Elements of Electrical & Electronics Engineering (1313202) - Winter 2024 Solution

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Question 1(a) [3 marks]

Explain difference between Active and passive network.

Solution

Active Network	**Passive Network**
Contains at least one active element (voltage/current source)	Contains only passive elements (R, L, C)
Can deliver energy to the circuit	Cannot deliver energy to the circuit
Can amplify signal power	Cannot amplify signal power

Mnemonic

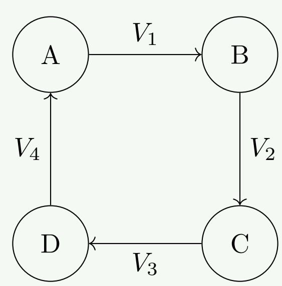
"Active Adds Power, Passive Parts Take"

Question 1(b) [4 marks]

State and explain Kirchhoff's voltage law (KVL).

Solution

Statement: Kirchhoff's Voltage Law (KVL) states that the algebraic sum of all voltages around any closed loop in a circuit is zero.
Mathematically: $V_1 + V_2 + V_3 + V_4 = 0$ or $\sum V = 0$



Sign Convention:

- **Voltage Drop**: When passing through a resistor in direction of current, voltage is negative.
- **Voltage Rise**: When passing through a source from negative to positive, voltage is positive.

Mnemonic

"Voltage Loop Equals Zero"

Question 1(c) [7 marks]

Define the following terms: (1) Charge (2) Current (3) Potential (4) E.M.F. (5) Inductance (6) Capacitance (7) Frequency.

Solution

Term	Definition
Charge	The quantity of electricity measured in coulombs (C).
Current	The rate of flow of electric charge measured in amperes (A).
Potential	The electrical pressure or energy per unit charge measured in volts (V).
E.M.F.	Electromotive Force is the energy supplied by a source per unit charge measured in volts (V).
Inductance	The property of an electric circuit that opposes change in current, measured in henries (H).
Capacitance	The ability of a body to store electrical charge, measured in farads (F).
Frequency	Number of complete cycles per second, measured in hertz (Hz).

Mnemonic

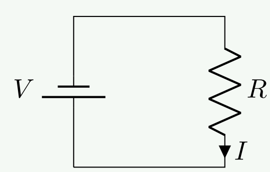
"Coulombs' Flow Pressurized by Energy Induces Capacitive Fluctuations"

Question 1(c) OR [7 marks]

State Ohm's law. Write its application and limitation.

Solution

Statement: Ohm's Law states that the current flowing through a conductor is directly proportional to the potential difference and inversely proportional to the resistance, provided physical conditions (temperature) remain constant.
Formula: $V = I \times R$



Where: V = Voltage (V), I = Current (A), R = Resistance (Ω).
Applications:
- Circuit design and analysis.
- Power consumption calculations.
- Component value determination.
- Voltage divider networks.
- Current divider networks.

Limitations:
- Valid only for linear components.
- Not applicable to non-ohmic devices (diodes, transistors).
- Invalid at high temperatures.
- Not valid for semiconductors.
- Cannot be applied to non-linear resistive elements.

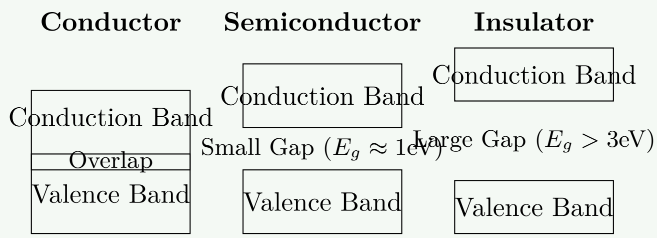
Mnemonic

"Volts Reveal Amps' Motion"

Question 2(a) [3 marks]

Draw and explain energy band diagrams for insulator, conductor and Semiconductor.

Solution



- **Conductor**: Valence and conduction bands overlap, allowing free electron movement.
- **Semiconductor**: Small energy gap (0.7-3 eV) between bands allows limited conduction.
- **Insulator**: Large energy gap (> 3 eV) prevents electrons from moving to conduction band.

Mnemonic

"Conductors Overlap, Semiconductors Jump Small, Insulators Block All"

Question 2(b) [4 marks]

Write statement of Maximum power transfer theorem and reciprocity theorem.

Solution

Theorem	Statement
Maximum Power Transfer Theorem	Maximum power is transferred from source to load when the load resistance equals the source internal resistance ($R_L = R_S$).
Reciprocity Theorem	In a linear, bilateral network, if voltage source E in branch 1 produces current I in branch 2, then the same voltage source E in branch 2 will produce the same current I in branch 1.

Mnemonic

"Match Resistance for Maximum Power; Swap Sources, Current Stays"

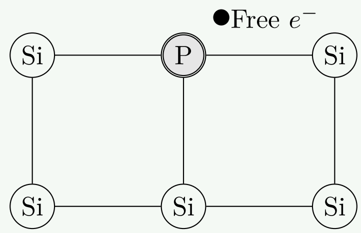
Question 2(c) [7 marks]

Explain the formation and conduction of N-type materials.

Solution

Formation Process:

- Pure silicon/germanium doped with pentavalent impurity atoms (P, As, Sb).
- Impurity atoms have 5 valence electrons (silicon has 4).
- Four electrons form covalent bonds, fifth becomes free electron.
- Creates excess negative charge carriers.



Conduction Mechanism:

- **Majority Carriers**: Electrons.
- **Minority Carriers**: Holes.
- Electron movement provides electrical conduction.
- Even at room temperature, free electrons enable current flow.

Mnemonic

"Pentavalent Provides Plus-One Electron"

Question 2(a) OR [3 marks]

Define valence band, conduction band and forbidden gap.

Solution

Term	Definition
Valence Band	Energy band occupied by valence electrons that are bound to specific atoms in the solid.
Conduction Band	Higher energy band where electrons can move freely throughout the material, enabling electrical conduction.
Forbidden Gap	Energy region between valence and conduction bands where no electron states exist.

Mnemonic

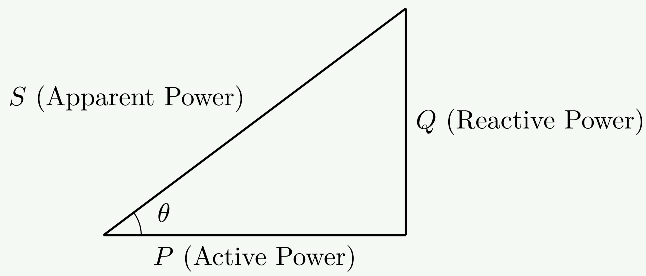
"Valence Binds, Conduction Flows, Forbidden Gaps Block"

Question 2(b) OR [4 marks]

Define the terms active power, reactive power and power factor with power triangle.

Solution

Power Triangle:



- **Active Power (P)**: Actual power consumed, measured in watts (W), $P = VI \cos\theta$.
- **Reactive Power (Q)**: Power oscillating between source and load, measured in volt-amperes reactive (VAR), $Q = VI \sin\theta$.
- **Power Factor**: Ratio of active power to apparent power, $PF = \cos\theta = P/S$.

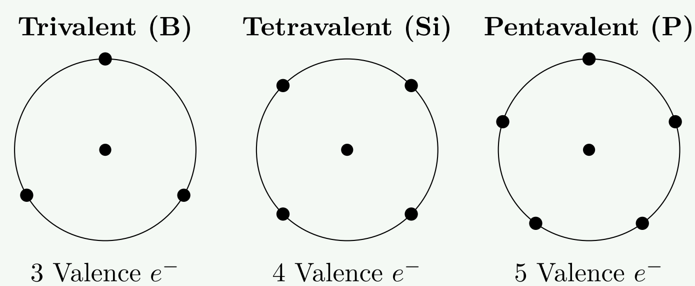
Mnemonic

"Real Power Works, Reactive Power Waits"

Question 2(c) OR [7 marks]

Explain the structure of atom of trivalent, tetravalent and pentavalent elements.

Solution



Element	Structure	Examples	Use
Trivalent	3 electrons in outer shell	B, Al, Ga, In	P-type dopant
Tetravalent	4 electrons in outer shell	Si, Ge, C	Semiconductor base
Pentavalent	5 electrons in outer shell	P, As, Sb	N-type dopant

Mnemonic

"Three Accepts, Four Forms, Five Donates"

Question 3(a) [3 marks]

Draw the symbol of photodiode and state its application.

Solution

Symbol:

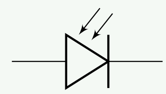


Figure 1. Photodiode Symbol

Applications:

- Light sensors and detectors.
- Optical communication systems.
- Solar cells and photovoltaic applications.
- Camera exposure controls.
- Medical equipment (pulse oximeters).

Mnemonic

"Light Triggers Electric Current"

Question 3(b) [4 marks]

Write a Short note on LED.

Solution

Symbol:

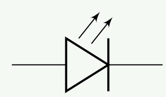


Figure 2. LED Symbol

Information:

- **Structure**: P-N junction diode that emits light when forward biased.
- **Working Principle**: Electron-hole recombination releases energy as photons.
- **Types**: Various colors based on semiconductor material (GaAs, GaP, GaN).
- **Advantages**: Low power consumption, long life, small size, fast switching.
- **Applications**: Displays, indicators, lighting, remote controls, optical communications.

Mnemonic

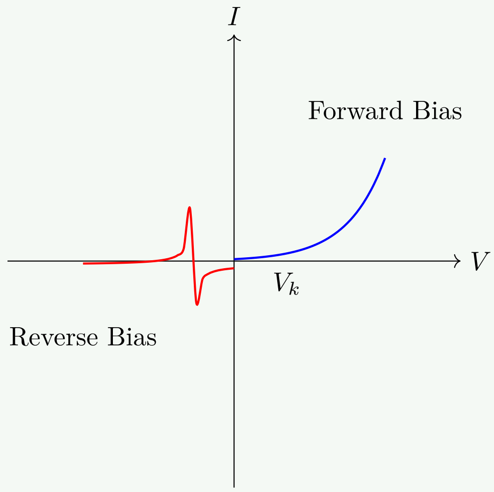
"Electrons Jump, Photons Emit"

Question 3(c) [7 marks]

Draw and explain VI characteristic of PN junction diode.

Solution

V-I Characteristics:



- **Forward Bias Region**:
  - Diode conducts when voltage exceeds knee/cut-in voltage (0.3V for Ge, 0.7V for Si).
  - Current increases exponentially with voltage.
  - Low resistance state.
- **Reverse Bias Region**:
  - Very small leakage current flows.
  - Current remains almost constant with increasing reverse voltage.
  - Breakdown occurs at high reverse voltage.

Mnemonic

"Forward Flows Freely, Reverse Resists Rigidly"

Question 3(a) OR [3 marks]

List the applications of PN junction diode.

Solution

Applications:
- Rectification in power supplies.
- Signal demodulation.
- Logic gates in digital circuits.
- Voltage regulation (with zener diodes).
- Signal clipping and clamping circuits.
- Protection circuits against reverse polarity.

Mnemonic

"Rectify, Detect, Clip, Protect"

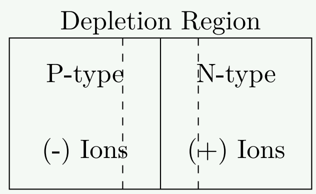
Question 3(b) OR [4 marks]

Explain the formation of depletion region in unbiased P-N junction.

Solution

Formation Process:

- Electrons from N-side diffuse into P-side.
- Holes from P-side diffuse into N-side.
- Recombination occurs at junction.
- Immobile ions remain (positive in N-side, negative in P-side).
- Electric field develops, opposing further diffusion.
- Equilibrium is established, creating depletion region.



Mnemonic

"Diffusion Creates Barrier Field"

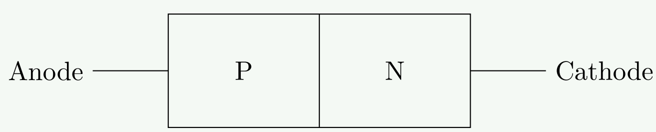
Question 3(c) OR [7 marks]

Explain construction, working and applications of PN junction diode.

Solution

Construction:

- P-type semiconductor joined with N-type semiconductor.
- Made from single crystal of silicon or germanium.
- Metal contacts connected to P and N regions.



Working:

- **Forward Bias**: Positive to P, negative to N. Depletion region narrows. Current flows when voltage exceeds barrier potential.
- **Reverse Bias**: Positive to N, negative to P. Depletion region widens. Only small leakage current flows.

Applications: Power rectification, Signal detection, Voltage regulation, Switching, Protection circuits.

Mnemonic

"Join P-N, Control Current Direction"

Question 4(a) [3 marks]

Define: (1) Ripple frequency (2) Ripple factor (3) PIV of a diode.

Solution

Term	Definition
Ripple Frequency	Frequency of the AC component remaining in the rectified DC output (2× input frequency for full-wave, 1× for half-wave).
Ripple Factor	Ratio of RMS value of AC component to the DC component in rectifier output ($\gamma = V_{ac(rms)}/V_{dc}$).
PIV of a diode	Peak Inverse Voltage is the maximum reverse voltage a diode can withstand without breakdown.

Mnemonic

"Frequency Fluctuates, Factor Measures, PIV Protects"

Question 4(b) [4 marks]

Give comparison between full wave rectifier with two diodes and full wave bridge rectifier.

Solution

Parameter	Center-Tapped Full Wave	Bridge Rectifier
Number of Diodes	2	4
Transformer	Center-tapped required	Simple transformer
PIV	$2V_m$	V_m
Efficiency	81.2%	81.2%
Ripple Factor	0.48	0.48
Output	V_m/π	$2V_m/\pi$
Cost	Higher transformer cost	Higher diode cost

Mnemonic

"Two Diodes Tap Center, Four Make Bridge"

Question 4(c) [7 marks]

Explain zener diode as voltage regulator.

Solution

Circuit Diagram:

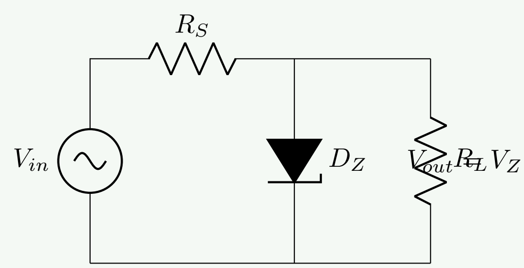


Figure 3. Zener Voltage Regulator

Working Principle:

- Zener diode operates in reverse breakdown region.
- Maintains constant voltage across its terminals.
- Acts as voltage reference.

Circuit Operation:
- Series resistor R_S limits current.
- Zener conducts when input exceeds breakdown voltage.
- Excess current flows through zener diode.
- Output voltage remains constant at zener voltage.

Advantages: Simple circuit, Low cost, Good regulation for small load changes.

Mnemonic

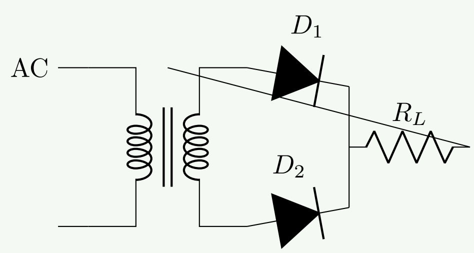
"Zener Breaks Down to Hold Voltage Steady"

Question 4(a) OR [3 marks]

What is rectifier? Explain full wave rectifier with waveforms.

Solution

Rectifier: A circuit that converts AC voltage to pulsating DC voltage.
Full Wave Rectifier (Center-Tapped):



Waveforms:

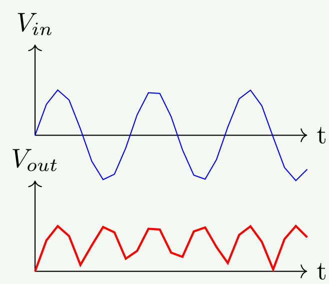


Figure 4. Full Wave Rectifier Waveforms

Mnemonic

"Both Half-Cycles Become Positive"

Question 4(b) OR [4 marks]

Why filter is required in rectifier? State the different types of filter and explain any one type of filter.

Solution

Need for Filter:

- Rectifier output contains AC ripple component.
- Pure DC required for electronic circuits.
- Filters smooth pulsating DC by removing AC components.

Types of Filters: Capacitor (C), Inductor (L), LC, π (Pi), CLC filter.

Capacitor Filter:

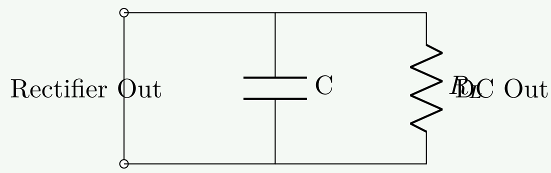


Figure 5. Capacitor Filter

Working:

- Capacitor charges during voltage rise.
- Discharges slowly during voltage fall.
- Reduces ripple voltage.

Mnemonic

"Capacitor Catches Peaks, Releases Slowly"

Question 4(c) OR [7 marks]

Write the need of rectifier. Explain bridge rectifier with circuit diagram and draw its input and output waveforms.

Solution

Need of Rectifier: Convert AC to DC for electronic devices, power supplies, charging systems.

Bridge Rectifier Circuit:

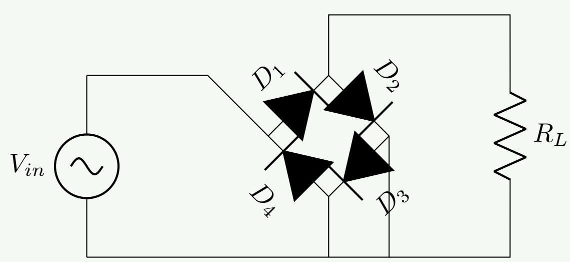


Figure 6. Bridge Rectifier

Waveforms: Input is sine wave, Output is pulsating DC (full-wave rectified).

Mnemonic

"Four Diodes Direct All Current One Way"

Question 5(a) [3 marks]

Explain causes of electronic waste.

Solution

Causes:

- Rapid technological advancement.
- Planned obsolescence of products.
- Decreasing product lifespan.
- Consumer behavior preferring new devices.
- Limited repair options for electronics.
- High repair costs compared to replacement.

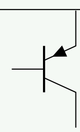
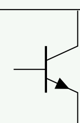
Mnemonic

"Technology Advances, Products Expire Rapidly"

Question 5(b) [4 marks]

Compare PNP and NPN transistors.

Solution

Parameter	**PNP Transistor**	**NPN Transistor**
Symbol		
Majority Carriers	Holes	Electrons
Current Flow	Emitter to Collector	Collector to Emitter
Biasing	Emitter +ve, Base -ve	Collector +ve, Base +ve
Switching Speed	Slower	Faster

Mnemonic

"Negative-Positive-Negative vs Positive-Negative-Positive"

Question 5(c) [7 marks]

Draw the symbol, explain the construction and working of MOSFET.

Solution

Symbol:

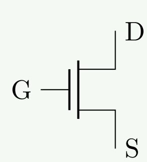


Figure 7. MOSFET Symbol

Construction:

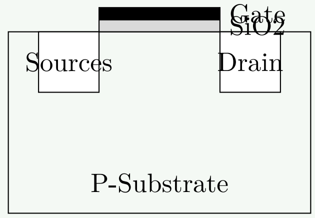


Figure 8. MOSFET Construction

Working Principle (Enhancement Mode):

- No channel exists without gate voltage.
- Positive gate voltage attracts electrons from substrate.
- Induced channel allows current flow from drain to source.
- Increasing gate voltage enhances conductivity.

Mnemonic

"Gate Voltage Creates Electron Channel"

Question 5(a) OR [3 marks]

Explain methods to handle electronic waste.

Solution

Methods:

Method	Description
Reduce	Designing longer-lasting electronics.
Reuse	Donating or selling functional devices.
Recycle	Material recovery (precious metals).
Regulation	E-waste management policies.
Recovery	Extracting valuable materials.

Mnemonic

"Reduce, Reuse, Recycle, Regulate, Recover"

Question 5(b) OR [4 marks]

Derive the relationship between α_{dc} and β_{dc}.

Solution

Relations: $I_E = I_C + I_B$, $\alpha_{dc} = I_C/I_E$, $\beta_{dc} = I_C/I_B$.

Derivation:

- From $I_E = I_C + I_B$, divide by I_C:

$$\frac{I_E}{I_C} = 1 + \frac{I_B}{I_C}$$

$$\frac{1}{\alpha_{dc}} = 1 + \frac{1}{\beta_{dc}}$$

$$\frac{1}{\alpha_{dc}} = \frac{\beta_{dc} + 1}{\beta_{dc}}$$

$$\alpha_{dc} = \frac{\beta_{dc}}{1 + \beta_{dc}}$$

- Rearranging for β_{dc}:

$$\beta_{dc} = \frac{\alpha_{dc}}{1 - \alpha_{dc}}$$

Mnemonic

"Alpha-Beta Relate as Alpha = Beta/(1+Beta)"

Question 5(c) OR [7 marks]

Explain common collector configuration with its input and output characteristics.

Solution

Common Collector (Emitter Follower):

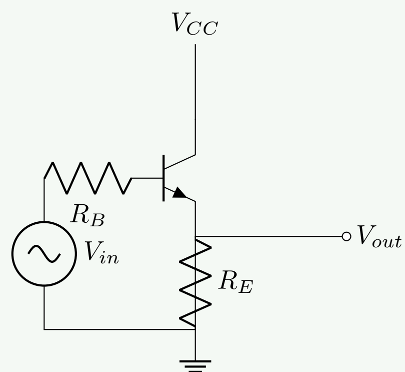


Figure 9. Common Collector Circuit

Characteristics:
- **Input Characteristics**: Plot of I_B vs V_{BC}. High input impedance.
- **Output Characteristics**: Plot of I_E vs V_{CE}. Low output impedance.

Key Features: Voltage gain ≈ 1, High current gain $(\beta + 1)$, used as buffer.

Mnemonic

"Emitter Follows Base Voltage"