

# Subject Name Solutions

1313202 – Winter 2023

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

Explain difference between Active and passive network.

### Solution

#### Active Network

Contains at least one energy source  
Can deliver power to other elements  
Examples: Transistors, Op-amps, Batteries

#### Passive Network

Contains no energy source  
Cannot deliver power to other elements  
Examples: Resistors, Capacitors, Inductors

### Mnemonic

“Active Adds Power, Passive Pulls Power”

## Question 1(b) [4 marks]

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

### Solution

**Kirchhoff's Voltage Law (KVL):** The algebraic sum of all voltages around any closed path (loop) in a circuit is zero.

**Diagram:**

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A((A)) -- V1 --> B((B))
    B -- V2 --> C((C))
    C -- V3 --> D((D))
    D -- V4 --> A
{Highlighting}
{Shaded}
```

**Mathematical Form:**  $V_1 + V_2 + V_3 + V_4 = 0$

- **Circuit Application:** When moving around a loop, voltage rises (batteries) are positive and voltage drops (components) are negative
- **Physical Meaning:** Total energy in a closed loop is conserved

### Mnemonic

“Voltage Loop Sum 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 basic electrical quantity measured in coulombs (C); flow of electrons creates electricity
Current	The rate of flow of electric charge, measured in amperes (A); $I = dQ/dt$
Potential E.M.F.	Electric potential energy per unit charge, measured in volts (V) Electromotive force, energy supplied by source per unit charge, measured in volts (V)
Inductance	Property of a conductor to oppose change in current, measured in henry (H)
Capacitance	Ability of a component to store electric charge, measured in farad (F)
Frequency	Number of cycles per second of an alternating quantity, measured in hertz (Hz)

**Mnemonic**

“Careful Currents Pass Easily Into Circuit Frequently”

Question 1(c) OR [7 marks]

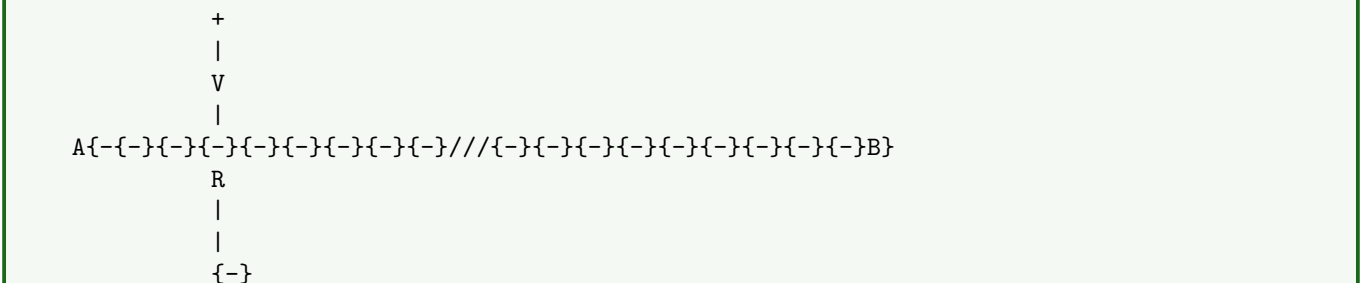
**State Ohm's law. Write its application and limitation.**

**Solution**

**Ohm's Law:** The current flowing through a conductor is directly proportional to the potential difference across it and inversely proportional to its resistance.

**Mathematical Form:**  $I = V/R$

Diagram:



### Applications of Ohm's Law:

- Computing current, voltage, resistance in circuits
- Design of electrical networks
- Power calculations ( $P = VI = I^2R = V^2/R$ )
- Voltage division and current division

### Limitations of Ohm's Law:

- Not valid for non-linear elements (diodes, transistors)
- Not applicable at very high frequencies
- Not valid for non-metallic conductors like semiconductors
- Not applicable for vacuum tubes and gaseous devices

**Mnemonic**

“Voltage Drives, Resistance Restricts”

**Question 2(a) [3 marks]**

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

**Solution**

[Shaded]

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Conductor"
        A1[Conduction Band] --{-}{-} B1[Overlap]}
        B1 --{-}{-} C1[Valence Band]}
    end

    subgraph "Semiconductor"
        A2[Conduction Band] --{-}{-} B2[Small Gap]}
        B2 --{-}{-} C2[Valence Band]}
    end

    subgraph "Insulator"
        A3[Conduction Band] --{-}{-} B3[Large Gap]}
        B3 --{-}{-} C3[Valence Band]}
    end
{Highlighting}
{Shaded}
```

- **Conductor:** Valence and conduction bands overlap, allowing easy electron flow
- **Semiconductor:** Small energy gap (~1eV) between bands; electrons can jump with thermal energy
- **Insulator:** Large energy gap (>5eV) prevents electron movement between bands

### Mnemonic

“Conductors Connect, Semiconductors Sometimes, Insulators Impede”

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 load resistance equals the source internal resistance ( $R_L = R_S$ )
Reciprocity Theorem	In a linear passive network with a single source, if the source is moved from position A to B, the current at A due to source at B will equal the current at B when source was at A

Diagram:

$$\begin{array}{c} \text{Maximum Power Transfer:} \\ +\{-\}\{-\}\text{[Source]}\{-\}\{-\}\{-\}+ \\ | \qquad \qquad \qquad | \\ R(\text{source}) \qquad \qquad R(\text{load}) \\ | \qquad \qquad \qquad | \\ +\{-\}\{-\}\{-\}\{-\}\{-\}\{-\}\{-\}+ \end{array}$$

### Mnemonic

“Match Resistance to Maximize Power; Switch Source and Sink, Current Stays Same”

### Question 2(c) [7 marks]

Explain the formation and conduction of N-type materials.

#### Solution

N-type Semiconductor Formation:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Silicon/Germanium Lattice] --{-}{ } B[Doped with Pentavalent Element]}
    B --{-}{ } C[Extra Electron from Each Dopant Atom]}
    C --{-}{ } D[Free Electrons {-} Majority Carriers]}
    D --{-}{ } E[Holes {-} Minority Carriers]}
    E --{-}{ } F[Net Negative Charge]}
{Highlighting}
{Shaded}
```

- **Doping Process:** Silicon/Germanium (4 valence  $e^-$ ) *doped with pentavalent elements (P, As, Sb)*
- **Extra Electron:** Each dopant atom provides 1 extra electron after covalent bonding
- **Conduction Mechanism:**
  - **Majority Carriers:** Free electrons (negative charge carriers)
  - **Minority Carriers:** Holes (very few)
- **Electrical Properties:** Increased conductivity and negative charge carriers

### Mnemonic

“Pentavalent Provides Plus one Electron, Negative-type”

### Question 2(a) OR [3 marks]

Define valence band, conduction band and forbidden gap.

#### Solution

Term	Definition
Valence Band	The highest energy band filled with electrons, where electrons are bound to atoms
Conduction Band	The band above valence band where electrons move freely and contribute to electrical conduction
Forbidden Gap	The energy range between valence and conduction bands where no electron states exist

Diagram:

### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Conduction Band] --{-}{-} B[Forbidden Gap]}
    B --{-}{-} C[Valence Band]}
{Highlighting}
{Shaded}
```

### Mnemonic

“Valence Holds, Forbidden Blocks, Conduction Flows”

## Question 2(b) OR [4 marks]

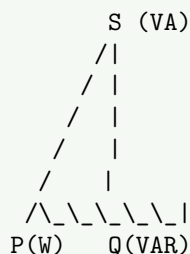
Define the terms active power, reactive power and power factor with power triangle.

### Solution

#### Power Terms in AC Circuits:

Term	Definition
Active Power (P)	Actual power consumed, measured in watts (W); $P = VI \cos$
Reactive Power (Q)	Power oscillating between source and load, measured in VAR; $Q = VI \sin$
Power Factor (PF)	Ratio of active power to apparent power; $PF = \cos$

#### Power Triangle:



- **Apparent Power (S):** Vector sum of active and reactive power
- **Power Triangle:** Right triangle with P, Q, and S as sides
- **Power Factor:**  $\cos = P/S$  (0 to 1)

### Mnemonic

“Active Power Works, Reactive Power Waits”

## Question 2(c) OR [7 marks]

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

### Solution

#### Atomic Structures:



### Mnemonic

“Photons Produce Current”

### Question 3(b) [4 marks]

Write a Short note on LED.

#### Solution

**LED (Light Emitting Diode):**

Parameter	Description
Structure	p-n junction with special doping materials
Working	Electrons recombine with holes, releasing energy as photons
Materials	GaAs (red), GaP (green), GaN (blue), etc.
Voltage	Forward voltage typically 1.8V to 3.3V depending on color

#### Advantages:

- High efficiency (low power consumption)
- Long life (50,000+ hours)
- Small size and durability
- Various colors available

#### Applications:

- Indicators and displays
- Lighting systems
- TV/monitor backlights
- Traffic signals

### Mnemonic

“Light Emits when Diode conducts”

### Question 3(c) [7 marks]

Draw and explain VI characteristic of PN junction diode.

#### Solution

**P-N Junction Diode V-I Characteristic:**



**Forward Bias Region:**

- **Knee Voltage:** 0.3V (Ge), 0.7V (Si) where current starts flowing
- **Current Equation:**  $I = I_s(e^{(qV/kT)} - 1)$
- **Conductivity:** High (low resistance)

#### Reverse Bias Region:

- **Leakage Current:** Very small reverse current (micro-amps)
- **Breakdown Region:** Sharp increase in current at breakdown voltage
- **Conductivity:** Very low (high resistance)

#### Key Points:

- **Barrier Potential:** Decreases in forward bias, increases in reverse bias
- **Diode Resistance:** Dynamic resistance changes with applied voltage
- **Temperature Effect:** Voltage drop decreases with temperature increase

#### Mnemonic

“Forward Flows Freely, Reverse Resists”

### Question 3(a) OR [3 marks]

List the applications of PN junction diode.

#### Solution

##### Applications of PN Junction Diode:

Application Category	Examples
Rectification	Half-wave rectifier, Full-wave rectifier, Bridge rectifier
Signal Processing	Signal demodulation, Clipping circuits, Clamping circuits
Protection	Voltage spike protection, Reverse polarity protection
Logic Gates	Diode logic circuits, Switching applications
Voltage Regulation	Zener diodes for voltage references
Light Applications	LEDs, Photodiodes, Solar cells

#### Mnemonic

“Rectify, Process, Protect, Logic, Regulate, Light”

### Question 3(b) OR [4 marks]

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

#### Solution

##### Depletion Region Formation:

##### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    subgraph "P{-Type}"
        A[Holes]
    end

    subgraph "Depletion Region"
        B[No Free Carriers]
    end
end
```



### Process:

- ### Properties of Depletion Region:

- ### Mnemonic

Explain construction, working and applications of PN junction diode.

### Working Principle:

9

**Applications:**

- Rectification in power supplies
- Signal demodulation in radios
- Voltage regulation (Zener)
- Signal clipping and clamping
- Logic gates and switching
- Light emission and detection

**Mnemonic**

“Forward Flow, Reverse Restrict, Convert AC to DC”

**Question 4(a) [3 marks]**

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

**Solution**

Term	Definition
<b>Ripple Frequency</b>	The frequency of AC component present in rectified DC output; for half-wave $f = \text{supply frequency}$ , for full-wave $f = 2 \times \text{supply frequency}$
<b>Ripple Factor ( )</b>	Ratio of RMS value of AC component to DC component in rectifier output; $= V_{ac(rms)}/V_{dc}$
<b>PIV of Diode</b>	Peak Inverse Voltage - maximum reverse voltage a diode can withstand without breakdown

**Mnemonic**

“Ripples Per second, Ripple Proportion, Reverse Peak Voltage”

**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
<b>Diodes Used</b>	2 diodes	4 diodes
<b>Transformer</b>	Center-tapped required	No center tap needed
<b>PIV of Diode</b>	$2V_m$	$V_m$
<b>Output Voltage</b>	$V_{dc} = 0.637V_m$	$V_{dc} = 0.637V_m$
<b>Ripple Factor</b>	0.48	0.48
<b>Efficiency</b>	81.2%	81.2%
<b>TUF</b>	0.693	0.693

Diagram:

### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Center{-Tapped}"
        A[Transformer with center{-tap} {-}{-}{}] B[2 Diodes]]
    end

    subgraph "Bridge"
        C[Transformer] {-}{-}{}] D[4 Diodes in Bridge]]
    end
{Highlighting}
{Shaded}
```

### Mnemonic

### “Bridge Beats Tap with Lower PIV but Needs More Diodes”

Question 4(c) [7 marks]

**Explain zener diode as voltage regulator.**

## Solution

### Zener Diode Voltage Regulator:

### Working Principle:

- **Reverse Biased:** Zener operates in breakdown region
- **Constant Voltage:** Maintains fixed voltage ( $V_z$ ) across its terminals
- **Current Regulation:** Series resistor ( $R_s$ ) limits current
- **Load Changes:** When load current changes, Zener current changes to maintain constant output voltage

### Design Equations:

- Rs = (Vin - Vz) / (IL + Iz)
- Power rating of Zener:  $P_Z = V_Z \times I_{Z(max)}$

### Advantages:

- Simple circuit
- Low cost
- Good regulation for small loads
- Fast response to load changes

**Limitations:**

- Power wastage in  $R_s$  and Zener
- Limited output current capability
- Temperature dependence of  $V_z$

### Mnemonic

### “Zener Stays at breakdown Voltage despite Current changes”

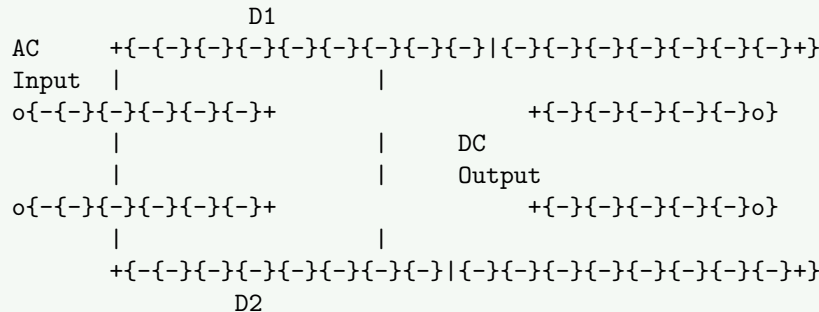
### Question 4(a) OR [3 marks]

What is rectifier? Explain full wave rectifier with waveforms.

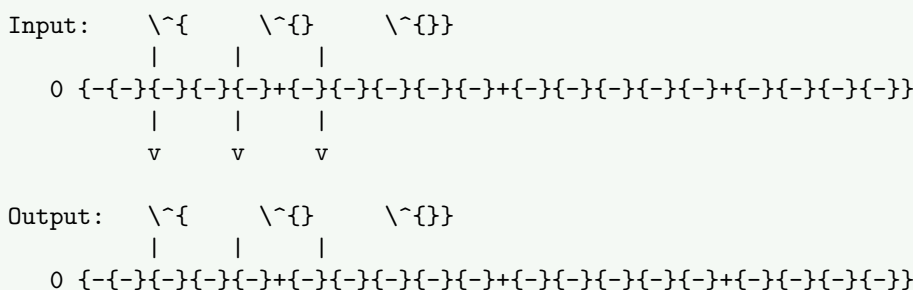
#### Solution

**Rectifier:** A circuit that converts AC voltage to pulsating DC voltage by allowing current flow in one direction only.

**Full Wave Rectifier:**



**Waveforms:**



- **Operation:** Both half cycles of AC input are converted to same polarity
- **Frequency:** Output ripple frequency is twice the input frequency
- **Voltage:**  $V_{dc} = 0.637V_m$  (where  $V_m$  is peak input voltage)

#### Mnemonic

“Full Wave Forms Full Output”

### 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.

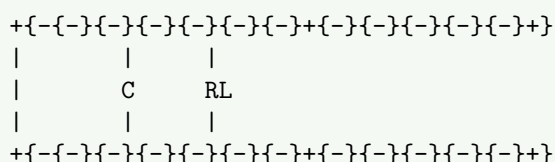
#### Solution

**Need for Filters:** Rectifiers produce pulsating DC with large ripples; filters smooth this output to provide steady DC voltage.

**Types of Filters:**

- Capacitor (C) filter
- Inductor (L) filter
- LC filter
- (Pi) filter
- RC filter

**Capacitor Filter:**



**Working:**

- Capacitor charges during voltage rise
- Discharges slowly through load during voltage fall
- Acts as temporary storage element
- Time constant RC determines discharge rate
- Reduces ripple by providing discharge path

**Advantages:**

- Simple and economical
- Good smoothing for light loads
- Increases DC output voltage

**Mnemonic**

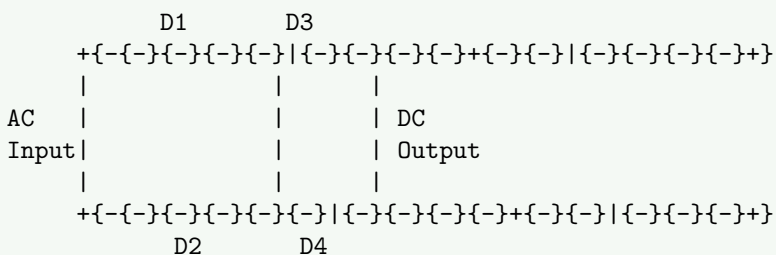
“Capacitor Catches Charge and Releases Slowly”

**Question 4(c) OR [7 marks]**

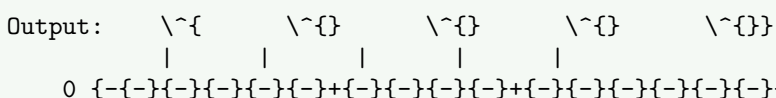
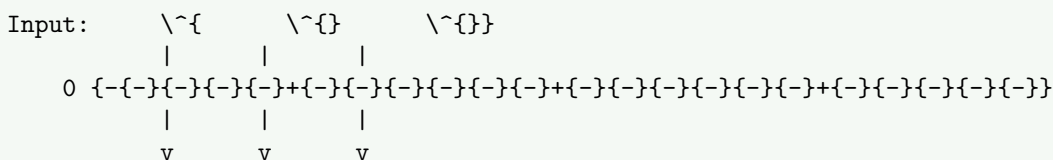
Write the need of rectifier. Explain bridge rectifier with circuit diagram and draw its input and output waveforms.

**Solution****Need for Rectifiers:**

- Convert AC to DC for electronic devices
- Power supplies for DC-operated equipment
- Battery charging circuits
- DC power for industrial drives
- Signal demodulation in communication

**Bridge Rectifier Circuit:****Working Principle:**

- **Positive Half Cycle:** D1 and D4 conduct, D2 and D3 block
- **Negative Half Cycle:** D2 and D3 conduct, D1 and D4 block
- **Both Half Cycles:** Current flows in same direction through load

**Input-Output Waveforms:****Characteristics:**

- $V_{dc} = 0.637V_m$  ( $V_m$ : peak input voltage)
- PIV of each diode =  $V_m$
- Ripple factor = 0.48
- Efficiency = 81.2%
- TUF = 0.693

### Mnemonic

“Bridge Brings Both halves to Direct Current”

### Question 5(a) [3 marks]

Explain causes of electronic waste.

#### Solution

##### Causes of Electronic Waste:

Cause	Description
Rapid Technology Change	Frequent upgrades and obsolescence of electronics
Short Lifecycle	Devices designed with limited useful life
Consumer Behavior	Preference for new gadgets over repair
Manufacturing Issues	Poor quality leading to early failures
Economic Factors	Sometimes cheaper to replace than repair
Marketing Strategies	Promoting new models through planned obsolescence

### Mnemonic

“Upgrade, Use, Throw, Repeat”

### Question 5(b) [4 marks]

Compare PNP and NPN transistors.

#### Solution

Parameter	PNP Transistor	NPN Transistor
Symbol		
Current Flow	Emitter to Collector	Collector to Emitter
Majority Carriers	Holes	Electrons
Biasing	Emitter positive, Collector negative	Collector positive, Emitter negative
Switching Speed	Slower	Faster
Usage	Less common	More common

### Mnemonic

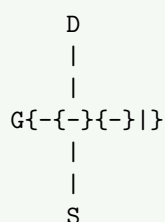
“PNP: Positive to Negative to Positive; NPN: Negative to Positive to Negative”

### Question 5(c) [7 marks]

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

#### Solution

##### MOSFET Symbol (N-Channel Enhancement):



##### Construction:

### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Source {- n+} {-}{-}{-} B[Channel region {-} p]]
    B {-}{-}{-} C[Drain {-} n+]]
    D[Gate] {-}{-}{-} E[Silicon Dioxide Insulator]]
    E {-}{-}{-} B]
{Highlighting}
{Shaded}
```

#### Components:

- **Substrate:** P-type semiconductor body
- **Source/Drain:** Heavily doped n+ regions
- **Gate:** Metal electrode separated by insulator (SiO<sub>2</sub>)
- **Channel:** Forms between source and drain when biased

#### Working Principle:

- **Enhancement Mode:** No channel exists initially; gate voltage creates channel
- **Threshold Voltage (V<sub>T</sub>):** Minimum gate voltage needed to form channel
- **Conducting State:** When  $V_{GS} > V_T$ , electrons form channel, allowing current flow
- **Saturation Region:** Current remains constant despite increase in V<sub>DS</sub>
- **Linear Region:** Current proportional to V<sub>DS</sub> at low drain voltages

#### Applications:

- Digital circuits (logic gates)
- Power amplifiers
- Switching applications
- Memory devices

### Mnemonic

“Gate Voltage Controls Electron Channel”

### Question 5(a) OR [3 marks]

Explain methods to handle electronic waste.

#### Solution

##### Methods to Handle Electronic Waste:

Method	Description
Reduce	Designing products with longer lifecycle and upgradability
Reuse	Refurbishing and donating electronics for secondary use
Recycle	Systematic disassembly to recover valuable materials
Responsible Disposal	Proper collection and processing by certified facilities
Extended Producer Responsibility	Manufacturers take back used products
Urban Mining	Recovering precious metals from discarded electronics

Diagram:

### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[E{-Waste} {-}{-}{-} B[Collection]]
    B {-}{-}{-} C[Sorting]
    C {-}{-}{-} D[Dismantling]
    D {-}{-}{-} E[Material Recovery]
    E {-}{-}{-} F[Remanufacturing]
{Highlighting}
{Shaded}
```

### Mnemonic

“Reduce, Reuse, Recycle, Recover Resources”

## Question 5(b) OR [4 marks]

Derive the relationship between  $\alpha$  and  $\beta$ .

### Solution

**Relationship between  $\alpha$  and  $\beta$ :**

**Given:**

- $\beta = I_C/I_E$  (Common base current gain)
- $\alpha = I_C/I_B$  (Common emitter current gain)

**Derivation:** From Kirchhoff's current law:  $I_E = I_C + I_B$

Dividing both sides by  $I_C$ :  $I_E/I_C = 1 + I_B/I_C$

Since  $\beta = I_C/I_E$ :  $1/\beta = 1 + I_B/I_C$

Since  $\alpha = I_C/I_B$ :  $1/\alpha = 1 + 1/\beta$

**Final Relations:**

- $\alpha = \beta/(1 + \beta)$
- $\beta = \alpha/(1 - \alpha)$

**Table:** | Value | Value | |-----|-----| 0.9 | 9 | | 0.95 | 19 | | 0.99 | 99 |

### Mnemonic

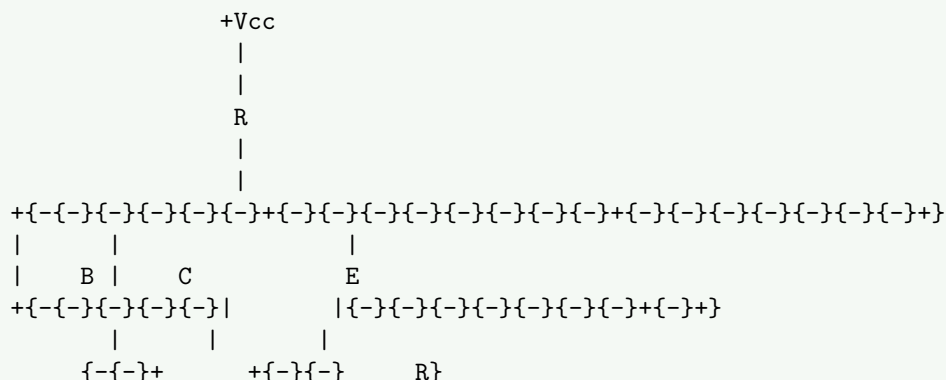
“Alpha approaches One as Beta approaches Infinity”

## Question 5(c) OR [7 marks]

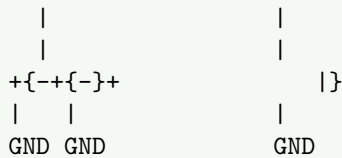
Explain common collector configuration with its input and output characteristics.

### Solution

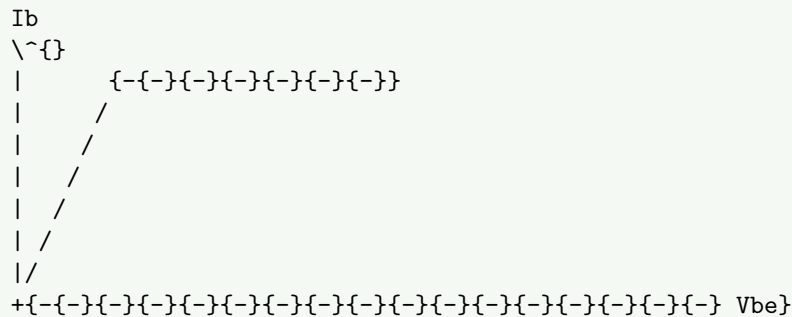
**Common Collector (Emitter Follower) Configuration:**



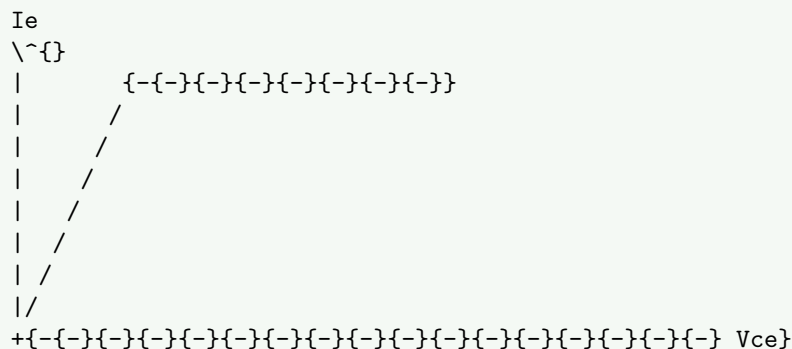




#### Input Characteristics:



#### Output Characteristics:



#### Key Features:

- **Voltage Gain ( $A_v$ ):** Approximately 1 (unity)
- **Current Gain ( $A_i$ ):** High ( $\beta + 1$ )
- **Input Impedance:** High ( $\beta \times R_E$ )
- **Output Impedance:** Low ( $1/g_m$ ) where  $g_m$  is transconductance
- **Phase Relationship:** No phase inversion between input and output
- **Applications:** Impedance matching, buffers, voltage regulators

#### Characteristics:

- **Input Resistance:**  $R_i = \beta \times (r_e + R_L)$
- **Output Resistance:**  $R_o = (r_s + r_e) / (\beta + 1)$
- **Voltage Gain:**  $A_v = R_L / (R_L + r_e) \approx 1$
- **Current Gain:**  $A_i = (\beta + 1)$

#### Advantages:

- Very high input impedance
- Low output impedance
- Good impedance matching properties
- No phase inversion

#### Limitations:

- No voltage gain (slightly less than 1)
- Used only for impedance matching

#### Mnemonic

“Collector Common, Current amplifies, Voltage follows”

This completes the full solutions for the Elements of Electrical & Electronics Engineering (1313202) Winter 2023 examination.