Formulas

- $\Psi = \Psi_0 \sin \omega t$ or $\Psi = \Psi_0 \cos \omega t$

- $\Psi_{rms} = \frac{\Psi_0}{\sqrt{2}}$

- Amplitude $= \Psi_0$

- Frequency $= \frac{\omega}{2\pi}$

- $I_{rms} = \frac{I_0}{\sqrt{2}}$ $V_{rms} = \frac{V_0}{\sqrt{2}}$ } for sinusodial waves.

Voltage in primary coil of a transformer

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

Number of turns in secondary coil

- The r.m.s value of alternating current or voltage is that value of direct current or voltage that would produce thermal energy at the same rate in a resistor.

Equation of Alternating Current

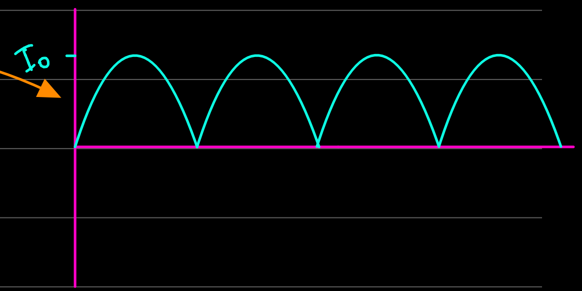
- $I = I_0 \sin \omega t$ (1)

$\therefore P = I^2 R$

sub (1) into

$\therefore P = I_0^2 \sin^2 \omega t \; R$

graph of sin²



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

these "Brackets" show we are finding mean power

- Direct Current Power = Mean value of AC power

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

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

$$\langle P \rangle = \frac{V_0^2 \times \frac{1}{2}}{R} = \frac{V_0^2}{2} \div \frac{R}{1} = \frac{V_0^2}{2R}$$

Deriving root mean square Current and Voltage

- Alternating Current equation $\Rightarrow$ $I = I_0 \sin \omega t$

$\therefore$ $I_{rms} =$

$$I^2 = I_0^2 \sin^2 \omega t$$

$$\langle I^2 \rangle = I_0^2 \times \frac{1}{2}$$

$$\sqrt{\langle I^2 \rangle} = \frac{\sqrt{I_0^2}}{\sqrt{2}}$$

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

- Similary V_{rms} can be derived too

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

$$V^2 = V_0^2 \sin^2 \omega t$$

$$\langle V^2 \rangle = V_0^2 \times \frac{1}{2}$$

$$\sqrt{\langle V^2 \rangle} = \frac{\sqrt{V_0^2}}{\sqrt{2}}$$

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

Conclusion: For any sinusoidal variables, its RMS value is

$$\frac{\text{Peak Value of Variable}}{\sqrt{2}}$$

A few more Examples

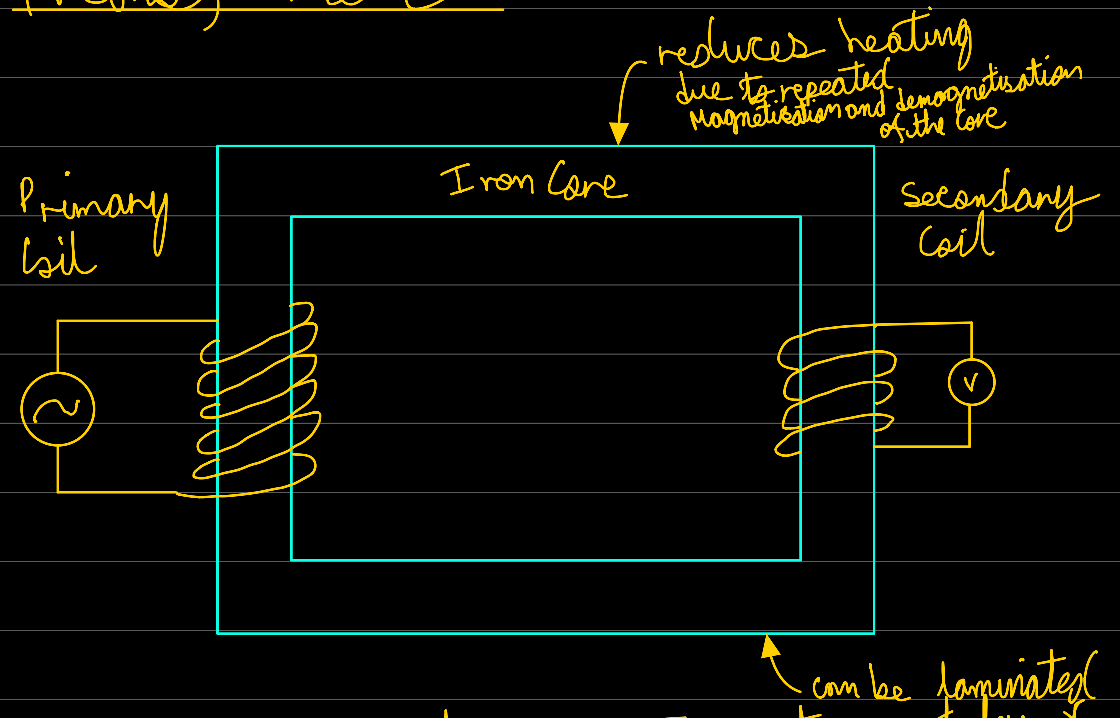
- $F = BIL \sin\theta$

$$F_{rms} = \frac{BIL}{\sqrt{2}}$$

- $V_H = \frac{B \sin\theta \, I}{net}$

$$V_{H rms} = \frac{\left(\frac{BI}{net}\right)}{\sqrt{2}}$$

Transformers



EMF in secondary coil = $\frac{-d\Phi}{dt}$

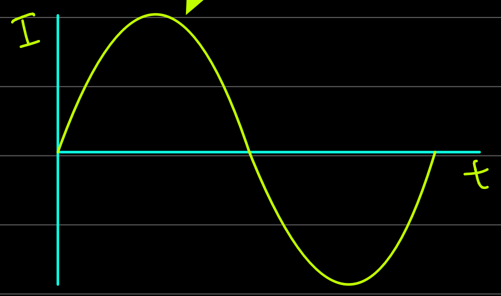
- if $V_p > V_s$ then its a step-down transformer, and vise versa

In practice, the transformer will not be 100% efficient due to power losses. Some sources of these losses are:

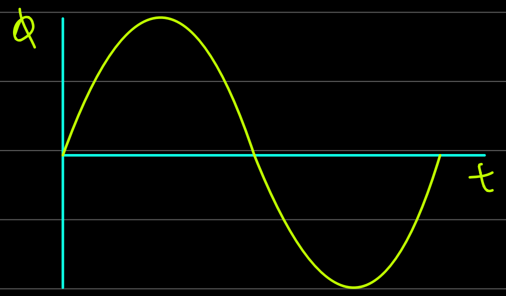
- loss of magnetic flux between the primary and secondary coils. The core is designed for maximum flux linkage. The iron core forms a closed loop and the primary and secondary coils are wound on each other.
- resistive heating in the primary and secondary coils. The coils are made of a low resistivity metal.
- heating of the core due to eddy currents.
- heating of the core due to repeated magnetisation and demagnetisation.

Graphs

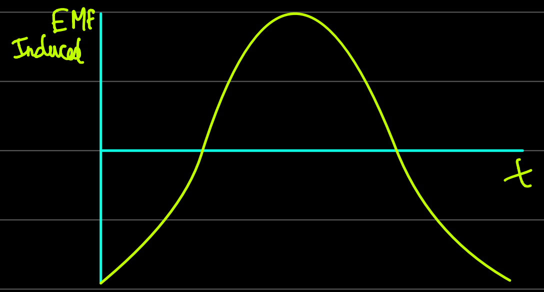
- if given this I vs t graph and asked to draw Φ vs t and EMF vs t



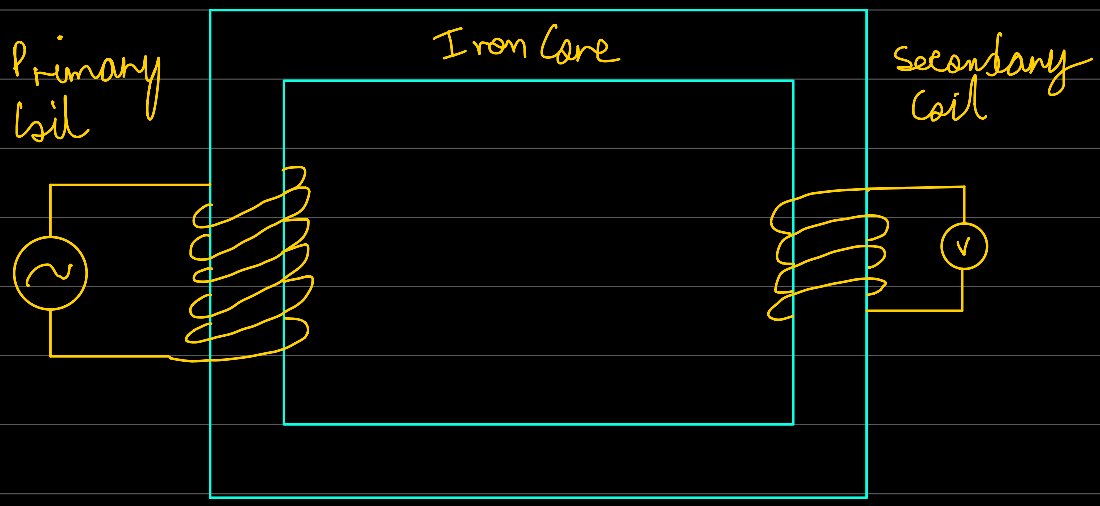
- draw Φ vs t $\qquad I \propto \Phi$



- draw EMF induced vs t $\qquad EMF = -\frac{dI}{dt}(NB)$



Ideal transformers



- In an ideal transformer there are no losses so Power in primary coil = Power in Secondary Coil.

$$P_p = P_s$$

$$I_{rms\_p} \times V_{rms\_p} = I_{rms\_s} \times V_{rms\_s}$$

$$\therefore \frac{I_p}{I_s} = \frac{V_s}{V_p}$$

- Also, connection between No. of turns and voltage:

$$V_{induced} = \frac{-d\Phi}{dt} = \frac{N\,d\Phi}{dt}$$

$$\therefore \quad V_p = \frac{N_p\,d\Phi}{dt} \quad \text{and} \quad V_s = \frac{N_s\,d\Phi}{dt}$$

dividing both the Equations

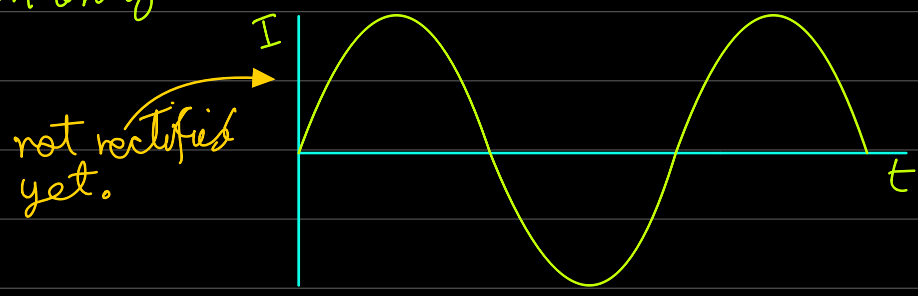
$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

keep in mind, this is upside down.

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

Rectification

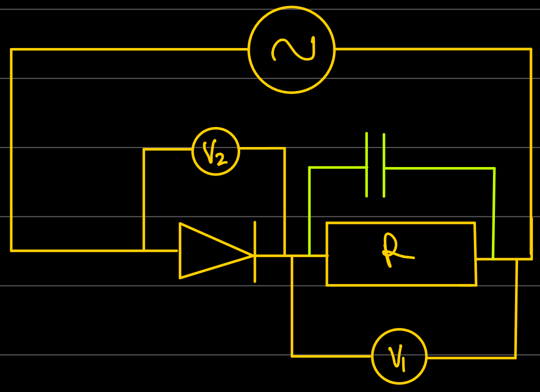
- Used to convert AC to DC
- Is done using a diode as it allows flowing current in 1 direction only



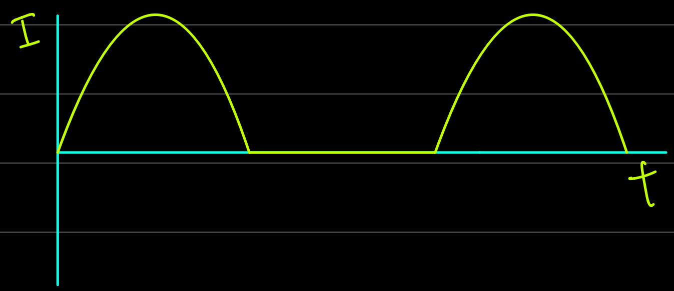
Types of rectification

1) Half wave rectification

- As the diode allows only positive current, the negative part of the graph becomes 0

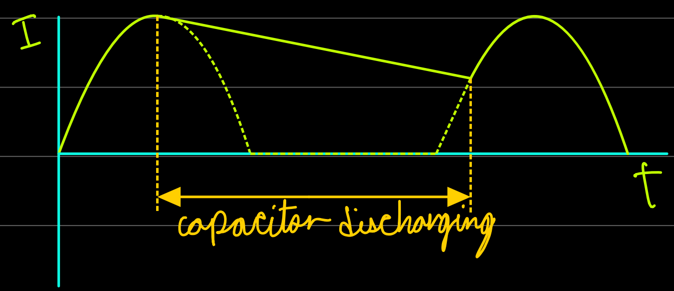


- After Half wave rectification, no capacitor



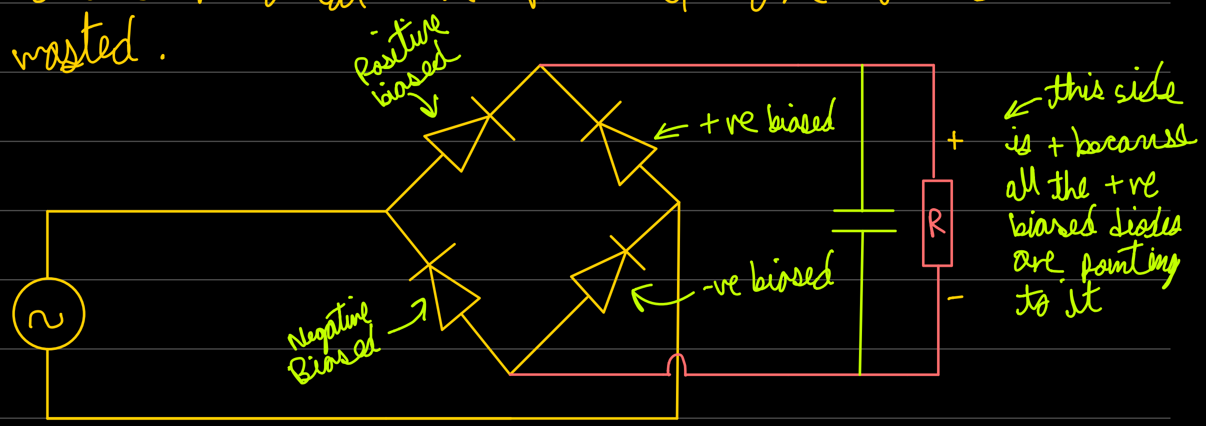
- A capacitor can then be added to the circuit to make it a bit more like DC, however full bridge rectification is required for making full DC

- After Half wave rectification with capacitor

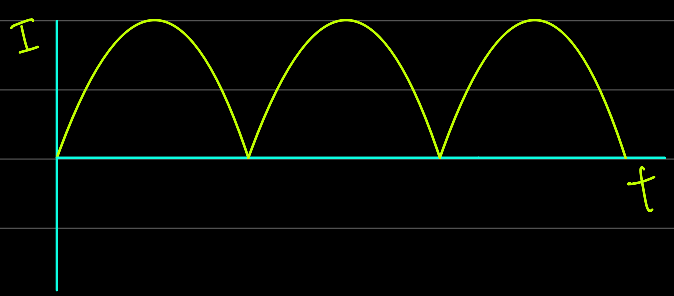


2) Full wave rectification

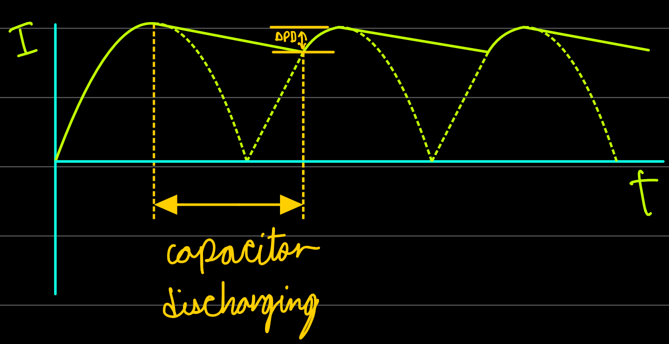
- Uses 4 diodes instead, and in a specific arrangement to ensure that -ve part of the wave isnt wasted.

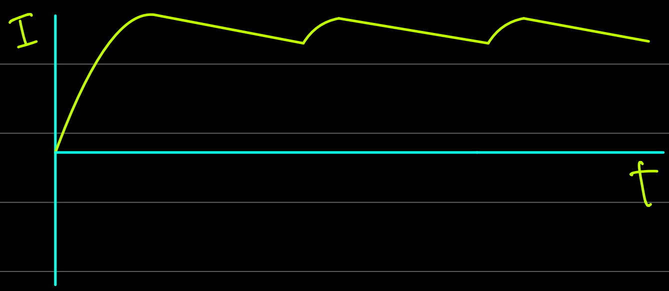


- After full wave rectification, no capacitor

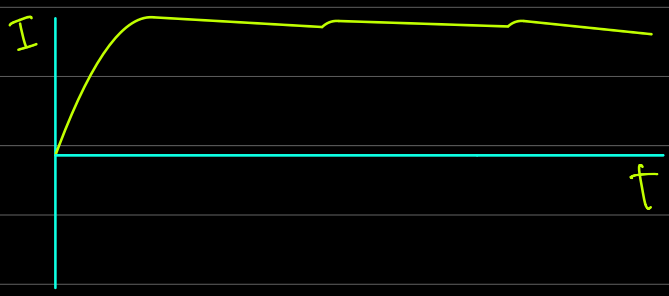


- After full wave rectification with capacitor





- This use of capacitors is called "smoothing"
- If R or C is increased the ΔPD decreases and the current becomes smoother, thus "better" DC forms.



FAQ about transformers

1) Suggest why the iron core is
a) a continuous loop
To improve the magnetic flux linkage with secondary

b) laminated
To reduce energy losses due to eddy currents

2) Suggest why the primary and secondary coils are wound on a core made up of iron
To improve the magnetic flux linkage

3) Suggest why thermal energy is generated in the core when the transformer is in use.
The flux in the core is constantly changing, so the current is induced in the core which contributes to heating.

4) Use Faraday law to explain why the potential difference in the secondary coil and the emf of the supply are not in phase
the magnetic flux is in phase with the current in the primary coil and the emf across the secondary coil is proportional to the rate of change of flux, so

Emf of supply is not phase with the secondary

$\frac{dy}{dt}$ ∴ sin turns into cos

5) Electrical energy is usually transmitted using AC, suggest why the transmission is acheived using

a) High voltage

for the same power trasmission, high voltages are trasfered with low current and as the energy losses in the transmission cable is proportional to I^2, the enerengy loss will be less

b) Alternating current

so the voltage is easily changed, so that it can be used for various appliances

Example of how there is less power loss at higher voltage

A small town, several kilometres from an electricity generating station, requires 120 kW of power on average. The total resistance of the transmission lines is 0.40 Ω. Calculate the power loss if the transmission is made at a voltage of **(a)** 240 V, **(b)** 24 kV.

First calculate the current I in the transmission lines in each case.

In **(a)**, $I = P/V = 1.2 \times 10^5/240 = 500\,\text{A}$.

In **(b)**, the same calculation gives $I = 5.0\,\text{A}$.

Now find the power loss in the transmission lines from $P = I^2R$.

In **(a)**, it is $(500)^2 \times 0.40 =$ **100 kW**, or more than 80% of the power required by the town.

In **(b)**, the power loss is $5.0^2 \times 0.40 =$ **10 W**, less than one-hundredth of 1% of the power requirement.