

Alternating currents

A-Level Physics 9702 · Topic 21 revision notes · A2

Sinusoidal alternating currents described by period, frequency, peak and r.m.s. values, then rectified with diodes and smoothed with a capacitor.

9 definitions to learn word for word, 6 equations in their own column, 5 diagrams and graphs. Read it, cover it, test yourself.

1. 21.1 Characteristics of alternating currents
2. 21.2 Rectification and smoothing.

Definitions (mark-scheme wording) Equations Exam traps

21.1 Characteristics of alternating currents

Definitions

Alternating current: a current that changes direction periodically (repeatedly reverses).

Period (T): the time taken for one complete cycle of the alternating current or voltage.

Frequency (f): the number of complete cycles per unit time.

Peak value (I_0 , V_0): the maximum value of the current or voltage (measured from zero).

Root-mean-square (r.m.s.) value: the value of the steady direct current (or voltage) that would produce the same mean power in a resistor as the alternating current (or voltage).

Key points

- ✓ A sinusoidal a.c. is written $x = x_0 \sin \omega t$, with $\omega = 2\pi f$.
- ✓ Power in a resistor $P = I^2 R$ is **always positive** and varies at twice the supply frequency.
- ✓ Mean of $\sin^2$ over a cycle = $\frac{1}{2}$, so **mean power = $\frac{1}{2}$ peak power** (resistive load).
- ✓ For a sinusoid, $I_{rms} = I_0 / \sqrt{2} \approx 0.71 I_0$; the mean current over a cycle is zero.
- ✓ Peak-to-peak value = $2 \times$ peak value; read peaks from the centre line on an oscilloscope trace.
- ✓ Oscilloscope: T from time-base $\times$ divisions per cycle; V_0 from Y-gain $\times$ divisions.
- ✓ Mains 230 V is the **r.m.s.** value (peak ≈ 325 V).

Equations

$$x = x_0 \sin \omega t$$

sinusoidal current or voltage

$$\omega = 2\pi f = 2\pi/T$$

angular frequency
 rad s^{-1}

$$I_{rms} = I_0 / \sqrt{2}$$

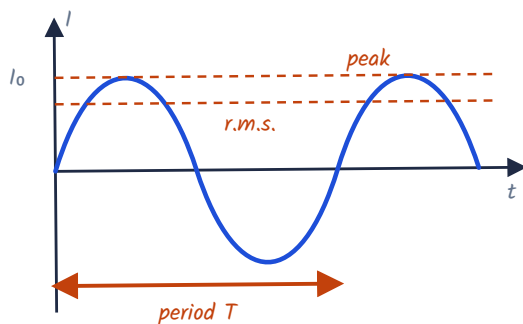
r.m.s. current (sinusoidal)
A

$$V_{rms} = V_0 / \sqrt{2}$$

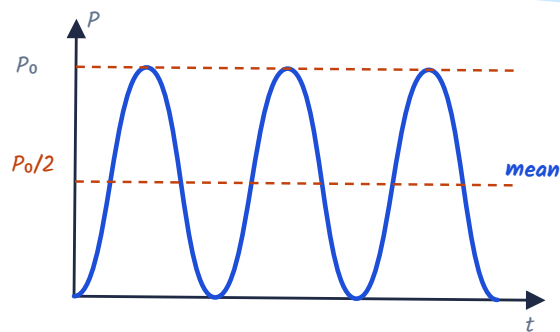
r.m.s. voltage (sinusoidal)
V

$$\langle P \rangle = \frac{1}{2} I_0 V_0 = I_{rms} V_{rms}$$

mean power in a resistive load
W



Sinusoidal current: peak I_0 , period T , and the r.m.s. level at $0.71 I_0$.



Power in a resistor: always positive, frequency $2f$; the mean is half the peak power.

Watch out!

- ! Use r.m.s. values for power; the peak matters for insulation and breakdown. 230 V mains peaks at $230 \times \sqrt{2} \approx 325$ V.
- ! $I_{rms} = I_0/\sqrt{2}$ holds **only** for sinusoidal waveforms (a square wave has $I_{rms} = I_0$).
- ! Mean power is $\frac{1}{2}I_0V_0$, not $I_0V_0/\sqrt{2}$.

21.2 Rectification and smoothing

Definitions

Rectification: the conversion of an alternating current (or voltage) into a direct current (or voltage), one that flows in one direction only.

Half-wave rectification: rectification in which only one half of each cycle is passed; the other half is blocked (one diode).

Full-wave rectification: rectification in which both halves of each cycle give output in the same direction (bridge of four diodes).

Smoothing: reducing the variation (ripple) of a rectified output, using a capacitor in parallel with the load.

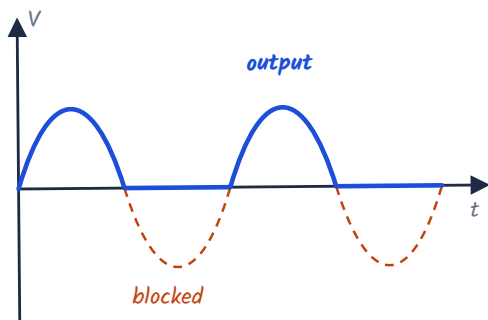
Equations

$$\tau = RC$$

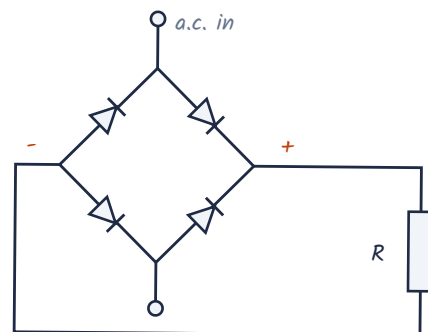
time constant of the smoothing capacitor and load; want $\tau \gg$ time between peaks

Key points

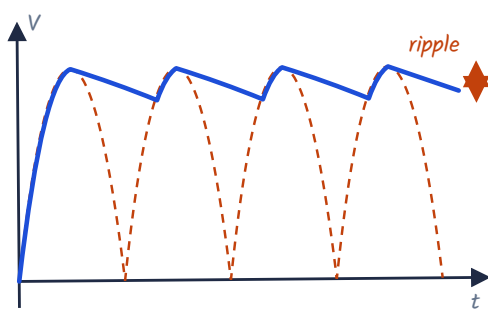
- ✓ A **diode** conducts in one direction only (arrow = direction of conventional current).
- ✓ Half-wave: **one diode** in series with the load; output is zero for half of each cycle.
- ✓ Full-wave: **bridge rectifier**; two diodes conduct in each half-cycle, current through the load always in the same direction.
- ✓ Smoothing capacitor charges to the peak, then **discharges through the load** between peaks, holding the p.d. up.
- ✓ Ripple is smaller when the time constant **RC is large** compared with the time between peaks.
- ✓ Larger C (or larger load R) gives **smoother** output; a smaller load resistance gives more ripple.
- ✓ Full-wave output has ripple at **$2f$** , so it smooths more easily than half-wave.



Half-wave rectification: the input (dashed) and the output (solid), which is zero during the negative half-cycles.



Bridge rectifier: whichever input is positive, current leaves at + and returns at -, always the same way through the load R.



Full-wave output (humps) smoothed by a capacitor: it charges at each peak and discharges through R between them, leaving a small ripple.

Watch out!

- ! Full-wave rectified 50 Hz a.c. has ripple at **100 Hz**: both half-cycles give a hump.
- ! The smoothing capacitor goes in **parallel** with the load, not in series.
- ! More smoothing needs a **larger** time constant (bigger C or bigger R), not a smaller one.