Question 1(a) [3 marks]

Define: 1. Node, 2. Loop, 3. Branch

Answer:

Term	Definition
Node	A point in a circuit where two or more circuit elements meet or connect
Loop	A closed path in a circuit that starts and ends at the same point without passing through any node more than once
Branch	A path or element connecting two nodes in a circuit

Mnemonic: "Never Loop Between" - Nodes Link, Loops Bound, Branches Establish connections

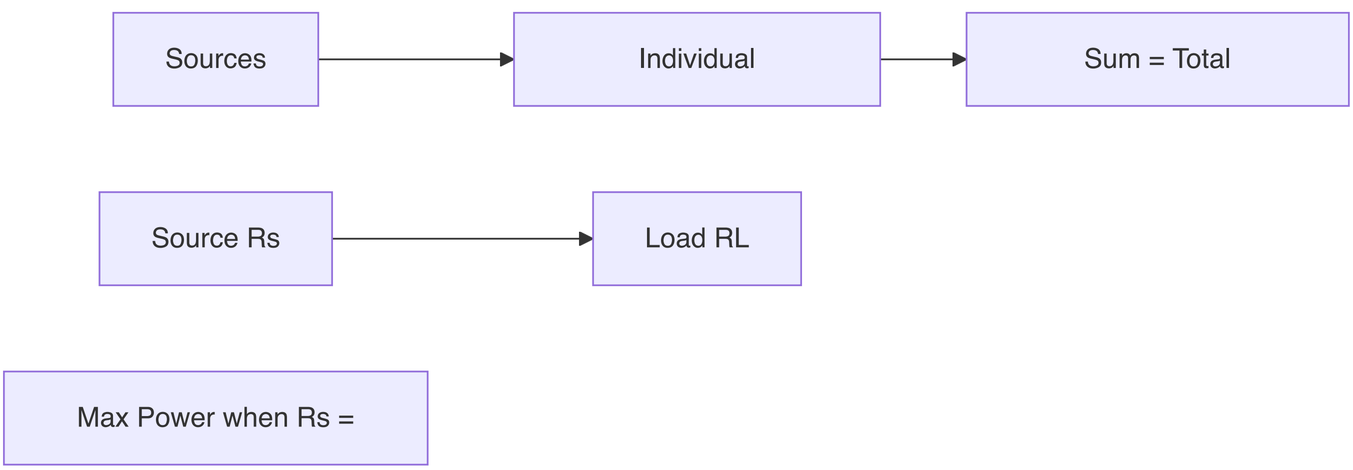
Question 1(b) [4 marks]

Write statement of Superposition theorem and Maximum power transfer theorem.

Answer:

Theorem	Statement
Superposition Theorem	In a linear circuit with multiple sources, the response (voltage or current) in any element equals the algebraic sum of responses caused by each source acting alone, with all other sources replaced by their internal impedances
Maximum Power Transfer Theorem	Maximum power is transferred from source to load when the load resistance equals the source's internal resistance

Diagram:



Mnemonic: "Sum Powers Matched" - Sum individual powers; Match resistance for maximum

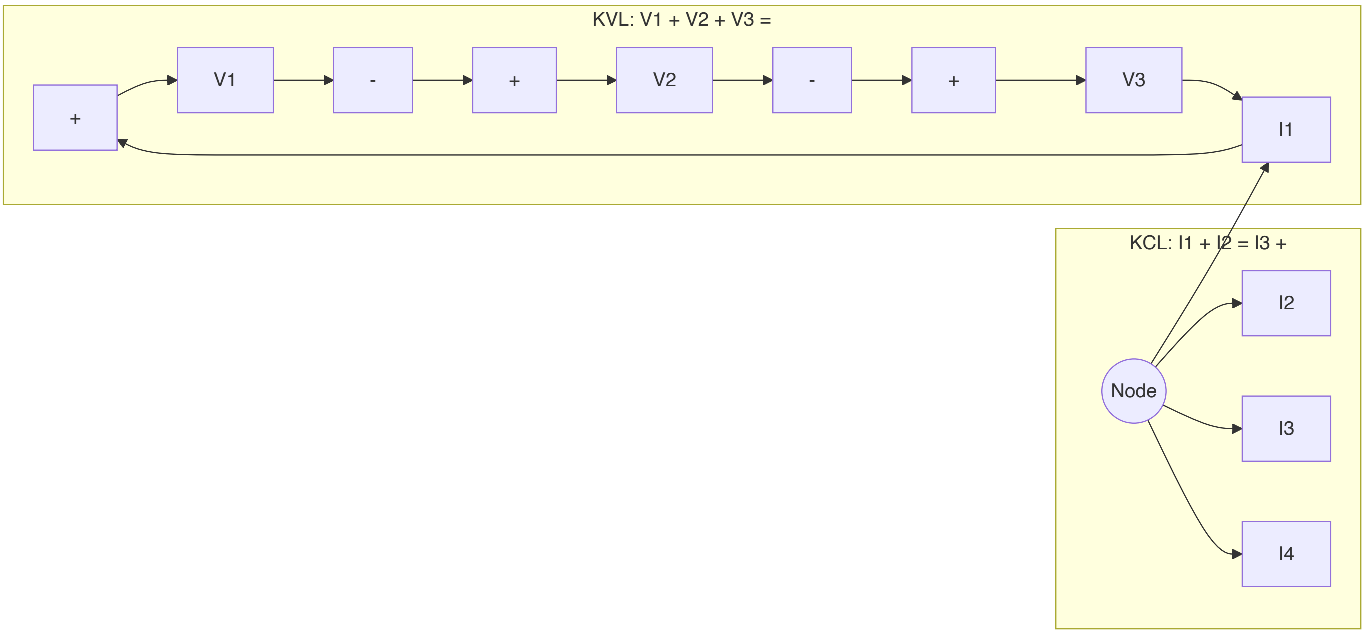
Question 1(c) [7 marks]

Explain Kirchhoff's Voltage Law and Kirchhoff's current Law.

Answer:

Law	Explanation	Mathematical Form
Kirchhoff's Voltage Law (KVL)	The algebraic sum of all voltages around any closed loop in a circuit equals zero	$\Sigma V = 0$
Kirchhoff's Current Law (KCL)	The algebraic sum of all currents entering and leaving a node equals zero	$\Sigma I = 0$

Diagram:



- **Physical interpretation of KVL**: Energy is conserved in a circuit loop
- **Physical interpretation of KCL**: Charge is conserved at circuit nodes
- **Application of KVL**: Finding unknown voltages in circuit loops
- **Application of KCL**: Finding unknown currents at circuit junctions

Mnemonic: "Voltages Loop to Zero, Currents Node to Zero"

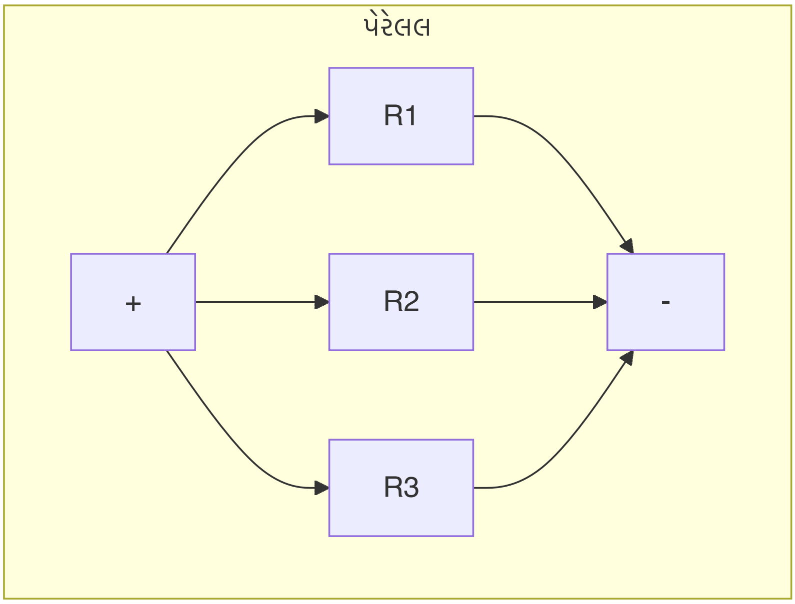
Question 1(c) OR [7 marks]

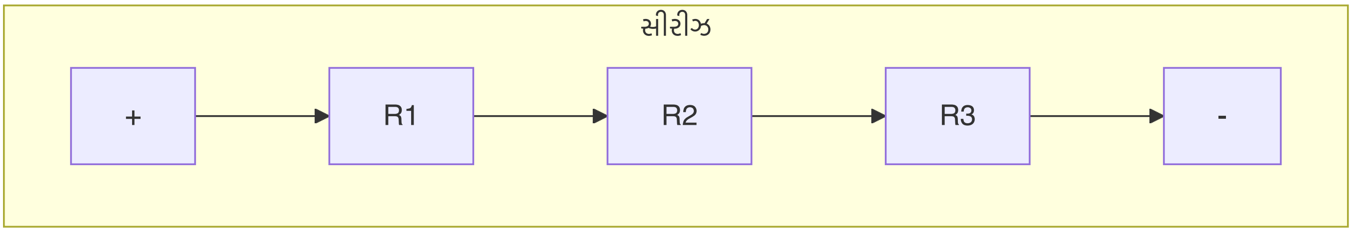
Explain series and parallel connection of resistors with necessary equations.

Answer:

Connection	Characteristics	Equivalent Resistance	Current-Voltage Relationship
Series Connection	Same current flows through all resistors	Req = R1 + R2 + R3 + ... + Rn	I = V/Req
Parallel Connection	Same voltage appears across all resistors	1/Req = 1/R1 + 1/R2 + 1/R3 + ... + 1/Rn	I = I1 + I2 + I3 + ... + In

Diagram:





- **Current in series**: I = I1 = I2 = I3 = ... = In
- **Voltage in series**: V = V1 + V2 + V3 + ... + Vn
- **Current in parallel**: I = I1 + I2 + I3 + ... + In
- **Voltage in parallel**: V = V1 = V2 = V3 = ... = Vn

Mnemonic: "Same Current Series, Same Voltage Parallel"

Question 2(a) [3 marks]

State limitations of Ohm's law.

Answer:

Limitations of Ohm's Law
Non-linear components: Does not apply to components like diodes, transistors
Temperature changes: Not valid when temperature varies significantly
High frequencies: Breaks down at very high frequencies

Mnemonic: "Ohm's Not Linear Thermal High" - Non-linear, Temperature, High frequency

Question 2(b) [4 marks]

Define: 1. Doping, 2. Intrinsic Semiconductor, 3. Extrinsic Semiconductor, 4. Dopant

Answer:

Term	Definition
Doping	Process of adding impurity atoms to pure semiconductor to modify electrical properties
Intrinsic Semiconductor	Pure semiconductor with equal number of electrons and holes
Extrinsic Semiconductor	Doped semiconductor with unequal number of electrons and holes
Dopant	Impurity element added to semiconductor during doping process

Mnemonic: "Do In-Ex-Do" - Doping Introduces Extrinsic properties through Dopants

Question 2(c) [7 marks]

Define Trivalent material and give examples of it. Explain Formation of P-type Semiconductor with the help of proper diagram.

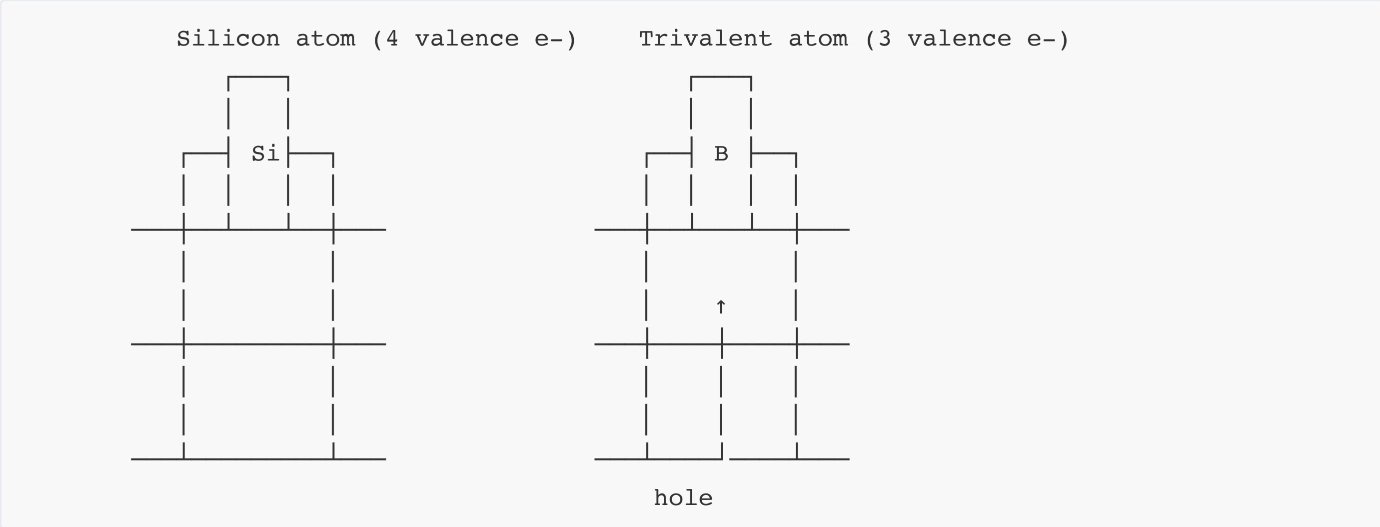
Answer:

Trivalent material: Elements with 3 valence electrons in their outermost shell.

Examples: Boron (B), Aluminum (Al), Gallium (Ga), Indium (In)

P-type Semiconductor Formation:

Diagram:



Process	Result
Doping	Silicon doped with trivalent atoms like Boron
Bond formation	Trivalent atoms form 3 covalent bonds with 4 neighboring Silicon atoms
Hole creation	One bond remains incomplete, creating a hole (positive charge carrier)
Majority carriers	Holes become majority carriers
Minority carriers	Electrons become minority carriers

Mnemonic: "Three Makes Positive" - Three valence electrons make a Positive hole

Question 2(a) OR [3 marks]

Enlist factors affecting Resistance and explain any one of them.

Answer:

Factors Affecting Resistance
Length of conductor
Cross-sectional area
Material (resistivity)
Temperature

Explanation of Temperature effect:
The resistance of most metallic conductors increases with temperature as:
$R = R_0[1 + \alpha(T - T_0)]$
where:

- R = Resistance at temperature T
- R_0 = Resistance at reference temperature T_0

- α = Temperature coefficient of resistance

Mnemonic: "LAMT" - Length, Area, Material, Temperature affect resistance

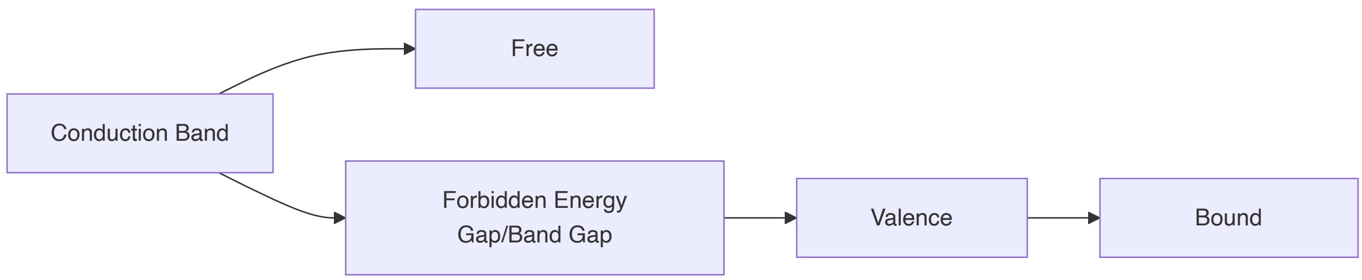
Question 2(b) OR [4 marks]

Define: 1. Valance band, 2. Conduction band, 3. Forbidden energy gap, 4. Free electron

Answer:

Term	Definition
Valence band	Energy band filled with valence electrons that are bound to atoms
Conduction band	Higher energy band where electrons can move freely and conduct electricity
Forbidden energy gap	Energy range between valence and conduction bands where no electron states exist
Free electron	Electron that has gained enough energy to escape from valence band to conduction band

Diagram:



Mnemonic: "Very Clearly Freedom Follows" - Valence, Conduction, Forbidden gap, Free electrons

Question 2(c) OR [7 marks]

Define Pentavalent material and give examples of it. Explain Formation of N-type material with the help of proper diagram.

Answer:

Pentavalent material: Elements with 5 valence electrons in their outermost shell.

Examples: Phosphorus (P), Arsenic (As), Antimony (Sb)

N-type Semiconductor Formation:

Diagram:

```
        Silicon atom (4 valence e-)    Pentavalent atom (5 valence e-)
               ┌───┐                          ┌───┐
               │   │                          │   │
            ┌──┤ Si├──┐                    ┌──┤ P ├──┐
            │  │   │  │                    │  │   │  │
        ────┼──┴───┴──┼────            ────┼──┴───┴──┼────
            │         │                    │         │
            │         │                    │         │
        ────┼─────────┼────            ────┼─────────┼────
            │         │                    │    ↓    │
            │         │                    │    │    │
        ────┴─────────┴────            ────┴────┼────┴────
                                              free electron
```

Process	Result
Doping	Silicon doped with pentavalent atoms like Phosphorus
Bond formation	Pentavalent atoms form 4 covalent bonds with 4 neighboring Silicon atoms
Free electron	Fifth valence electron remains free (negative charge carrier)
Majority carriers	Electrons become majority carriers
Minority carriers	Holes become minority carriers

Mnemonic: "Five Makes Negative" - Five valence electrons make a Negative carrier

Question 3(a) [3 marks]

Define: 1. Depletion region, 2. Knee voltage, 3. Breakdown voltage in accordance of diode.

Answer:

Term	Definition
Depletion region	Region at P-N junction devoid of mobile charge carriers due to diffusion and recombination
Knee voltage	Forward voltage at which current begins to increase rapidly (typically 0.7V for silicon, 0.3V for germanium)
Breakdown voltage	Reverse voltage at which diode rapidly conducts current in reverse direction

Mnemonic: "Depleted Knees Break" - Depletion occurs, Knee begins conduction, Breakdown ends blocking

Question 3(b) [4 marks]

Explain V-I characteristics of P-N junction diode with necessary graph.

Answer:

V-I Characteristics of P-N Junction Diode:

Diagram:

```
     I
     ↑
     |                        /
     |                      /
     |                    /
     |                  /
     |                /
     |              /
     |            /
     |          /
     |        /
     |      /
     |    /
     | Knee voltage (≈0.7V)
     |  /
     |/
─────┼──────────────────────────── V
     |
     |
     |
     |
     |
     |          Breakdown
     |          voltage
     |         /
     |       /
     |     /
     |   /
     v
```

Region	Behavior
Forward Bias (V > 0)	Current increases exponentially after knee voltage
Reverse Bias (V < 0)	Very small leakage current until breakdown voltage
Breakdown Region	Sharp increase in reverse current at breakdown voltage

- **Forward equation**: $I = I_s(e^{qV/nkT} - 1)$
- **Knee voltage**: ~0.7V for silicon, ~0.3V for germanium

Mnemonic: "Forward Flows, Reverse Restricts, Breakdown Bursts"

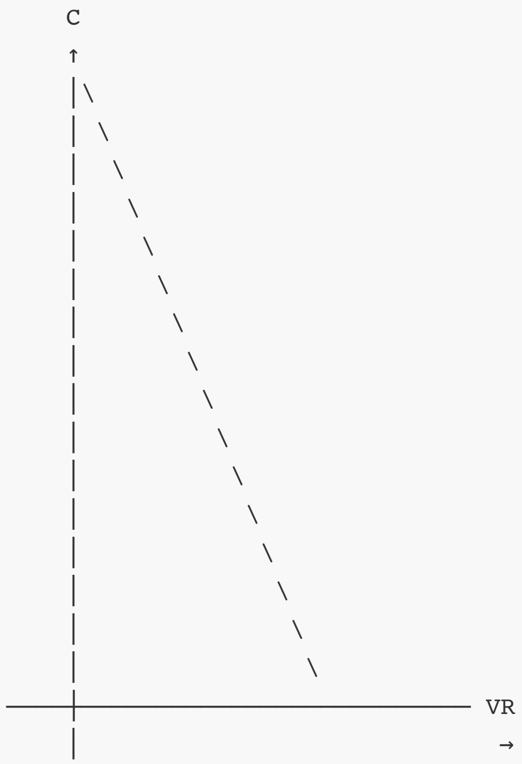
Question 3(c) [7 marks]

Draw characteristic of Varactor diode. Explain working of Varactor diode with diagram and write its application.

Answer:

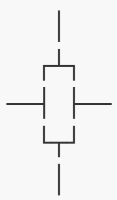
Varactor Diode Characteristics:

Diagram:



Working of Varactor Diode:

Circuit Symbol:



Principle	Explanation
Basic structure	Special P-N junction diode optimized for variable capacitance
Reverse bias operation	Always operated in reverse bias condition
Depletion region	Width varies with applied reverse voltage
Capacitance variation	Capacitance decreases as reverse voltage increases
Mathematical relation	$C \propto 1/\sqrt{VR}$ where VR is reverse voltage

Applications of Varactor Diode:

- Voltage-controlled oscillators (VCOs)
- Frequency modulators
- Electronic tuning circuits
- Automatic frequency control circuits
- Phase-locked loops (PLLs)

Mnemonic: "Capacitance Varies Reversely" - Capacitance Varies with Reverse voltage

Question 3(a) OR [3 marks]

Write application of following diode: 1. Varactor diode, 2. Photo diode, 3. Light Emitting Diode

Answer:

Diode Type	Applications
Varactor Diode	Voltage-controlled oscillators, Frequency modulators, Electronic tuning circuits
Photo Diode	Light sensors, Optical communication, Smoke detectors, Camera light meters
Light Emitting Diode (LED)	Display devices, Indicators, Lighting systems, Optical communication

Mnemonic: "Vary Photo Emit" - Varactor varies frequency, Photo detects light, LED emits light

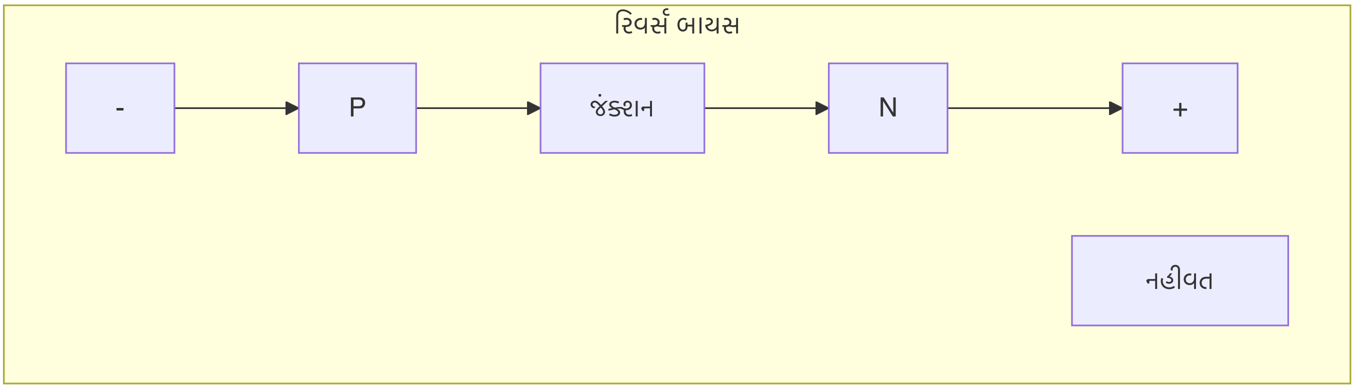
Question 3(b) OR [4 marks]

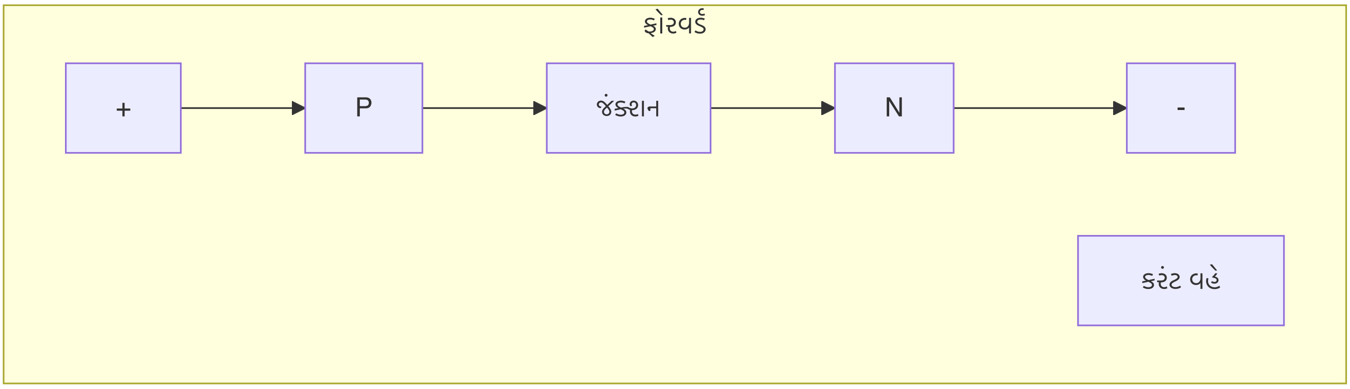
Explain working of P-N junction diode in forward bias and reverse bias.

Answer:

Bias Condition	Working Principle	Characteristics
Forward Bias	P-side connected to positive terminal, N-side to negative terminal	Depletion region narrows, current flows easily after knee voltage (~0.7V)
Reverse Bias	P-side connected to negative terminal, N-side to positive terminal	Depletion region widens, only small leakage current flows until breakdown

Diagram:





Mnemonic: "Forward Flows, Reverse Resists"

Question 3(c) OR [7 marks]

Draw characteristic of Photo diode. Explain working of Photo diode with diagram and write its application.

Answer:

Photo Diode Characteristics:

Diagram:

```
       I
       ↑
       |                    Light intensity
       |                    increasing
       |                /
       |              /
       |            /
       |          /
       |        /
       |      /
       |    /
       |  /
       |/
 ------+--------------------------------  V
       |\                                 →
```

```
       | \
       |  \
       |   \
       |    \
       |     \
       |
       v
```

Working of Photo Diode:

Circuit Symbol:

```
     │    ↙↙
    ┌┴┐  ↙
  ──┤ ├──
    └┬┘
     │
```

Principle	Explanation
Basic structure	P-N junction diode with transparent window or lens
Reverse bias operation	Typically operated in reverse bias condition
Light absorption	Photons create electron-hole pairs in depletion region
Carrier generation	Light intensity proportional to generated carriers
Current generation	Reverse current increases with light intensity

Applications of Photo Diode:

- Light detectors in optical communication
- Photometers and light meters
- Smoke detectors
- Barcode readers
- Medical equipment (pulse oximeters)

Mnemonic: "Light In, Current Out" - Light intensity controls current output

Question 4(a) [3 marks]

Explain working of Half wave rectifier with circuit diagram.

Answer:

Half Wave Rectifier:

Circuit Diagram:

```
           D
  AC      ┌─┬─┐       R
  o───────┤>├─┼───────┬──────o
          └─┘ │       │
              │       │
              │       │
  o───────────┘       └──────o
                        Output
```

Operation Phase	Description
Positive Half Cycle	Diode conducts, current flows through load, output follows input
Negative Half Cycle	Diode blocks, no current flows, output is zero

- **Output frequency**: Same as input frequency
- **Form factor**: 1.57
- **Ripple factor**: 1.21
- **Efficiency**: 40.6%
- **PIV of diode**: Vmax

Mnemonic: "Half Passes Positive" - Only positive half-cycle passes through

Question 4(b) [4 marks]

Explain Zener diode as a voltage regulator.

Answer:

Zener Diode Voltage Regulator:

Circuit Diagram:

```
           Rs
  o────────┬──────┐
  Vin      │      │
           │      │    Zener   RL     Vout
           │      ├─────┐ ┌┬┐ ┌───┬──────o
           │      │     │ │>│ │   │
           │      │     │ └┬┘ │   │
  o────────┴──────┴─────┴──┴──┴───┴──────o
```

Component	Function
Series resistor Rs	Limits current and drops excess voltage
Zener diode	Maintains constant voltage across load
Load resistor RL	Represents the circuit being powered

Working Principle:

- Zener operates in reverse breakdown region
- Maintains constant voltage regardless of input changes
- Excess current flows through Zener diode
- Voltage regulation equation: Vout = Vz (Zener voltage)

Mnemonic: "Zener Zeros Voltage Variations"

Question 4(c) [7 marks]

Write need of Rectifier. Explain Bridge wave rectifier with circuit diagram and draw its input and output waveform.

Answer:

Need of Rectifier:

- To convert AC voltage to DC voltage
- Most electronic devices require DC for operation
- Power supply systems need DC output from AC mains

Bridge Wave Rectifier:

Circuit Diagram:

```
                D1       D3
              ┌─┬─┐    ┌─┬─┐
              │>├─┼────┤<├─┐
              └─┘ │    └─┘ │
  AC              │         RL   Output
  o───────────────┼────────┬────o
                  │        │
             ┌─┬─┐│    ┌─┬─┐
             │<├─┼─────┤>├─┘
             └─┘       └─┘
               D2       D4
```

Input and Output Waveform:

```
  Input
    ↑
    |    /\      /\      /\
    |   /  \    /  \    /  \
    |  /    \  /    \  /    \
  ──┼─┼─────┼┼──────┼┼──────┼──────► t
    | |\    /||\    /||\    /|
    | | \  / || \  / || \  / |
    | |  \/  ||  \/  ||  \/  |
    v
```

```
Output
  ↑
  |    /\      /\      /\
  |   /  \    /  \    /  \
  |  /    \  /    \  /    \
──┼─┼──────┼┼──────┼┼──────┼──────► t
  |
  |
  v
```

Working in Positive Half Cycle	Working in Negative Half Cycle
D1 and D4 conduct	D2 and D3 conduct
Current flows through load in same direction	Current flows through load in same direction

- **Output frequency**: Twice the input frequency
- **Form factor**: 1.11
- **Ripple factor**: 0.48
- **Efficiency**: 81.2%
- **PIV of diode**: Vmax

Mnemonic: "Bridge Both Better" - Bridge rectifier uses both half cycles

Question 4(a) OR [3 marks]

Explain working of Shunt capacitor filter.

Answer:

Shunt Capacitor Filter:

Circuit Diagram:

```
             D
          ┌─┬─┐
          │>├─┤
          └─┘ │
AC            │       C     RL
o─────────────┼───────┬─────┬───o
              │       │     │    Output
              │       │     │
o─────────────┴───────┴─────┴───o
```

Operation	Description
Charging	Capacitor charges during peak of rectified output
Discharging	Capacitor discharges slowly through load when voltage drops
Smoothing effect	Provides almost constant DC output by filling gaps

- **Ripple reduction**: Significant reduction in ripple voltage
- **Time constant**: RC must be much larger than period of input
- **Discharge equation**: $V = V_0e^{(-t/RC)}$

Mnemonic: "Capacitor Catches Peaks" - Capacitor stores peak voltage

Question 4(b) OR [4 marks]

Compare Center tap full wave rectifier and Bridge wave rectifier

Answer:

Parameter	Center Tap Full Wave Rectifier	Bridge Wave Rectifier
Number of diodes	2	4
Transformer	Center-tapped transformer required	Simple transformer sufficient
PIV of diode	2Vmax	Vmax
Efficiency	81.2%	81.2%
Output frequency	Twice input frequency	Twice input frequency
Cost	Higher due to center-tapped transformer	Lower, simpler transformer but more diodes
Size	Larger	Smaller

Mnemonic: "Center Taps Transformer, Bridge Bypasses Tapping"

Question 4(c) OR [7 marks]

Write need of Filter circuit in rectifier. Explain π filter with circuit diagram and draw its input and output waveform.

Answer:

Need of Filter Circuit in Rectifier:

- Reduces ripple in rectified output

- Provides steady DC voltage required by electronic circuits
- Improves efficiency of power supply
- Prevents damage to sensitive electronic components

π Filter:

Circuit Diagram:

```
                D
            ┌─┬─┐         L
            │>├─┼─────────┬─────────┐
            └─┘ │         │         │
    AC          │         │         │
    o───────────┼─────────┘         │
                │                   │
                │   C1    C2        │   RL
    o───────────┴─────┬─────┬───────┴─────┬─────o
                      │     │             │       Output
                      │     │             │
                      ┴─────┴─────────────┴─────o
```

Input and Output Waveform:

```
Input (Rectified)
  ↑
  │    /\       /\       /\
  │   /  \     /  \     /  \
  │  /    \   /    \   /    \
──┼─┼──────┼┼──────┼┼──────┼────► t
  │
  │
  v

Output
  ↑
  │───────────────────────────
  │
  │
──┼─────────────────────────────► t
  │
  │
  v
```

Component	Function
Input capacitor (C1)	Initial filtering of rectified output
Choke (L)	Blocks AC ripple and allows DC to pass
Output capacitor (C2)	Further filtering for smoother output

- **Superior filtering**: Better ripple reduction than simple capacitor filter
- **Ripple factor**: Much lower than capacitor filter alone
- **Voltage regulation**: Better voltage regulation under load variations

Mnemonic: "Capacitor-Inductor-Capacitor Perfectly Irons" (π shape resembling CIC filter)

Question 5(a) [3 marks]

Explain Working of PNP Transistor with the necessary diagram.

Answer:

PNP Transistor Working:

Diagram:

```
             Collector
                 ↑
                 |
                 P
              ┌──┴──┐
     Base →   |     |
              N     |
              |     |
              P     |
                 |
                 ↓
             Emitter
```

Biasing	Working
Base-Emitter junction	Forward biased
Base-Collector junction	Reverse biased
Majority carriers	Holes
Current flow	Emitter to Collector

- **Emitter**: Heavily doped P-region that emits holes
- **Base**: Thin, lightly doped N-region that controls current flow
- **Collector**: Moderately doped P-region that collects holes

Mnemonic: "Positive-Negative-Positive" - PNP structure

Question 5(b) [4 marks]

Explain working of N-channel JFET with diagram.

Answer:

N-channel JFET Working:

Diagram:

```
             Drain
               ↑
               |
       ┌───────┴───────┐
       |               |
Gate →  P              P  ← Gate
       |               |
       |       N       |
       |               |
       └───────┬───────┘
               |
               ↓
             Source
```

Terminal	Function
Source	Source of charge carriers (electrons)
Drain	Collects charge carriers
Gate	Controls width of the channel

Working Principle:

- Channel formed by N-type material between source and drain
- P-type gate regions form PN junctions with channel
- Gate-to-source junction always reverse biased
- Increasing negative gate voltage widens depletion region
- Narrower channel increases resistance between source and drain
- FET operates as voltage-controlled resistor

Mnemonic: "Negative Channel Junction Effect" - N-channel JFET

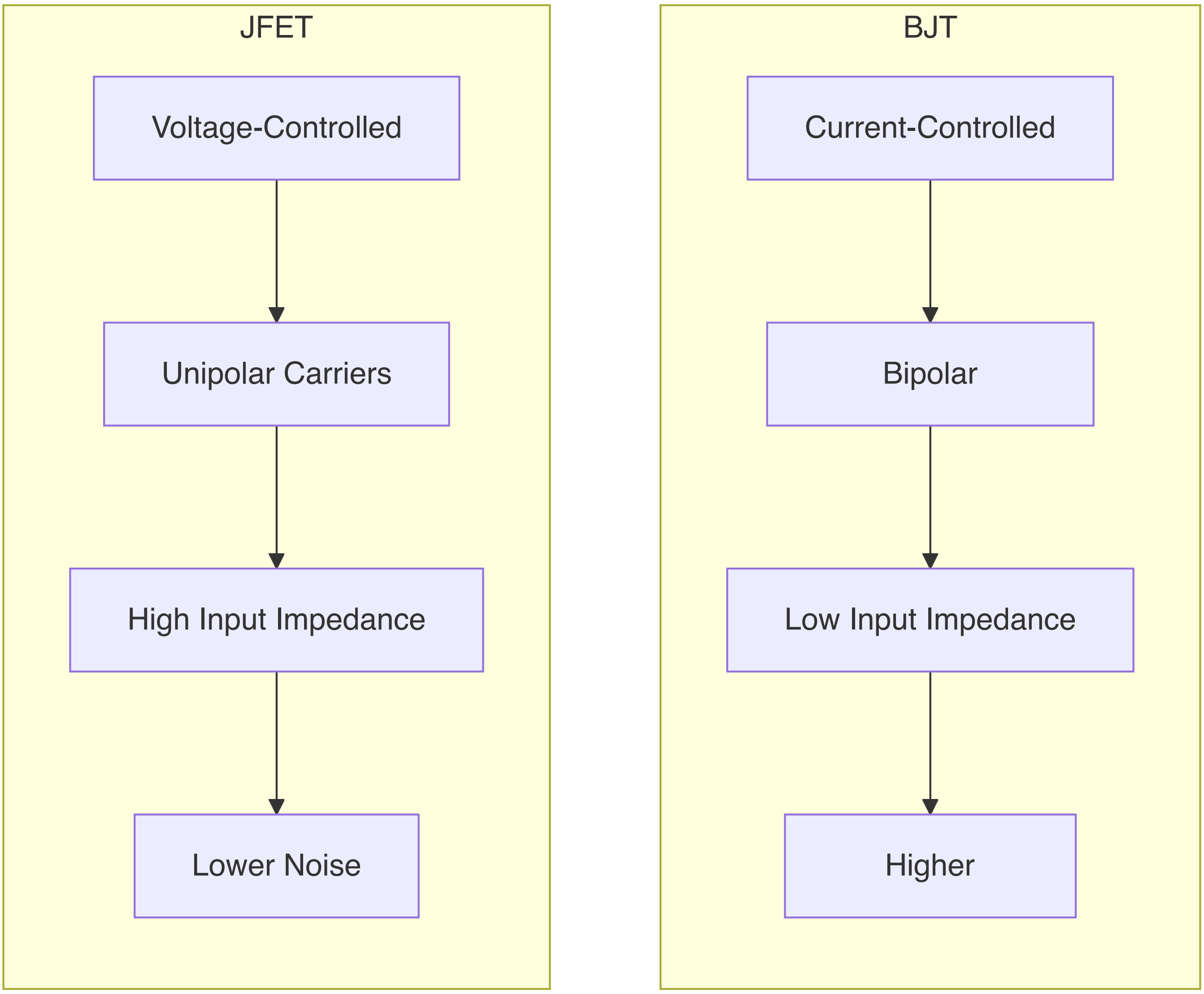
Question 5(c) [7 marks]

Compare BJT and JFET

Answer:

Parameter	BJT (Bipolar Junction Transistor)	JFET (Junction Field Effect Transistor)
Structure	Three-layer structure (NPN or PNP)	Single channel with gate junctions
Control mechanism	Current-controlled device	Voltage-controlled device
Carriers	Both majority and minority carriers (bipolar)	Only majority carriers (unipolar)
Input impedance	Low to medium (1-10 kΩ)	Very high (10^8-10^{12} Ω)
Noise	Higher noise	Lower noise
Power consumption	Higher	Lower
Switching speed	Slower due to charge storage	Faster due to absence of charge storage
Temperature stability	Less stable	More stable

Diagram:



Mnemonic: "Current Bipolar Low, Voltage Unipolar High" - BJT vs JFET key differences

Question 5(a) OR [3 marks]

Enlist methods to dispose E-waste and explain any one method of them.

Answer:

E-waste Disposal Methods
Recycling
Reuse
Incineration
Landfilling
Take-back systems

Explanation of Recycling:
E-waste recycling involves collecting, dismantling, and separating electronic waste into recoverable materials. Components are shredded and sorted into raw materials like plastic, glass, and metals (including precious metals like gold, silver, copper). These materials are then processed and can be used to manufacture new products. Recycling reduces environmental impact, conserves resources, and recovers valuable materials.

Mnemonic: "RRIL-T" - Recycling, Reuse, Incineration, Landfill, Take-back

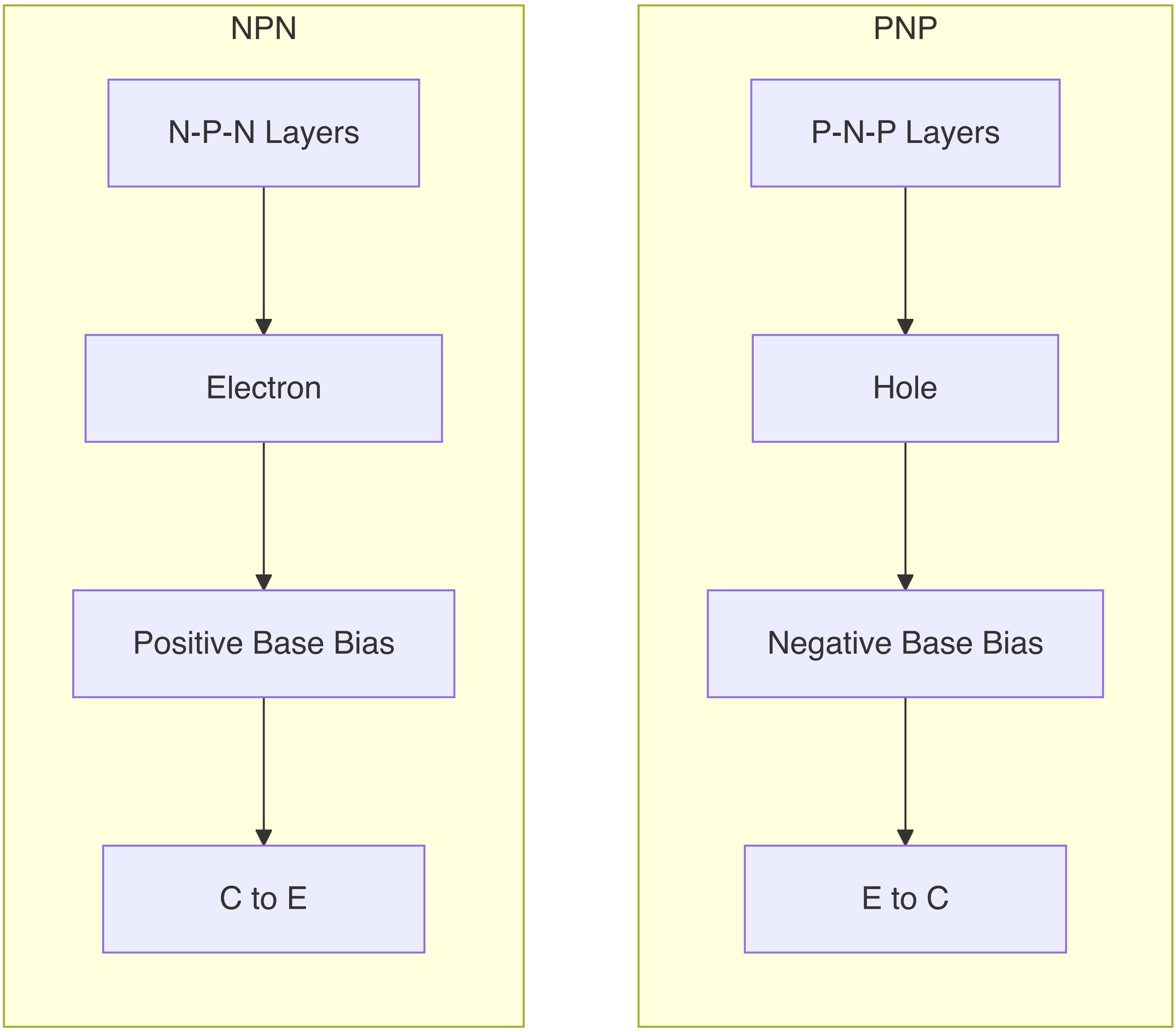
Question 5(b) OR [4 marks]

Compare PNP and NPN Transistor.

Answer:

Parameter	PNP Transistor	NPN Transistor
Symbol	Arrow points inward to base	Arrow points outward from base
Structure	P-type, N-type, P-type layers	N-type, P-type, N-type layers
Majority carriers	Holes	Electrons
Biasing voltage	Base negative with respect to emitter	Base positive with respect to emitter
Current direction	Emitter to collector	Collector to emitter
Speed	Slower (holes mobility is less)	Faster (electrons mobility is more)

Diagram:



Mnemonic: "Positive-Negative-Positive (Holes), Negative-Positive-Negative (Electrons)"

Question 5(c) OR [7 marks]

Draw and explain Input and Output Characteristics of CE configuration.

Answer:

Input Characteristics of CE Configuration:

Diagram:

```
Ib(μA)
 ↑
 |                        VCE=10V
 |                      /
 |                    /
 |                  /  VCE=5V
 |                /
 |              /
 |            /  VCE=0V
```

```
    |         /
    |       /
    |     /
    |   /
    | /
    |/
────┼──────────────────────────── VBE(V)
    |                              →
```

Output Characteristics of CE Configuration:

Diagram:

```
    Ic(mA)
    ↑
    |                  Ib=50μA
    |                /──────────────
    |               /
    |              / Ib=40μA
    |             /──────────────
    |            /
    |           / Ib=30μA
    |          /──────────────
    |         /
    |        / Ib=20μA
    |       /──────────────
    |      /
    |     / Ib=10μA
    |    /──────────────
    |   /
    |  / Ib=0
    | /
    |/
────┼──────────────────────────── VCE(V)
    |                              →
    |
    | Active     |  Saturation
    | Region     |  Region
    v            v
```

Characteristic	Description
Input Characteristics	Relationship between base current (IB) and base-emitter voltage (VBE) at constant collector-emitter voltage (VCE)
Output Characteristics	Relationship between collector current (IC) and collector-emitter voltage (VCE) at constant base current (IB)

Regions in Output Characteristics:

Region	Description
Saturation Region	Both junctions forward biased, VCE is small, IC is almost constant regardless of VCE
Active Region	Base-emitter junction forward biased, base-collector junction reverse biased, IC proportional to IB
Cutoff Region	Both junctions reverse biased, negligible current flows

Important Parameters:

- **Current gain (β)**: Ratio of collector current to base current (IC/IB)
- **Input resistance**: Ratio of change in VBE to change in IB at constant VCE
- **Output resistance**: Ratio of change in VCE to change in IC at constant IB

Mnemonic: "Input Shows Voltage Effects, Output Shows Current Control"