Past-paper walk-through

Rectification and smoothing ▪ 21.2

eXercise

Questions in this set

- 9702/44 N25 Q6 ▪ 15 marks
- 9702/41 J25 Q6 ▪ 12 marks
- 9702/42 J25 Q8 ▪ 10 marks
- 9702/43 J25 Q6 ▪ 12 marks
- 9702/44 J25 Q8 ▪ 10 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 6

9702/44 N25 ▪ Q6 ▪ 15 marks

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

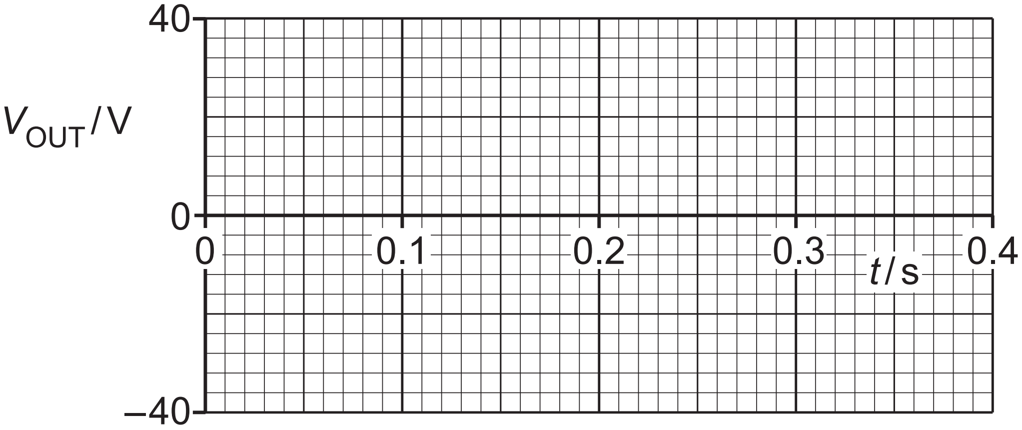
The circuit contains four diodes, one of which is shown. The rectified output voltage V_{OUT} is applied across load resistor R.

(a)(i) State what is meant by rectification. **[1]**

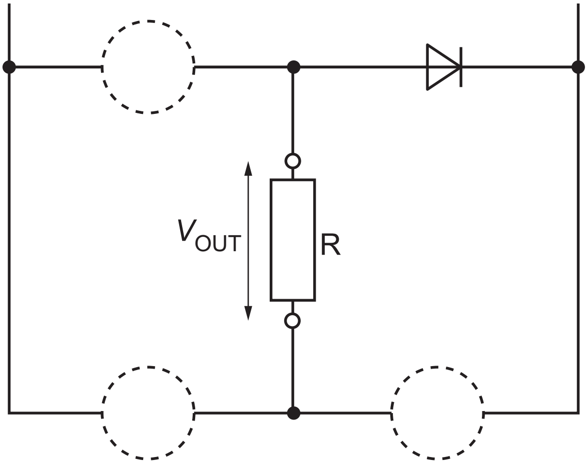
(a)(ii) State the name of the type of rectification produced by a bridge rectifier circuit. **[1]**

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

Question 6



Question 6



Question 6

9702/44 N25 ▪ Q6 ▪ 15 marks

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.

(b)(i) Show that the period of the input voltage is 0.35 s. **[2]**

(b)(ii) Calculate the root-mean-square (r.m.s.) input voltage. **[1]**

(b)(iii) On Fig. 6.2, sketch the variation of V_{OUT} with t from $t = 0$ to $t = 0.35$ s. **[3]**

Question 6

9702/44 N25 ▪ Q6 ▪ 15 marks

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.

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

(c)(ii) Calculate the time constant of the smoothing circuit. **[2]**

(c)(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. **[2]**

Solution 6

(a)(i)

Mark scheme

- conversion of a.c. to d.c. B1

(a)(ii)

Mark scheme

- full-wave (rectification) B1

Solution 6

(a)(iii)

Mark scheme

- three diodes with correct symbols connected into the circuit **B1**
- lower-left diode shown pointing towards the right and upper-left and lower-right diodes both shown pointing towards the left **B1**

Solution 6

(b)(i) Worked steps

The angular frequency is read off the input equation (or the graph), then converted.

- $\omega = 18$ rad s^{-1}
- $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{18}$
- $T = 0.35$ s, as required.

Solution 6

Mark scheme

- $\omega = 18$ (rad s–1) **C1**
- $T = 2\pi \;/\; 18 = 0.35$ s **A1**

Solution 6

(b)(ii) Worked steps

- $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}} = \dfrac{34}{\sqrt{2}}$
- $V_{\text{rms}} = 24\ \text{V}$

Solution 6

Mark scheme

- Vr.m.s.$= 34 \ / \ \sqrt{2}$
- $= 24$ V **A1**

Solution 6

(b)(iii) Worked steps

A **bridge** rectifier is full-wave: every half-cycle appears, and all of them on the same side of the axis.

- Draw sinusoidal "humps", each touching $V_{\text{OUT}} = 0$ at its ends.
- Every hump has the **same sign** — the negative half-cycles are flipped up, not removed.
- Peak value 34 V, the same as the input peak (ignoring diode drops).
- Two humps between $t = 0$ and $t = 0.35$ s, with zeros at $t = 0$, 0.175 and 0.35 s: the output period is **half** the input period.

Solution 6

Two humps rather than one is what distinguishes full-wave from half-wave, and it is a mark.

Mark scheme

- sinusoidal 'humps' with minimum VOUT = 0 and non-zero VOUT all same sign **B1**
- peak VOUT shown as 34 V or –34 V **B1**
- two 'humps' shown, with VOUT always with same sign and VOUT = 0 at t = 0, t = 0.175 s and t = 0.350 s and non-zero in between **B1**

Solution 6

(c)(i)

Worked steps

- Draw the capacitor's symbol (two parallel plates) connected **in parallel** with the load resistor, across the rectifier's output.

In parallel is the whole point: the capacitor charges to the peak and then holds the p.d. up across the resistor while the rectified voltage falls.

Mark scheme

- correct circuit symbol for capacitor, connected in parallel with resistor **B1**

Solution 6

(c)(ii)

Worked steps

- $\tau = RC = 56 \times 10^3 \times 12 \times 10^{-6}$
- $\tau = 0.67$ s

Mark scheme

- time constant = RC **C1**
- = 56 × 103 × 12 × 10–6
- = 0.67 s **A1**

Solution 6

(c)(iii) Worked steps

Between peaks the capacitor discharges exponentially through the resistor.

- $V = V_0 e^{-t/\tau} = 34 \times e^{-0.14/0.67}$
- $V_{\text{min}} = 28$ V

Solution 6

The ripple is therefore about 6 V on a 34 V peak. That is the calculation that decides whether a smoothing capacitor is big enough: a longer time constant than the gap between peaks means a flatter output.

Mark scheme

- Vmin = 34 exp (–0.14 / 0.67) **C1**
- = 28 V **A1**

Question 6

9702/41 J25 ▪ Q6 ▪ 12 marks

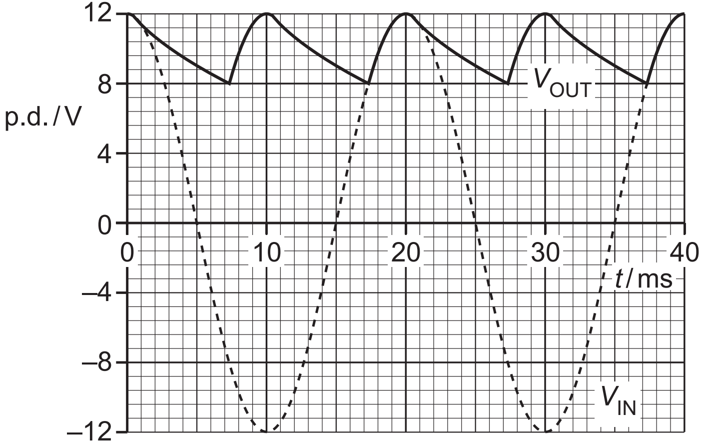
Fig. 6.1 shows a circuit that rectifies an alternating input voltage V_{IN} and produces an output voltage V_{OUT} across a resistor R.

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

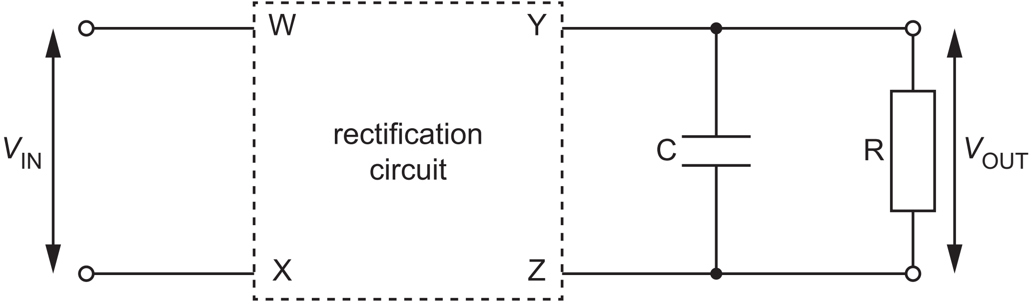
(a)(i) State what is meant by rectification. **[1]**

(a)(ii) State the purpose of capacitor C. **[1]**

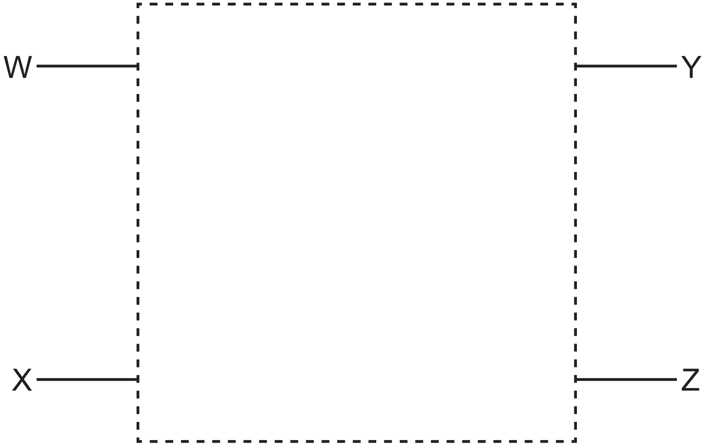
Question 6



Question 6



Question 6



Question 6

9702/41 J25 ▪ Q6 ▪ 12 marks

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.

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

(b)(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. **[2]**

(b)(ii) Determine the type of rectification produced by the circuit in Fig. 6.1. **[1]**

Question 6

(b)(iii) On Fig. 6.3, draw the circuit diagram for the components inside the rectification circuit. **[2]**

(b)(iv) Determine a value for the time constant for the discharge of the capacitor C through the resistor R in Fig. 6.1. **[3]**

Question 6

9702/41 J25 ▪ Q6 ▪ 12 marks

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.

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

(c) The capacitor C has a capacitance of $570\ \mu$F.

Use your answer in **(b)(iv)** to determine the resistance of resistor R. **[2]**

Solution 6

(a)(i)

Mark scheme

- conversion from a.c. to d.c. **B1**

(a)(ii)

Mark scheme

- smoothing **B1**

Solution 6

(b)(i) Worked steps

Match the given form term by term against what the graph shows.

- A is the **peak** voltage: $A = 12$ V.
- B is the angular frequency: $B = \dfrac{2\pi}{T} = \dfrac{2\pi}{20 \times 10^{-3}}$
- $B = 310$ rad s^{-1}

Solution 6

Convert the period to seconds first; leaving it in milliseconds gives an answer 1000 times too small.

Mark scheme

- $A = 12$ V **A1**
- $B = 2\pi\ /\ (20 \times 10–3)$
- $= 310$ rad s–1 **A1**

Solution 6

(b)(ii)

Worked steps

- **Full-wave** rectification.

Both halves of every cycle appear in the output, on the same side of the axis, so the output frequency is twice the input's.

Mark scheme

- full-wave (rectification) **B1**

Solution 6

(b)(iii)

Worked steps

- Draw **four diodes** in a diamond, using the correct symbol (a triangle against a bar).
- Connect them as a bridge: the a.c. input to one pair of opposite corners, the output across the other pair.
- Check the directions: following either input polarity, current must reach the output the same way round — that is what makes the output single-signed, and it is the second mark.

Mark scheme

- four diodes shown, with correct circuit symbols **B1**
- four diodes correctly connected to form a bridge rectifier **B1**

Solution 6

(b)(iv) Worked steps

The smoothed output decays exponentially between peaks, so take logs to get the time constant out of the exponent.

- $V = V_0 e^{-t/\tau}$, with $V_0 = 12$ V, $V = 8.0$ V and $t = 7.3 \times 10^{-3}$ s.
- $\frac{8.0}{12} = e^{-t/\tau}$, so $\ln\left(\frac{8.0}{12}\right) = -\frac{t}{\tau}$.
- $\tau = \frac{-7.3 \times 10^{-3}}{\ln(0.667)} = 0.018$ s

Solution 6

Mark scheme

- $V = V0 \exp(-t / \tau)$ or
- $V = V0 \exp(-t / RC)$ and $\tau = RC$ **C1**
- $8.0 = 12 \exp(-7.3 \times 10–3 / \tau)$ **C1**
- $\tau = 0.018$ s **A1**

Solution 6

(c) Worked steps

- $\tau = RC$, so $R = \dfrac{\tau}{C}$.
- $R = \dfrac{0.018}{570 \times 10^{-6}}$
- $R = 32\ \Omega$

Solution 6

Mark scheme

- time constant $=$ RC **C1**
- R $=$ (0.018 / 570 $\times$ 10–6)
- $=$ 32 Ω **A1**

Question 8

9702/42 J25 ▪ Q8 ▪ 10 marks

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

(a)(ii) Calculate V_0. **[1]**

(b)(i) Determine the peak power P_0 in the resistor. **[2]**

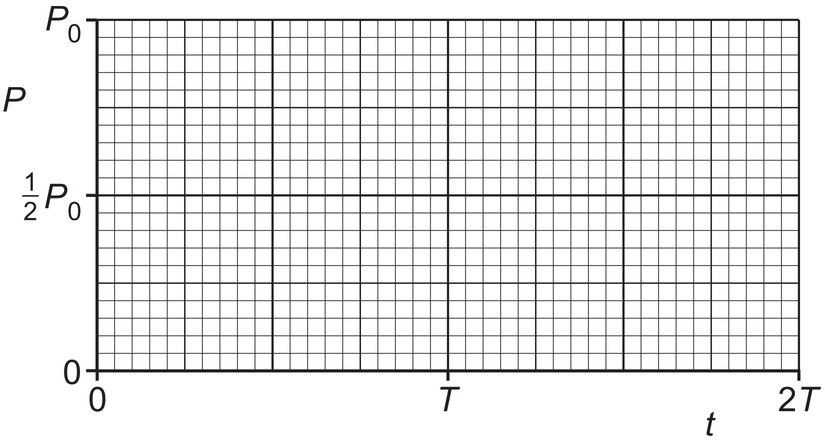
(b)(ii) On Fig. 8.3, sketch the variation of the power P in the resistor with t between $t = 0$ and $t = 2T$. **[3]**

(b)(iii) Use the answer in **(b)(ii)** to explain why the mean power in the resistor is $\frac{1}{4}P_0$. **[2]**

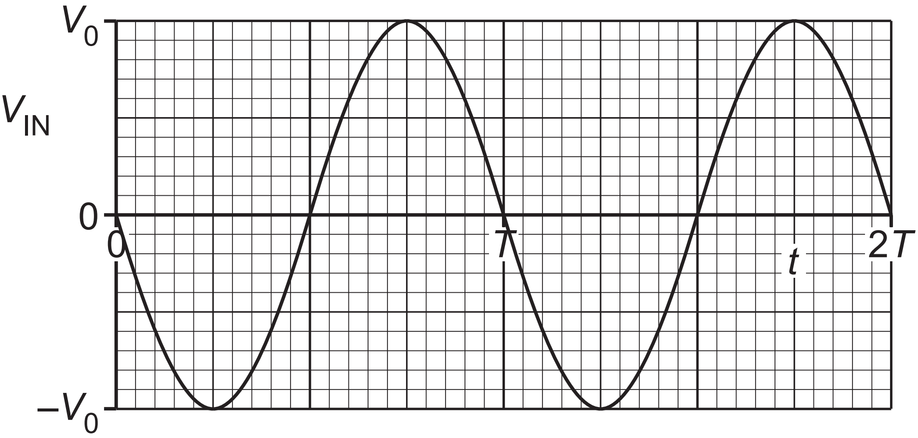
Question 8

(b)(iv) Use the information in **(b)(iii)** to determine the r.m.s. value of V_{OUT}. **[1]**

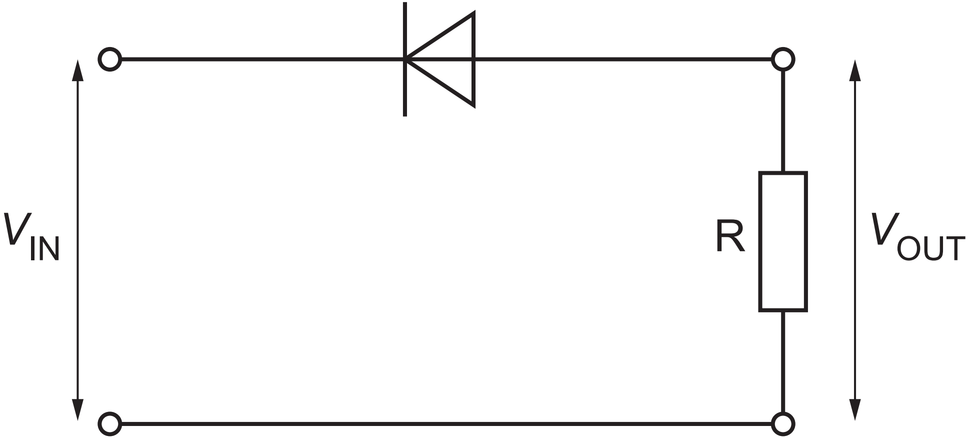
Question 8



Question 8



Question 8



Solution 8

(a)(i)

Mark scheme

- half-wave (rectification) **B1**

Solution 8

(a)(ii)

Worked steps

- $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}}$, so $V_0 = \sqrt{2}\,V_{\text{rms}} = 6.0 \times \sqrt{2}$
- $V_0 = 8.5$ V

Mark scheme

- V0 $= 6.0 \times 2$
- $= 8.5$ V **A1**

Solution 8

(b)(i)

Worked steps

Peak power goes with peak voltage, so use V_0 and not the r.m.s. value.

- $P_0 = \dfrac{V_0^2}{R} = \dfrac{8.5^2}{45}$
- $P_0 = 1.6$ W

Mark scheme

- P = V2 / R **C1**
- P0 = 8.52 / 45
- = 1.6 W **A1**

Solution 8

(b)(ii) Worked steps

Power depends on V^2, so it is positive everywhere the voltage is non-zero, and its shape is a squared sine — humps that sit **smoothly** on the axis rather than meeting it in a point.

- Two humps between $t = 0$ and $t = 2T$, each of width $0.5T$, separated by two flat stretches of zero power, also $0.5T$ wide (this circuit is half-wave).
- Each hump peaks at $P_0 = 1.6$ W and its minima touch $P = 0$.
- Draw smooth troughs: the curve is $\sin^2$, so it flattens as it reaches zero.

Solution 8

Mark scheme

- two humps of width $0.5T$ and two sections of zero power of width $0.5T$ **B1**
- all humps drawn have width $0.5T$, minima at $P = 0$ and peaks at $P = P0$ **B1**
- correct sinusoidal shape, with smooth troughs sitting on t-axis at $P = 0$ **B1**

Solution 8

(b)(iii)

Mark scheme

- mean power within each hump is
- 0
- 1
- 2 P from the symmetry of the curve **B1**
- additional half factor from removal of half of the power in each cycle **B1**

Solution 8

(b)(iv) Worked steps

Work back from the **mean** power, because that is what an r.m.s. voltage is defined to deliver.

- For this half-wave output the power is zero for half the cycle, so the mean power is half the peak: $\langle P\rangle = \frac{P_0}{2}$... but read the value asked for from part (b)(iii) rather than assuming the duty cycle.
- $\langle P\rangle = \frac{V_{\text{rms}}^2}{R}$, so $V_{\text{rms}} = \sqrt{\langle P\rangle R}$.
- With $\langle P\rangle = \frac{1.6}{4}$ W and $R = 45\ \Omega$: $V_{\text{rms}} = \sqrt{0.4 \times 45} = 4.2$ V

Solution 8

The r.m.s. value is **not** the peak divided by $\sqrt{2}$ here: that relation holds for a full sinusoid, and this output is rectified with gaps, so it must come from the mean power.

Mark scheme

- $\langle P \rangle =$ Vr.m.s.2 / R
- Vr.m.s. $=$
- (
-)
- 1.6 / 4
- 45

Solution 8

-
- $\times$
-
- $= 4.2\ \mathrm{V}$ **A1**

Question 6

9702/43 J25 ▪ Q6 ▪ 12 marks

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.

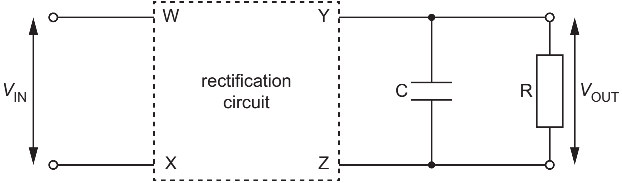


Fig. 6.1

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

Question 6

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

Question 6

(ii) State the purpose of capacitor C.

Question 6

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

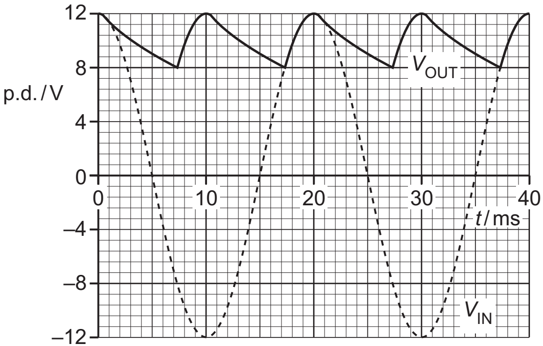


Fig. 6.2

Question 6

(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.

Question 6

Question 6

[2]

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

Question 6

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

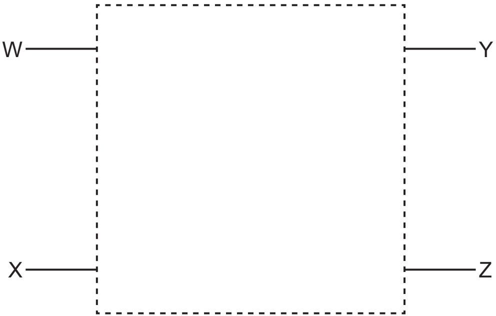


Fig. 6.3

Question 6

Fig. 6.3

Question 6

[2]

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

Question 6

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

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

Question 6

[Total: 12]

Solution 6

(a)(i)

Mark scheme

- conversion from a.c. to d.c.

(a)(ii)

Mark scheme

- smoothing

Solution 6

(b)(i) Worked steps

- A is the **peak** voltage read off the graph: $A = 12$ V.
- B is the angular frequency: $B = \dfrac{2\pi}{T} = \dfrac{2\pi}{20 \times 10^{-3}} = 310$ rad s^{-1}.

Solution 6

Convert the period to seconds first — leaving it in milliseconds makes B a thousand times too small.

Mark scheme

- $\mathrm{A} = 12\,\mathrm{V}$
- $\mathrm{B} = 2\pi \,/\, (20 \times 10\text{–}3)$
- $= 310\ \mathrm{rad\ s\text{–}1}$

Solution 6

(b)(ii)

Mark scheme

- full-wave (rectification)

(b)(iii)

Mark scheme

- four diodes shown, with correct circuit symbols
- four diodes correctly connected to form a bridge rectifier

Solution 6

(b)(iv) Worked steps

- $V = V_0 e^{-t/\tau}$, with $V_0 = 12$ V, $V = 8.0$ V, $t = 7.3 \times 10^{-3}$ s.
- $\ln\left(\frac{8.0}{12}\right) = -\frac{t}{\tau}$
- $\tau = \frac{-7.3 \times 10^{-3}}{\ln(0.667)} = 0.018$ s

Solution 6

Mark scheme

- $V = V0 \exp(–t / \tau)$
- or
- $V = V0 \exp(–t / RC)$ and $\tau = RC$
- $8.0 = 12 \exp(-7.3 \times 10–3 / \tau)$
- $\tau = 0.018\,s$

Solution 6

(c) Worked steps

- $\tau = RC$, so $R = \dfrac{\tau}{C} = \dfrac{0.018}{570 \times 10^{-6}}$
- $R = 32\ \Omega$

Solution 6

Sanity check the design: the time constant is 18 ms against a 20 ms input period, so the capacitor barely discharges between peaks — which is what smoothing is for.

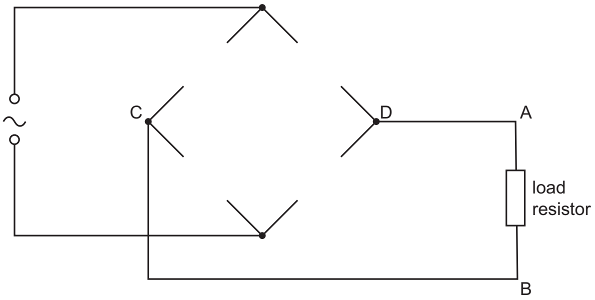
Mark scheme

- time constant $=$ RC
- R $= (0.018 / 570 \times 10\text{–}6)$
- $= 32\,\Omega$
- 9702/43
- May/June 2025

Question 8

9702/44 J25 ▪ Q8 ▪ 10 marks

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

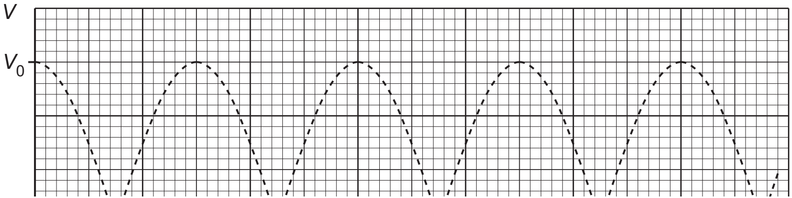


Question 8

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.



Question 8

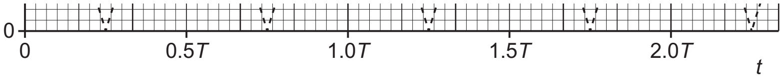


Fig. 8.2

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.

Question 8

Question 8

(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.

Question 8

[Total: 10]

Solution 8

(a)

Mark scheme

- four diodes shown (one in each gap) with correct circuit symbols
- all four diodes connected in correct direction (pointing left to right)

Solution 8

(b)(i) Worked steps

A smoothing capacitor turns the rectified humps into a sawtooth, and the sketch has to show both halves of that cycle.
Full-wave rectification puts a peak every half period, at $0.5T$, $1.0T$, $1.5T$ and $2.0T$. Between them the capacitor **discharges through the load**, so:

1. From each peak, draw an **exponential decay** — three of them, from the peaks at $0.5T$, $1.0T$ and $1.5T$, each ending where it meets the next rising hump.
2. Then draw the **rising** part: a curve climbing back up to the following peak, at $1.0T$, $1.5T$ and $2.0T$. The capacitor recharges along the rectifier's own output, so this part follows the incoming waveform, not a straight line.
3. The **minimum** sits at $\frac{2}{3}V_0$ — that is the value the discharge reaches just before the next peak takes over.

Solution 8

The commonest error is drawing a straight-line fall. The discharge is exponential, and its curvature is exactly what part (b)(ii) then measures.

Mark scheme

- three lines showing exponential decay from the peaks at 0.5T, 1.0T and 1.5T, ending at the point where the decay meets
- the next rising peak
- three curved lines rising along the upwards dotted lines from the minima to the peaks at 1.0T, 1.5T and 2.0T
- minimum V at $(2\,/\,3)\,V0$

Solution 8

(b)(ii) Worked steps

Read the discharge interval off the sketch, then use the decay equation over that interval.

- From the graph, the fall from V_0 to $\frac{2}{3}V_0$ takes $\dfrac{11}{30}T$.
- $V = V_0 e^{-t/\tau}$, so $\frac{2}{3}V_0 = V_0 e^{-(11T/30)/\tau}$.
- V_0 cancels: $\ln\frac{2}{3} = -\dfrac{11T}{30\tau}$, and $\ln\frac{2}{3} = -0.405$.
- $\tau = \dfrac{11T}{30 \times 0.405} = 0.90\ T$

Solution 8

The answer is **in terms of** T, so leave it there — the question never gives a numerical period. And note the time is the *discharge* interval only, not a whole period: the capacitor is charging for the rest of it.

Mark scheme

- from graph: discharge time (from V0 to (2 / 3)V0) $=$ (11 / 30) T
- (2 / 3) V0 $=$ V0 exp (– (11 / 30)T / τ)
- ln (2 / 3) $=$ – 11T / 30τ
- τ $=$ 0.90 T

Solution 8

(b)(iii) Worked steps

One quantity changes and everything else follows from it.

- A larger capacitance **increases the time constant** $\tau = RC$.
- A larger τ means the capacitor discharges more slowly between peaks, so the voltage falls less far.
- So the **minimum voltage is higher** — equivalently, the difference between maximum and minimum is smaller, and the ripple is reduced.

Solution 8

Say both halves: the time constant increases, *and* what that does to the trace. A bare "smoother output" is the observation, not the reason, and the marks are for the reason.

Mark scheme

- time constant is increased
- line shows a larger minimum voltage
- or
- smaller difference between maximum and minimum voltages
- 9702/44
- May/June 2025