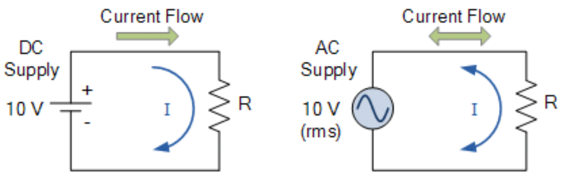
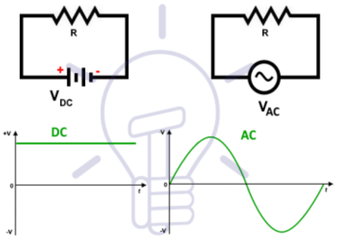
Alternating Current

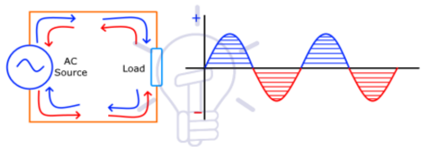
A. DEFINITION

An alternating current is a current whose magnitude and direction varies periodically.

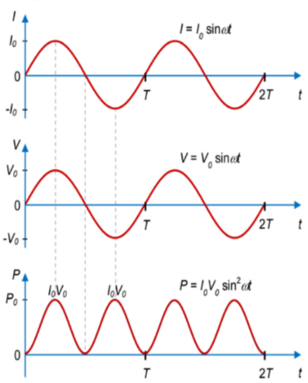


- Direct Current (DC), the current flowing around the loop in only one direction
- Alternating Current (AC), the direction of current around the loop goes back and forward





Alternating Current



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

$$V = V_0 sin\omega t$$

$$P = I_0^2 R \sin^2 \omega t = \frac{V_0^2 \sin^2 \omega t}{R} = I_0 V_0 \sin^2 \omega t$$

(instantaneous power)

From the power-time graph, average/mean power is equal to half of P_0

For a fluctuating power of an AC, the mean or average value of its power is more useful & representative.

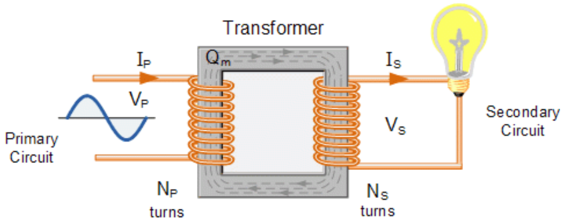
Mean Power
$< P > = \frac{1}{2} I_0 V_0 = \frac{1}{2} I_0^2 R = \frac{V_0^2}{2R}$
$< P > = R < I^2 > = \frac{< V^2 >}{R}$
$\frac{1}{2} I_0^2 = < I^2 >$ and $\frac{1}{2} V_0^2 = < V^2 >$
RMS
$I_{RMS} = \sqrt{< I^2 >}$
$I_{RMS} = \frac{I_0}{\sqrt{2}} = 0.707\ I_0$
$V_{RMS} = \frac{V_0}{\sqrt{2}} = 0,707\ V_0$

- $< P >$: average power
- RMS: Is a voltage or current that can deliver the same amount of power as its equivalent DC voltage or current over a resistive load.

Hence,

- $1V_{RMS}$ AC delivers the same power as $1V$ DC over a 1 ohm resistor
- $1A_{RMS}$ AC will produce exactly the same heating effect in a resistor as $1A$ DC

B. TRANSFORMER



A transformer converts an a.c. voltage to another a.c. voltage of different magnitude using electromagnetic induction.

- The I_p produces magnetic field on the primary coil
- The alternating current allows the magnetic field to change direction regularly as the current reverses its direction. In other word, direct current cannot be used in transformer
- The secondary coil is thus in a changing magnetic field since the magnetic field from the primary coil cuts the secondary coil
- e.m.f is induced on the secondary coil and the Induced current flows towards the lamp

The main function of the **iron core** is to drastically increase the flux linkage between the primary and secondary coils and thereby improve the efficiency of conversion.

Ideal transformer:

- no power loss in the transformer
- Input Power = Output Power

$$P_p = P_s$$

$$I_p V_p = I_s V_s$$

$$\frac{N_p}{N_s} = \frac{V_p}{V_p} = \frac{I_s}{I_p}$$

Step Up Transformer: Used to increase voltage

- AC voltage is stepped up before transmitting electrical power over long distance transmission lines
- $V_s > V_p$ and $N_s > N_p$

Step Down Transformer: Used to decrease voltage

- Voltage is stepped down near the users or before reaching housing
- $V_s < V_p$ and $N_s < N_p$

Real transformers have efficiency of about 94% to 99%

C. ENERGY LOSS IN PRACTICAL TRANSFORMER

- Some power is lost as the magnetic flux flows back and forth. To minimize this, a soft magnetic material is used where magnetic flux direction can change easily.
- Some power lost due to resistive heating in the primary and secondary coils. The coils are made of a low resistivity metal.
- Heating of the core due to repeated magnetisation and demagnetisation.
- Heating of the core due to eddy currents.

Eddy Currents: if a metallic conductor moves in a magnetic field, an e.m.f. is induced which will make free e^-s in the metal move, causing electric current

D. TRANSMISSION OF ELECTRICAL ENERGY

Electricity transmission lines have resistance, therefore, energy will be lost through heating in the wires.

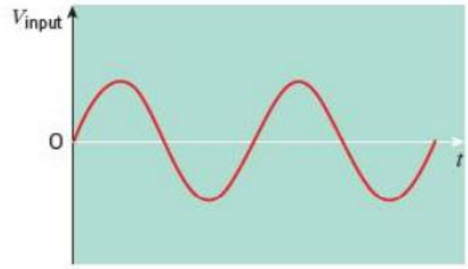
Electricity transmitted at high voltage a.c. supply:

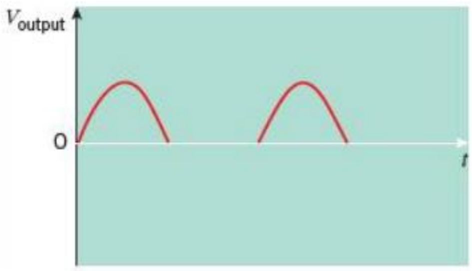
- **High voltage:** for same power, current is smaller so less heating and voltage loss in cables/wires
- **A.c. supply:** can change output voltage efficiently using transformers

E. RECTIFICATION

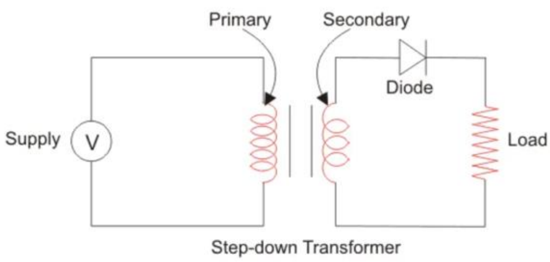
Half-wave rectifier

Half-wave rectifier is defined as a type of rectifier that only allows one half-cycle of an AC voltage waveform to pass, blocking the other half-cycle.



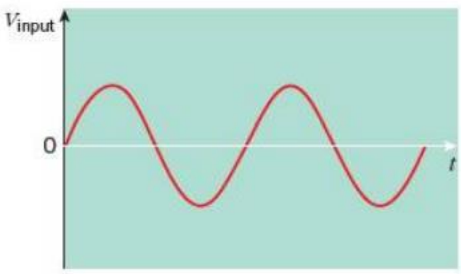


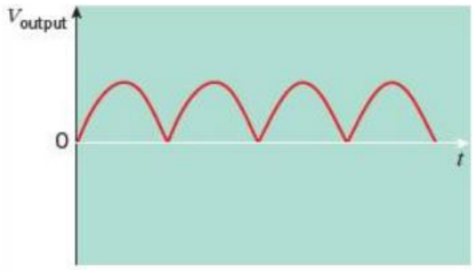
A half-wave rectifier circuit diagram looks like:



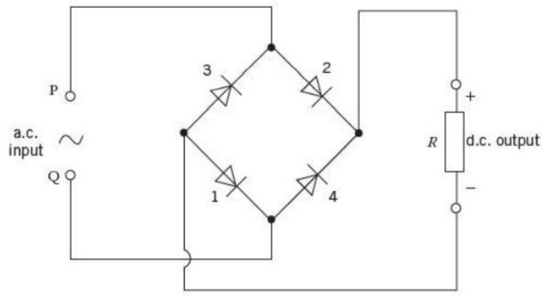
Full-wave rectifier

Full-wave rectifier is defined as a type of rectifier that coverts both halves of each cycles of an alternating wave (AC signal) into a pulsating DC signal.



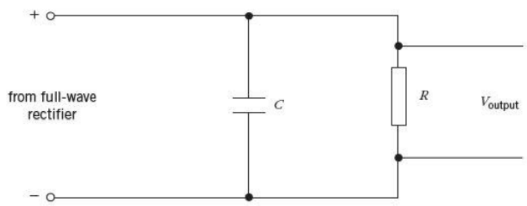


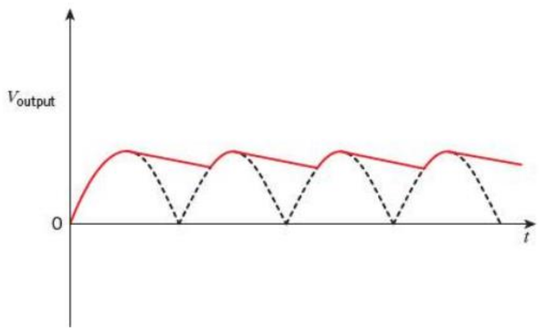
A full-wave rectifier circuit diagram looks like:



F. SMOOTHING

The capacitor charges up on the rising part of the half-cycle, and then discharges through the resistor as the output voltage falls. The effect is to reduce the fluctuations in the unidirectional output. This process is called **smoothing.**





C. EXERCISE

- Write down the equation for a sinusoidal voltage of 50 Hz and its peak value is 20 V. Draw the corresponding voltage versus time graph.

Solution:

$f = 50\ Hz$

$V_0 = 20\ V$

Instantaneous voltage,

$V = V_0 sin\omega t = V_0 sin2\pi vt$

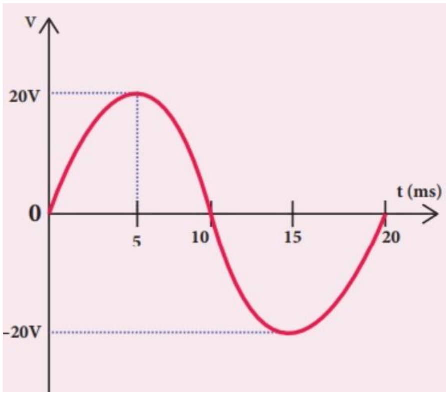
$V = 20\sin(2\pi \times 50)\,t$

$\quad = 20\sin(100 \times 3.14)\,t$

$V = 20sin3.14t$

Time for one cycle, $T = \frac{1}{f} = \frac{1}{50} = 0.02s$

$= 20 \times 10^{-3}s = 20\ ms$



- (a) the peak voltage of an ac supply is 300V. what is the rms voltage?
(b) the rms value of current in an ac is 10A. what is the peak current?

Solution:

(a) Rms voltage is given as $V = \frac{V_0}{\sqrt{2}}$

$$V = \frac{300}{\sqrt{2}} = 212.1\ V$$

(b) Peak current is given as $I_0 = \sqrt{2}I$

$$I_0 = 10\sqrt{2} = 14.1\ A$$