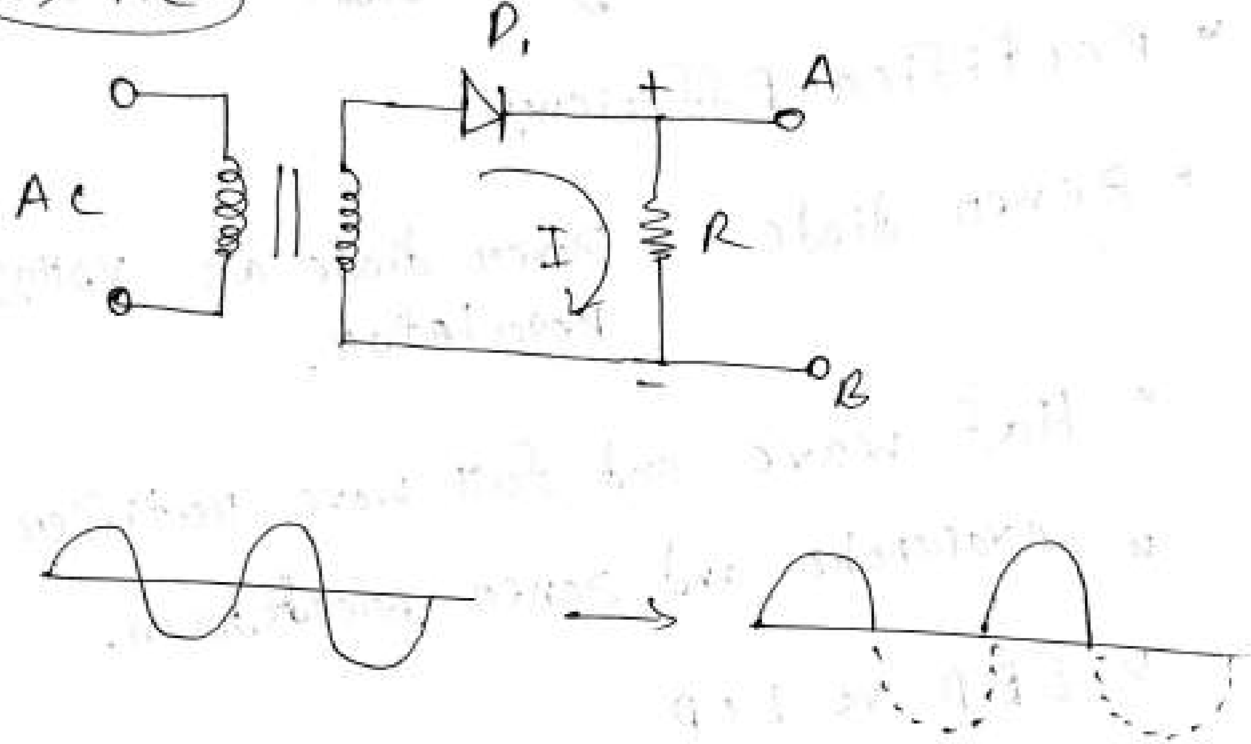
6,7. Topics

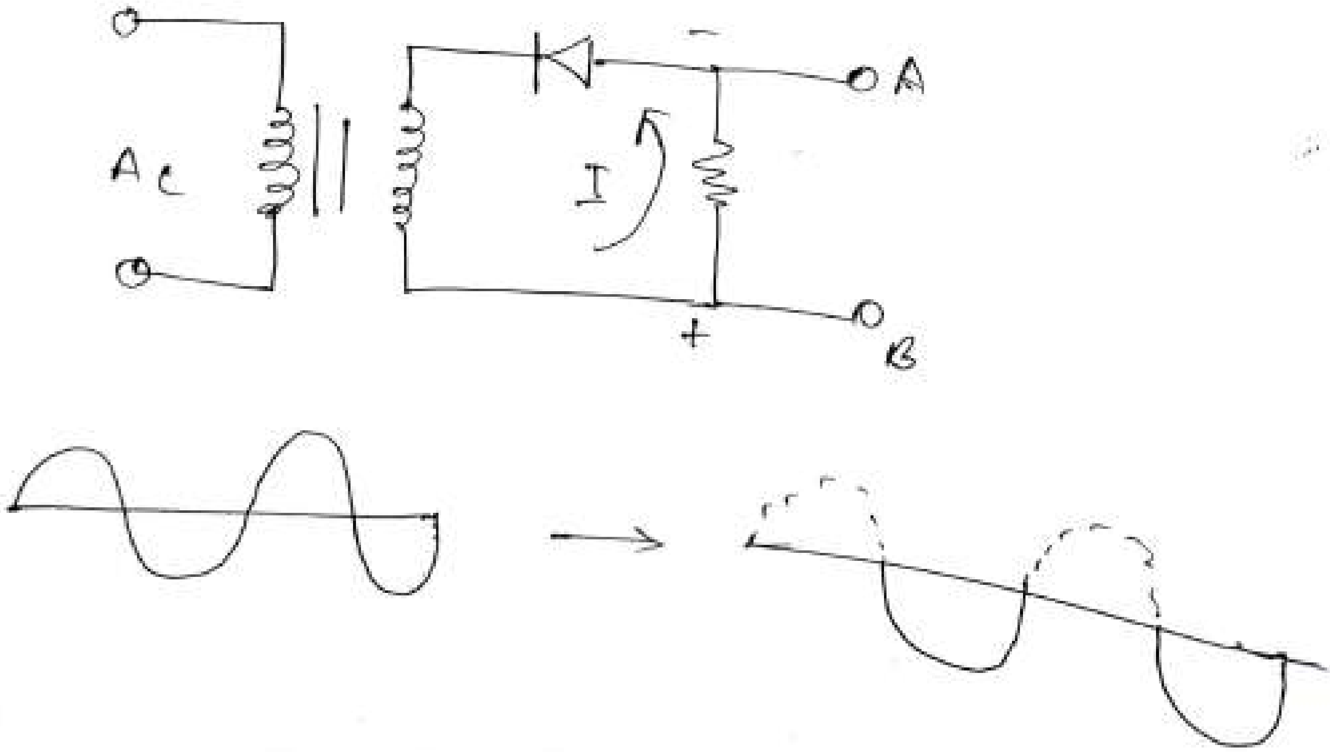
* Rectifier
* Crystal diode
* Rectifier Efficiency
* Zener diode
* Zener diode as voltage Regulator.
* Haf wave and full wave rectifier.
* avalanche and zener breakdown.
* LED vs LCD

Half wave Rectifiers

Positive



Negative



$\boxed{\text{Equation}} \rightarrow \dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$

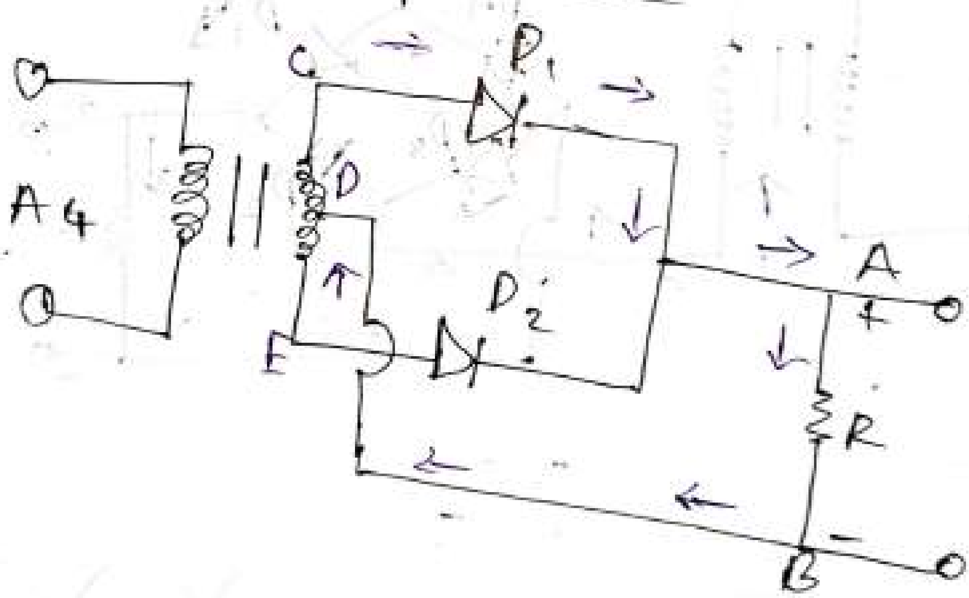
here, $V_s = V_{s\,rms}$ [V_{rms} = root mean square voltage]

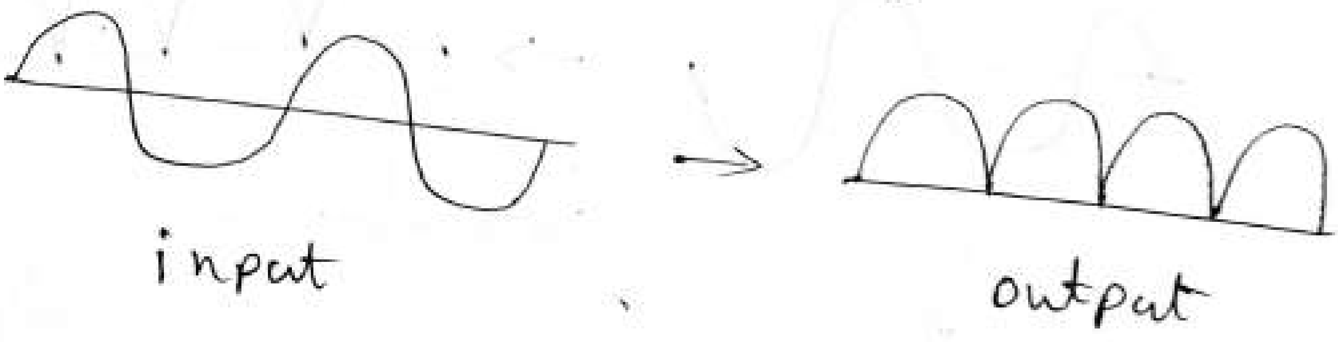
Also, $V_{s\,peak} = V_{s\,rms} \times \sqrt{2}$

For halfwave,

[average] $V_{avg} = \dfrac{V_{peak}}{\pi}$

<u>Full-wave</u>





For full wave,

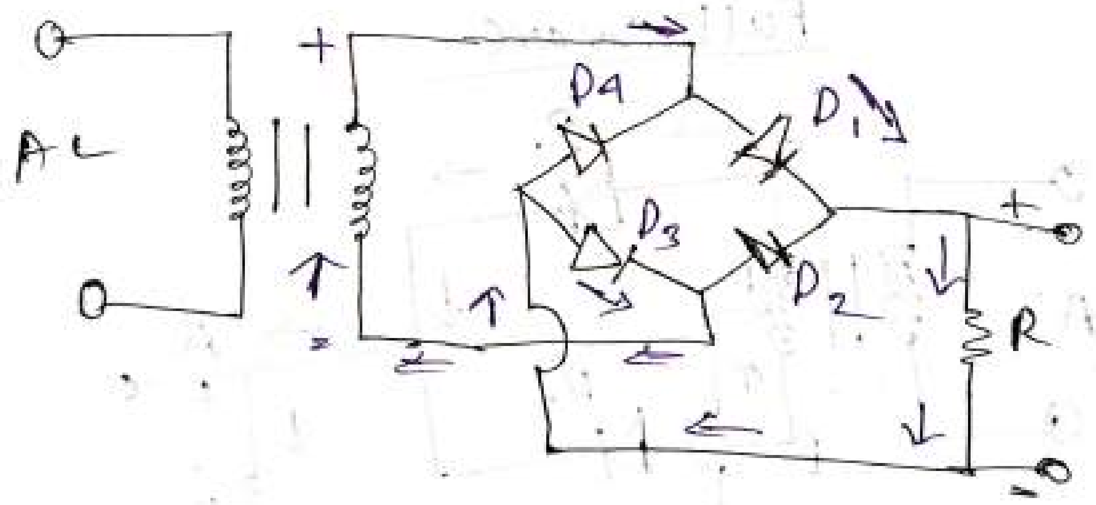
$$V_{CE} = V_S$$

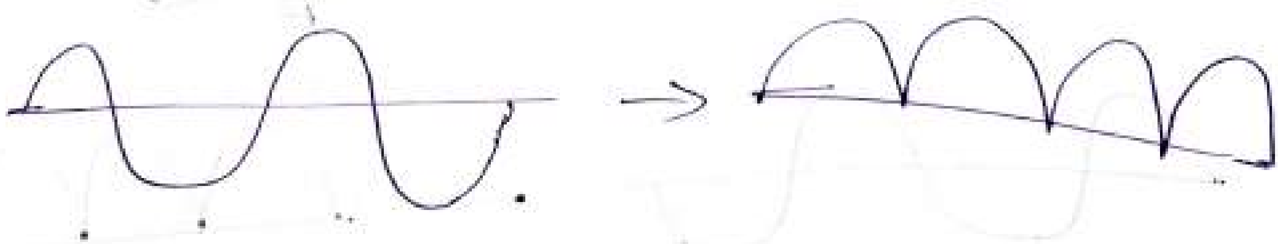
$$\therefore V_{DC} = \frac{V_S}{2}$$

$$V_{PK} = V_{DC}\sqrt{2}$$

$$V_{avg} = \frac{2 V_{PK}}{\pi}$$

Full-Bridge Rectifier





Half wave rectifier efficiency

$$\eta = \frac{P_{Load}}{P_{in}} \times 100\%$$

$$= \frac{I_{dc}^2 R}{I_{rms}^2 R} \times 100\% \qquad \Bigg| \quad I_{dc} = \frac{I_m}{\pi}, \quad I_{rms} = \frac{I_m}{2}$$

peak current

$$= \frac{I_m^2/\pi^2}{I_m^2/4} \times 100\%$$

$$= \frac{4}{\pi^2} \times 100\% = 40.56\%$$

Full wave Rectifier efficiency

$$\eta = \frac{P_{Load}}{P_{in}} \times 100\%$$

$$= \frac{I_{dc}^2 \times R}{I_{rms}^2 \times R} \times 100\% \qquad \Bigg| \quad I_{dc} = \frac{2 I_m}{\pi}, \quad I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$= \frac{4 I_m^2/\pi^2}{I_m^2/2} \times 100\%$$

$$= \frac{8}{\pi^2} \times 100\% = 81.13\%$$

20-21

3(c)

A rectifier is an electrical device that converts Alternating current (AC), into direct current (DC).

A crystal diode is commonly used for rectification due to its ability to allow current to flow in only one direction (forward bias) and block current in the opposite direction (reverse bias)

Rectification process:

i) In a half-wave rectifier a single crystal diode is used to allow only the positive half cycles of AC to pass, blocking the negative half-cycles.

ii) In a full wave rectifier, two or more diodes are used in a bridge configuration to convert both half of the AC signal into DC.

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3(d)

here, Applied voltage, $V = 10\ V$.

D_1 and D_3 diodes are forward biased and they are in series with the $48\ \Omega$ load resistance.

thus, total resistance, $R = (1 + 1 + 48)\ \Omega$

$= 50\ \Omega$

$\therefore$ current through $48\ \Omega$,

$$I = \frac{V}{R} = \frac{10}{50}\ A$$

$$= 0.2\ A$$

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4(a)

Forward current is the current that flows through a diode when it is forward-biased.

Peak Inverse voltage is the maximum reverse voltage a diode can withstand without breaking down.

Leakage current is the current that flows through a diode when it is reverse biased.

Importance in diode operation:

Forward current defines the conduction capacity of the diode, crucial for its role in circuits like rectifiers.

Peak inverse voltage ensures the diode operates reliably in reverse-bias condition without breakdown. Leakage current impacts efficiency and power dissipation in circuits.

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4(b)

Rectifier efficiency, $\eta = \dfrac{\text{d.c Power output}}{\text{Input a.c. Power}}$

Let, r_f = Diode resistance

R_L = load resistance

$v = V_m \sin\theta$

d.c Power:

$$I_{av} = \frac{1}{2\pi}\int_0^{\pi} i \, d\theta$$

$$= \frac{1}{2\pi}\int_0^{\pi} \frac{V_m \sin\theta}{r_f + R_L} d\theta$$

$$= \frac{V_m}{2\pi(r_f+R_L)} \int_0^\pi \sin\theta \, d\theta$$

$$= \frac{V_m}{2\pi(r_f+R_L)} \cdot \left[-\cos\theta\right]_0^\pi$$

$$= \frac{V_m}{\cancel{2}\pi(r_f+R_L)} \times \cancel{2}$$

$$= \frac{V_m}{r_f+R_L} \times \frac{1}{\pi}$$

$$= I_m \times \frac{1}{\pi}$$

$$\therefore P_{dc} = I_{dc}^2 \times R_L = \left(\frac{I_m}{\pi}\right)^2 \times R_L$$

<u>a.c power:</u>

$$P_{ac} = I_{rms}^2 \times (r_f + R_L) \qquad \Big| \; I_{rms} = \frac{I_m}{2}$$

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

∴ Rectifier efficiency

$$= \frac{\text{d.c. output power}}{\text{a.c input power}}$$

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

$$= \frac{0.406 R_L}{r_f + R_L}$$

The efficiency will be max if r_f is negligible

$= 40.6\%$

— c —

4(c)

here, $V_{S(RMS)} = ?$

$V_{P(RMS)} = 230V$

$\frac{N_P}{N_S} = \frac{10}{1}$

$\therefore \frac{V_{S(RMS)}}{V_{P(RMS)}} = \frac{N_S}{N_P}$ $\therefore V_{S(RMS)} = \frac{230}{10} = 23V$

Peak voltage on the secondary,

$$V_{S(m)} = \sqrt{2}\, V_{RMS}$$

$$= \sqrt{2} \cdot 23 = 32.52\, V$$

∴ i) Output DC voltage,

$$V_{DC} = \frac{V_m}{\pi} = \frac{32.52}{\pi}$$

$$= 10.35\, V$$

ii) The peak inverse voltage for a half-wave rectifier is equal to the maximum voltage the diode must block when it is reverse biased.

$$PIV = V_{S(m)} = 32.52\, V$$

19-20

2(a)

A zener diode is a special type of Diode designed to allow current to flow in the reverse direction when the voltage across it exceeds a certain value, known as the zener breakdown voltage.

A zener diode is commonly used to maintain a constant output voltage across a load, even if the input voltage is much higher.

Zener diode used as voltage Regulator:

The zener diode is connected in reverse bias parallel to the load resistor. A series resistor is connected to limit the input current.

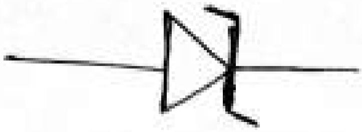
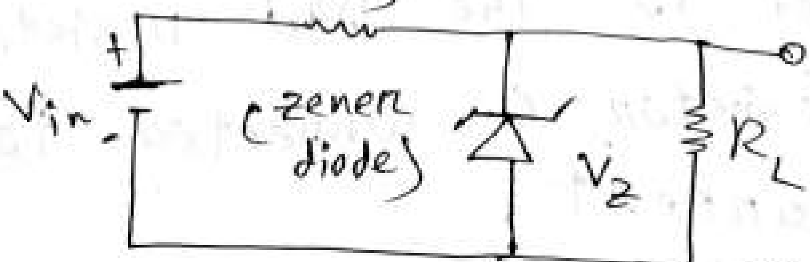


fig: zener diode symbol.

when the input voltage (V_{in}) exceeds the zener breakdown voltage (V_Z) the zener diode starts conducting. To maintain constant voltage the zener diode clamps the voltage across the load to its breakdown voltage (V_Z). This way the load receives a stable voltage.

If V_{in} is less than V_Z, the zener diode does not conduct.



2(b)

A half-wave rectifier is a circuit that converts Ac into Dc using a single diode. It allows only one half cycle of the input Ac signal to pass through while blocking the other half.

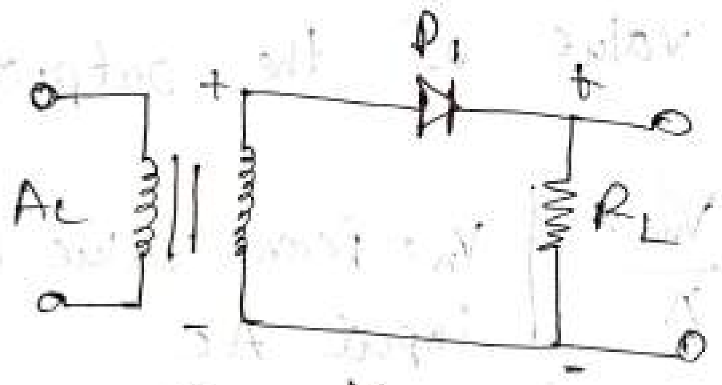


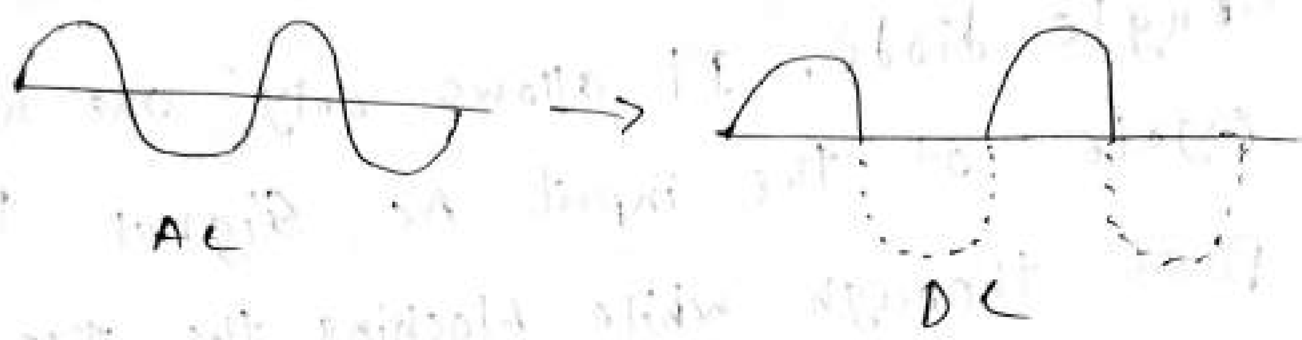
fig: ~~H~~alf-wave Rectifier.

Operation:

i) During the positive half cycle of the Ac input, the diode is forward biased and conducts current.

ii) During the negative half-cycle of the Ac input, the diode is reverse-biased and does not conduct.

Thus, input AC is converted to DC signal.



The average value of the output voltage,

$$V_{DC} = \frac{V_m}{\pi}$$ | V_m = peak value of input AC

The average current through the load resistor (R_L),

$$I_{DC} = \frac{V_{DC}}{R_L} = \frac{V_m}{\pi R_L}$$

The ripple factor is a measure of the AC fluctuations in the output relative to the DC output.

For a half wave rectifier,

$RF = 1.21$.

Efficiency of a half-wave rectifier, $\eta = \frac{P_{DC}}{P_{AC}} \times 100$

$= \frac{40.6}{100} \approx 40.6\%$

This shows that a half wave rectifier is not very efficient due to significant power loss in the blocked half-cycles.

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18-19

2 (a)

ii) A Full wave rectifier is a circuit that converts AC into DC using two diodes. It converts both positive and negative half cycles of an AC signal.

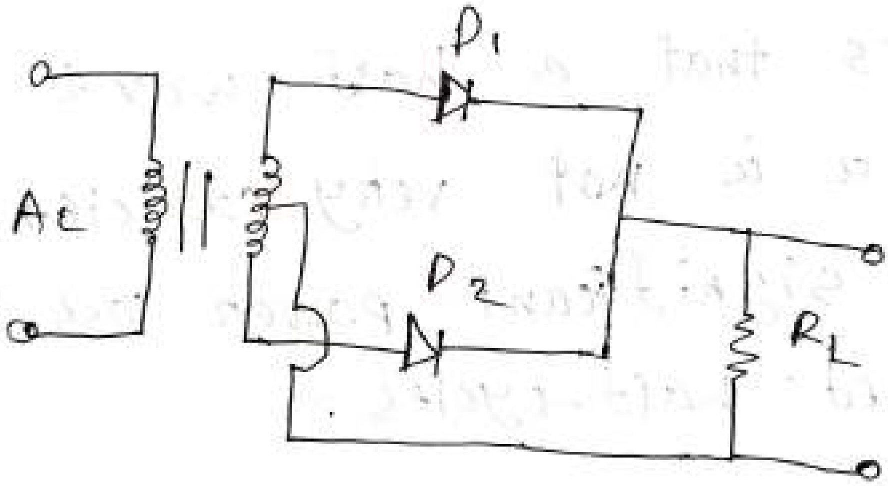


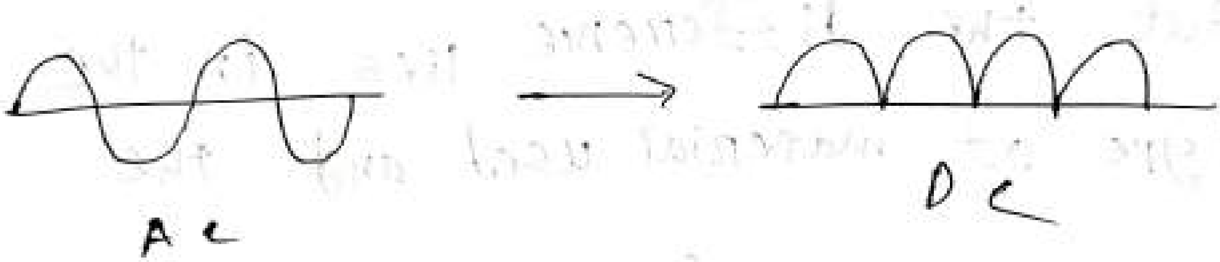
fig: full wave rectifier,

Operation:

i) During the positive half of the AC input, one diode conducts and current flows through the load.

ii) During the negative half of the AC input, the other diode conducts, and current flows through the load in the same direction.

thus converting AC into DC.



2(b)

voltage regulation refers to the ability of the circuit to maintain a constant output voltage regardless of variations in input voltage or load current.

4 (a)

Both the general - purpose diode and the LED (Light emitting Diode) are formed by Joining P- type and N- type semiconductors. But the difference lies in the type of material used and the energy conversion mechanism.

1) P-N Junction Diode:

when a P-N Junction diode is forward biased, electrons from N-region move to the P-region and fill the empty spaces, they release energy. It is mostly heat energy. This occurs because materials used (silicon, germanium) do not emit photons efficiently.

2) LED:

These are made from gallium arsenide or gallium phosphide. When electrons and holes recombine in an LED, the energy released is emitted as photons due to the materials direct bandgap property.

4(b)

Avalanche: Occurs in ordinary diodes at high reverse voltages. When the reverse voltage is high enough free electrons in the depletion region gain sufficient energy to knock other electrons from their atoms, creating an avalanche of charge carriers.

Result: A sudden, large reverse current flows through the diode.

Zener breakdown occurs in a Zener diode when it is operated in reverse bias and the reverse voltage exceeds a specific Zener voltage (V_Z). This Zener breakdown typically occurs at lower reverse voltages.

When the reverse voltage increases and reaches the Zener breakdown voltage, the electric field across the depletion region becomes strong enough to pull electrons from their atomic bonds, causing a sharp increase in current.

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17-18

2 (a)

Breakdown voltage refers to the minimum voltage required to make an insulating material conduct electricity. It is the voltage at which an insulating material becomes conductor. When the material's resistance collapses, a large current can pass through.

Example:

In air, this happens as a spark or lightning when the breakdown voltage is exceeded.

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2(b)

LED (Light emitting Diode)	LCD (Liquid crystal Display)
i) Produces light through electroluminescence when current passes through.	i) Blocks or allows light from a back light using Liquid crystals.
ii) No backlight required.	ii) Requires a backlight.
iii) Brighter and more vibrant.	iii) Less bright compared to LEDs.
iv) energy efficient.	iv) consumes more energy.

2(d)

Given, $R_f = 20\Omega$

$V_{rms} = 50V$

$R_L = 980\Omega$

Peak voltage, $V_m = \sqrt{2}\, V_{rms}$

$= \sqrt{2} \times 50 = 70.71V$

Total resistance, $R = R_L + R_f$. [only one diode conducts at any given time]

$= 980 + 20$

$= 1000\Omega$

$\therefore$ Peak load current, $I_m = \frac{V_m}{R_{total}} = \frac{70.71}{1000}$

$= 70.71mA$

$\therefore$ mean " " , $I_{mean} = \frac{2I_m}{\pi} = \frac{2 \times 70.71}{\pi}$

$= 45.03mA$

— c —

3(a)

The ripple factor is a measure of the effectiveness of a rectifier in converting AC to DC. It is defined as the ratio of the RMS value of the AC component in the rectified output to the DC component in the output.

$$\text{Ripple Factor}(\gamma) = \frac{\text{RMS value of AC}}{\text{DC Value}}$$

Ripple factor of,

half wave Rectifier; 1.21

Full " " "; 0.48

3(c)

here, Transformer turn ratio = 10 : 1

Input AC voltag = 230 V

$$V_{secondary} = \frac{230}{10} = 23V$$

Peak voltage, $V_{peak} = (\sqrt{2} \cdot 23)$

$= 32.52 V$.

∴ DC output,

$$V_{DC} = \frac{V_{peak}}{\pi} = \frac{32.52}{\pi}$$

$= 10.35 V$

20-21

1(c)

The diode equation, also known as the Shockley diode equation is;

$$I = I_s \left(e^{\frac{qv}{KT}} - 1\right)$$

here,

I = current flowing through Diode.

I_s = The saturation current, a very small current that flows through the diode when it is reverse biased.

q = the charge of an electron, 1.6×10^{-19} coulombs.

v = the voltage across diode.

K = boltzmann's constant
$= 1.38 \times 10^{-23}$ J/K.

T = Temperature in kelvins.

e = base of the natural log.
$= 2.718$

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