

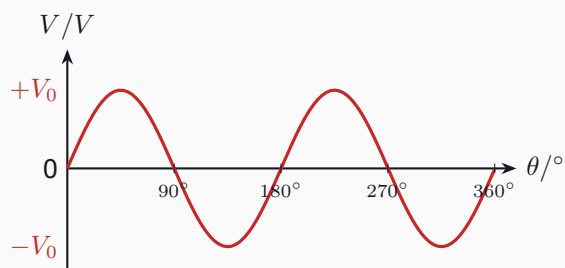
Alternating Currents

Chapter 14 / A2 Level / Apollo Physics 9702



General Equation of Alternating Voltage and Current

General equation



For a sine graph,

$$Y = A \sin(BX) + C$$

A amplitude

B number of cycles in 360°

C y -intercept / mean value

$$Y : V \quad A : V_0 \quad X : \theta$$

$$B : 1 \quad C : 0$$

$$V = V_0 \sin \theta$$

Angular speed:

$$\omega = \frac{\Delta \theta}{\Delta t}$$

hence

$$\theta = \omega t$$

Therefore,

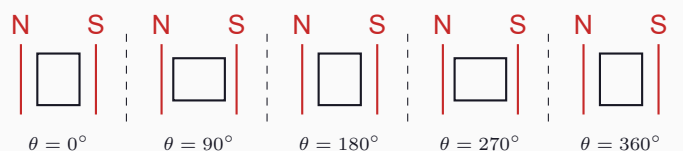
$$V = V_0 \sin \omega t$$

similarly

$$I = I_0 \sin \omega t$$

Generator idea

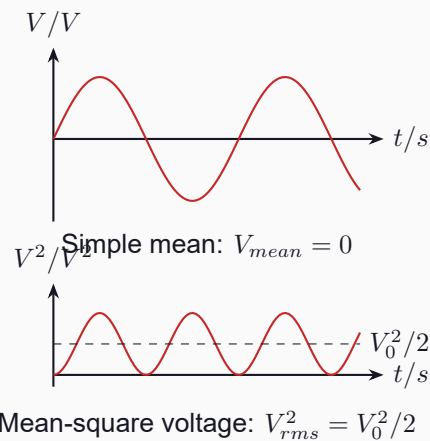
- **Max voltage:** coil crosses horizontal, because rate of change of flux linkage is maximum.
- **Min voltage:** coil crosses vertical, because rate of change of flux linkage is minimum.
- Induced emf is proportional to $N \Delta \Phi / \Delta t$.



The changing orientation of the coil in the magnetic field produces alternating voltage and alternating current.

Root-Mean-Square Voltage and Current

Mean and rms values



For one full cycle of a symmetrical alternating voltage,

$$V_{mean} = 0$$

The square graph is always positive. The mean of the square graph is

$$V_{rms}^2 = \frac{V_0^2}{2}$$

Hence, for a sine wave,

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

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

Meaning of rms value

- The rms value of alternating voltage/current is the value of direct voltage/current which supplies the same mean power to the same resistor.
- The simple mean value is zero because the positive half cycle cancels the negative half cycle.
- We square first so that both half cycles contribute positive heating effect.

Peak value	rms value
V_0	$V_0/\sqrt{2}$
I_0	$I_0/\sqrt{2}$

Only for a sinusoidal wave form : rms = peak / $\sqrt{2}$.

Power in an A.C. Circuit

What rms tells us

- The rms value of direct voltage/current supplying to an alternating one should give the same mean power output as an alternating voltage/current would.
- 220 V a.c. or 220 V d.c. gives the same mean power output across the same resistor.

$$P = IV$$

$$P = I^2 R$$

$$P = \frac{V^2}{R}$$

For a resistor in an a.c. circuit,

$$P_{\text{mean}} = I_{\text{rms}} V_{\text{rms}} = I_{\text{rms}}^2 R = \frac{V_{\text{rms}}^2}{R}$$

Since $I = I_0 \sin \omega t$,

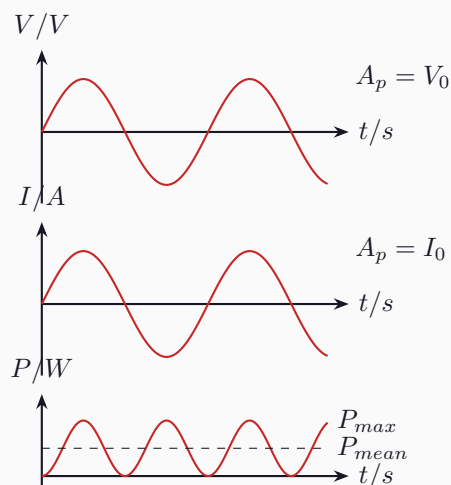
$$P = I^2 R = I_0^2 R \sin^2 \omega t.$$

Thus,

$$P_{\text{max}} = I_0^2 R$$

$$P_{\text{mean}} = \frac{P_{\text{max}}}{2}$$

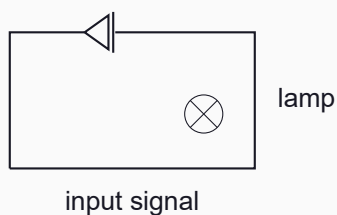
Voltage, current and power graphs



Power is never negative for a resistor because heating depends on I^2 .

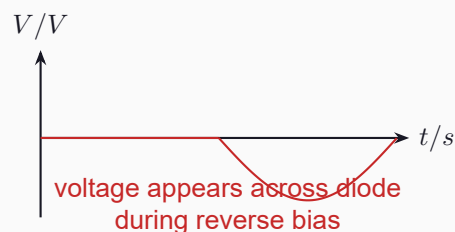
Half-Wave Rectification

Half-wave rectifier



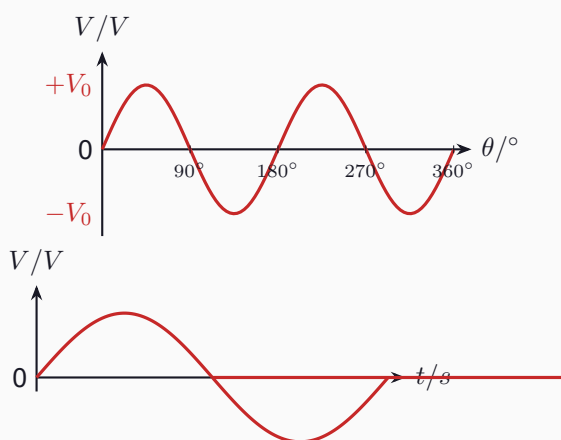
A diode allows current to pass only when it is forward biased.

Forward bias	voltage on load / lamp on
Reverse bias	no voltage on load / lamp off



During the positive half-cycle the diode conducts, so almost all the voltage appears across the load. During the negative half-cycle it blocks, so the load has no output voltage.

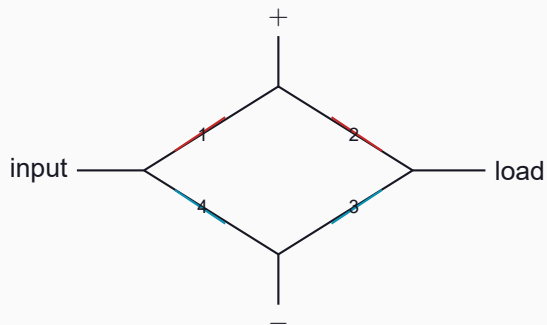
Input and output



The output is **rippling d.c.** because it has one direction but its magnitude changes with time. **Voltage on diode**

Full-Wave Rectification

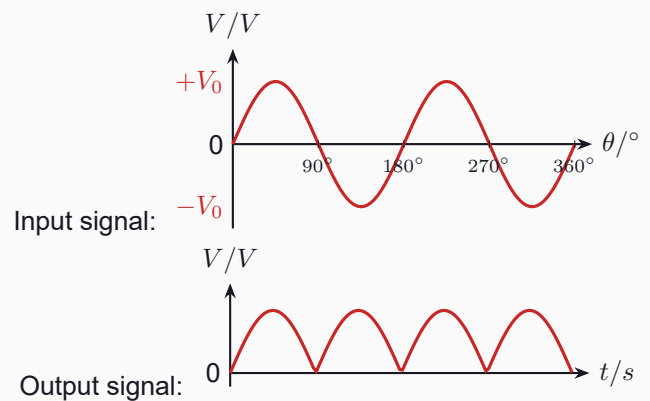
Bridge rectifier



In a full-wave rectifier, both halves of the input signal are used. The negative half cycle is turned into a positive output across the load.

- During the positive half cycle, one pair of diodes conducts.
- During the negative half cycle, the other pair of diodes conducts.
- The current through the load remains in the same direction.

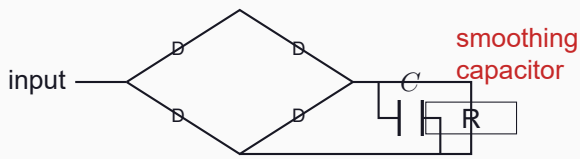
Waveforms



Full-wave rectification gives a larger mean output than half-wave rectification, because both half cycles contribute to the output.

Smoothing with a Capacitor

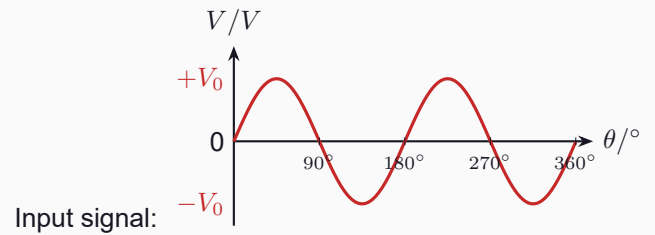
Why a smoothing capacitor is used



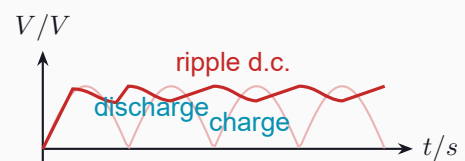
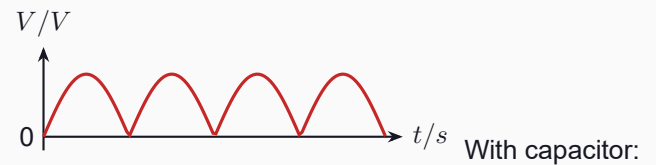
During the drop in output voltage, capacitor maintains current in the resistor.

- The capacitor charges when the rectified voltage rises.
- It discharges through the load when the rectified voltage falls.
- This reduces the ripple and increases the mean output voltage.

Ripple d.c. and smoothed output



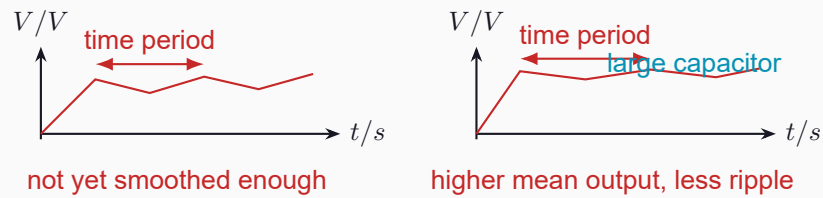
Output signal before smoothing:



Time Period and Effect of Capacitance

Effect of adding capacitance

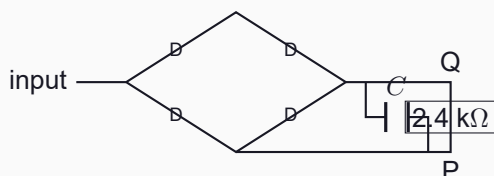
- Adding capacitance increases the mean output voltage.
- It increases the time taken for the output to fall, so the ripple becomes smaller.
- The time period of a rectified full-wave signal is smaller than the time period of the original a.c. signal because both half cycles appear as positive pulses.



Large capacitor $\Rightarrow$ slower discharge $\Rightarrow$ smaller ripple $\Rightarrow$ smoother d.c. output.

Exam-Style Rectifier Question

Question setup



A bridge rectifier contains four ideal diodes and a capacitor. The output of the rectifier is connected to a load of resistance 2.4 k.

1. Calculate the mean-square current in the load.
2. Explain how the potential difference across the load is smoothed.

Calculation Using the rms output voltage from the rectified sinusoidal input,

$$I_{rms} = \frac{V_{rms}}{R}.$$

For the values shown in the note,

$$I_{rms} = \frac{8.5}{2400} = 3.5 \times 10^{-3} \text{ A}.$$

Therefore,

$$I_{rms}^2 = (3.5 \times 10^{-3})^2 = 1.3 \times 10^{-5} \text{ A}^2$$

Smoothing explanation

- The capacitor is connected in parallel with the load.
- It charges when the rectified output is increasing.
- It discharges through the load when the rectified output is decreasing.
- This keeps the p.d. across the load nearly constant.

Summary: A.C., Rectification and Smoothing

Core equations

Quantity	Equation
Alternating voltage	$V = V_0 \sin \omega t$
Alternating current	$I = I_0 \sin \omega t$
Angular displacement	$\theta = \omega t$
RMS voltage	$V_{rms} = V_0 / \sqrt{2}$
RMS current	$I_{rms} = I_0 / \sqrt{2}$
Mean power	$P_{mean} = I_{rms} V_{rms}$
Resistor power	$P_{mean} = I_{rms}^2 R = V_{rms}^2 / R$

Rectification

- Half-wave rectification uses one half cycle only.
- Full-wave rectification uses both half cycles.
- A diode conducts in forward bias and blocks in reverse bias.

Smoothing

- The capacitor is placed parallel to the load.
- It charges to the peak of the rectified output.
- It discharges when the rectified voltage drops.
- Larger capacitance gives smaller ripple and greater mean output p.d.

