Q. No. 2 Part (i) **Coulumb's Law :-**

Coulumb's Force is given by following formula,

$$F = \frac{K q_1 q_2}{r^2}\hat{n}$$

$$F_{vacuum} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} \quad -(1)$$

here ε_0 is the permittivity of free space.

But if we add a medium, the permittivity is,

$$\therefore \varepsilon_r = \frac{\varepsilon_{med}}{\varepsilon_{vac}}$$

$$\varepsilon_{med} = \varepsilon_r \varepsilon_0$$

$$F_{med} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1 q_2}{r^2}$$

$$F_{med} = \frac{1}{4\pi\varepsilon_{med}}\frac{q_1 q_2}{r^2}$$

using - (1)

$$F_{med} = \left(\frac{F_{vac}}{\varepsilon_r}\right)$$

$$\varepsilon_r = \frac{F_{vac}}{F_{med}}$$

NOW we know that $\varepsilon_r > 1$, which implies that $F_{vac} > F_{med}$

hence when a medium is placed, the **Coulumb's Force decreases** and has a greater value in free space.

Q. No. 2 Part (ii) **Bohr's model :-**

(1) For Bohr's model, the electrostatic force between positively charged nucleus and electron is equal to the centripetal force, and **centripetal force** is provided by Coulumb's electrostatic force,

$$F_c = F_{coulumb}$$
$$\frac{mv^2}{r} = \frac{ke^2}{r^2}$$

(2) electron can only revolve in certain orbits, whose **angular** momentum is an integral multiple of $h/2\pi$, hence

$$L_n = mvr = \frac{nh}{2\pi}$$

(3) lastly, bohr's model states that when an electron shifts between an energy level of $E_n = nhf$ to or from $E_p = nhf$, it emits or absorbs an energy of $E = hf$. When it goes to a higher orbit, it absorbs energy and when it goes to lower orbit it emits energy. It can only orbit in an orbit of energy $E_n = nhf$

$$hf = E_n - E_p$$

Q. No. 2 Part (iii) **Electron and proton :-**

A protons mass is **1840** times greater as that of an electron, and the deborgiie wavelength is given as $\lambda = \frac{h}{mv}$, now if we are to find the relation between speed and mass, while keeping 'h' and 'λ' constant.

$\lambda = \frac{h}{mv}$

$v = \frac{h}{m\lambda}$

$v \propto \frac{1}{m}$

$\mathbf{v \propto \frac{1}{m}}$

- Thus a particle with greater **mass** has less **velocity** as they're inversely proportional
- **Electron** has less mass than a proton, so its speed shall be **more** than proton.

Q. No. 2 Part (iv) **Max compton shift :-**

The mathematical expression is as,

$\Delta\lambda = \frac{h}{m_o c}(1-\cos\theta)$

where compton shift is $\Delta\lambda$.

$\Delta\lambda = \frac{h}{m_o c}(1-\cos 180)$

compton shift is maximum at an angle of **180°**.

$\Delta\lambda = \frac{h}{m_o c}(1+1)$

$\Delta\lambda = \frac{2h}{m_o c}$

NOW to put values,

$h = 6.63\times10^{-34}$ Js

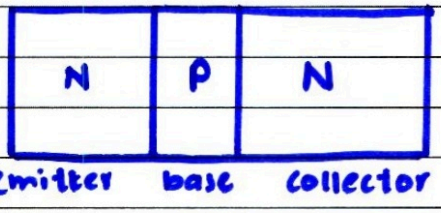
$m_o = 9.1\times10^{-31}$ kg

$c = 3\times10^{8}$ m/s

$\Delta\lambda = \frac{2\times6.63\times10^{-34}}{9.1\times10^{-31}\times3\times10^{8}}$

$\Delta\lambda \approx 4.85\times10^{-12}$ m

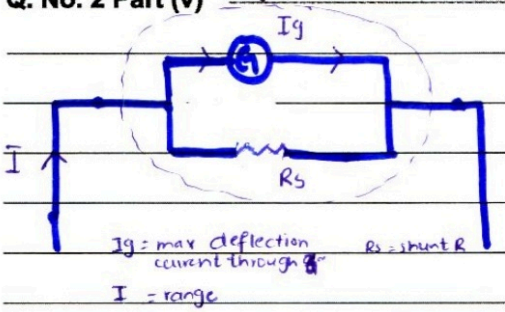
Q. No. 2 Part (ix) **NPN transistor:-**



In an NPN transistor, there are three regions, that are called emitter, base and collector respectively, and in NPN transistor, the **P-type** semiconductor is sandwiched between two N-type and it has a majority charge carriers as **electrons** and minority as **holes** and NPN transistors give more mobility as electrons are **3 times** more mobile than protons. The area of emitter is less than collector and electrons move from emitter to collector, due to high voltage of the collector. The **impurity** of emitter however is greatest, and that of base region is lowest so it doesn't allow more **transit** time and any **recombination** of charges.

$$I_e = I_B + I_C$$

Q. No. 2 Part (v) **Galvanometer to ammeter:-** $R_s = \frac{I_g R_g}{I - I_g}$



Following is the conversion of galvanometer into an ammeter by connecting a **shunt resistance** parallel to the galvanometer. Shunt resistance is a **low** resistance that is used to divert the **current flow** so that maximum current can flow through a second path as the galvanometer shows **full deflection** at a low current so it must be **calibrated** so that it may measure **large** current, and for that a parallel path to current should be provided so max current flows through (R_s) and (I_g) flows through G, in parallel,

voltage through shunt = V through G

$V_s = V_g$

$I_s R_s = I_g R_g$

$(I - I_g) R_s = I_g R_g$

$$R_s = \frac{I_g R_g}{I - I_g}$$

Q. No. 2 Part (vi) **Power Losses:-**

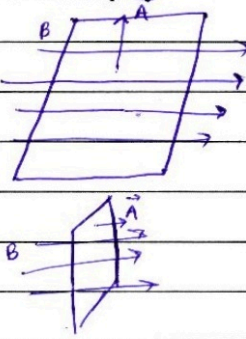
The following can cause power losses,

① **Eddy current:** are produced when a conductor is placed in a changing mag field, and flow perpendicular to mag field lines. Eddy currents cause heating and then cause power loss.

② **Flux leakage:-** Flux leakage due to gaps between primary and secondary causes some flux to be lost and then causes power losses, so we must do **tight coupling** is transformer to ensure that no air space is left.

③ **Hysterisis Loss:-** Hysterisis loss is due to the magnetisation and de magnetisation of the conductor makrial and some energy is lost, so a material of low hysterisis loss should be used for example **laminated soft iron** is a good material for this purpose.

Q. No. 2 Part (vii) **Magnetic Flux:-**



Magnetic flux is described as the **number of magnetic field lines** that pass through an area (that is placed perpendicular to it.) following is mathematical relation,

$$\Phi = \vec{B} \cdot \vec{A}$$

$$\boxed{\Phi = BA\cos\theta}$$

the unit of magnetic flux is **(Tm^2)** ore **(Wb)** (SI unit) and flux helps as determine the **strength of field** by analysing the field lines passing through an area, it is the **dot product** of magfield and area vector, it is when area vector is parallel to field ie. $\cos 0 = 1$, its called max flux and when area vector is perperdicular, it is ($\cos 90$) or minimum flux.

Q. No. 2 Part (viii) Current :-

$\mathcal{E} = 120\ V$

$R = 1000\ \Omega$

$r = 0.01\ \Omega$

$V_t = \mathcal{E} - Ir$

$IR = \mathcal{E} - Ir$

$IR + Ir = \mathcal{E}$

$I = \frac{\mathcal{E}}{R + r}$

$I = \frac{120}{1000 + 0.01}$

$I = 0.119\ A$

$I = 0.12\ A$

Q. No. 2 Part (x)

EMF	Potential Diff.
• It is the work done is moving a unit positive charge from -ve to +ve terminal of battery.	• It is the workdone is moving a unit positive charge from one point to other without acceleration.
• emf is the **cause**	• potential diff is **affect**
• emf has a **constant value**	• Potential difference has a **variable** value.
• Eemf is present even when circuit is open, **I=0.**	• Potential difference is not present when the circuit is open. **I=0.**
• It is represented by **$\mathcal{E}$**	• It is represented by **ΔV.**

Q. No. 2 Part (xi) **Moderators :-**

Moderators are used in a nuclear reactor, because they **slow down** the **thermal neutrons** and they are made of light materials for example **graphite and heavy water**, due to these a fissim thermal reaction is made possible.

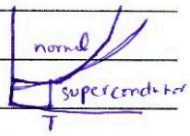
Control Rods:-

Control rods are also called arrestors and they **absorb** the fast moving neutrons, to control the **critical mass** and make sure that a **controlled fission reaction** happens as they're made of **hafnium, cadmium** and **Boron.**

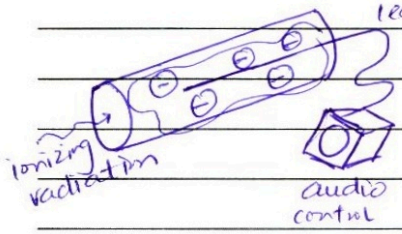
Q. No. 2 Part (xii) **Super conductors:-**

Super conductors are conductors that have very high conductivity at **zero resistance** such that no energy is lost as **heat**, and super conductors have a **critical temp** below which and at which a makrial becomes super conductive **(Tc)**, following are uses :-

1. **MRI** leads are made of super conductors.
2. **Maglev trains** are made of super conducton.
3. Super conductors are used in **particle acceleratn** in labs like **SCERN**
4. They are used in **magnetic leviatim** when a magnet opposes the super conductor like Yattrium banum copperoxide.



Q. No. 2 Part (xiii) **Geiger Muller:-**



When an ionizing radiation enters a gas cylinder that keeps gas at lower pressure, it **ionizes** that gas and makes it remove **free electron** and the wire is made positively charged so it conducts and attract the free electrons to make a **current** and electrons **ionize** the atoms in the way and constitute a **large current** such that it is heard at the **audio and control device** that counts are detects the current change and **pulses.**

Q. No. 2 Part (xiv) **Maximum Power:-**

When $R = r$, max power is transmitted,

$P = I^2 R$

$P = \frac{(\mathcal{E})^2}{(R+r)^2} R$

$P = \frac{\mathcal{E}^2 R}{(R-r)^2 + 4Rr}$ $\because (R=r)$

$P = \frac{\mathcal{E}^2 R}{(R-R)^2 + 4RR}$

$P = \frac{\mathcal{E}^2 R}{4RR}$

$P = \frac{\mathcal{E}^2}{4R} = \frac{\mathcal{E}^2}{4r}$

$\because (R+r)^2 = R^2 + 2Rr + r^2$
$= R^2 + 4Rr + r^2 - 2Rr$
$= (R-r)^2 + 4Rr$

, so max power is delivered in such a way.

Q. No. 3 (Page 1)

AC GENERATOR :-

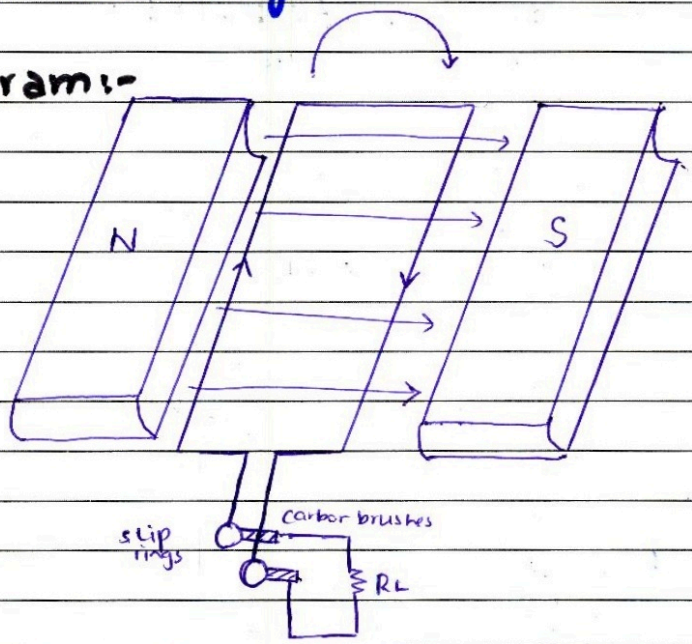
Definition :- AC generator is a device that converts input mechanical energy into output electrical energy.

AC generator :- is a device that converts mechanical energy into AC current.

Principle :- Faraday's law of electromagnetic induction

Construction :- The ac generator is made up of a **coil / armature** that is placed in a **radial** magnetic field or between **concave** poles of a magnet. The mag field is directed from N to S, and the ends of coil is connected to two **slip rings** and the slip ring are connected to **carbon brushes**, such that brushes are connected to a **load** and remain **stationary.**

Diagram :-



Working :-

As per the stated principle, when a conductor (coil) with 'N' turns is rotated in a mag field, an emf is induced that allows a current to flow through the coil, such that the direction of the current is found by Flemming **right hand rule** and it rotates **CLOCKWISE** in this case. Due to induced emf, an **INDUCED CURRENT** flows.

Mathematically :-

Induced emf is given as,

$\mathcal{E}$: emf induced
N : number of turns
$\frac{\Delta\phi}{\Delta T}$: rate of change of flux.

$$\mathcal{E} = -N \frac{\Delta \phi}{\Delta T}$$

as the expression is direction sensitive, the negative sign as per **Lenz's** law must be incorporated, so now,

$$\mathcal{E} = -N \frac{\Delta AB \cos\theta}{\Delta T}$$

$$\mathcal{E} = -NAB \frac{\Delta}{\Delta T} \cos\theta$$

Here N, A, B are all constants.

$$\mathcal{E} = -NAB \frac{\Delta}{\Delta T} \cos \omega t \qquad \therefore \theta = \omega t$$

$$\mathcal{E} = -NAB(-\sin \omega t)\omega$$

$$\mathcal{E} = N\omega AB \sin \omega t$$

$$\mathcal{E} = N\omega AB \sin 2\pi f t$$

$$\mathcal{E} = \mathbf{N\omega AB \sin \frac{2\pi}{T} (t)}$$

max emf is at $\sin 90$.

Q. No. 3 (Page 3) hence, it can be written,

$\mathcal{E} = \mathcal{E}_{max} \sin \omega t$, $I_{induced} = I_m \sin \omega t$

Induced Current:-

$\mathcal{E}_{max} = NwAB \sin 90$

$\mathcal{E}_{max} = NwAB$

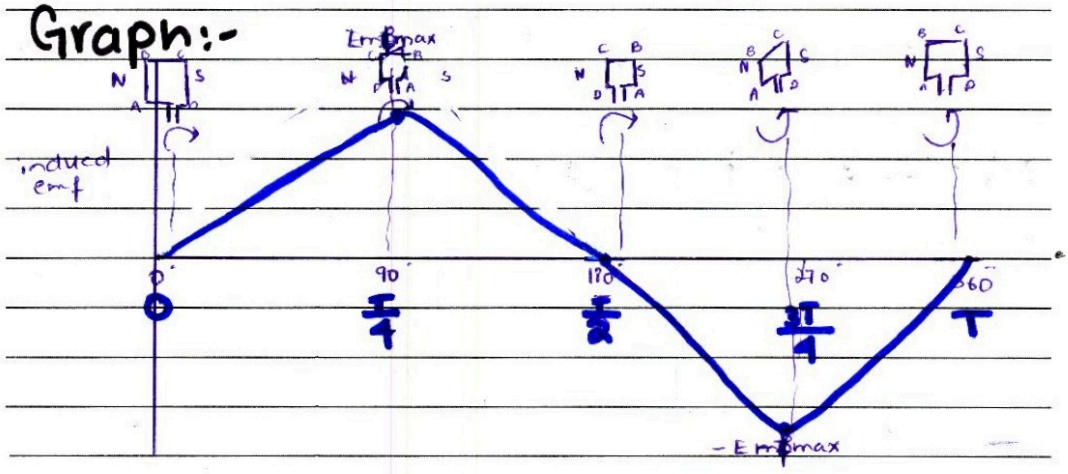
$\mathcal{E} = \mathcal{E}_{max} \sin \omega t$

$\frac{\mathcal{E}}{R} = \frac{\mathcal{E}_{max}}{R} \sin \omega t$

$I = I_{max} \sin \omega t$.

$I = I_{max} \sin \omega t$.

Graph:-

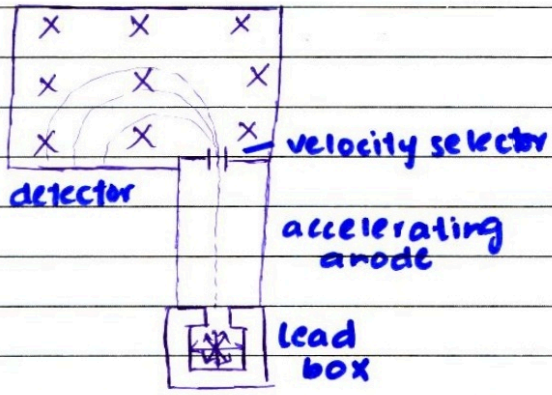


- At time T=0, the flux is max, but the $\Delta\phi$ change in flux is **min** and induced emf is also min, and indued current is min.
- At time T=T/4, the flux is min, but the $\Delta\phi$ is **max** so the induced emf is max, and induced current is max.
- At time T= T/2, flux is max, but $\Delta\phi$ is minimum so the induced emf in min and induced current is minimum
- At time T=3T/4, the direction of current reverses, and the change in flux is min, but $\Delta\Phi$ max, so emf is max and opposite to what was induced at T=0.
- At time T= T, the flux is ~~minimum~~ max, the change in flux is minimum, and emf induced and current induced is at its minimum value.

Q. No. 4 (Page 1) **MASS SPECTROGRAPH :-**

Definition:- A mass spectrograph is a device used to find **masses** of charged nuclei, and it is also used to find the **abundance** of an isotope. Mass spectrograph can **seperate** isotopes of an element by **physical** means.

Diagram:-



Construction and Working :-

A mass spectrometer has a **lead box**, that is a very dense material that shields from radioative radiations, and an ~~excited~~ isotope placed in it, so when the isotope is **vapnized** it becomes charged, and the **accelerating plates** increase its speed, and the **velocity selector** only allows specific velocities to enter. The beam is projected **perpendicularly** into the magnetic field, such that it is made to deflect in a **semicircular path** and that path is detected by the detectors.

Q. No. 4 (Page 2) **Working:-**

lead is used as it is a dense makrial and protects from radiation, the accelerating plates provide electric field to the vaporized beam, such that it is kept at point pressure to vaporize and velocity selector is used to seprate different ~~mass~~ velocities of particles such that due to centripetal force, the semicircular path occurs.

Mathematically:-

the beam is provided a kinetic energy by applying a potential difference **V** so that, following value for velocity is obtained,

$$\frac{1}{2}mv^2 = qV$$

$$v^2 = \frac{2qV}{m}$$

$$v = \sqrt{\frac{2qV}{m}} \quad -①$$

now we know that the magnetic force provides the centripetal force,

$$\frac{mv^2}{r} = qvB$$

$$\frac{mv}{r} = qB$$

$$v = \frac{qrB}{m}$$

using -①

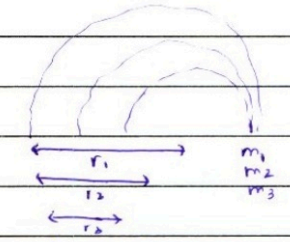
$$\sqrt{\frac{2qV}{m}} = \frac{qrB}{m}$$

$$\frac{2qV}{m} = \frac{q^2r^2B^2}{m^2}$$

Q. No. 4 (Page 3) $\frac{2Vm}{qB^2} = r^2$

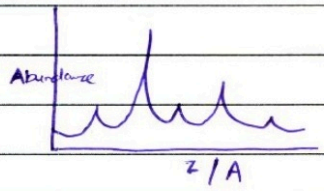
$$\sqrt{\frac{2Vm}{qB^2}} = r$$

hence, we are with the following expression that $r \propto \sqrt{m}$ (of isotopes), thus it is said that a greater mass leads to a greater radius of the semi circular path, such that. We can see through the **detector** that greater mass of isotopes produced a greater **length** of path, as in the given diagram.



$m_1 > m_2 > m_3$

Abundance :-



We may also find the **abundance** of different nuclei in the nature, and make an abundance **graph** based on the **concentrations** in the environment and the earth. Abundance of Nitrogen for example and its isotopes is found so..

Q. No. 5 (Page 1)

X-RAYS :-

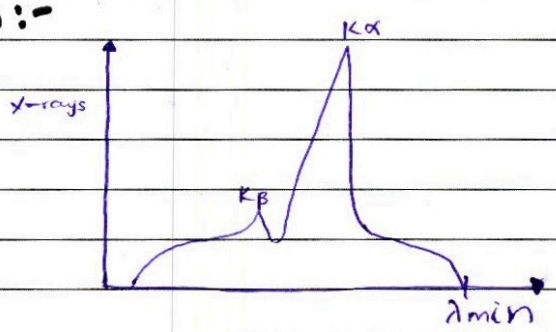
X-rays are **high energy photons** that have wavelengths in the orders of **Angstorms (1×10^{-10})** X-rays are generated only by the inner shell transition of heavy elements and into deeper levels like $n=1$, $n=2$.

Production :-

X-ray production is opposite of photoelectric effect such that electrons are made to fall on an **anode** target and high **frequency** and **energy X-rays** are generated in this process. There are 2 types of X-rays,

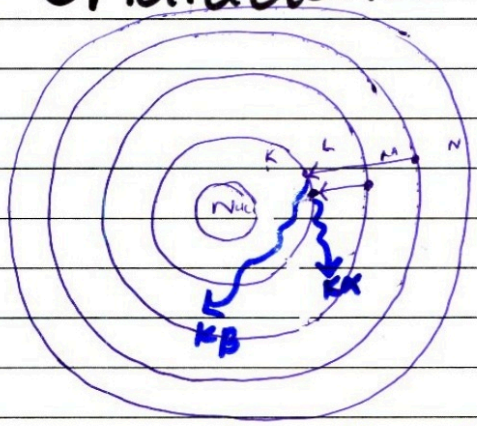
1. **Characteristic X-rays**
2. **Bremstauhling X-rays / continuous.**

Diagram :-

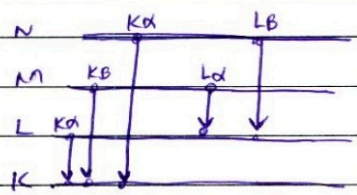


Following is the general diagram for X-rays that shows continuous aswell as characteristic X-rays, and the λmin represents an x-ray that comes out with max frq and energy and minimum wavelength.

Characteristic X-rays:-



Following is the diagram for characteristic X-rays such that, when an electron from higher orbit comes to **knock out** an electron from a lower orbit, it leaves a holes and a second electron comes to **fill the vacancy** such that a **photon** of some energy and some **freq and wavelength** is emitted and that photon's energy is characteristic because energy levels are **defined** and only a level of **E=hf** can cause an electron, to exist. Following diagram shows that a transition into the level n=1 or K, is represented by Kα and from n=2 is represented by Kβ. Like wise transition from M shell into L shell takes form of ~~energy~~ M and N cause **Lα and Lβ.**



Frequencies and Wavelengths:-

Lastly, we must acknowledge that wavelength of $K\alpha$ is greater than that of $K\beta$ and also $K\alpha$, such that

$$\lambda_{K\alpha} > \lambda_{K\beta} > \lambda_{K\gamma}$$

and also for frequencies and energies,

$$\text{Energy}_{K\alpha} < \text{Energy}_{K\beta} < \text{Energy}_{K\gamma}$$

So $K\alpha$ has the lowest energy and highest wavelength.

USES:-

They are used for diagnostic, medical, and industrial processes.

Q. No. 6 (Page 1)

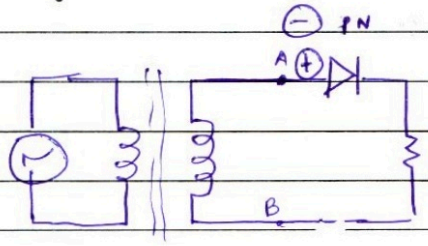
RECTIFICATION:-

Definition:

Rectification is defined as the process in which an AC current is converted into DC current by a PN junction, and it is because AC current is not required by a specific circuit and DC current is required.

DC sources have low power, expensive price and are short lived, so we convert AC to DC by a **PN-junction diode.**

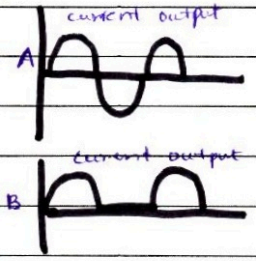
① Half Wave Rectifier:-



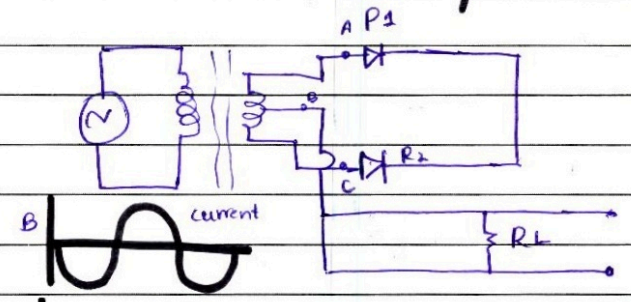
For a half wave rectifier, a single **diode** is used with a step down **transformer** that converts a voltage input of **220 to 240 V** to **5-10 V** by a single diode. Usually these are not **sufficient** enough for practises, as they only transform one half cycle.

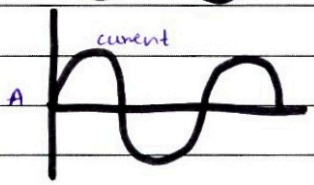
When the alternating current is turned on, an alternating current flows and

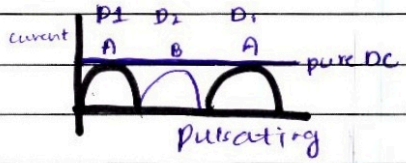
transformer allows to protect from electrical hazards, point A becomes positively charged and the current flows are it is forward biased, but in the negative half, the current flows but the junction becomes negative from P-side such that its **reverse biased** and no current flows. We say that only half wave is conducted, and we say that **PIV** is the peak inverse voltage diode has to withstand and **V_{max}** is max voltage that appears across diodes. The whole wave has not been rectified in half-wave rectification.



(2) Full Wave Rectifier:-







In the positive half cycle, point A becomes **positive** with respect to point B, and it allows point B to become **positive** with respect to point C, such that now the first diode is **forward** biased and **second diode**

is reverse biased.
In the negative half cycle, point A becomes negative with respect to point B and point B becomes **negative** with respect to C, so only current flows due to **D_2** and we say D1 is **reverse biased** and D2 is **forward biased.** so in first cycle current flows due to D1 and in second cycle due to D2 only.

Full wave rectifier uses a **filter circuit** to convert the **pulsating DC** into a **pure DC**, and thus the whole wave is completely **rectified, during both cycles.**

It basically uses a **transformer and** the phenomenon of **mutual induction** to allow current to pass through both coils and it is **most commonly used** rectifier.