# Alternating Currents

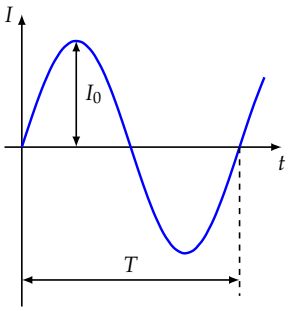
Name _____ Date _____

**By the end of this topic I can…**

- describe sinusoidal a.c. and use peak, r.m.s. and mean power
- read voltage, period and frequency from an oscilloscope trace
- explain the transformer and why electricity is transmitted at high voltage
- explain half-wave and full-wave rectification and smoothing

## Sinusoidal alternating current

A _____ (d.c.) flows in one direction only. An _____ (a.c.) reverses its direction repeatedly. Generators produce _____ a.c., which is the main kind in this course.




### The sinusoidal waveform

- $I_0$, $V_0$ are the _____ current and voltage (the amplitudes)
- $\omega$ is the _____: and

$$T = \frac{1}{f}$$

- the mean current and mean voltage over a cycle are _____: the positive and negative halves cancel

**Question 28.1** An alternating voltage has a peak value of 16 V and a period of 0.10 s. Write an equation for the voltage.

**Question 28.2** The rotation speed of the coil in a simple generator doubles. Describe the change in peak voltage and frequency.

**Question 28.3** A student says the mean current in a resistor is zero, so an alternating current produces no heating. Is this correct?

## Power and r.m.s. values

• power in a resistor: $P = I^2R = \dfrac{V^2}{R}$, never negative, but it varies with time. We usually want the _____:

$$\langle P \rangle = \langle I^2 \rangle R = \frac{\langle V^2 \rangle}{R}$$

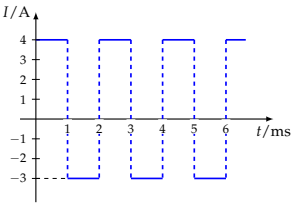
• the _____ values are $I_{\text{rms}} = \sqrt{\langle I^2 \rangle}$ and $V_{\text{rms}} = \sqrt{\langle V^2 \rangle}$, so

The _____ value of an alternating current (voltage) is the _____ current (voltage) that delivers the _____ to a resistive load.

• for a **sine wave** only:

• mains voltages (e.g. 230 V) are _____ values

**Why $1/\sqrt{2}$?** $\langle P \rangle = \dfrac{1}{T}\displaystyle\int_0^T I_0^2 R \sin^2 \omega t \, \mathrm{d}t$ and $\displaystyle\int_0^T \sin^2 \omega t \, \mathrm{d}t = \tfrac{1}{2}\int_0^T (1 - \cos 2\omega t)\mathrm{d}t = \frac{T}{2}$, so $\langle P \rangle = \tfrac{1}{2} I_0^2 R = I_{\text{rms}}^2 R$.




*Current through the resistor.*

**Example 28.1** The alternating current in a 120 Ω resistor is shown (square wave: +4 A for half the period and −3 A for the other half). Find (a) the r.m.s. current and (b) the mean power.

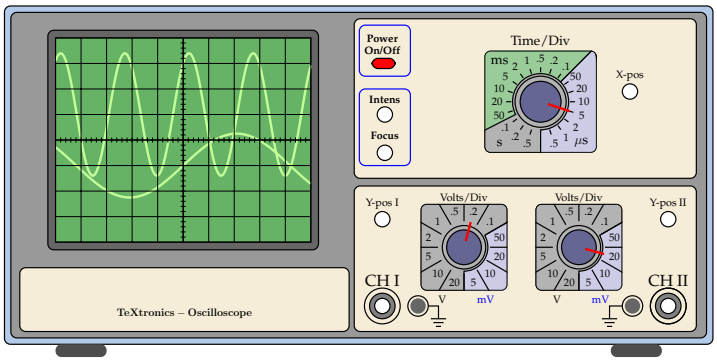
**Example 28.2** A sinusoidal supply with maximum voltage 75 V is connected across a 30 Ω resistor. Find the energy dissipated in 2.0 minutes.

**Question 28.4** $V = 310\sin(100\pi t)$ (SI units). Find (a) the peak voltage, (b) the r.m.s. voltage, (c) the frequency, (d) the mean power across a 250 Ω resistor.

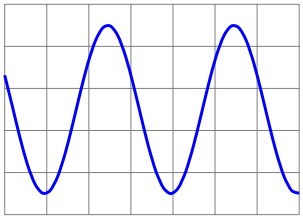
**Question 28.5** What is the mean power in a resistor when the supply has peak current 5.0 A and peak voltage 8.0 V?

**Question 28.6** The peak value of a sinusoidal current equals a steady d.c. current. Both are applied to the same load. Find $P_{\text{d.c.}}/P_{\text{a.c.}}$.

## Measuring a.c. with an oscilloscope




A _____ (c.r.o.) uses a beam of _____. The time base moves the beam _____ (time axis); the signal on the _____ deflects it up and down. It shows a graph of _____.



- _____: volts per vertical division
- _____: time per horizontal division

**Example 28.3** The trace is shown (4 divisions peak to peak, 3 divisions per cycle). The time base is 10 ms/div and the Y-gain is 5 V/div. Find the peak voltage, period and frequency.

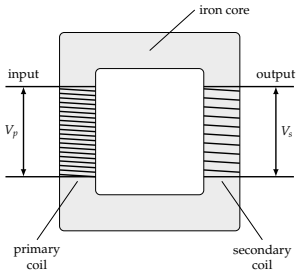
**Question 28.7** The time base is now 5 ms/div and the Y-gain is 2 V/div with the same trace. Write an equation for the voltage.

# Power supply systems

## High-voltage transmission

power station → 5 ∼ 30 kV → step-up transformer → 100 ∼ 750 kV power grid → step-down transformer → 100 ∼ 250 V → home or factory

- cable loss is $I^2R$, so we want a _____
- power station output $P = IV$ is fixed, so low current means _____
- but low voltages are safer at generator and consumer, so we need _____ to step the voltage up and down




## Transformers

A _____ changes an alternating voltage.

- a.c. in the _____ coil gives a changing flux in the _____; this links with the _____ coil and induces an a.c. voltage of the _____
- with no flux loss, Faraday's law gives $V_p = N_p \frac{d\phi}{dt}$ and $V_s = N_s \frac{d\phi}{dt}$, so

- $N_s > N_p$: _____; $N_s < N_p$: _____
- ideal transformer (100% efficient): input power = output power

- losses in a real transformer: _____ in the core (reduced by a _____ core); _____ of the coils (thick copper wire); _____ (continuous iron loop)

**Example 28.4** An ideal transformer has 200 primary turns and 5000 secondary turns. The r.m.s. primary voltage is 8.0 V. What is the *peak* voltage across a resistor on the secondary?

**Question 28.8** An ideal transformer has 6000 primary turns. It converts a 220 V r.m.s. supply to an a.c. voltage with a peak value of 12.0 V. Find the number of secondary turns.

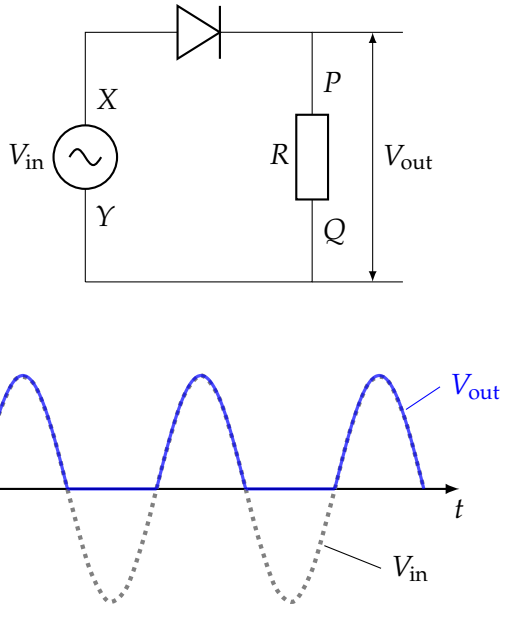
**Question 28.9** What is the output if a steady d.c. voltage is applied to the input?

**Question 28.10** Is the primary current in phase with the voltage induced in the secondary? Explain.

## Rectification and smoothing

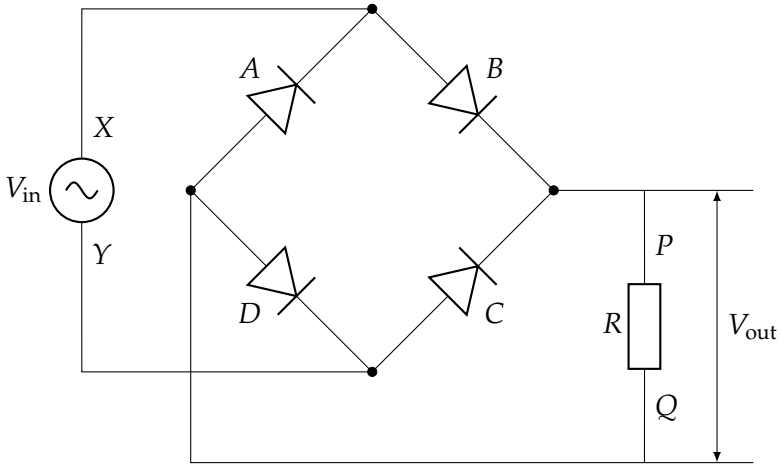
Many devices need d.c. _____ converts a.c. to d.c. using _____, which allow current in one direction only.

### Half-wave rectification

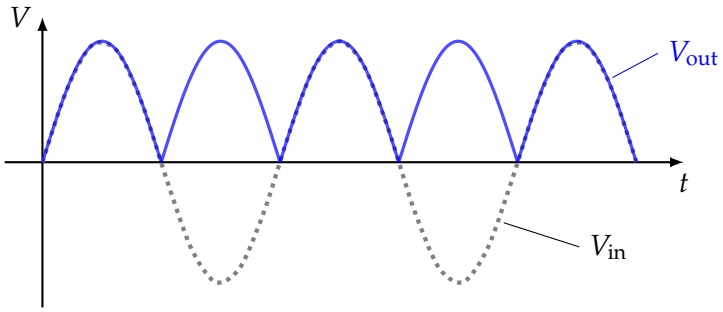



A _____ conducts only when $X$ is positive, so $V_{out}$ is in one direction, with zero output for half of each cycle. Only half of the supply power is available.

### Full-wave rectification



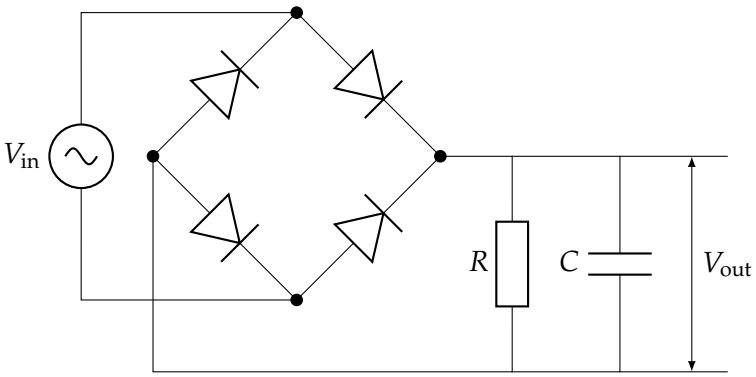

A _____ of four diodes: when $X$ is positive, the current path is $X \to B \to R \to D \to Y$; when $Y$ is positive, it is $Y \to C \to R \to A \to X$. In both cases the current in $R$ is in the _____, so $P$ is always positive relative to $Q$.

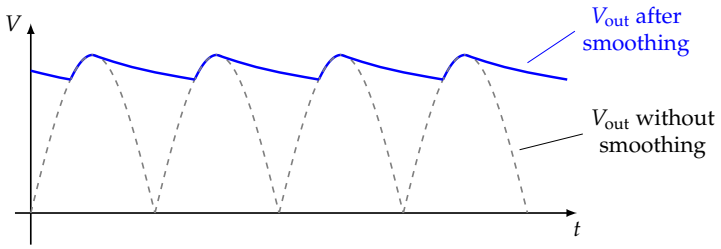



**Question 28.11** How should the four diodes be rearranged so that $Q$ is positive with respect to $P$?

## Smoothing

The rectified d.c. still varies. A _____ connected in _____ with the load stores energy as the voltage rises and discharges through the load as it falls, reducing the _____.




- the time constant $\tau = RC$ matters: larger $RC$ means _____ discharge and _____
- if $RC$ is too large the capacitor may not fully charge on each cycle

**Question 28.12** A second capacitor is added in *series* with the smoothing capacitor. Sketch and explain the change in the output voltage.