CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 21: Alternating Currents

Past Papers 2021 – 2025

MARK SCHEME 18 Questions

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Question 1 — Mark Scheme

Question	Answer	Marks
9(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

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Question 2 — Mark Scheme

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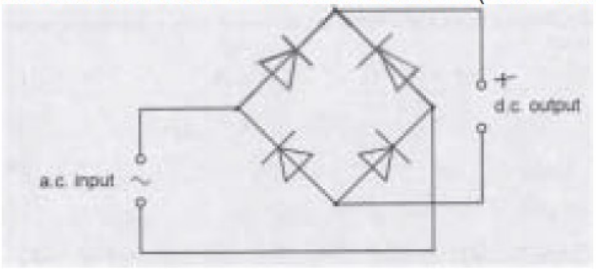
Question	Answer	Marks
10(a)	the steady current **or** the direct current	**M1**
	that produces the same heating effect (as the alternating current)	**A1**
10(b)(i)	peak current = 2.6 A **and** r.m.s. current = 1.8 A	**A1**
10(b)(ii)	peak current = 2.0 A **and** r.m.s. current = 2.0 A	**A1**
10(c)(i)	$k = 2\pi f$	**C1**
	$= 2\pi \times 50$ $= 310 \text{ rad s}^{-1}$	**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**

Question 3 — Mark Scheme

Question	Answer	Marks
10(a)	**230** V	**A1**
10(b)	$\omega = 100\pi$ $T = \frac{2\pi}{\omega} = \frac{2\pi}{100\pi}$	**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**

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Question 4 — Mark Scheme

Question	Answer	Marks
7(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**

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Question	Answer	Marks
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**

Question 5 — Mark Scheme

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Question	Answer	Marks
5(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)	$V = 0.90 \times 6.0$ (= 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**

Question 6 — Mark Scheme

Question	Answer	Marks
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**
7(b)(i)	(alternating p.d. makes) the crystal vibrate	**B1**
	vibrations (of crystal) causes air to vibrate	**B1**
	frequency is in ultrasound range	**B1**
7(b)(ii)	(air makes) crystal vibrate, which causes an e.m.f. to be generated across the (second) crystal	**B1**

Question 7 — Mark Scheme

Question	Answer	Marks
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**

Question 8 — Mark Scheme

Question	Answer	Marks
7(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**
	peak 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**

Question 9 — Mark Scheme

Question	Answer	Marks
7(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**

Question 10 — Mark Scheme

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**
	$\tau = 36$ ms	**A1**

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Question	Answer	Marks
4(d)(i)	8.0 W	**A1**
4(d)(ii)	4.0 W	**A1**

Question 11 — Mark Scheme

Question	Answer	Marks
7(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

Question 12 — Mark Scheme

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Question	Answer	Marks
6(a)(i)	conversion (from a.c.) to d.c.	**B1**
6(a)(ii)	half-wave: voltage in one direction is removed	**B1**
	full-wave: voltage in one direction is reversed	**B1**
6(b)(i)	one gap connected by a single diode and other gap connected directly	**B1**
	diode drawn (in a circuit) with correct circuit symbol	**B1**
6(b)(ii)	smoothing	**B1**
6(c)(i)	$E = ½CV^2$	**C1**
	$C = 2 \times 0.041 / 12^2 = 5.7 \times 10^{-4}$ F = 570 μF	**A1**
6(c)(ii)	$8.0 = 12.0 \exp(-0.010 / RC)$	**C1**
	$\ln(8.0 / 12.0) = -0.010 / (R \times 5.7 \times 10^{-4})$	**C1**
	$R = 43\ \Omega$	**A1**

Question 13 — Mark Scheme

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Question	Answer	Marks
8(a)	number of cycles per unit time	**B1**
8(b)(i)	period = $2\pi / 40\pi$ = 0.050 s = 50 ms	**A1**
8(b)(ii)	sinusoidal curve, starting at (0, 0) and initially increasing from there	**B1**
	periodic line showing 2 cycles with period 50 ms from t = 0 to t = 100 ms	**B1**
	all peaks shown at I = +3.5 A and all troughs shown at I = –3.5 A	**B1**
8(b)(iii)	$I_{r.m.s} = 3.5 / \sqrt{2}$ $= 2.5$ A	**A1**
8(c)	$P = I^2R$	**C1**
	peak power = $3.5^2 \times 680$ (= 8330 W) **or** mean power = $2.47^2 \times 680$ (= 4170 W)	**M1**
	peak and mean powers both calculated correctly, with supporting working, and compared leading to conclusion that mean power is half the peak power	**A1**

Question 14 — Mark Scheme

Question	Answer	Marks
6(a)(i)	conversion from a.c. to d.c.	**B1**
6(a)(ii)	smoothing	**B1**
6(b)(i)	$A = 12\ \text{V}$	**A1**
	$B = 2\pi / (20 \times 10^{-3})$ $= 310\ \text{rad s}^{-1}$	**A1**
6(b)(ii)	full-wave (rectification)	**B1**
6(b)(iii)	four diodes shown, with correct circuit symbols	**B1**
	four diodes correctly connected to form a bridge rectifier	**B1**
6(b)(iv)	$V = V_0 \exp(-t / \tau)$ **or** $V = V_0 \exp(-t / RC)$ **and** $\tau = RC$	**C1**
	$8.0 = 12 \exp(-7.3 \times 10^{-3} / \tau)$	**C1**
	$\tau = 0.018\ \text{s}$	**A1**
6(c)	time constant = RC	**C1**
	$R = (0.018 / 570 \times 10^{-6})$ $= 32\ \Omega$	**A1**

Question 15 — Mark Scheme

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Question	Answer	Marks
8(a)(i)	half-wave (rectification)	**B1**
8(a)(ii)	$V_0 = 6.0 \times \sqrt{2}$ $= 8.5\,\text{V}$	**A1**
8(b)(i)	$P = V^2 / R$	**C1**
	$P_0 = 8.5^2 / 45$ $= 1.6\,\text{W}$	**A1**
8(b)(ii)	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 $P = P_0$	**B1**
	correct sinusoidal shape, with smooth troughs sitting on t-axis at $P = 0$	**B1**
8(b)(iii)	mean power within each hump is $\frac{1}{2}P_0$ from the symmetry of the curve	**B1**
	additional half factor from removal of half of the power in each cycle	**B1**
8(b)(iv)	$\langle P \rangle = V_{\text{r.m.s.}}^2 / R$ $V_{\text{r.m.s.}} = \sqrt{[(1.6/4) \times 45]}$ $= 4.2\,\text{V}$	**A1**

Question 16 — Mark Scheme

Question	Answer	Marks
8(a)	four diodes shown (one in each gap) with correct circuit symbols	**B1**
	all four diodes connected in correct direction (pointing left to right)	**B1**
8(b)(i)	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	**B1**
	three curved lines rising along the upwards dotted lines from the minima to the peaks at 1.0T, 1.5T and 2.0T	**B1**
	minimum V at (2 / 3) V_0	**B1**
8(b)(ii)	from graph: discharge time (from V_0 to (2 / 3)V_0) = (11 / 30) T	**C1**
	(2 / 3) V_0 = V_0 exp (– (11 / 30)T / τ)	**C1**
	ln (2 / 3) = – 11T / 30τ τ = 0.90 T	**A1**
8(b)(iii)	time constant is increased	**B1**
	line shows a larger minimum voltage **or** smaller difference between maximum and minimum voltages	**B1**

Question 17 — Mark Scheme

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Question	Answer	Marks
7(a)(i)	$T = 2\pi / 40\pi = 0.050$ s	**A1**
7(a)(ii)	$V_{r.m.s.} = 18 / \sqrt{2}$ $= 13$ V	**A1**
7(b)	sinusoidal curve of period 50 ms from $t = 0$ to $t = 100$ ms	**B1**
	correct phase (V_{MAX} at $t = 0$, 50, 100 ms and $-V_{MAX}$ at 25, 75 ms etc.)	**B1**
	maximum and minimum voltages shown as ±18 V	**B1**
7(c)	*Any three points from*: • rectification is full-wave • mean power = 14 W • resistance of R = 12 Ω • peak current in R = 1.6 A **or** r.m.s. current in R = 1.1 A • period of output voltage / power = 25 ms ***or*** frequency of output voltage / power = 40 Hz **or** angular frequency of output voltage / power = 250 rad s^{-1}	**B3**

Question 18 — Mark Scheme

Question	Answer	Marks
6(a)(i)	conversion of a.c. to d.c.	**B1**
6(a)(ii)	full-wave (rectification)	**B1**
6(a)(iii)	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**
6(b)(i)	$\omega = 18$ (rad s^{-1})	**C1**
	$T = 2\pi / 18 = 0.35$ s	**A1**

Question	Answer	Marks
6(b)(ii)	$V_{r.m.s.} = 34 / \sqrt{2}$ $= 24$ V	**A1**
6(b)(iii)	sinusoidal 'humps' with minimum $V_{OUT} = 0$ and non-zero V_{OUT} all same sign	**B1**
	peak V_{OUT} shown as 34 V **or** –34 V	**B1**
	two 'humps' shown, with V_{OUT} always with same sign **and** $V_{OUT} = 0$ at $t = 0$, $t = 0.175$ s and $t = 0.350$ s **and** non-zero in between	**B1**
6(c)(i)	correct circuit symbol for capacitor, connected in parallel with resistor	**B1**
6(c)(ii)	time constant = RC	**C1**
	$= 56 \times 10^3 \times 12 \times 10^{-6}$ $= 0.67$ s	**A1**
6(c)(iii)	$V_{min} = 34 \exp(-0.14 / 0.67)$	**C1**
	$= 28$ V	**A1**