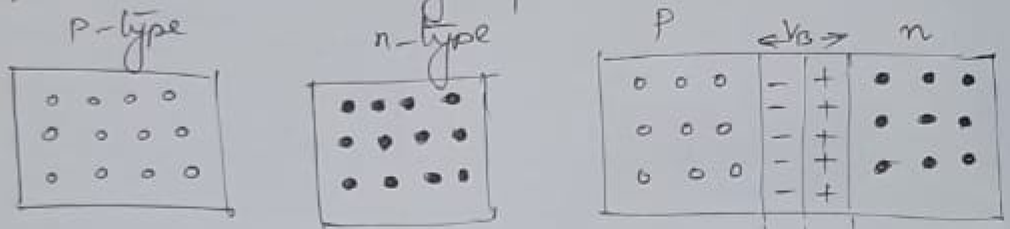
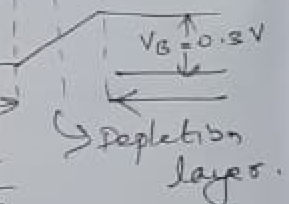
PN Junction:

When a p-type semiconductor is suitably joined to n-type semiconductor the contact surface is called pn junction.

Most of the semiconductors have more than one or more pn junction. PN junction is ~~fabib~~ fabricated by special techniques.

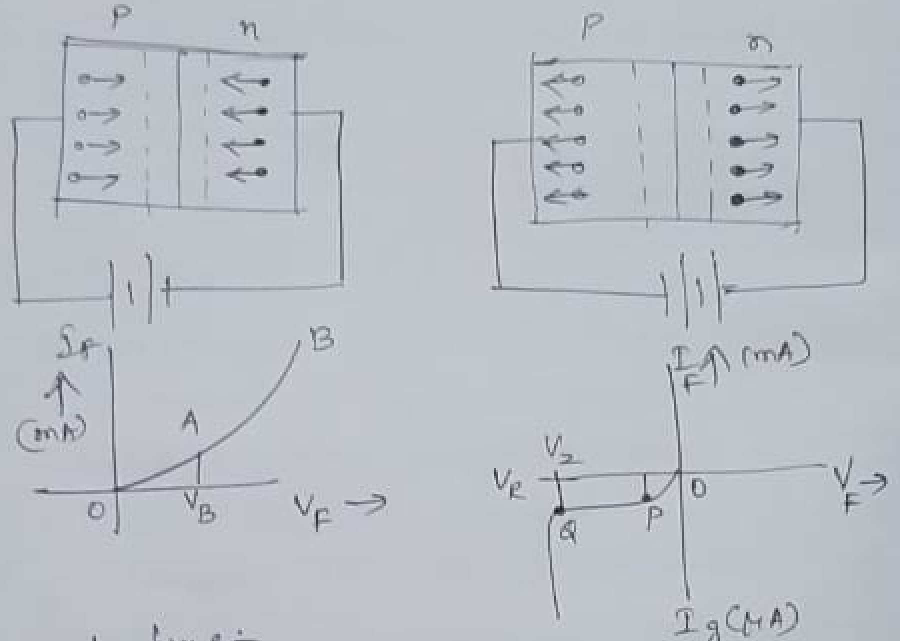


When a pn junction is formulated suitably. There is a tendency for the free electrons from n-side to diffuse over the p-side of the junction and holes from p-side to n-side. Both the regions are initially electrically neutral, a positive charge is built on the n-side and negative charge in the p-side of the junction. This situation soon prevents further diffusion. It is because how positive charge on n-side repels holes to cross from p type to n-type and negative charge on the p-side repels free electrons to



ent from n-type to p-type. This a barrier is set up against further movement of charge carriers i.e., holes and free electrons. This is called potential barrier. potential barrier is of the order of 0.1 to 0.7 V.

V-I characteristics of pn junction diode:-



Forward bias:-

To apply forward bias connect positive terminal of the battery to p-type and negative terminal to n-type. The applied forward potential establishes an electric field which acts against the field due to potential barrier. As potential barrier is very small (0.1 to 0.7 V), therefore a small forward voltage is sufficient to completely eliminate the potential barrier. Once the pot. barrier is eliminated by the forward bias, junction resistance becomes almost zero and current flows in the circuit.

(1) The potential barrier is reduced and at some forward bias it is eliminated. (0.3 to 0.7 V)

(2) The junction offers low resistance to current flow.

(3) Current flows in the circuit. depends on applied foward voltage.

$V_F - I_F$ curve: The current increases very slowly and the curve is non-linear. It is because the external applied voltage is used in overcoming the potential barrier. However once the external voltage exceeds the potential barrior voltage the pn junction becomes like an ordinary conductor. The curve is almost linear.

Reverse biasing:

When an external d.c voltage applied to a pn junction, is in such a direction that potential barrior is increased, it is called reverse biasing.

To apply reverse bias, connect negative terminal of battery to p-type and positive terminal to n-type. Graph shows clearly that reverse voltage establishes an electric field which acts in the same direction as the field due to potential barrier. The increased potential barrier prevents the flow of charge carriers across the junction. Thus a high resistance path is established for the entire circuit and hence current does not flow.

1. Potential barrier is increased.
2. The junction offers very high resistance to current flow.
3. No current flows in the circuit due to high resistance path.

$V_R - I_R$ curve: A small current in μA flows in the circuit under reverse bias. This is called as reverse current due to minority carriers. Electrons in p-type and holes in N-type are called minority carriers. Hence very small current flows in reverse direction called as leakage current and as the reverse voltage is increased breakdown (V_z) occurs. or reaches breakdown voltage (V_z). It breaks the covalent bonds, creating a large number of minority carriers. Consequently a sudden rise of reverse current and sudden fall of resistance of barrier region. This may permanently damage the junction due to excess heat.

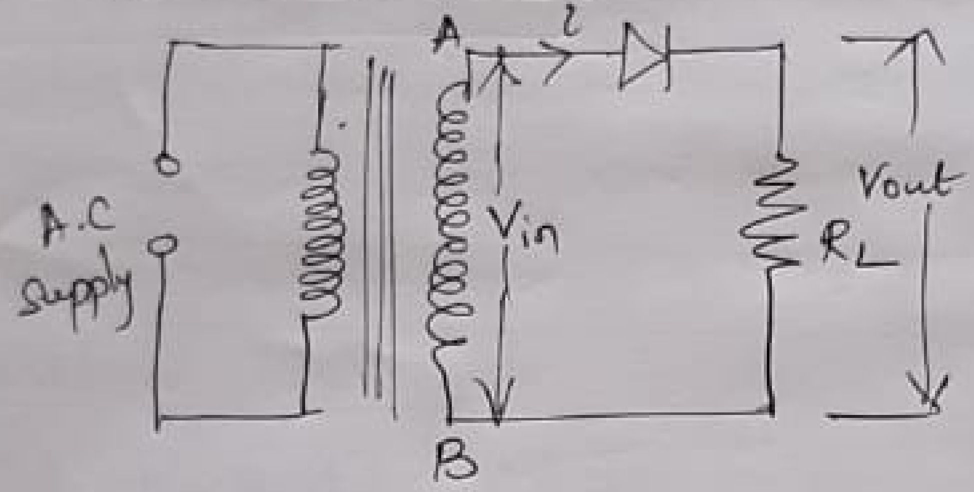
<u>Breakdown voltage</u>: It is the minimum reverse voltage at which the pn junction breaks down with sudden rise in reverse current. When high reverse voltage is applied electrons acquire high velocity, we get an avalanche of free electrons. Therefore pn junction conducts large reverse current.

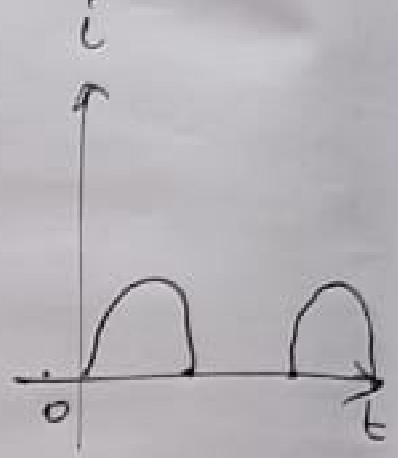
<u>Knee voltage</u>: It is the forward voltage at which the current through the junction starts to increase rapidly.

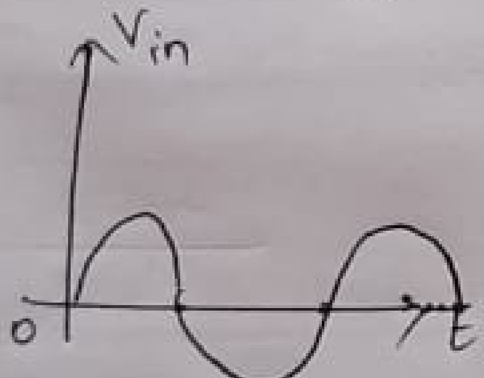
silicon

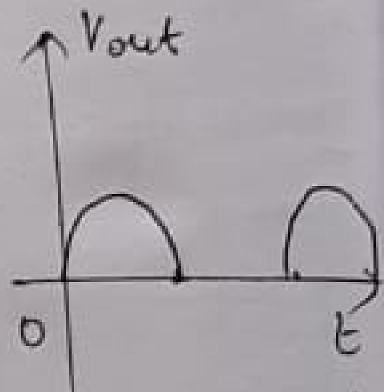
When a diode is forward biased, it conducts (I). current slowly until we overcome the potential barrier. For silicon potential barrier is 0.7eV. Once the applied force voltage exceeds the knee voltage, the current starts increasing rapidly. The applied voltage should exceed knee voltage.

Half wave rectifier:-









Rectifiers:

There are many appliances where d.c supply is needed. When such a d.c supply is needed, the main a.c supply is rectified by using crystal diodes.

1) Half wave rectifier 2) Full wave rectifier

Working! The a.c voltage across the secondary winding AB changes polarity after every half-cycle. During the half-cycle of input ac voltage, end A becomes positive wrt end B. This makes the diode forward biased and hence it conducts current. (2)

During -ve half cycle end A is negative wrt end B. Under this condition the diode is reverse biased and it conducts no current.

∴ current flows through the diode during positive half cycle of input a.c voltage, only and blocked during -ve half cycle. current flows through the load R_L always in the same direction. Hence d.c output is obtained across R_L. It may be noted that output across the load is pulsating d.c. These are smoothened with the help of filter circuit.

O/p frequency: O/p frequency is the same as i/p frequency. In both the cases the waveform completes one cycle every 368. or repeats same pattern every 360°.

$$f_{out} = f_{in}.$$

Disadvantages:

① The output is a pulsating current, ∴ an elaborate filtering is required to produce steady current.

② The a.c supply delivers only half the time. ∴ O/p is very low.

Efficiency: $$\eta = \frac{\text{d.c power o/p}}{\text{i/p a.c. power}}$$

$V_{in} = V_m \sin\theta$ — across AB

r_f and R_L - diode and load resistances

$$\therefore i = \frac{V}{r_f + R_L} = \frac{V_m \sin\theta}{r_f + R_L}$$

when $\theta = 90^\circ$ d.current is maximum

$$\therefore I_m = \frac{V_m}{r_f + R_L}$$

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(4)

d.c power: Since it is pulsating current, In order to find power, average current has to be found out.

Average current $I_{dc} = \frac{I_m}{\pi}$

$$I_m = \frac{V_m}{r_f + R_L}$$

Average voltage $= \frac{V_m}{\pi}$

D.c power $P_{dc} = I_{dc}^2 R_L$

$$= \left(\frac{I_m}{\pi}\right)^2 R_L$$

a.c power: $P_{ac} = I_{rms}^2 (r_f + R_L)$

for a half-wave rectified wave $I_{rms} = \frac{I_m}{2}$

$$\therefore P_{ac} = \left(I_m/2\right)^2 (r_f + R_L)$$

$$\therefore \eta = \frac{P_{dc}}{P_{ac}} = \frac{\left(I_m/\pi\right)^2 R_L}{\left(\frac{I_m}{2}\right)^2 \times (r_f + R_L)}$$

$$= \frac{0.406 R_L}{r_f + R_L} = \frac{0.406}{1 + r_f/R_f}$$

η is maximum when r_f is negligible when compared to R_L

Max. rectifier efficiency = 40.6%.

Peak Inverse Voltage: When the diode is reverse biased, the load current is zero. So that there is no voltage across load R_L
∴ entire V_m will appear across diode as reverse bias $PIV = V_m$ — Half wave rectifier.

Problem: A crystal diode having $r_f = 20\,\Omega$ is used for half-wave rectification. If the applied voltage is $V = 50 \sin\omega t$ and load resistance $R_L = 800\,\Omega$ find (i) I_m, I_{dc}, I_{rms} (ii) a.c. power input, d.c power output (iii) d.c. o/p voltage (iv) η

Maximum voltage = 50 V.

$$I_m = \frac{V_m}{r_f + R_L} = \frac{50}{20+800} = 0.061 \text{ A}$$
$$= 61 \text{ mA}.$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{61}{\pi} = 19.4 \text{ mA}$$

$$I_{rms} = \frac{I_m}{2} = \frac{61}{2} = 30.5 \text{ mA}.$$

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$
$$= (30.5 \times 10^{-3})^2 \times (20+800) = 0.763 \text{ W}$$

$$P_{dc} = I_{dc}^2 \times R_L = (19.4 \times 10^{-3})^2 \times 800$$
$$= 0.301 \text{ W}$$

D.C. o/p voltage $= I_{dc} \times R_L = 19.4\text{mA} \times 800\Omega$
$= 15.52 \text{ V}$

also

D.C o/p voltage $= \frac{V_m}{\pi} = \frac{50}{\pi} = 15.52 \text{ V}$

$$\eta = \frac{0.301}{0.763} \times 100 = 39.5\%.$$

D.C. power, $P_{dc} = I_{dc}^2 R_L = (I_m/\pi)^2 \times R_L$

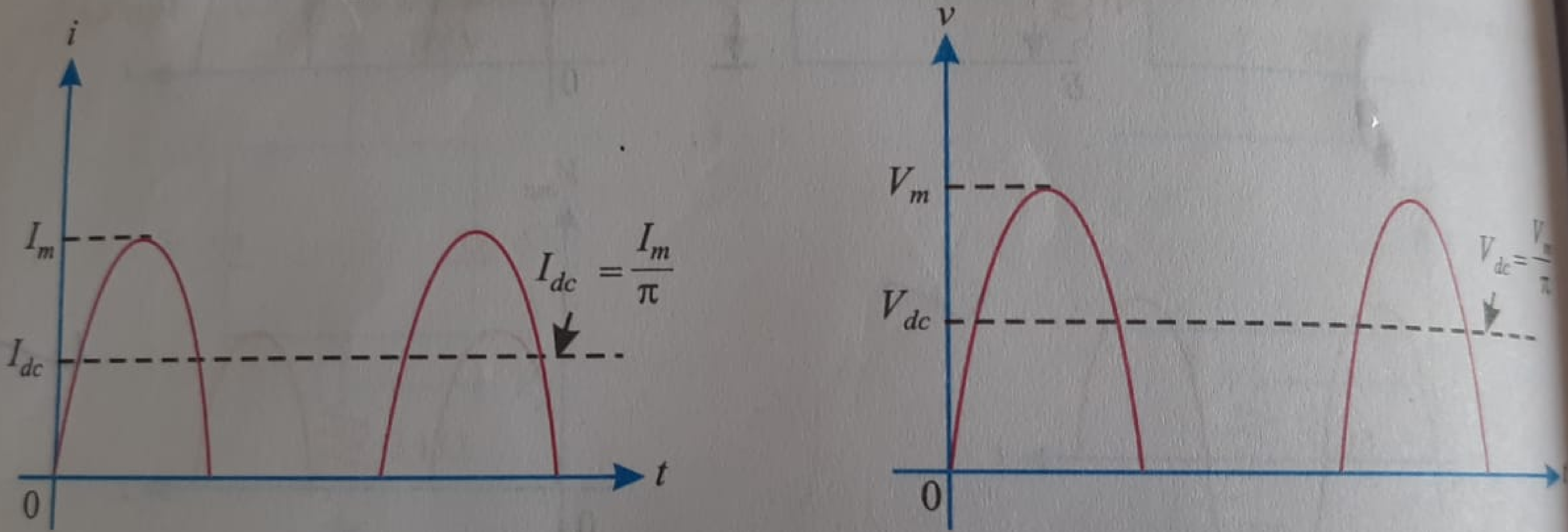


Fig. 26.14

a.c. power input

$$P_{ac} = I_{r.m.s.}^2 (r_f + R_L)$$

For a half-wave rectified wave, $I_{r.m.s.} = I_m/2$.

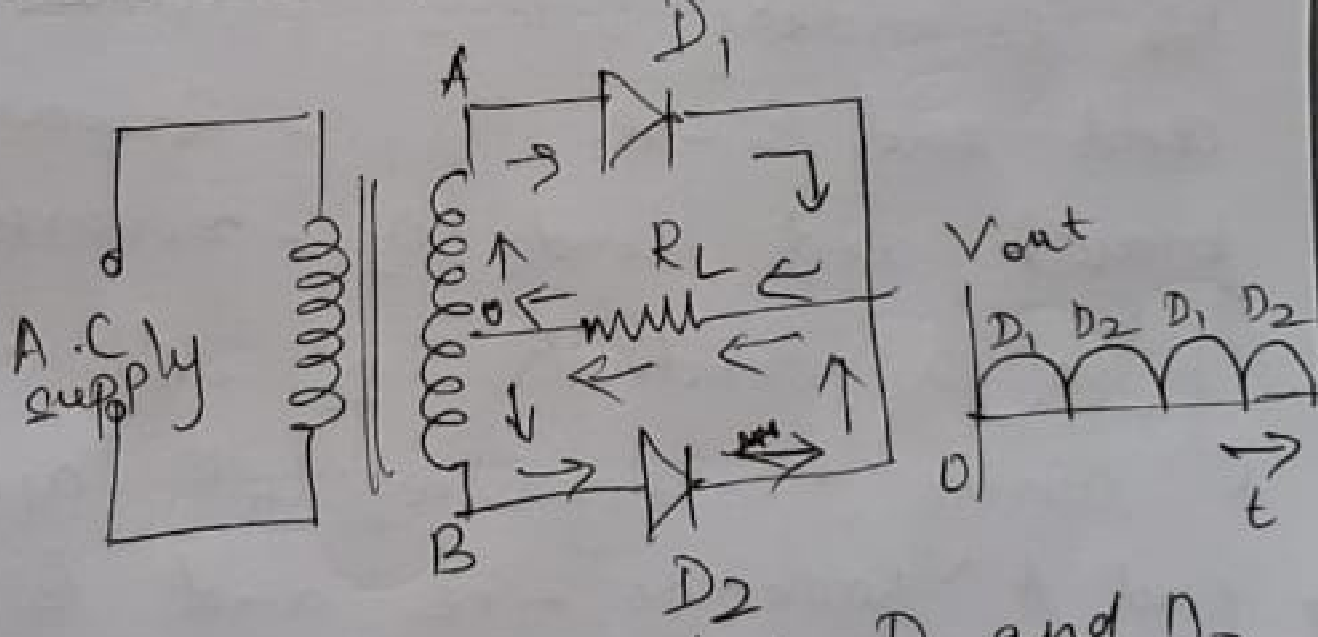
PAGE NO.

problem: 2 A half wave rectifier is used to supply 50V d.c to a resistive load of 800 Ω. The diode has a resistance of 25Ω. Calculate the maximum value of a.c. voltage required.

Full -wave Rectifier:

In full wave rectifier, current flows through the load in the same direction for both half cycles of i/p a.c voltage.

Centre - Tap Full- wave Rectifier



There two diodes D_1 and D_2

A centre tapped secondary windings AB is used with diode connected so that each uses half cycle of input a.c voltag

(2)

Diode D_1 utilizes the a.c voltage appearing across the upper half OA of secondary windings while D_2 uses lower half.

Operation: (i) During +ve half-cycle of secondary voltage, the end A of the secondary wings becomes +ve and end B -ve. D_1 - forward biased and diode D_2 - reverse biased. When D_1 conducts D_2 will not.

(ii) During the negative half-cycle end A becomes -ve and B +ve.
∴ D_2 conducts while D_1 does not

Dis advantages: (i) ~~Its~~ difficult to Locate the centre tap on the secondary windings.
(ii) O/p is small utlizes only ½ of voltage
(iii) Diodes should have hig PIV

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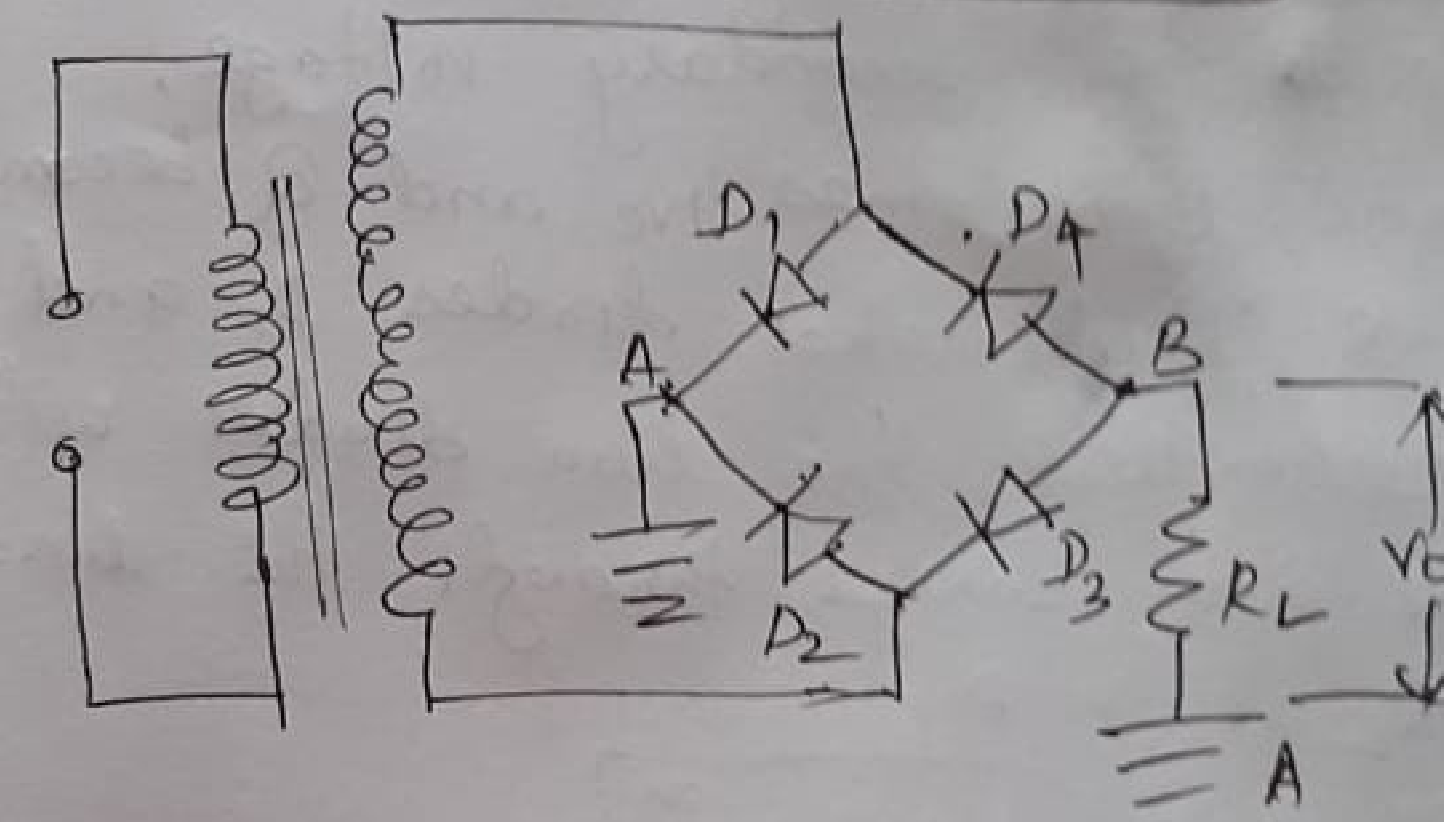
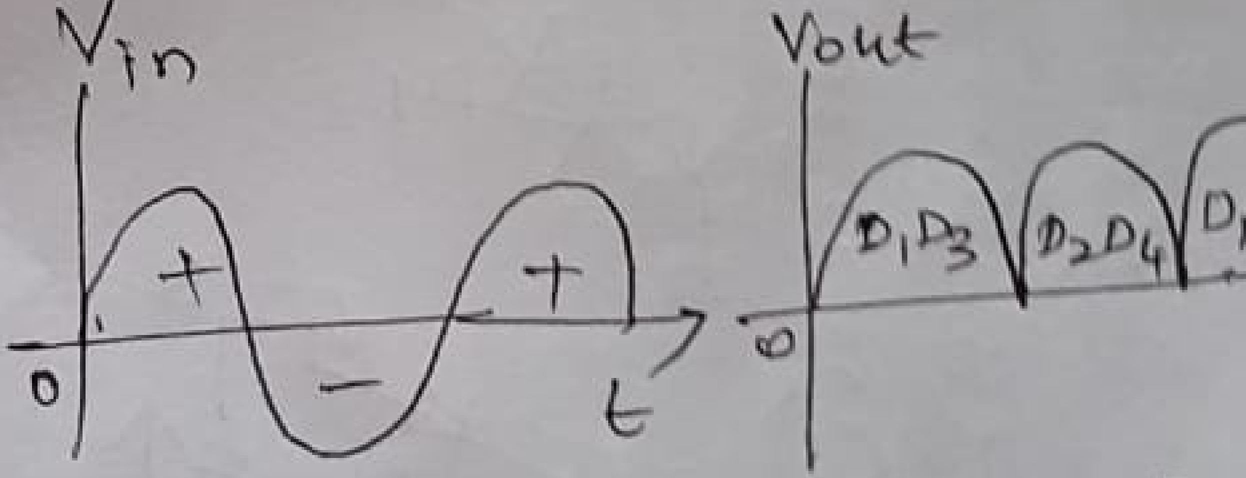
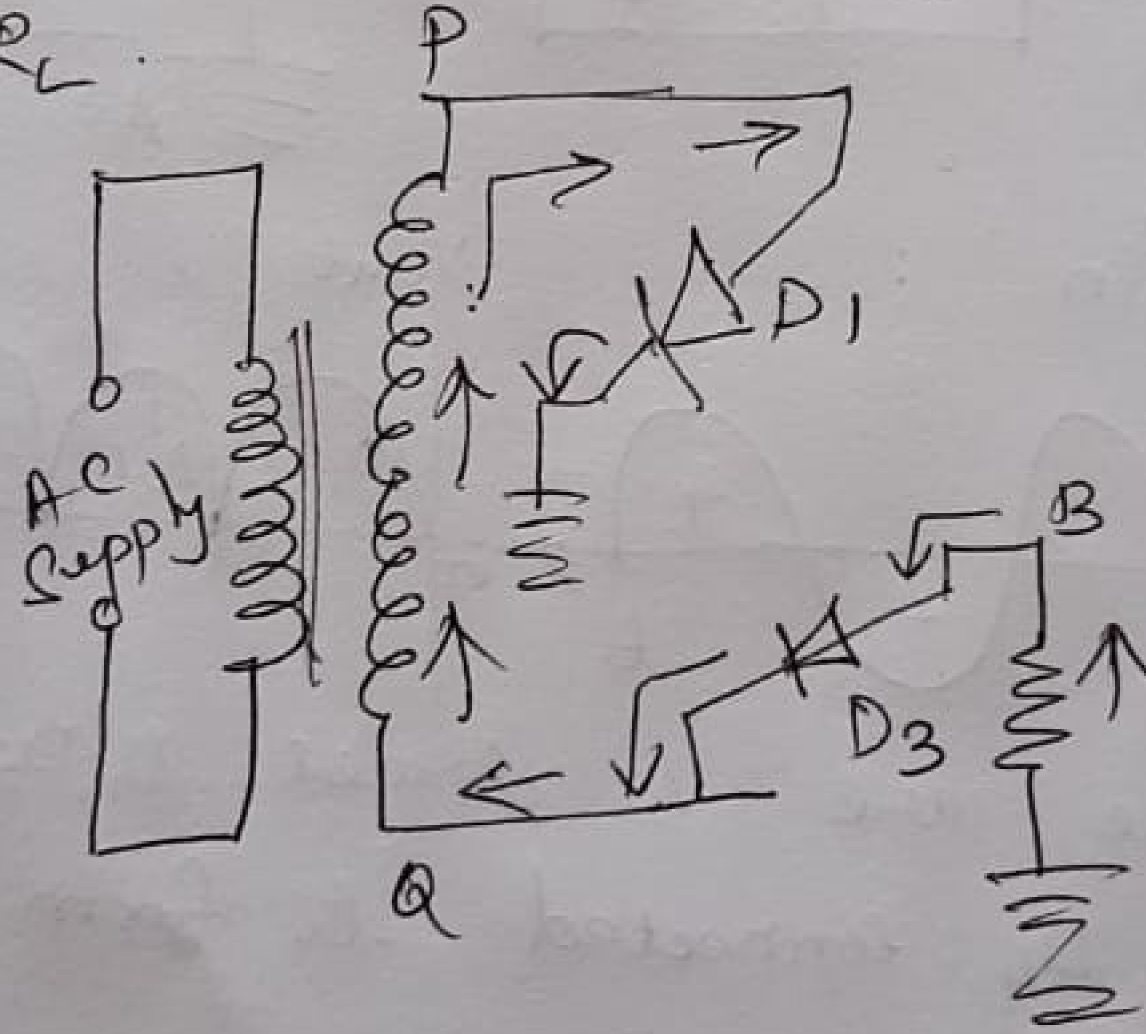
Full wave Bridge Rectifier



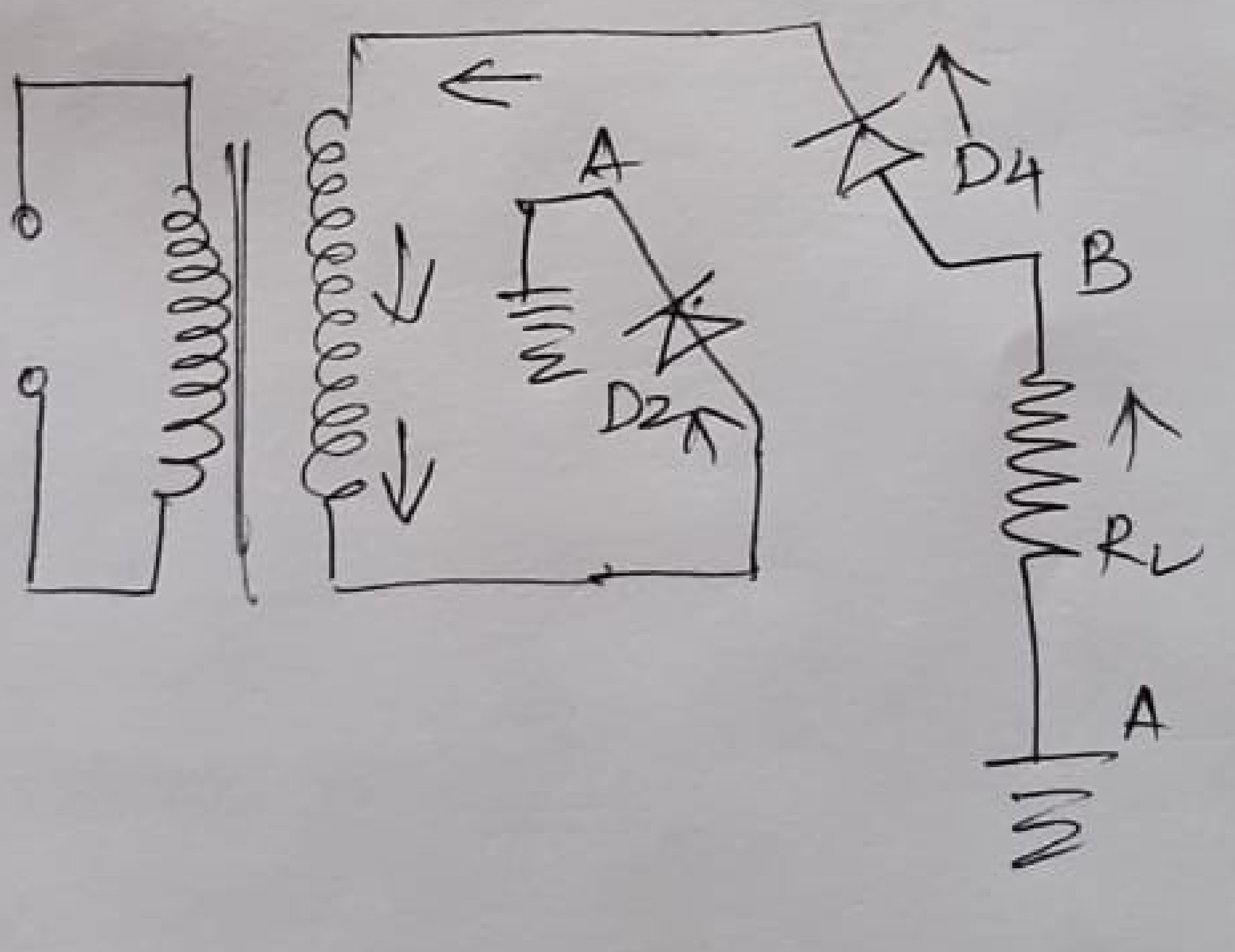


There are 4 diodes D_1, D_2
and D_4 connected to form
bridge

Operation: During positive half cycle of secondary voltage, end P becomes +ve and Q becomes -ve. This makes diodes D_1 and D_3 conduct. The two diodes will be in series through the load R_L.



During -ve half cycle end P becomes negative and Q +ve. this makes diodes D_2 and D_4 forward biased while diodes D_1 and D_3 are reverse biased ∴ D_2 and D_4 will conduct. DC output is obtained across the load R_L.



6

Advantages:

(i) No need for centre tap

(ii) O/p is twice that of centre tap circuit

(iii) For the same d.c output voltage PIV of bridge circuit is half that of the centre tap. circuit.

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half (4)

Q: $v = V_m \sin\theta$ (7)

r_f, R_L - diode and load resistance. The rectifier will conduct current through the load in the same direction for both half-cycles of input ac voltage.

$$i = \frac{v}{r_f + R_L} = \frac{V_m \sin\theta}{r_f + R_L}$$

i is maximum when $\theta = 90^0$

$$I_m = \frac{V_m}{r_f + R_L}$$

d.c power output

$$I_{dc} = \frac{2 I_m}{\pi} \qquad I_m = \frac{V_m}{r_f + R_L}$$

$$V_m = \frac{2 V_m}{\pi}, \qquad P_{dc} = I_{dc}^2 \times R_L$$
$$= (2 I_m / \pi)^2 \times R_L$$

a.c power i/p

$I_{rms} = \frac{I_m}{\sqrt{2}}$, $P_{ac} = I_{rms}^2 (r_f + R_L)$

$= \left(\frac{I_m}{\sqrt{2}}\right)^2 \times (r_f + R_L)$

Rectifier $\eta = \frac{P_{dc}}{P_{ac}}$

$= \frac{\left(\frac{2I_m}{\pi}\right)^2 \times R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)} = \frac{0.812 R_L}{r_f + R_L}$

$= \frac{0.812}{1 + \left(\frac{r_f}{R_L}\right)}$

If r_f is negligible η is maximum $= 81\%$.

Twice that of half-wave rectifier.

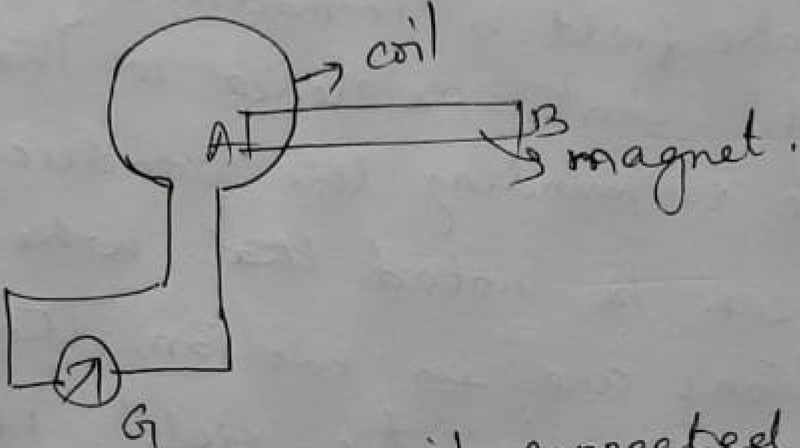
Electromagnetism :

Electromagnetic Induction :-

Whenever an electric current flows through a conductor, a magnetic field is immediately brought into existence in the space surrounding the conductor. It can be noted that when electrons are in motion, they produce a magnetic field. The converse of this is true.

When a magnetic field embracing a conductor moves relative to the conductor, it produces flow of electrons in the conductor. When current is induced in any conductor which is cut across a magnetic flux is known as electro magnetic induction.

Production of Emf :



Consider a coil connected to a galvanometer, AB is a magnet, when the magnet is brought near the coil and moved through the coil we can see the galvano meter is deflected. When the Magnet is stationary there is no generation of emf. Only when the flux

lines linked with coil is (3).
disturbed there is generation
of emf.

When the magnet AB is
kept stationary and the coil is
moved suddenly towards or away, the
coil current is generated.

Faradays law:

First law: Whenever the magnetic
flux linked with a circuit
changes, an emf is always induced in it

Second law:

The magnitude of the induced
emf is equal to the rate of
change of flux-linkages.

If there are N number of (4)
coils, and flux through it
changes from an initial value
of ϕ_1 to the final value ϕ_2
webers in t seconds, then

induced emf $= e = \frac{N\phi_2 - N\phi_1}{t}$ wb/s

or $e = N\left(\frac{\phi_2 - \phi_1}{t}\right)$ volt.

$$e = \frac{d}{dt}(N\phi) = -N\frac{d\phi}{dt} \text{ volt}$$

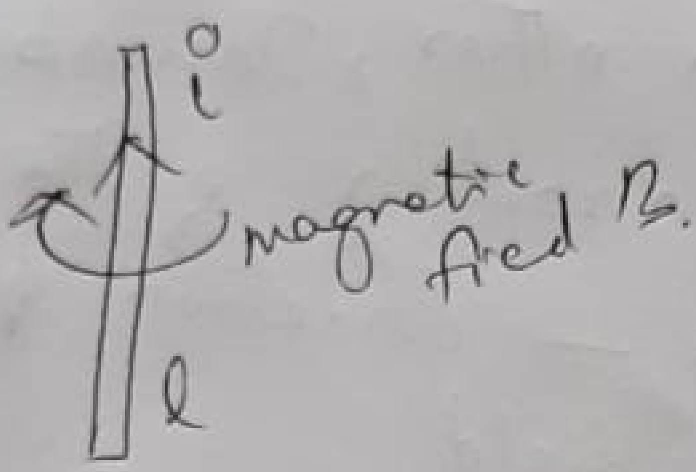
– ve sign indicates that
induced emf is opposite to the
direction of magnetic effect.
According to Fleming's Right
hand rule, when fore finger,
middle finger and thumb are
kept

$\perp^r$ to each other, Thumb — ⑤
Points the direction of the conduc
Fore finger — direction of the
magnetic field
Middle finger direction of the
emf.

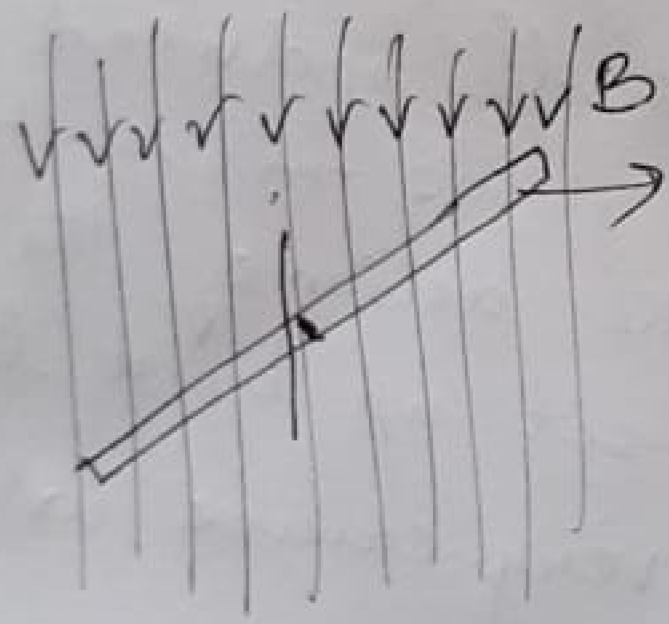
Lenz's law :-

Electromagnetically induced current always flows in such direction that the action of the magnetic field set up by it tends to oppose the very cause which produces it.

When a wire carries current of length l and current i, A magnetic field developed perpendicular to the wire.



Dynamically induced emf:

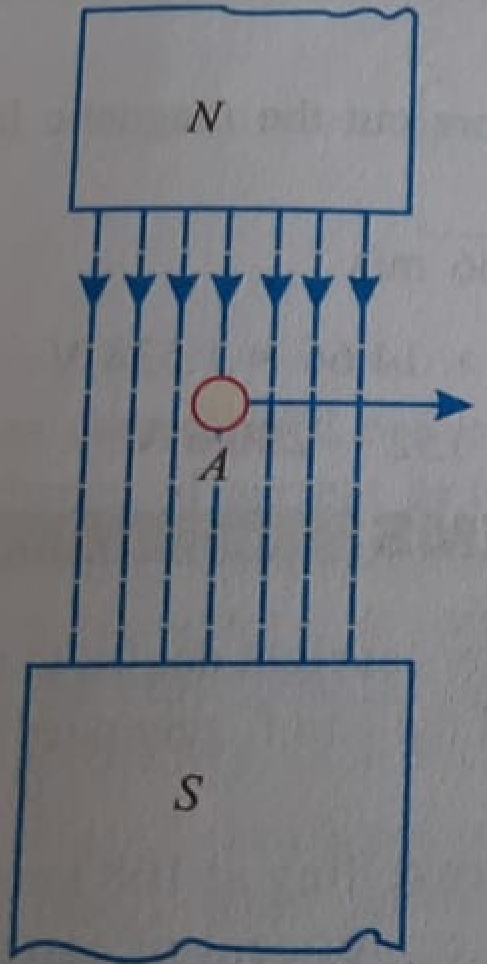


Rate of change of flux linkages $= Bl\frac{dx}{dt}$

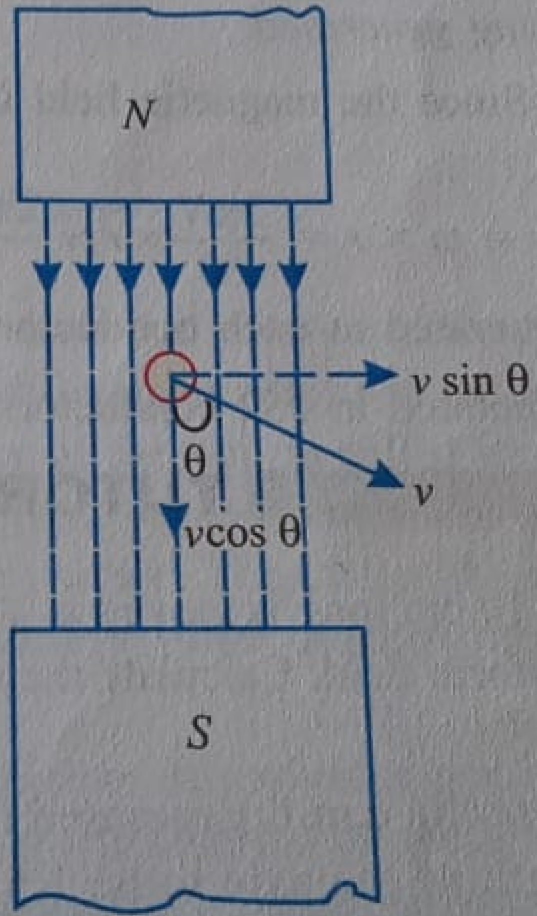
$= Blv\sin\theta$.

θ ⊥ with direction of flux.

$$\therefore \qquad e = B\,l\,v \text{ volts} \qquad (\because \; dx/dt = v)$$



(i)

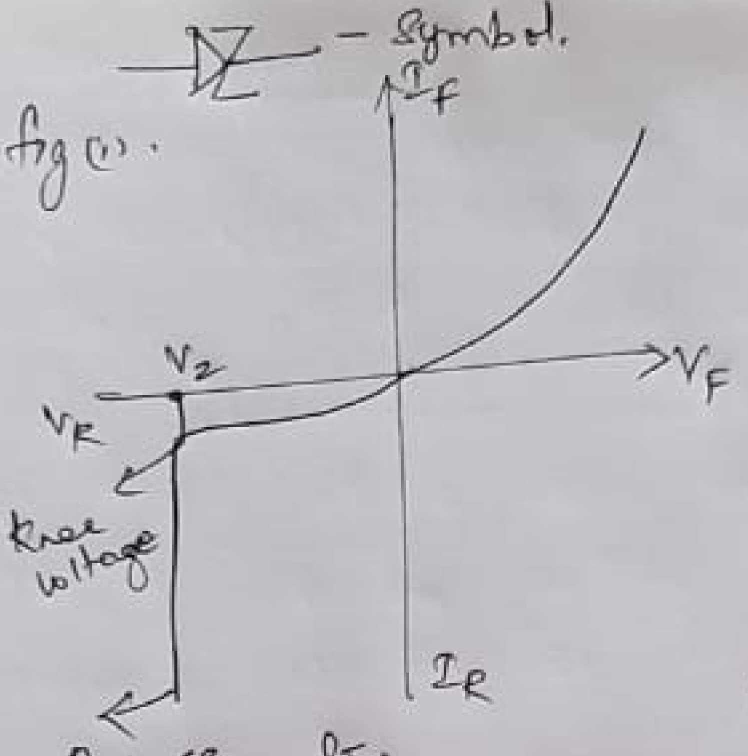


(ii)

Zener Diode:

1. Already we know that when reverse bias on a crystal diode is increased a critical voltage called breakdown voltage is reached where the reverse current increases rapidly or sharply at a high value.
2. The breakdown region is the knee of the reverse characteristics. as shown in diagram (i)
3. The breakdown voltage some times called as zener voltage and the sudden increase in current is known as zener current.
4. The breakdown or zener voltage depends on the amount of doping. If the diode is heavily doped, depletion layer will be very thin, the junction will occur at low reverse voltage.
5. If the diode is lightly doped, has a higher breakdown voltage
6. When an ordinary diode is properly doped so that it has a sharp breakdown voltage. It is called as zener diode.

fig (1).



Reverse characteristics

① A zener diode is like an ordinary diode except that it is properly doped so that it has a sharp breakdown voltage.

② It is always reverse biased.

③ Sharp breakdown voltage V_Z

④ When forward biased behaves as an ordinary diode.

⑤ Zener diode will not be immediately burnt since it has a breakdown region which limits diode current. Unless the external applied current exceeds burn out value the diode will not be burnt.

2. Diode's Equivalent circuit:

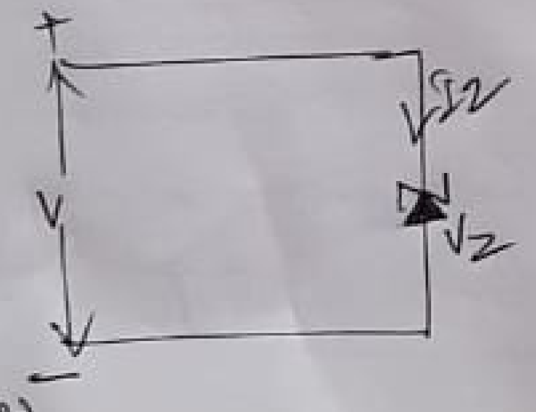


fig (2)

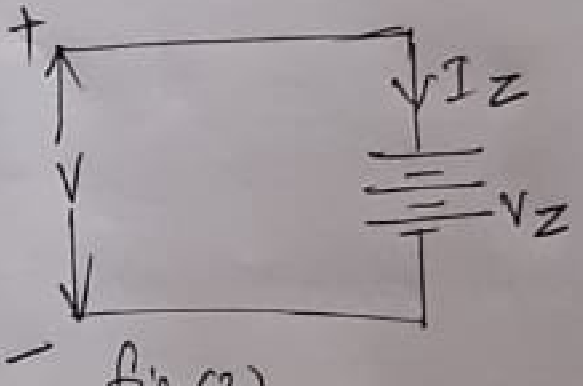
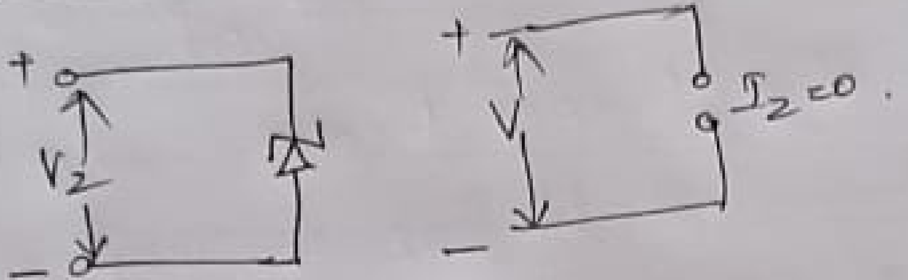


fig (3)

1. **ON state**: When reverse voltage across a zener diode is equal to or more than breakdown voltage V_Z, the current increases very sharply. voltage across the zener diode is constant V_Z even though the current through it changes.. Now diode is in the ON state.

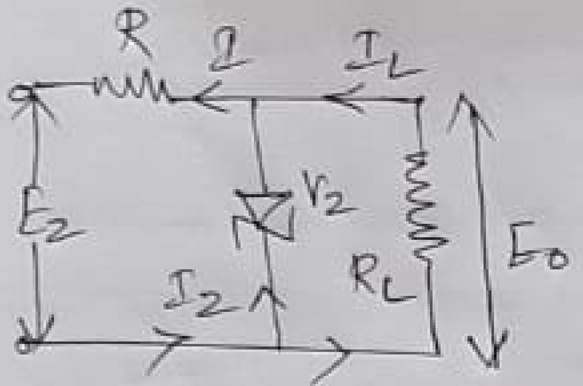
2. **OFF state**:

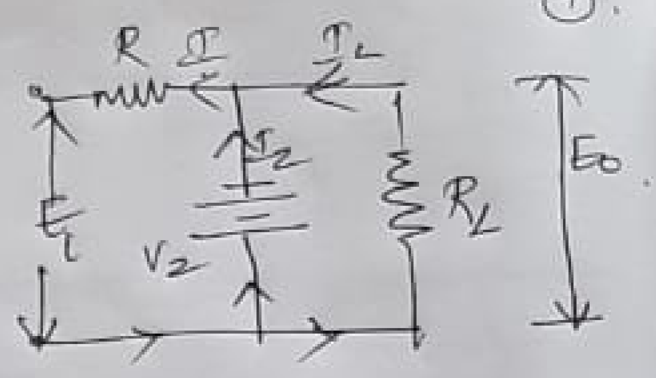


When the reverse voltage across the zener diode is less than V_Z but greater than 0V, is in the OFF state, Now the zener diode is in the OFF state, Now it can be represented as open-circuit

zener diode as a voltage stabilizer.

A zener diode can be used as a voltage regulator to provide a constant voltage from a source whose voltage may vary.





① The zener diode of zener voltage V_2 is reverse connected across the load R_L across which the constant output is desired. The series resistance R absorbs the output voltage fluctuations so as to maintain constant voltage across the load.

② zener diode will maintain a constant voltage ($V_2 = E_0$) across the load so as long as the input voltage does not fall below V_2.

③ suppose the input voltage increases; since zener is in the breakdown region the zener diode is equivalent to a battery V_2. It is clear that the output voltage remains constant at V_2. The excess voltage is droped across the series resistance R.

This will cause an increase in the value of total current I. The zener will conduct the increase of current in I while the load current remains constant. The o/p voltage E_0 remains constant irrespective of change in input voltage E_i

(4) If $R_L \downarrow$ - will cause an increase in load current. The extra current cannot come from the source because drop in R. will not change as the zener is within its regulating range. The additional load current will come from a ↓ of zener current I_Z, o/p voltage is constant.

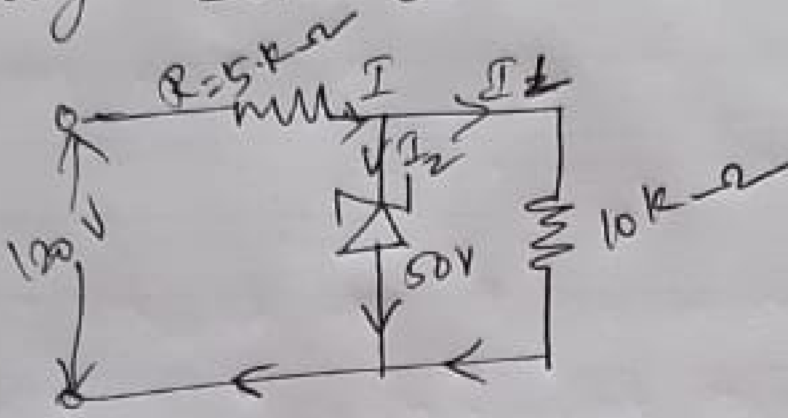
voltage drop across $R = E_i - E_0$

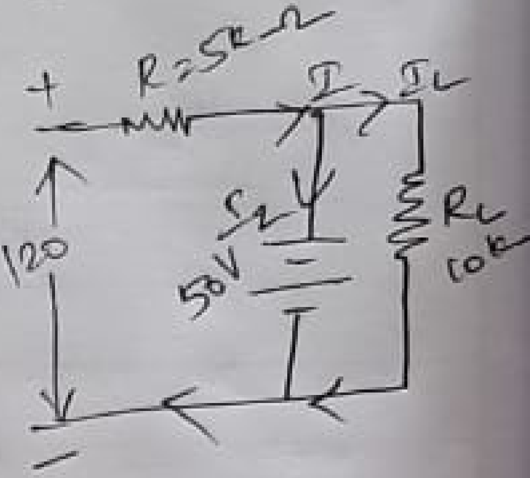
current through R, $I = I_Z + I_L$

$$R = \frac{E_i - E_0}{I_Z + I_L} = \frac{V}{I}$$

(6)

Problem:- Find (i) the o/p voltage (ii) voltage drop across series resistance (iii) the current through zener diode.





If we remove zener diode, V across open circuit $V = \frac{R_L E_i}{R+R_L} = \frac{10 \times 120}{5+10} = 80\,V$

Since voltage across zener diode is greater than $V_Z = 50\,V$ the diode is in the ON state.

Output voltage, $V_Z = 50\,V$

Voltage drop across R = Input voltage $- V_Z$

$= 120 - 50 = 70\,V$

Load current $I_L = V_Z / R_L = \frac{50\,V}{10k\Omega} = 5\,mA$

current through R, $I = \frac{70\,V}{5k\Omega} = 14\,m$

$I = I_L + I_Z$

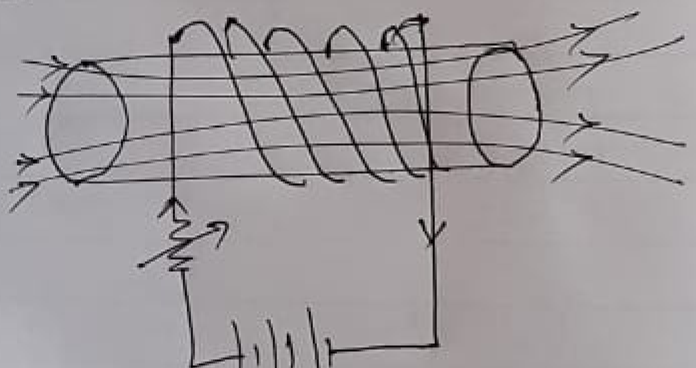
$I_Z = I - I_L = 14 - 5 = 9\,mA$

Statically Induced emf:

When the conductor is stationary and field is moving or changing, the emf is induced in the conductor is called statically induced emf.

1) Self induced emf
2) Mutually induced emf.

1) **Self induced emf:** The emf induced in a coil due to the change of its own magnetic flux with it is called self-induced emf.



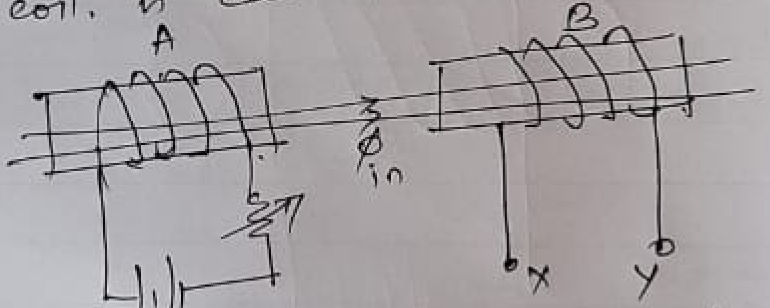
When a coil is carrying current a magnetic field is established through the coil. If the current in the coil changes, Then magnetic flux linking the coil also changes. Hence by Faraday's laws, an emf will be induced in the coil.

Self induced emf $= -N\frac{d\phi}{dt}$

Lenz's law: The direction of induced emf is always such as to oppose the cause responsible for inducing the emf namely change in current and hence field in the coil.

2) Mutually induced emf:

The emf induced in a coil due to the changing current in the neighbouring coil, is called mutually induced emf.



Two coils A and B placed adjacent to each other. Magnetic flux produced by the coil A link with B. The flux common to both A and B is called mutual flux (ϕ_m). If the current in the coil is varied the actual flux also varies and hence emf is induced in both the coils. Emf induced in coil A is called self inductance and coil B is called as mutual inductance.

$$e_M = N_B \, d\phi_m/dt.$$

N_B – no of turns in coil B.

$\frac{d\phi_m}{dt}$ = rate of change of flux in both the coils.

① The mutually induced emf in coil B persists so long as the current in the coil A. is changing. If the current becomes steady the mutual flux becomes steady and mutually induced emf reduces to zero.

② The property of two neighbouring coils to induced voltage in one coil due to the change of current in the other is called mutual inductance.

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Expression for self inductance:

$$e = N\frac{d\phi}{dt} = \frac{d}{dt}(N\phi)$$

$$e = \frac{d}{dt}(N\phi) \propto \frac{dI}{dt}$$

$$e = \text{constant} \times \frac{dI}{dt}$$

$$\boxed{e = L\frac{dI}{dt}}$$

$$e = -L\frac{dI}{dt}.$$

-ve sign opposite to direction of direction of flux.

$$L = \frac{e}{(dI/dt)}$$

Expression for mutual inductance:-

$$e_M \propto \frac{dI_1}{dt}$$

$$e_M = -M\frac{dI_1}{dt}$$

$$M = \frac{e_M}{dI_1/dt}.$$

Inductance in series

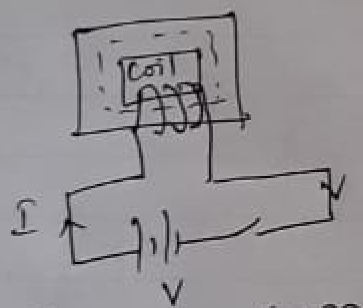
$$L_T = L_1 + L_2$$

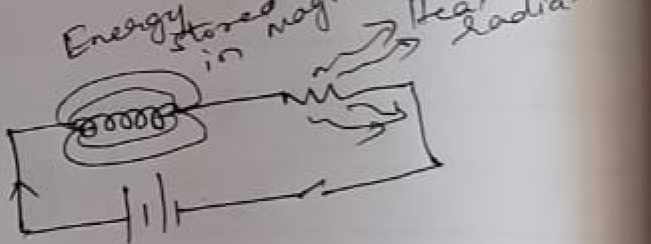
Inductance in parallel

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2}$$

$$\text{or } L_T = \frac{L_1 + L_2}{L_1 L_2}$$

Energy stored in a magnetic field.





Energy supplied to the circuit is spent in two ways.

1) A part of supplied energy is spent to meet I^2R losses and cannot be recovered.

2) The remaining part is spent to create magnetic flux around the coil and is stored in the magnetic field. When the field collapses, this stored energy is returned to the circuit.

Instantaneous power:

$$p = ei = Li\frac{di}{dt}$$

Short interval of time dt, the energy dw put into the magnetic field is equal to power multiplied by time i.e.

$$dw = p\,dt = \left(Li\frac{di}{dt}\right)dt = Li\,di$$

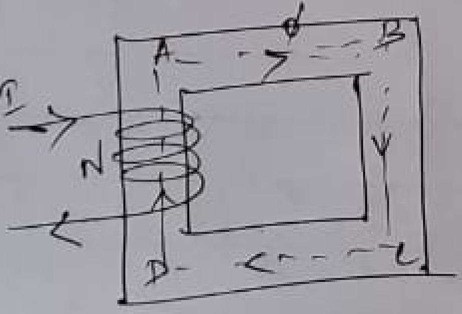
$$W = \int_0^I Li\,di = \frac{1}{2}LI^2$$

Energy stored in magnetic field $E = \frac{1}{2}LI^2$ joules

Magnetic energy stored $\} = \frac{B^2}{2\mu_0}$ joules.

Magnetic circuits:

The closed path followed by magnetic flux is called a magnetic circuit:



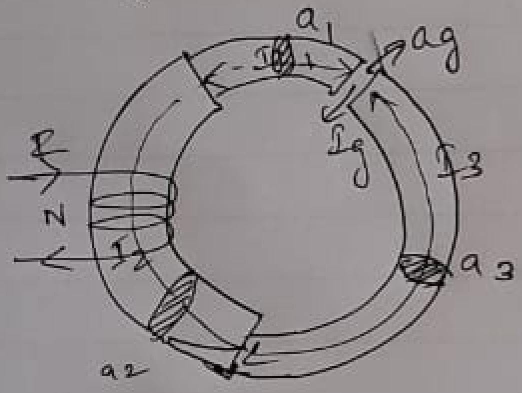
Consider a coil of N Turns wound on an iron core. When a current I is passed through the coil magnetic flux ϕ is set up in the core

The flux follows a closed path ABCDA. Hence ABCDA is the magnetic circuit.

mmf — NI ampere turns.
magneto motive force

The magnetic circuit offers a resistance to the magnetic flux is called as reluctance of the magnetic circuit.

Series magnetic circuits:



Total reluctance $= \frac{I_1}{a_1 \mu_0 \mu_{r1}} + \frac{I_2}{a_2 \mu_0 \mu_{r2}} + \frac{I_3}{a_3 \mu_0 \mu_{r3}} + \frac{I_g}{a_g \mu_0}$

Total mmf = Magnetic flux × Total reluctance

$$= \phi \left[\frac{I_1}{a_1 \mu_0 \mu_{r1}} + \frac{I_2}{a_2 \mu_0 \mu_{r2}} + \frac{I_3}{a_3 \mu_0 \mu_{r3}} + \frac{I_g}{a_g \mu_0} \right]$$

$\therefore B = \frac{\phi}{A}$

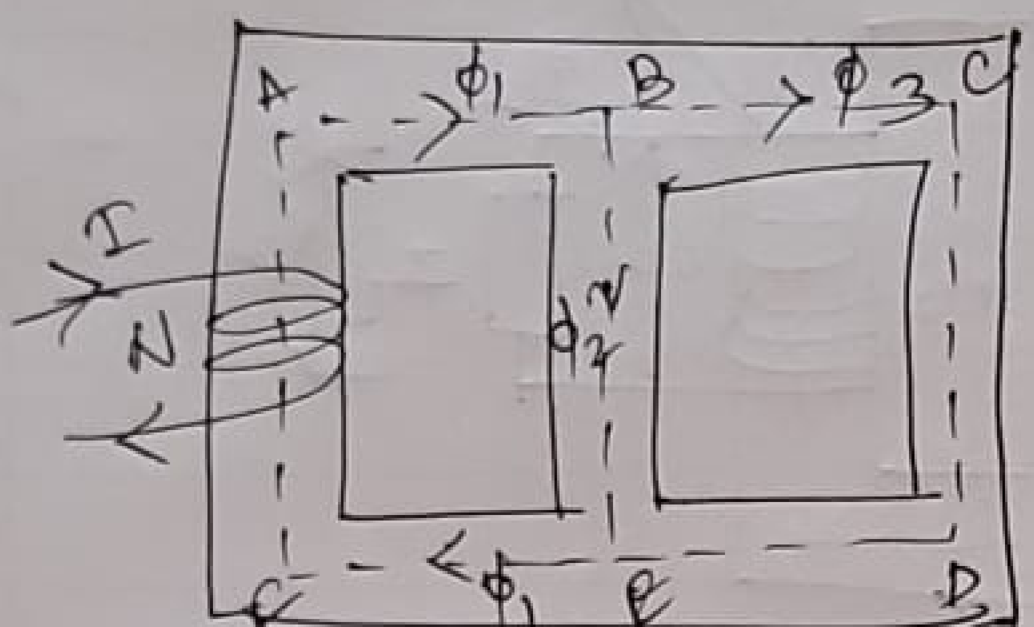
$$= \frac{B_1}{\mu_0 \mu_{r1}} \times I_1 + \frac{B_2}{\mu_0 \mu_{r2}} \times I_2 + \frac{B_3}{\mu_0 \mu_{r3}} \times I_3 \times I_g \times$$

(8)

$= H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g$.

where $H = \dfrac{B}{\mu_0 \mu_r}$

Parallel Magnetic Circuit :-



Here there are N turns, wound on a Limb AF carries a current I

A magnetic circuit which has more than one path for magnetic flux is called a $\parallel^{el}$ magnetic circuit.

The magnetic flux ϕ_1 is divided into two paths.

① magnetic flux ϕ_2 passes along the path BE

② magnetic flux ϕ_3 follows the path BCDE

clearly $\phi = \phi_1 + \phi_2$.

The magnetic paths BE and BCDE are in parallel and forms $\parallel^{el}$ mag. circuit

The ampereturns required for the parallel circuit is equal to AT required for any one of the paths.

S_1 = reluctance of the path EFAB

S_2 = reluctance of the path BE

S_3 - reluctance of the path BCDE

Total mmf required = mmf of path EFAB + mmf of path BE or BCDE

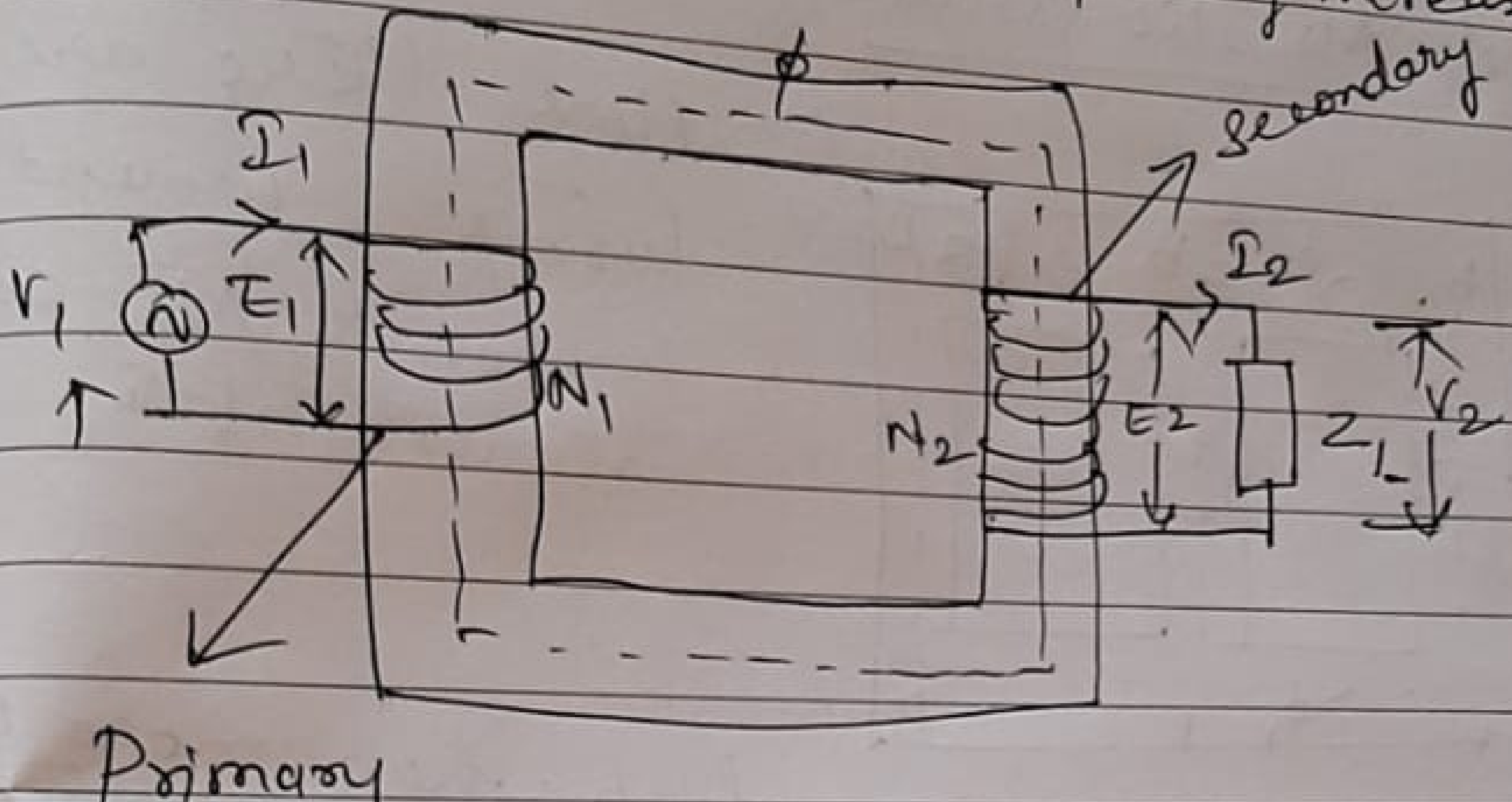
$$NI = \phi_1 S_1 + \phi_2 S_2$$

$$= \phi_1 S_1 + \phi_3 S_3$$

The reluctances S_1, S_2 and S_3 must be determined from a calculation of $l/a\mu_0\mu_r$ for those paths of magnetic circuit in which ϕ_1, ϕ_2 and ϕ_3 exist respectively.

Transformer :-

It is a static a.c. machine used for raising or lowering the voltage of an ac supply with a corresponding increase or decrease of current.



Consists of two windings primary and secondary wound on a magnetic core. The winding connected to a.c source is called primary and the one connected to load is called secondary.

The alternating voltage whose magnitude is to be changed is applied to the primary. Depending upon the number of turns of the primary (N_1) and secondary (N_2) an alternating emf is induced in the secondary. The induced emf E_2 appear across the load. If $V_2 > V_1$ it is called as step-up transformer. On the other hand if $V_2 < V_1$ it is called step down transformer.

Principle:

It is based on mutual inductance between two coils wound on the same laminated core.

Working :-

When an alternating voltage is applied to the primary, an alternating flux ϕ is set up in the core. The alternating flux links both the windings and induces emfs E_1 in the primary and E_2 in the secondary according Faraday's law of electromagnetic induction.

$$E_1 = -N_1 \frac{d\phi}{dt}$$

$$E_2 = -N_2 \frac{d\phi}{dt}$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

If $N_2 > N_1$ then $E_2 > E_1$ - step up transformer

If $N_2 < N_1$ then $E_2 < E_1$ - step down transformer

Thus the transformer enables to transfer a.c power from on circuit to another with a change in voltage level.

(1) Based on em induction

(2) There is no electrical connection between primary and secondary. a.c power is tranferred through magnetic flux from primary to secondary

(3) There is no change in frequency between primary and secondary o/p power

(4) There are core losses and copper losses

Core losses → Eddy current losses, Hysteresis losses.

Copper losses → due to resistance of windings.

Theory of an Ideal Transformer:

An ideal transformer has

(1) no losses due to winding resistance

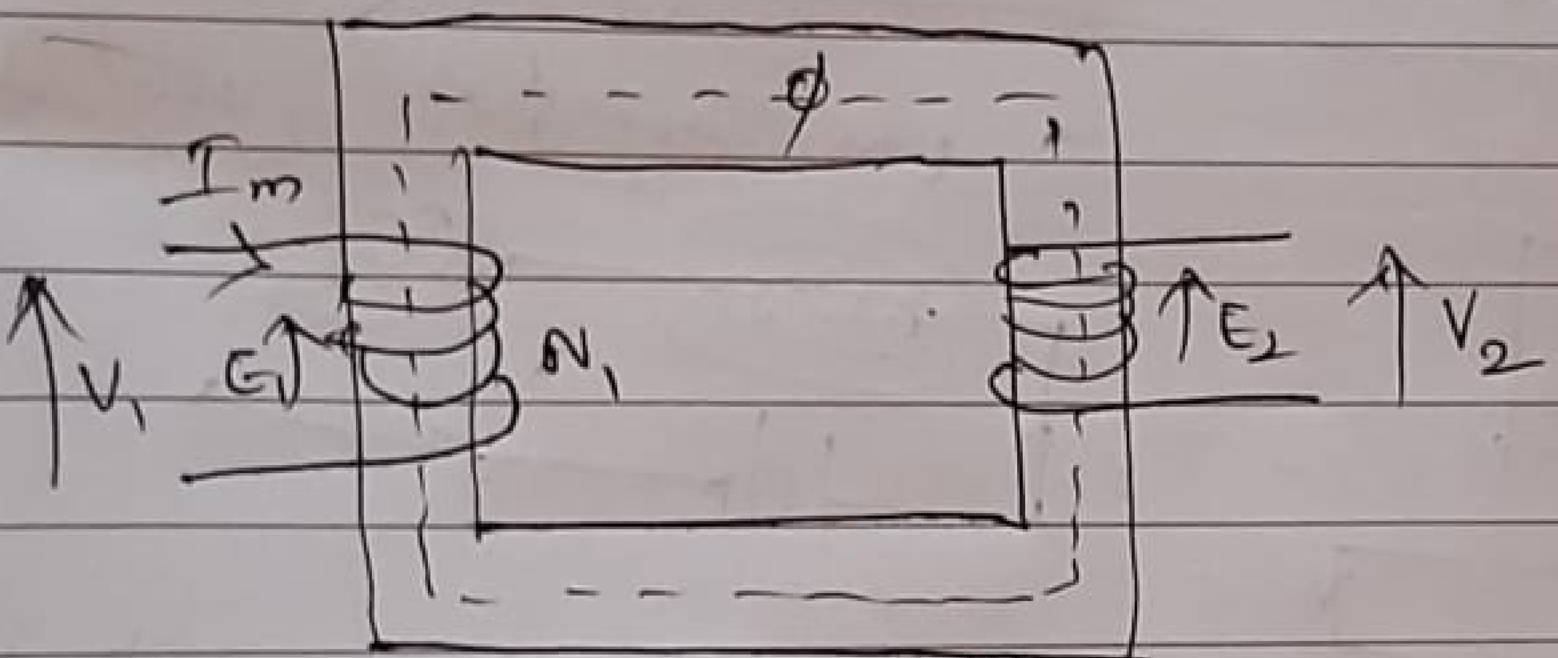
(2) no leakage flux (same flux linked with both coils)

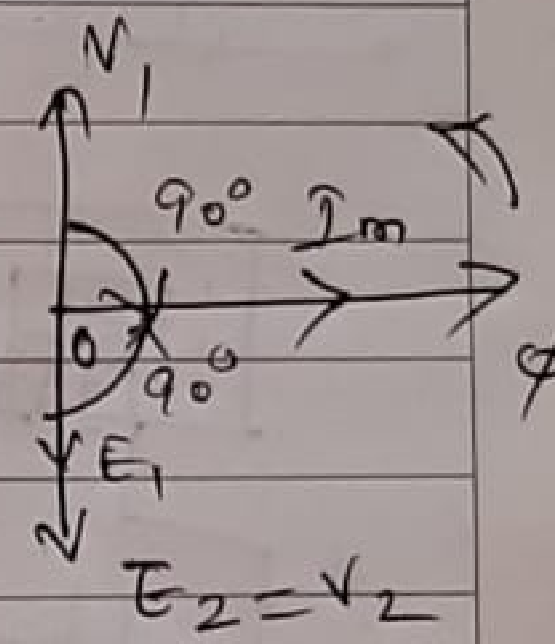
(3) no iron losses (eddy and hysteresis)

Though we cannot have an ideal transformer it helps us to analyse the practical transformer

Consider an ideal transformer on no load. secondary is open. The primary is simply a coil of pure inductance. When an a.c voltage is applied to the primary it draws a small magnetising current I_m which lags behind the applied voltage by 90°. The a.c current I_m

produced an alternating flux ϕ. which is proportional and inphase with I_m. The alternating flux links both the windings and induces an Emf E_1 in the primary and E_2 in the secondary. The primary emf E_1 is equal to V_1 but in opposite direction (Lenz's law). Both E_1 and E_2 lag behind flux ϕ by 90°. Magnitude depends upon no of turns.





Phasor diagram

ϕ is taken as reference since it is common to both the windings.

Consider alternating voltage V_1 of frequency f is applied to the primary. The sinusoidal flux ϕ produced by the primary $\phi = \phi_m \sin\omega t$

Instantaneous emf produced in the primary is e_1

$$e_1 = -N_1 \frac{d\phi}{dt} = -N_1 \frac{d}{dt}(\phi_m \sin\omega t)$$

$$= -\omega N_1 \phi_m \cos\omega t$$

$$= -2\pi f N_1 \phi_m \cos\omega t$$

$$= 2\pi f N_1 \phi_m \sin(\omega t - 90^\circ)$$

$$E_{m_1} = 2\pi f N_1 \phi_m$$

The rms value of E_1 of the primary emf is

$$E_1 = \frac{E_{m_1}}{\sqrt{2}} = \frac{2\pi f N_1 \phi_m}{\sqrt{2}}$$

$$E_1 = 4.44 f N_1 \phi_m$$

$$E_2 = 4.44 f N_2 \phi_m$$

For an ideal transformer

$$E_1 = V_1 \text{ and } E_2 = V_2$$

$$\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2}$$

E_1 and E_2 lags behind ϕ primary gr

or $$\frac{E_1}{N_1} = \frac{E_2}{N_2}$$

(3)

(1) **Magnetic materials :-** (1)

Magnetic field:-

The force experienced by magnetic material, around which there exists a force which attracts magnetic materials like iron fillings.

(2) **Magnetic force : (F)**

$$F \propto \frac{m_1 m_2}{\mu r^2}$$

$$F = K \frac{m_1 m_2}{\mu r^2}$$

$$F = \frac{\mu_0 \mu_r}{4\pi} \frac{m_1 m_2}{r^2} \ N$$

(3) **Magnetic moment (M)**

$M = m \times 2l$

Product of the pole strength and length of the magnete. It is measured in A/m^2.

(4) Permeability of the medium:

$\mu = \mu_0 \times \mu_r$

Absolute permeability of a medium or material is defined as the product of permeability of free space (μ_0) and the relative permeability of the medium

$$\mu = \mu_0 \times \mu_r$$

(5) Magnetic field Intensity (H)

The space around the magnet in which its magnetic influence is felt. A magnetic field exists at a point, if it can exert a force on the moving charge

$$F = \frac{\mu_0 \mu_r}{4\pi} \times \frac{m \times 1}{r^2} \text{ A/m}$$

(6) Intensity of Magnetization (I)

$$I = \frac{\text{magnetic moment (M)}}{\text{volume (V)}} = \frac{M}{V}$$

$$I = \frac{M}{V} = \frac{m \times 2l}{a \times 2l} = \frac{m}{a} \text{ wb/m}^2$$

The measure of magnetization of a magnetized specimen is called intensity of magnetization.

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(7) Relation Between susceptibility and permeability (3)

$\mu = \mu_0 \mu_r = B/H$

When a magnetic material of cross-sectional area A and relative permeability μ_r, is placed in a uniform magnetic field H, two types of induction pass through it. one is due to magnetizing field H and the other due to the material itself being magnetised by induction, The total flux density B

$$B = \mu_0 H + \mu_0 I$$

$$\mu = \mu_0 \mu_r = \frac{B}{H}$$

$$= \frac{\mu_0 H + \mu_0 I}{H}$$

$$\mu_0 \mu_r = \mu_0 + \frac{\mu_0 I}{H} = \mu_0 + \mu_0 \chi$$

Diving both sides by μ_0

$$\mu_r = 1 + \chi$$

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4.

(8) Magnetic susceptibility : χ

$$\chi = \frac{I}{H}$$

It measures the ease with which a specimen ~~measures~~ can be magnetised.

(9) Magnetic flux density :

$$B = \frac{\phi}{A} \quad weber/m^2$$

It is the total number of lines of force per unit area due to magnetising field induced in the substance.

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