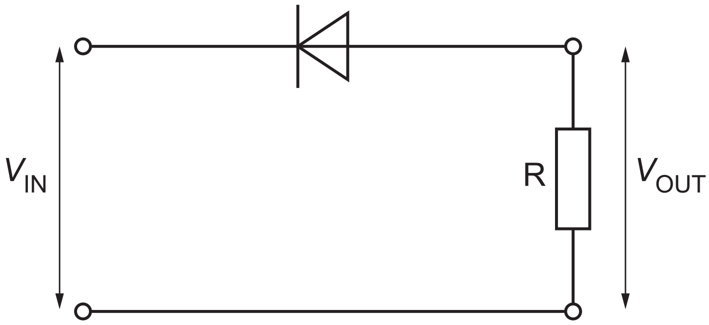


Fig. 8.1

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.

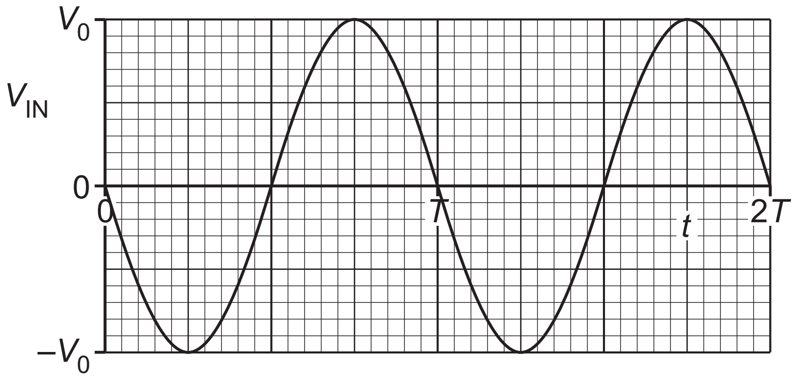


Fig. 8.2

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 $t = 2T$.

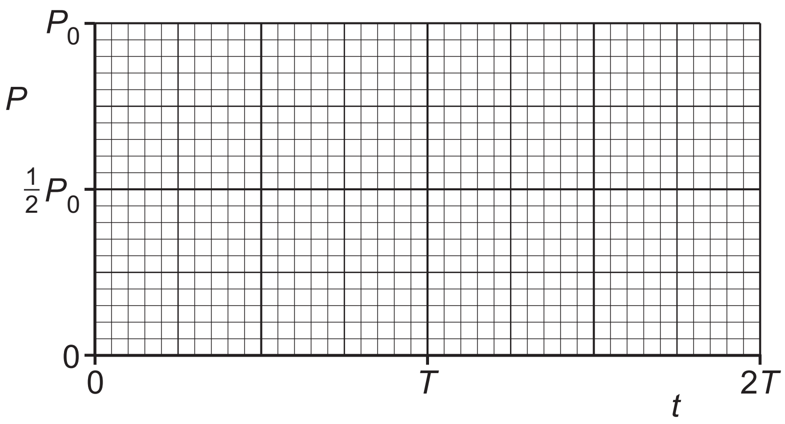


Fig. 8.3

[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]

6 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.

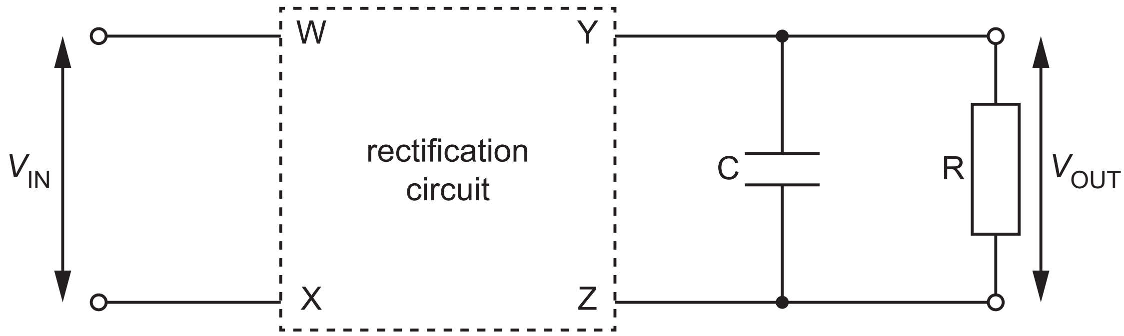


Fig. 6.1

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}.

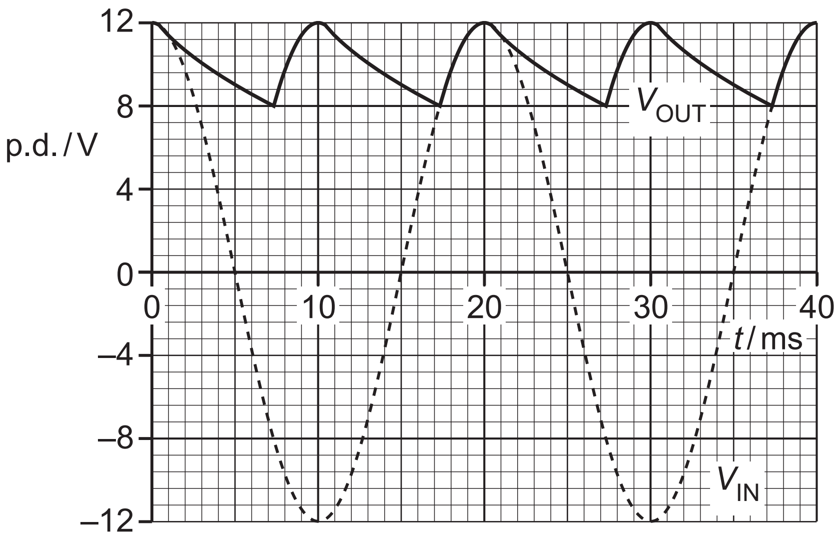


Fig. 6.2

(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.

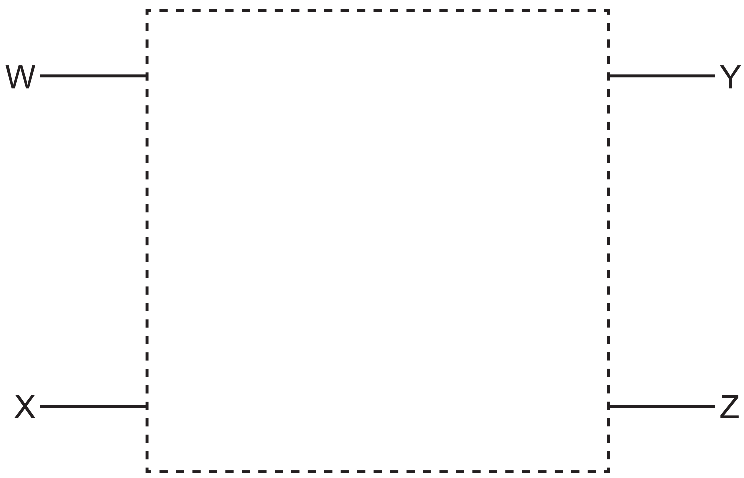


Fig. 6.3

[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]

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

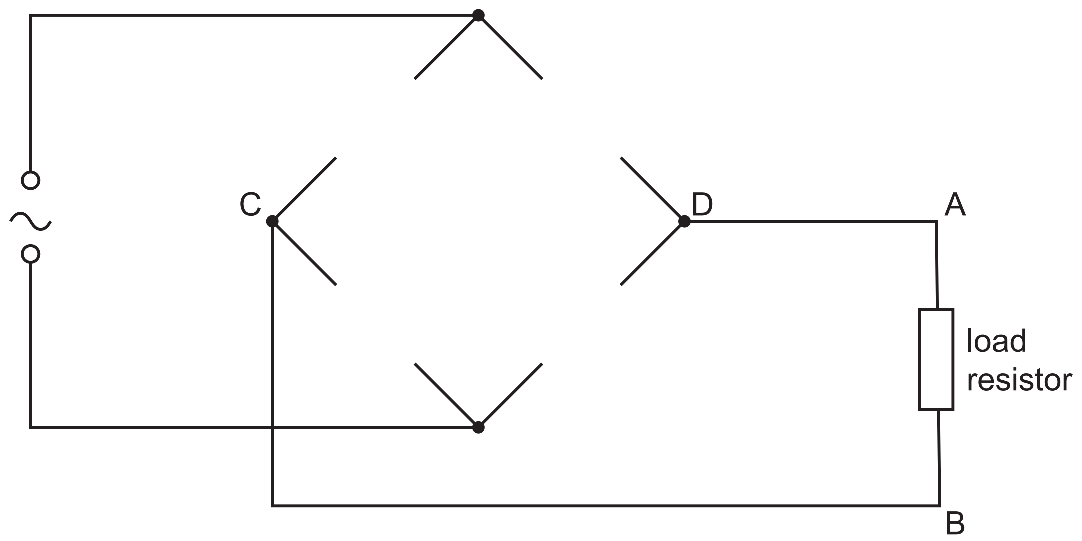


Fig. 8.1

(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]

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

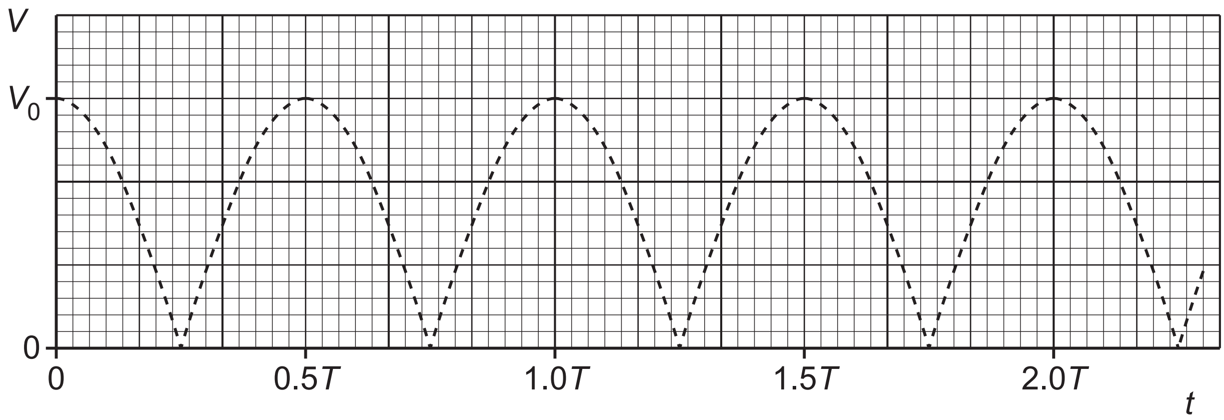


Fig. 8.2

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]