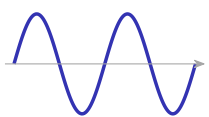
Alternating Current

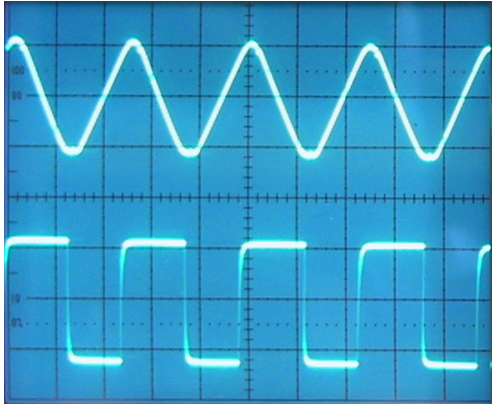
A2 Physics ▪ Topic 21

A-Level Physics

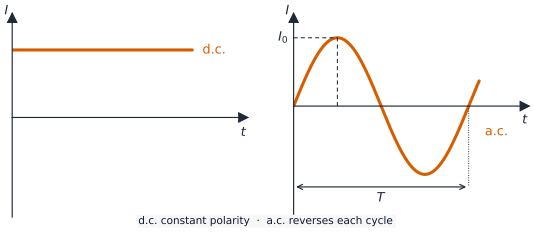


What we will cover

1. AC basics
2. Power in a resistor
3. Root-mean-square values
4. Rectification
5. Smoothing
6. Recap



Alternating current



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

substation

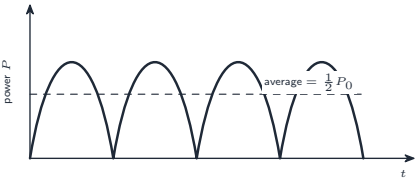
Power delivered to a resistor

The instantaneous power is $P = I^2 R$, which is always positive (squaring loses the sign):

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

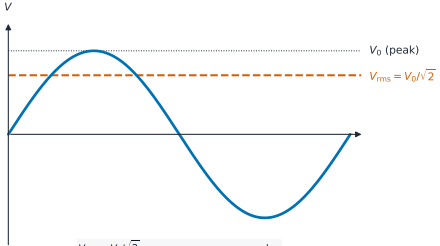
Over a cycle $\sin^2$ averages to $\frac{1}{2}$, so

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



> Power peaks twice per cycle – once each polarity – because the heating does not care which way the current flows.

R.m.s. values



The **r.m.s.** 均方根 value is the steady DC that would deliver the same average power:

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}, \qquad V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

$$\langle P \rangle = I_{\text{rms}}^2 R = \frac{V_{\text{rms}}^2}{R}$$

Divide by $\sqrt{2}$ only for a sine wave. R.m.s. is what a meter reads and what "$230\,\text{V}$" means.

Worked example – r.m.s. and power

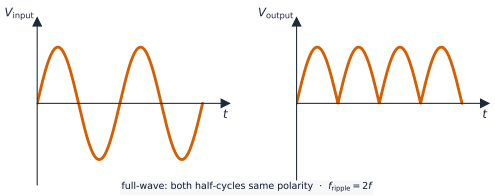
A sinusoidal supply has a peak voltage of $325\,\mathrm{V}$ across a $100\ \Omega$ resistor. Find V_{rms} and the mean power.

$$V_{\mathrm{rms}} = \frac{325}{\sqrt{2}} \approx 230\,\mathrm{V}$$

$$\langle P \rangle = \frac{V_{\mathrm{rms}}^2}{R} = \frac{230^2}{100} \approx 530\,\mathrm{W}$$

Use r.m.s. values in every power formula. Using the peak would overstate the power by a factor of two.

Rectification

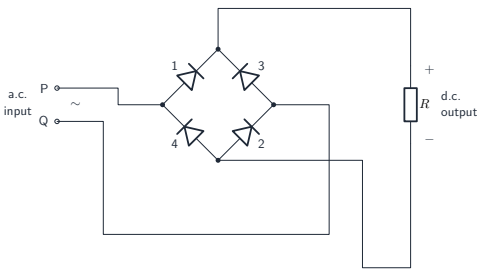


A **diode** 二极管 conducts one way only, turning AC into one-directional DC:

- half-wave: one diode, blocks the reverse half
- full-wave: a bridge of four diodes flips the reverse half up

> Full-wave uses both halves, so the output is smoother and delivers more power.

Smoothing with a capacitor



A capacitor across the output charges on each peak and discharges through the load between peaks:

- it fills in the dips, leaving a small **ripple** 纹波
- bigger C (or R) $\Rightarrow$ slower discharge $\Rightarrow$ smaller ripple

> The smoothing time constant RC must be long compared with the time between peaks.

Topic 21 – key takeaways

1 AC

$I = I_0 \sin(2\pi ft)$ – reverses each cycle

2 R.m.s.

$I_0/\sqrt{2}$ – the DC-equivalent for power

3 Rectify

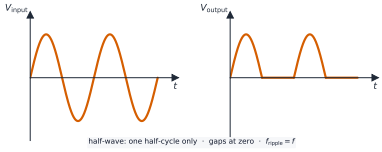
diodes make DC; a bridge is full-wave

4 Smooth

a capacitor fills the dips; big RC = small ripple

Check yourself

1. Peak voltage $325\,\mathrm{V}$ – what is V_{rms}?
2. Why is mean power $\frac{1}{2} I_0^2 R$?
3. How many diodes in a bridge rectifier?
4. What makes the ripple smaller?



Answers **1.** $\approx 230\,\mathrm{V}$ **2.** $\langle \sin^2 \rangle = \frac{1}{2}$ **3.** four **4.** a larger C (longer RC)