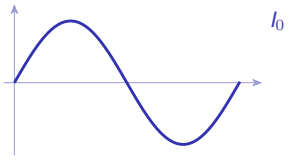
Alternating Currents

A2 Physics ▪ Topic 21

A-Level Physics



What we will cover

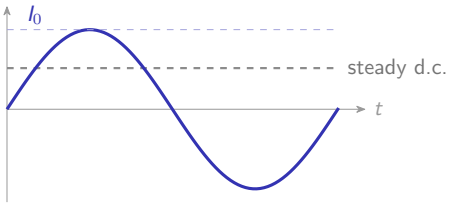
1 AC basics

Current that keeps reversing

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

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

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



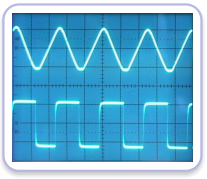
The words on a CRO trace

period T	time for one full cycle. $f = 1/T$. Mains is 50 or $60\,\mathrm{Hz}$.
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

Reading a CRO

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

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



2 Power

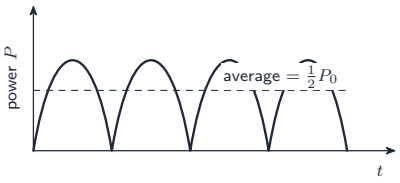
Power in a resistor pulses at $2f$

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

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

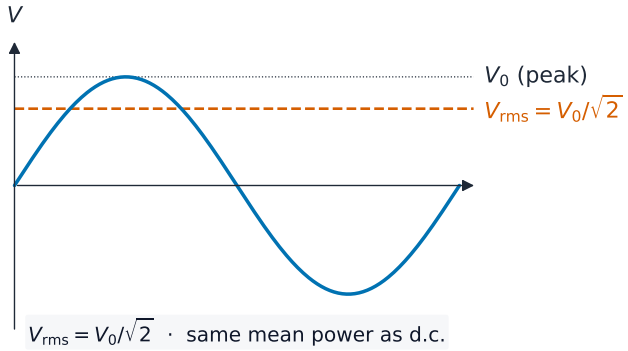


> Average a.c. power in a resistor is half the peak power.

3 Root-mean-square

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



$V_{\text{rms}} = V_0/\sqrt{2}$ · same mean power as d.c.

Quoted a.c. values are r.m.s.

"230 V mains" means $V_{\text{r.m.s.}} = 230\,\text{V}$, so the peak is $230\sqrt{2} \approx 325\,\text{V}$. Components must be rated for the peak, not the r.m.s.

$$\langle P \rangle = I_{\text{r.m.s.}}^2 R = V_{\text{r.m.s.}}^2/R = V_{\text{r.m.s.}} I_{\text{r.m.s.}}$$

Heater $R = 50\,\Omega$ on $230\,\text{V}$ r.m.s. mains

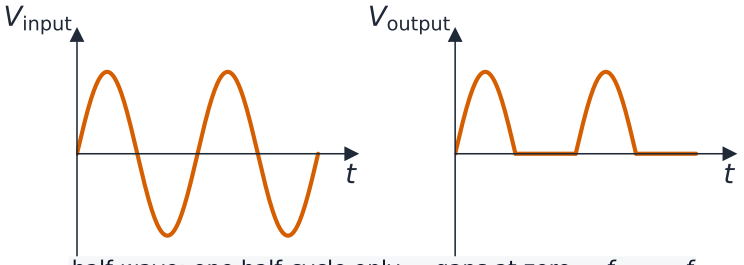
$I_{\text{r.m.s.}} = 230/50 = 4.6\,\text{A}$

$\langle P \rangle = 230 \times 4.6 \approx 1.1 \times 10^3\,\text{W}$

4 Rectification

Half-wave – one diode, half the cycle

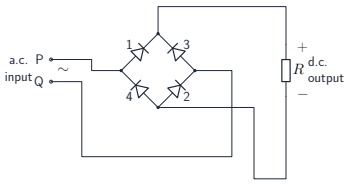
Rectification 整流 turns a.c. into one-direction voltage using **diodes** 二极管. A single diode passes only the positive half; the negative half is **reverse-biased** 反向偏置. Mean output $V_0/\pi \approx 0.32V_0$.



half-wave: one half-cycle only · gaps at zero · $f_{\text{ripple}} = f$

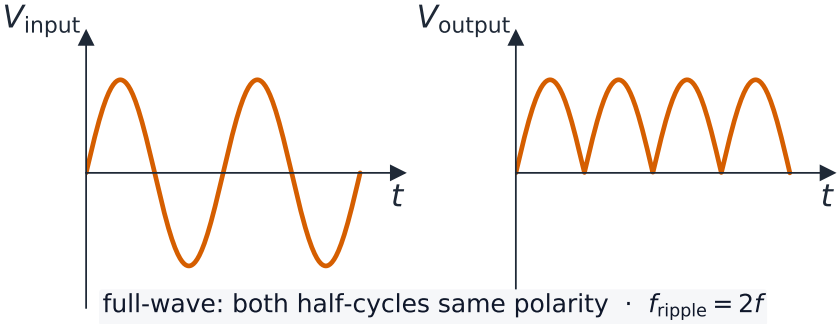
Full-wave – a four-diode bridge

A **bridge rectifier** 桥式整流器 uses four diodes so the load current always flows the same way. Output: a continuous run of positive half-waves at twice the input frequency. Mean $2V_0/\pi \approx 0.64V_0$ — double the half-wave value.



The rectified output

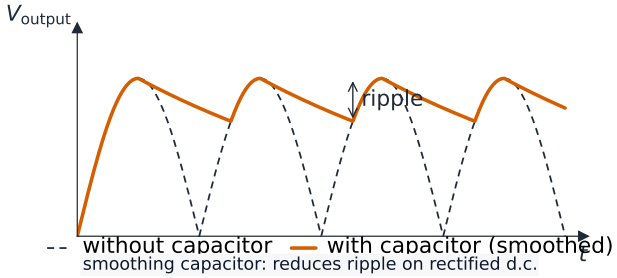
Full-wave flips the negative half rather than discarding it, so the output never rests at zero and its mean is twice the half-wave value.



full-wave: both half-cycles same polarity · $f_{\text{ripple}} = 2f$

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** 纹波: smaller for larger C, larger R, or full-wave rectification.



smoothing capacitor: reduces ripple on rectified d.c.

5 Recap

Topic 21 – key takeaways

1. **a.c.**
   $I = I_0 \sin(\omega t)$; $f = 1/T$; $\omega = 2\pi f$
2. **r.m.s.**
   $I_{\text{rms}} = I_0/\sqrt{2}$; 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 $230\,\mathrm{V}$ 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.** $\approx 325\,\mathrm{V}$ **2.** half **3.** four **4.** larger C or R, or full-wave (higher frequency)