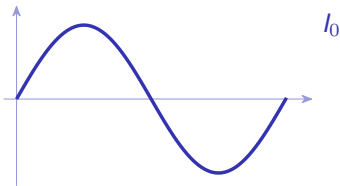


Alternating Currents

A2 Physics ■ Topic 21

A-Level Physics



What we will cover

- 1 Alternating current basics
- 2 Power in a resistor
- 3 Root-mean-square values
- 4 Rectification and smoothing
- 5 Recap

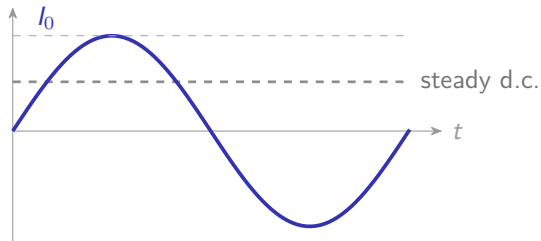


Current that keeps reversing

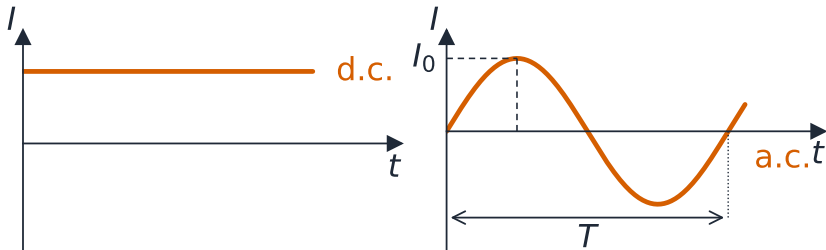
An **alternating current** keeps reversing direction. Mains is sinusoidal:

$$I = I_0 \sin(\omega t), \quad V = V_0 \sin(\omega t)$$

For a purely resistive load, V and I are in phase.



Alternating current basics



d.c. constant polarity · a.c. reverses each cycle

A steady direct current compared with a sinusoidal alternating current of peak I_0 and period T

The words on a CRO trace

period T

time for one full cycle. $f = 1/T$. Mains is 50 or 60 Hz.

angular frequency

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

peak I_0 or V_0

the largest value in a cycle (amplitude)

peak-to-peak

$2I_0$ – from $+I_0$ to $-I_0$; useful on a CRO

The values you read off an a.c. trace

Peak value

The **peak value** I_0 or V_0 : the largest value in a cycle – the amplitude.

Peak-to-peak value

The **peak-to-peak value** $2I_0$: from $+I_0$ down to $-I_0$, which is what a CRO screen shows most directly.

Period and frequency

One cycle spans the period T ; the frequency is $f = 1/T$. Read T off the time-base setting.

R.m.s. value

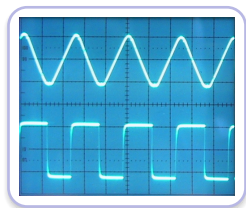
$V_{\text{rms}} = V_0/\sqrt{2}$: the d.c. voltage that would deliver the same mean power in the same **resistance**.

Mains “230 V” is an r.m.s. value; the peak is about 325 V, and insulation has to survive the peak.

Reading a CRO

Same as any wave (Topic 7), using a **cathode-ray oscilloscope** :

- horizontal divisions $\times$ **time-base** $\rightarrow$ period T , so $f = 1/T$
- vertical divisions $\times$ y -gain $\rightarrow$ peak voltage V_0 (centre to peak, or peak-to-peak then halve)





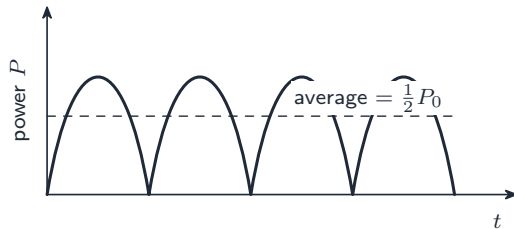
Power in a resistor pulses at $2f$

Instant power $P(t) = I(t)^2 R$. With $I = I_0 \sin(\omega t)$:

$$P(t) = I_0^2 R \sin^2(\omega t)$$

Always positive; peak $I_0^2 R$; minimum zero; oscillates at **twice** the frequency of I . The mean of $\sin^2$ over a cycle is $\frac{1}{2}$, so

$$\langle P \rangle = \frac{1}{2} I_0^2 R = \frac{1}{2} P_{\text{peak}}$$



Average a.c. power in a resistor is **half the peak power**.

Why r.m.s. matters

“230 V mains” means $V_{\text{r.m.s.}} = 230 \text{ V}$, with peak $V_0 = 230\sqrt{2} \approx 325 \text{ V}$.

Components must be rated for the peak, not the r.m.s.

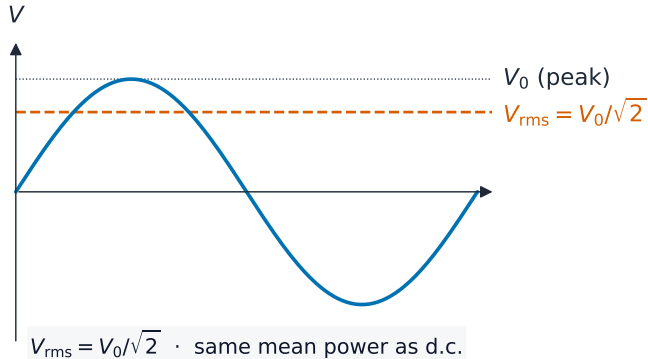
Drawing the diagrams

- half-wave: a.c. source – single diode – load R , in series.
- full-wave bridge: four diodes as the arms of a “diamond”; the a.c. input goes to one pair of opposite corners, the load R across the other pair.



r.m.s. is the equivalent steady d.c.

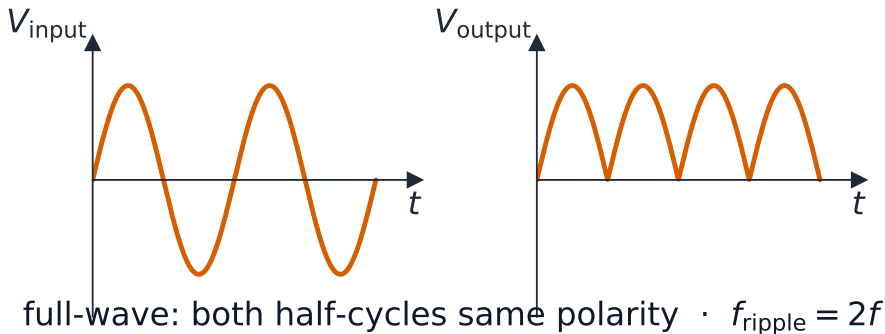
$I_{\text{r.m.s.}}$ is the **steady direct current** giving the same average power in the same R : $I_{\text{r.m.s.}} = I_0/\sqrt{2}$, $V_{\text{r.m.s.}} = V_0/\sqrt{2}$.





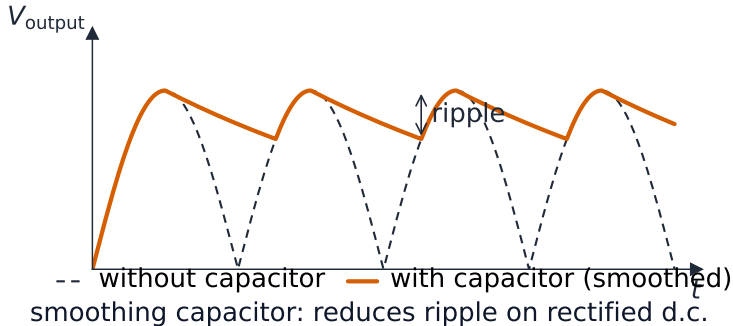
The rectified output

Full-wave flips the negative half rather than discarding it, so the output never rests at zero and its mean is **twice** the half-wave value.



Smoothing – a capacitor across the load

The capacitor charges to near the peak, then **discharges through the load** (time constant RC) while the diodes are cut off. The dips left are the **ripple** : smaller for larger C , larger R , or full-wave rectification.



How it works

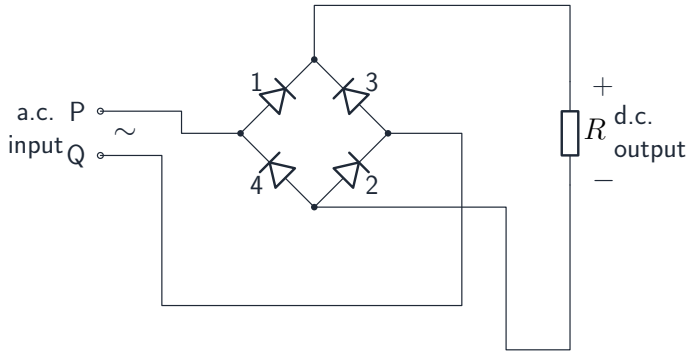
- on the **rising part** of each pulse, the capacitor charges up to near the peak.
- on the **falling part** (and any gap), the diodes are reverse-biased, so the capacitor **discharges through the load**, keeping current flowing.
- at the next peak, the capacitor charges again, and the cycle repeats.

Purpose in summary

The smoothing capacitor reduces the ripple, giving a steadier d.c.

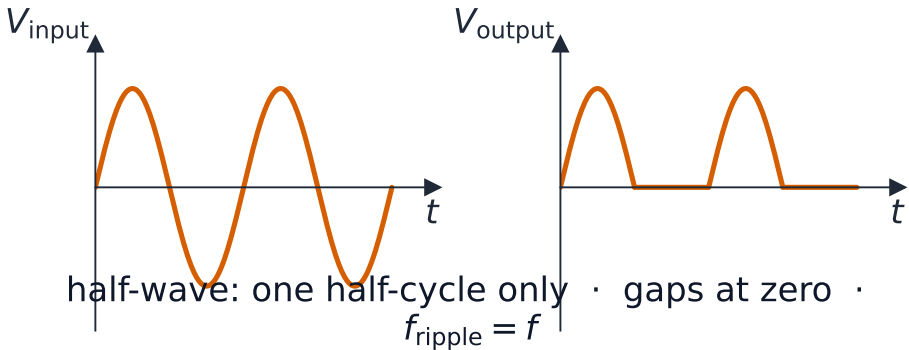
voltage suitable for sensitive electronics.

Full-wave rectification (bridge rectifier)



A four-diode bridge sends the load current the same way whichever a.c. terminal is positive

Half-wave rectification



In half-wave rectification a single diode passes only the positive half-cycles

Worked example – r.m.s. values in use

(a) An a.c. supply has a peak voltage of 12 V: find its r.m.s. voltage. (b) A $50\ \Omega$ heater runs on the 230 V r.m.s. mains: find the r.m.s. current and the average power.

- (a) $V_{\text{rms}} = V_0/\sqrt{2} = 12/\sqrt{2} \approx 8.5\ \text{V}.$
- (b) $I_{\text{rms}} = V_{\text{rms}}/R = 230/50 = 4.6\ \text{A}.$
- $\langle P \rangle = V_{\text{rms}} I_{\text{rms}} = 230 \times 4.6 \approx 1.06\ \text{kW}.$

Use r.m.s. values for power, peak values for insulation. Mixing them is the standard error here.

Exam tips

- $I_{rms} = I_0/\sqrt{2}$ for a sinusoidal current; use r.m.s. values for power ($P = I_{rms}^2 R$).
- Mean power in a resistor = $\frac{1}{2}$ of the peak power.
- Explain **rectification** (diode or bridge) and how a **smoothing capacitor** reduces the ripple.



Topic 21 – key takeaways

1 a.c.

$$I = I_0 \sin(\omega t); f = 1/T; \omega = 2\pi f$$

2 r.m.s.

$$I_{\text{rms}} = I_0/\sqrt{2}; \text{ power uses r.m.s.}$$

3 Rectify

one diode (half) or four-diode bridge (full)

4 Smooth

C in parallel with R ; large $RC \Rightarrow$ small ripple

Check yourself

- 1 Peak of 230 V r.m.s. mains?
- 2 Average power in a resistor, as a fraction of peak power?
- 3 How many diodes in a bridge rectifier?
- 4 Two ways to reduce ripple?

Answers 1. ≈ 325 V 2. half 3. four 4. larger C or R , or full-wave (higher frequency)