Fundamentals of Electronics (4311102) - Summer 2024 Solution

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Contents

1 Question 1

Answer any SEVEN out of the following TEN questions (2 marks each):

1.1 Question 1.1 [2 marks]

Define resistor and give its unit.

1.1.1 Solution

Definition: A **resistor** is a passive electrical component that opposes or restricts the flow of electric current in a circuit. It converts electrical energy into heat energy and is used to control current and voltage levels.

Unit: The SI unit of resistance is the **Ohm**, symbolized as Ω (Greek letter Omega). One ohm is the resistance that allows one ampere of current to flow when one volt is applied across it.

Mathematically: $R = \frac{V}{I}$ where V is voltage in volts and I is current in amperes.

Mnemonic: *"Resistor Resists, measured in Ohms"!*

1.2 Question 1.2 [2 marks]

Give two examples of active and passive components each.

1.2.1 Solution

Active Components: Components that can amplify signals and control electron flow by adding energy from external power source:

Transistor: Amplifies or switches electronic signals

Operational Amplifier (Op-Amp): Performs mathematical operations on signals

Passive Components: Components that cannot amplify signals and only consume or store energy:

Resistor: Opposes current flow

Capacitor: Stores energy in electric field

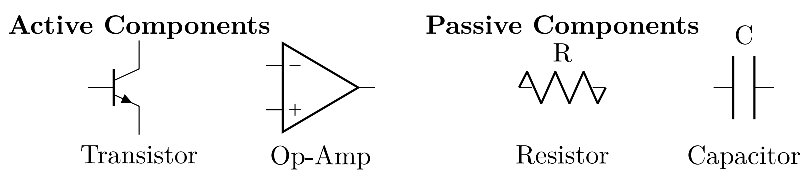


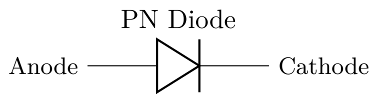
Figure 1: Examples of Active and Passive Components

Mnemonic: *"Active Adds energy, Passive only Passes"!*

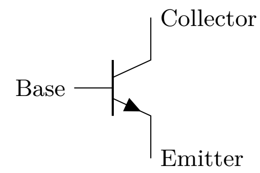
1.3 Question 1.3 [2 marks]

Draw symbols of any two semiconductor devices.

1.3.1 Solution



(a) PN Junction Diode



(b) NPN Transistor

Figure 2: Semiconductor Device Symbols

Explanation:

PN Diode: Triangle points in direction of conventional current flow (anode to cathode). Allows current in forward bias only.

NPN Transistor: Arrow on emitter points outward (Not Pointing iN). Has three terminals: Base (control), Collector, and Emitter.

Mnemonic: *"Diode arrow shows current Direction; NPN arrow points outwaNrd"!*

1.4 Question 1.4 [2 marks]

Differentiate between intrinsic and extrinsic semiconductor.

1.4.1 Solution

Table 1: Intrinsic vs Extrinsic Semiconductor

Parameter	Intrinsic	Extrinsic
Purity	Pure semiconductor (Si, Ge)	Doped with impurities
Conductivity	Low	Higher than intrinsic
Charge Carriers	$n = p$ (equal)	$n \neq p$ (unequal)
Temperature Effect	Highly sensitive	Less sensitive
Doping	No impurities added	Trivalent/Pentavalent added
Example	Pure Silicon at room temp	P-type, N-type Si

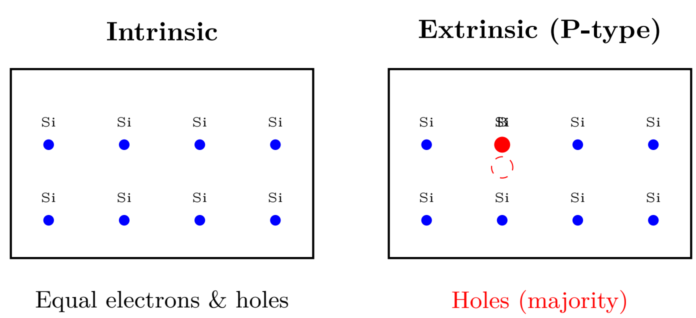


Figure 3: Intrinsic vs Extrinsic Semiconductor Structure

Mnemonic: *"Intrinsic is pure Inside; Extrinsic has Extra impurities"!*

1.5 Question 1.5 [2 marks]

LED stands for ____________________________.

1.5.1 Solution

Full Form: LED stands for **Light Emitting Diode**.

Explanation: It is a semiconductor device that emits light when current flows through it in forward bias direction. The light emission occurs due to electroluminescence - recombination of electrons and holes releases energy as photons.

Mnemonic: *"LED: Light Emits when Diode conducts"!*

1.6 Question 1.6 [2 marks]

State any two applications of Photo-diode.

1.6.1 Solution

Applications:

1. **Optical Communication:** Used as light detector in fiber optic systems to convert optical signals to electrical signals.
2. **Automatic Light Control:** Used in street lights, cameras, and displays to detect ambient light levels and adjust brightness automatically.

Additional Applications: Light meters, barcode readers, smoke detectors, solar cells, infrared remote controls.

Note: Photodiode always operates in reverse bias. It converts light energy into electrical energy. In industries, it is used in security systems.

Mnemonic: *"Photo-diode detects Photons, converts to current"!*

1.7 Question 1.7 [2 marks]

List the types of transistor and draw their symbols.

1.7.1 Solution

Types of Transistors:

BJT (Bipolar Junction Transistor): NPN and PNP types

FET (Field Effect Transistor): JFET and MOSFET types

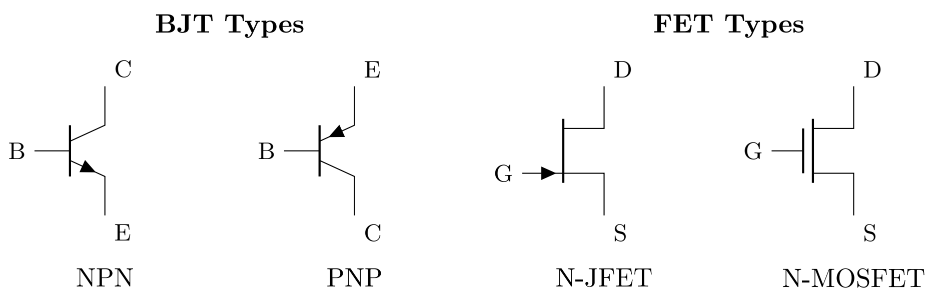


Figure 4: Transistor Types and Their Symbols

Remember: BJT is a current controlled device while FET is a voltage controlled device. Both are used for amplification and switching.

Mnemonic: *"NPN: Not Pointing iN; PNP: Pointing iN Please"!*

1.8 Question 1.8 [2 marks]

Give the value of forward voltage drop of Germanium and Silicon diode.

1.8.1 Solution

Forward Voltage Drop Values:

Germanium (Ge) Diode: $V_f \approx 0.3\,V$

Silicon (Si) Diode: $V_f \approx 0.7\,V$

Explanation: Forward voltage drop is the minimum voltage required across a diode for it to conduct in forward bias. Silicon has higher bandgap energy ($1.1\,eV$) than Germanium ($0.7\,eV$), hence requires more voltage to overcome barrier potential.

Comparison: Si diodes are more commonly used due to better temperature stability and lower reverse leakage current, despite higher forward drop.

Difference: Silicon (Si) is used more because it remains stable at higher temperatures. Germanium (Ge) has higher leakage current.

Mnemonic: *"Silicon Seven-tenths (0.7V); Germanium three-tenths (0.3V)"!*

1.9 Question 1.9 [2 marks]

The ____________________________ diode can be used as a light detector.

1.9.1 Solution

Answer: The **Photo** diode (or **Photodiode**) can be used as a light detector.

Explanation: A photodiode operates in reverse bias and generates current proportional to the intensity of light falling on it. When photons strike the PN junction, they create electron-hole pairs, producing photocurrent.

Reason: When light falls on the photodiode, minority carriers are generated, increasing reverse current. This principle is used for light detection.

Mnemonic: *"Photo-diode for Photos (light detection)"!*

1.10 Question 1.10 [2 marks]

Define Q-factor of a coil.

1.10.1 Solution

Definition: The **Quality factor (Q-factor)** of a coil is a dimensionless parameter that represents the ratio of its inductive reactance to its resistance at a particular frequency. It indicates how "pure" or "ideal" the inductor is.

Formula:

$$Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{2\pi f L}{R}$$

where X_L is inductive reactance, R is coil resistance, L is inductance, and f is frequency.

Significance: Higher Q-factor means lower energy loss, sharper resonance in tuned circuits, and better selectivity in RF applications. Typical values range from 10 to 100+ for good coils.

Importance: High Q-factor means the circuit is more selective and bandwidth is narrow. Q-factor is a very important parameter in resonant circuits.

Mnemonic: *"Q is Quality: reactance over resistance"!*

2 Question 2

2.1 Question 2(a) [3 marks]

Explain colour coding method of resistor.

2.1.1 Solution

The **resistor color code** is a standardized system used to indicate the resistance value, tolerance, and sometimes temperature coefficient of resistors through colored bands painted on the resistor body.

Table 2: Resistor Color Code Table

Color	Digit	Multiplier	Tolerance	Temp Coeff
Black	0	$\times 10^0$	-	-
Brown	1	$\times 10^1$	$\pm 1\%$	100 ppm
Red	2	$\times 10^2$	$\pm 2\%$	50 ppm
Orange	3	$\times 10^3$	-	15 ppm
Yellow	4	$\times 10^4$	-	25 ppm
Green	5	$\times 10^5$	$\pm 0.5\%$	-
Blue	6	$\times 10^6$	$\pm 0.25\%$	10 ppm
Violet	7	$\times 10^7$	$\pm 0.1\%$	5 ppm
Grey	8	$\times 10^8$	-	-
White	9	$\times 10^9$	-	-
Gold	-	$\times 0.1$	$\pm 5\%$	-
Silver	-	$\times 0.01$	$\pm 10\%$	-

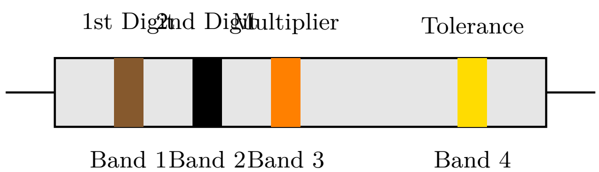


Figure 5: 4-Band Resistor Color Code Structure

Standard 4-Band Color Code:

Reading Method:

1. Identify tolerance band (Gold/Silver, slightly separated) on RIGHT
2. Read from LEFT to RIGHT
3. Bands 1 & 2: Significant digits
4. Band 3: Multiplier (number of zeros)
5. Band 4: Tolerance

Example: Brown-Black-Orange-Gold = 1, 0, $\times 10^3$, $\pm 5\%$ = $10{,}000\,\Omega \pm 5\% = 10\,k\Omega \pm 5\%$

Tip: Use the 'BBROYGBVGW' mnemonic to remember color codes. The Tolerance band should always be counted last.

Mnemonic: *"BB ROY Great Britain Very Good Wife" - Black Brown Red Orange Yellow Green Blue Violet Grey White!*

2.2 Question 2(a) OR [3 marks]

Explain Light Dependent Resistor with its characteristics.

2.2.1 Solution

A **Light Dependent Resistor (LDR)** or photoresistor is a passive component whose resistance varies inversely with the intensity of incident light.

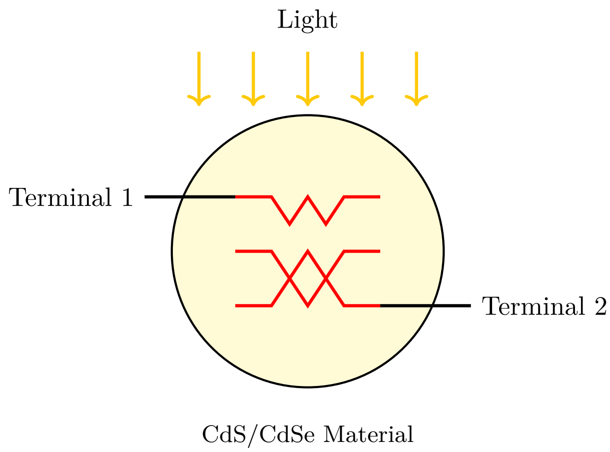


Figure 6: LDR Construction

Construction:

Working Principle: Based on photoconductivity - when light photons strike the semiconductor material (CdS/CdSe), they impart energy to electrons, creating electron-hole pairs. This increases conductivity and decreases resistance.

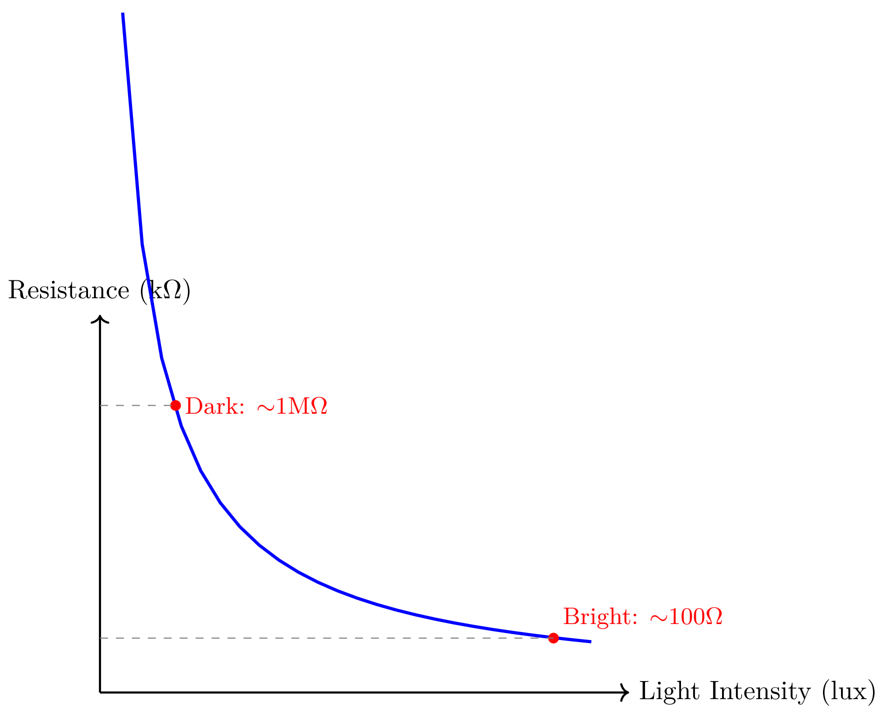


Figure 7: LDR Resistance vs Light Intensity Characteristic

Characteristics:

Specifications:

- Dark Resistance: 1MΩ - 10MΩ

- Light Resistance: 100Ω - 1kΩ
- Response Time: 10-100ms
- Peak Spectral Response: 550nm (green light)

Applications: Street lights, camera exposure control, alarm systems, light meters.

Tip: Use the 'BBROYGBVGW' mnemonic to remember color codes. The Tolerance band should always be counted last.

Mnemonic: *"LDR: Light Down, Resistance Down"!*

2.3 Question 2(b) [3 marks]

Explain classification of capacitors in detail.

2.3.1 Solution

Capacitors are classified based on dielectric material, polarity, and construction.

Classification by Dielectric Material:

Ceramic Capacitors: Use ceramic dielectric (barium titanate). Small, inexpensive, non-polarized. Values: pF to few μF.

Film Capacitors: Plastic film dielectric (polyester, polypropylene). Stable, low loss. Values: nF to μF range.

Electrolytic Capacitors: Aluminum oxide dielectric, polarized. High capacitance (1μF to 10000μF), used in power supplies.

Tantalum Capacitors: Tantalum pentoxide dielectric, polarized. Stable, compact, expensive. Values: 0.1μF to 100μF.

Mica Capacitors: Mica dielectric. Very stable, low loss, expensive. RF applications.

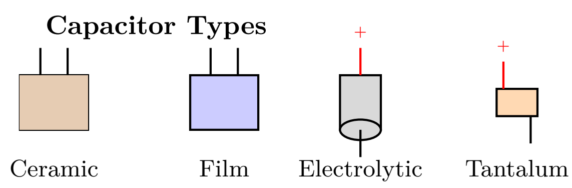


Figure 8: Types of Capacitors

Classification by Polarity:

Polarized: Must be connected with correct polarity (electrolytic, tantalum)

Non-Polarized: Can be connected either way (ceramic, film, mica)

Property: A capacitor blocks DC current and passes AC current.

Mnemonic: *"CEFMT: Ceramic, Electrolytic, Film, Mica, Tantalum - Capacitor types"!*

2.4 Question 2(b) OR [3 marks]

Explain classification of inductor in detail.

2.4.1 Solution

Inductors are classified based on core material, construction, and application.

Classification by Core Material:

Air Core Inductors: No magnetic core, just coiled wire. Low inductance (nH to μH), used in RF circuits. No core losses, no saturation.

Iron Core Inductors: Solid iron core. High inductance, used in low-frequency applications. Heavy, subject to core losses.

Ferrite Core Inductors: Ferrite (ceramic magnetic) core. Good for high-frequency switching applications. Lower losses than iron.

Powdered Iron Core: Iron powder mixed with binder. Distributed air gap reduces saturation. Used in filters and RF chokes.

Laminated Core Inductors: Thin iron sheets laminated together. Reduces eddy current losses. Used in transformers and power inductors.

Inductor Types

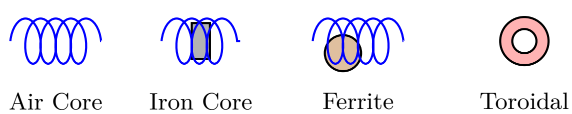


Figure 9: Types of Inductors by Core Material

Classification by Construction:

Solenoid: Helical coil wound on cylindrical form

Toroidal: Wire wound on donut-shaped core - self-shielding, compact

Multilayer: Multiple layers of winding for high inductance

Mnemonic: *"AIFPL: Air, Iron, Ferrite, Powdered, Laminated - Inductor cores"!*

2.5 Question 2(c) [4 marks]

State and explain Faraday's laws of Electromagnetic Induction.

2.5.1 Solution

Faraday's laws describe how a changing magnetic field induces an electromotive force (EMF) in a conductor.

First Law: **Statement:** Whenever the magnetic flux linking a conductor or coil changes, an EMF is induced in it.

Second Law: **Statement:** The magnitude of induced EMF is directly proportional to the rate of change of magnetic flux linkage.

Mathematical Expression:

$$\mathcal{E} = -N\frac{d\Phi}{dt}$$

where:

- $\mathcal{E}$ = Induced EMF (volts)
- N = Number of turns
- $\frac{d\Phi}{dt}$ = Rate of change of magnetic flux
- Negative sign indicates Lenz's Law (opposes the change)

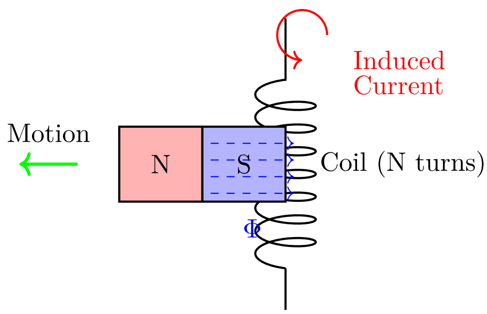


Figure 10: Electromagnetic Induction - Moving Magnet Induces EMF

Explanation: When a magnet moves toward/away from a coil, the magnetic flux through the coil changes. This changing flux induces an EMF that causes current to flow if the circuit is closed. The induced current creates its own magnetic field that opposes the original change (Lenz's Law).

Applications: Generators, transformers, inductors, induction motors, wireless charging.

Lenz's Law: The induced EMF always opposes its cause.

Mnemonic: *"Faraday: Flux change induces EMF, Rate determines magnitude"!*

2.6 Question 2(c) OR [4 marks]

Enlist specifications of capacitors and explain two in detail.

2.6.1 Solution

Capacitor Specifications:

1. **Capacitance Value** (C)
2. **Voltage Rating** (Working Voltage)
3. **Tolerance**
4. **Temperature Coefficient**
5. **ESR (Equivalent Series Resistance)**

6. **Leakage Current**
7. **Ripple Current Rating**
8. **Life Span / Endurance**

Detailed Explanation:

1. Capacitance Value (C): The ability to store electric charge, measured in Farads (F). Practical units: pF (picofarad), nF (nanofarad), μF (microfarad).
Formula: $C = \frac{Q}{V}$ where Q is charge in coulombs, V is voltage.
For parallel plate: $C = \frac{\epsilon_0 \epsilon_r A}{d}$
Typical ranges:

- Ceramic: 1pF - 1μF
- Film: 1nF - 100μF
- Electrolytic: 1μF - 10000μF

2. Voltage Rating (Working Voltage): Maximum DC voltage that can be continuously applied without breakdown. Exceeding this causes dielectric failure.
Derating: In practice, operate at 50-80% of rated voltage for reliability.
Example ratings: 6.3V, 10V, 16V, 25V, 50V, 100V, 450V (common values)

Safety Factor: Always select voltage rating $> 1.5 \times$ maximum circuit voltage

AC Applications: Peak voltage must be less than DC rating

Mnemonic: *"CV-TT-ELR-L: Capacitance, Voltage, Tolerance, Temperature, ESR, Leakage, Ripple, Life"!*

2.7 Question 2(d) [4 marks]

Write colour band of 47Ω±5% resistance.

2.7.1 Solution

For **47Ω ±5%** resistor using 4-band color code:

Calculation:

- Resistance = 47Ω = 47 $\times 10^0$
- First digit = 4 → **Yellow**
- Second digit = 7 → **Violet**
- Multiplier = $\times 10^0$ = $\times 1$ → **Black**
- Tolerance = ±5% → **Gold**

Color Band Sequence: **Yellow - Violet - Black - Gold**

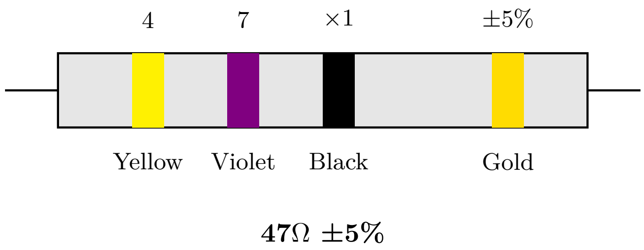


Figure 11: 47Ω ±5% Resistor Color Bands

Verification: Tolerance range: $47\Omega \pm 5\% = 47 \pm 2.35 = 44.65\Omega$ to 49.35Ω

Importance: The Tolerance band indicates the precision and quality of the resistor.

Mnemonic: *"Yellow Violet Black Gold = 47 ohms, Five percent told"!*

2.8 Question 2(d) OR [4 marks]

Calculate value of resistor and tolerance for a given colour code: Brown, Black, yellow.

2.8.1 Solution

Given color code: **Brown - Black - Yellow**

Reading the Colors:

- Band 1 (Brown): First digit = **1**
- Band 2 (Black): Second digit = **0**
- Band 3 (Yellow): Multiplier = $\times 10^4$
- Band 4: Not given, assume **no tolerance band** or ±20% (default for 3-band)

Calculation:

$$R = (10) \times 10^4 = 100{,}000\,\Omega = 100\,k\Omega$$

Tolerance: Since only 3 bands are given, tolerance is typically ±20% (standard for 3-band resistors).

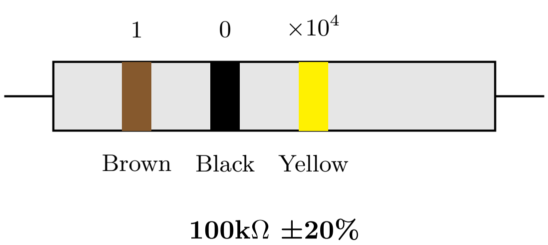


Figure 12: Brown-Black-Yellow = 100kΩ

Tolerance Range: $100k\Omega \pm 20\% = 100k \pm 20k = 80k\Omega$ to $120k\Omega$

Answer:

Resistance: 100 kΩ

Tolerance: ±20% (80kΩ - 120kΩ)

Mnemonic: *"Brown-Black-Yellow: 1-0 with 10000 fellow = 100k"!*

3 Question 3

3.1 Question 3(a) [3 marks]

Define doping. Give the name of semiconductor materials fabricated by doping with an example of each.

3.1.1 Solution

Definition: Doping is the process of intentionally introducing impurity atoms into a pure (intrinsic) semiconductor to modify its electrical properties by increasing the number of charge carriers.

Semiconductors Fabricated by Doping:

P-type Semiconductor: Created by doping with **trivalent** (Group III) impurities.

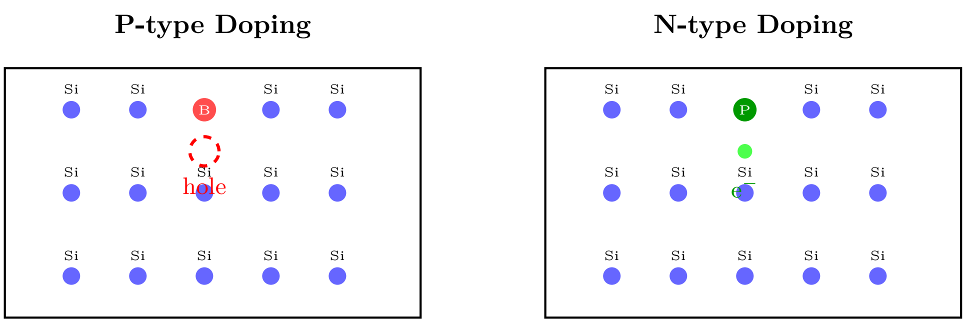
Example: Pure Silicon doped with Boron (B), Gallium (Ga), or Indium (In).

Result: Creates "holes" (positive charge carriers) as majority carriers.

N-type Semiconductor: Created by doping with **pentavalent** (Group V) impurities.

Example: Pure Silicon doped with Phosphorus (P), Arsenic (As), or Antimony (Sb).

Result: Extra electrons become majority carriers.



Boron (3 electrons) creates hole

Phosphorus (5 electrons) donates electron

Figure 13: P-type and N-type Doping Process

Process: Pentavalent impurity adds electrons (N-type), while Trivalent adds holes (P-type).

Mnemonic: *"P-type: Positive holes from Trivalent; N-type: Negative electrons from Pentavalent"!*

3.2 Question 3(a) OR [3 marks]

Define Ripple factor, Peak Inverse Voltage (PIV), Rectification efficiency.

3.2.1 Solution

1. Ripple Factor (r): Ratio of RMS value of AC component to DC component in rectifier output.

$$r = \frac{V_{ac(rms)}}{V_{dc}}$$

Lower ripple factor indicates better filtering. Values: Half-wave = 1.21, Full-wave = 0.48.

2. Peak Inverse Voltage (PIV): Maximum reverse voltage across a diode when non-conducting. Diode must withstand this without breakdown. Values: Half-wave = V_m, Full-wave center-tap = $2V_m$, Bridge = V_m.

3. Rectification Efficiency (η): Ratio of DC output power to AC input power.

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100\%$$

Values: Half-wave = 40.6%, Full-wave = 81.2%.

Significance: Low ripple factor is essential for audio circuits to prevent hum. PIV rating must be higher than peak voltage to avoid diode damage. Efficiency determines battery life in portable devices.

Mnemonic: *"RPE: Ripple shows AC remaining, PIV protects diode, Efficiency measures conversion"!*

3.3 Question 3(b) [3 marks]

Explain working of Crystal diode.

3.3.1 Solution

A **crystal diode** (PN junction diode) allows current flow in one direction only.

Construction: P-type and N-type semiconductors joined together form a PN junction with depletion region.

Working:

Forward Bias: P-side connected to positive, N-side to negative. Barrier potential reduces, current flows when $V > V_\gamma$ (0.7V for Si).

Reverse Bias: P-side connected to negative, N-side to positive. Barrier increases, only tiny leakage current flows.

Applications: Rectification, clipping, clamping, voltage regulation.

Depletion Region: The width of depletion region changes with applied voltage. It widens in reverse bias and narrows in forward bias, controlling current flow.

Biasing: In forward bias the depletion layer decreases, in reverse bias it increases.

Mnemonic: *"Crystal Clear: Forward flows, Reverse blocks"!*

3.4 Question 3(b) OR [3 marks]

Explain working of photodiode.

3.4.1 Solution

A **photodiode** converts light energy into electrical current, operating in reverse bias.

Working Principle: When photons strike the PN junction, they create electron-hole pairs. In reverse bias, these carriers are swept across junction by electric field, producing photocurrent proportional to light intensity.

Applications: Optical communication, light detection, solar cells, barcode readers.

Key Characteristic: Photodiodes are always operated in reverse bias because the change in minority carrier current due to light is more significant and easier to measure than forward current changes.

Mnemonic: *"Photodiode: Photons create current"!*

3.5 Question 3(c) [4 marks]

Explain half-wave rectifier with circuit diagram and waveforms.

3.5.1 Solution

A **half-wave rectifier** converts AC to pulsating DC using a single diode, utilizing only one half-cycle of input.

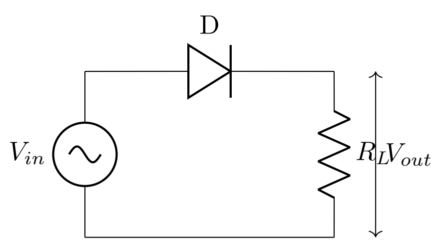


Figure 14: Half-Wave Rectifier Circuit

Circuit Diagram:

Working: **Positive half-cycle:** Diode forward-biased, conducts. Output follows input. **Negative half-cycle:** Diode reverse-biased, blocks. Output is zero.

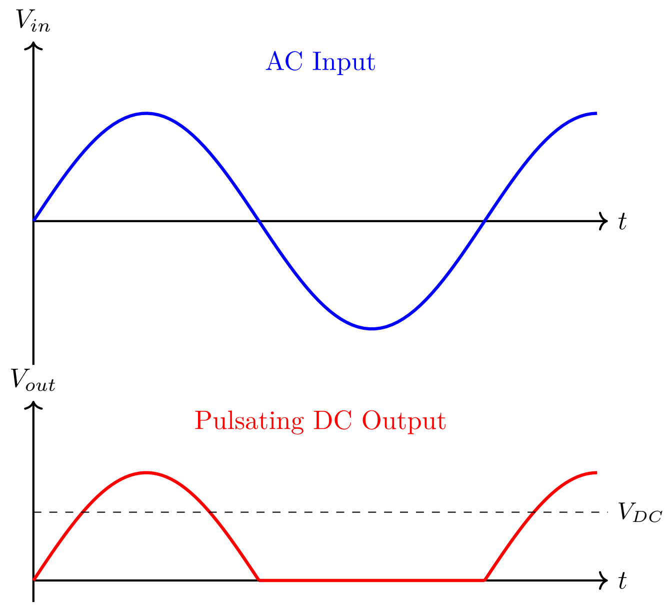


Figure 15: Half-Wave Rectifier Waveforms

Waveforms:

Specifications:

- DC Output: $V_{DC} = \frac{V_m}{\pi} = 0.318V_m$
- Efficiency: $\eta = 40.6\%$
- Ripple Factor: $r = 1.21$
- PIV: V_m

Filter: A filter circuit is needed to make the rectifier output smooth DC.

Mnemonic: *"Half-wave uses Half the cycle"!*

3.6 Question 3(c) OR [4 marks]

Explain full-wave rectifier with circuit diagram and waveforms.

3.6.1 Solution

A **full-wave rectifier** converts AC to pulsating DC using both half-cycles, with center-tapped transformer and two diodes.

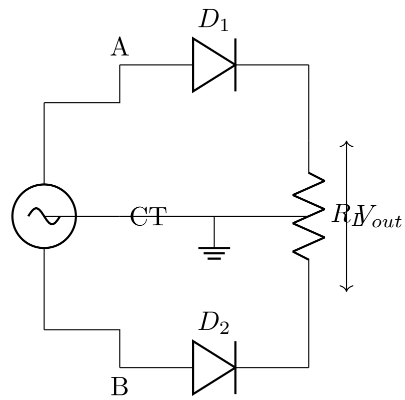


Figure 16: Full-Wave Rectifier (Center-Tap) Circuit

Circuit Diagram:

Working: **Positive half:** A positive, B negative. D_1 conducts, D_2 blocks. **Negative half:** B positive, A negative. D_2 conducts, D_1 blocks. Both halves produce output in same direction through load.

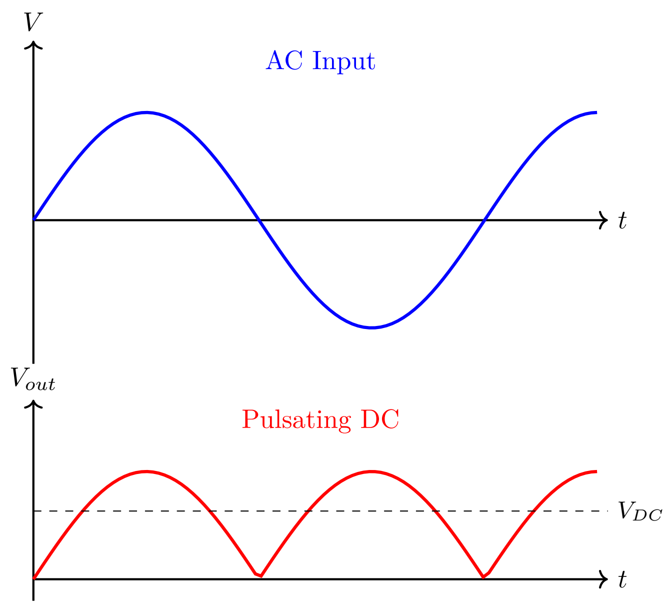


Figure 17: Full-Wave Rectifier Waveforms

Waveforms:

Specifications:

- DC Output: $V_{DC} = \frac{2V_m}{\pi} = 0.636V_m$
- Efficiency: $\eta = 81.2\%$
- Ripple Factor: $r = 0.48$
- PIV: $2V_m$
- Ripple Frequency: $2f$ (double input frequency)

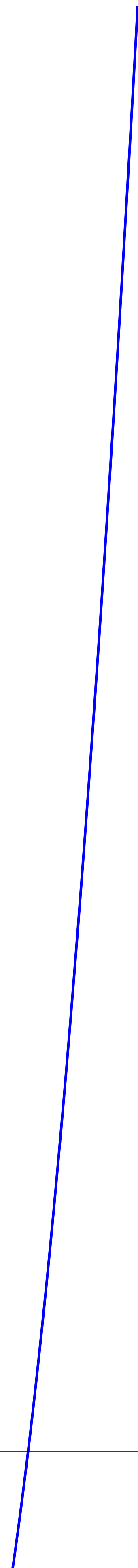
Mnemonic: *"Full-wave uses Full cycle, double efficiency"!*

3.7 Question 3(d) [4 marks]

Draw and explain VI characteristics of PN junction diode.

3.7.1 Solution

The **Voltage-Current (VI) characteristic** shows the relationship between voltage and current in a PN diode.



Regions:

Forward Bias ($V > 0$): Small current until V_γ (knee voltage). Beyond threshold, current increases exponentially.

Reverse Bias ($V < 0$): Small reverse saturation current I_S (few μA) due to minority carriers. Nearly constant.

Breakdown ($V < V_{BR}$): At large reverse voltage, avalanche/Zener breakdown occurs. Current increases rapidly.

Knee Voltage: It is 0.7V for Si diode and 0.3V for Ge diode.

Mnemonic: *"Forward flows after threshold; Reverse resists except breakdown"!*

3.8 Question 3(d) OR [4 marks]

Write difference between P-type and N-type semiconductor.

3.8.1 Solution

Table 3: P-type vs N-type Semiconductor

Parameter	P-type	N-type
Doping	Trivalent (B, Ga, In)	Pentavalent (P, As, Sb)
Majority Carriers	Holes (h^+)	Electrons (e^-)
Minority Carriers	Electrons	Holes
Donor/Acceptor	Acceptor atoms	Donor atoms
Conductivity	Hole conduction	Electron conduction
Fermi Level	Near valence band	Near conduction band

Energy Levels: In N-type, donor energy level is very close to the conduction band (0.01eV for Ge). In P-type, acceptor energy level is near the valence band. This requires less energy for ionization.

Conductivity: In N-type, conductivity is predominantly due to electrons which have higher mobility than holes. Hence N-type devices are generally faster than P-type devices.

Mnemonic: *"P for Positive holes; N for Negative electrons"!*

4 Question 4

4.1 Question 4(a) [3 marks]

Explain the principle of operation of LED.

4.1.1 Solution

A **Light Emitting Diode (LED)** converts electrical energy into light through **electroluminescence**.

Principle: When forward current flows, electrons from N-region recombine with holes in P-region at the junction. Energy is released as photons (light). The wavelength (color) depends on the semiconductor band gap energy.

Energy Relationship:

$$E = h\nu = \frac{hc}{\lambda} = E_g$$

where E_g is band gap energy, determining color.

Materials & Colors: GaAs (Red), GaP (Green), GaN (Blue), InGaN (White).

Material Selection: Silicon and Germanium are not used for LEDs because they release energy as heat (indirect bandgap). Gallium Arsenide/Phosphide are direct bandgap materials used for light emission.

Voltage: For a red LED, the forward voltage is typically 1.8V.

Mnemonic: *"LED: Light from Energy Drop during recombination"!*

4.2 Question 4(a) OR [3 marks]

State applications of LED.

4.2.1 Solution

Applications:

1. Display panels (seven-segment, dot-matrix)
2. Indicator lights (power, status)
3. Traffic signals
4. Automotive lighting
5. General illumination
6. Backlighting (LCD screens)
7. Optical communication

Advantages: LEDs consume very low power compared to incandescent bulbs, have longer life span (>50,000 hours), faster switching speed (ns), and high mechanical ruggedness.

Efficiency: LEDs convert about 80-90

Industrial Use: In automated industries, LEDs are used in sensor systems, quality control scanners, and machine vision lighting due to their reliability and consistent spectral output.

Mnemonic: *"LED everywhere: Displays, Indicators, Traffic, Automotive"!*

4.3 Question 4(b) [4 marks]

Explain Zener diode as voltage regulator.

4.3.1 Solution

A **Zener diode** maintains constant output voltage by operating in reverse breakdown region.

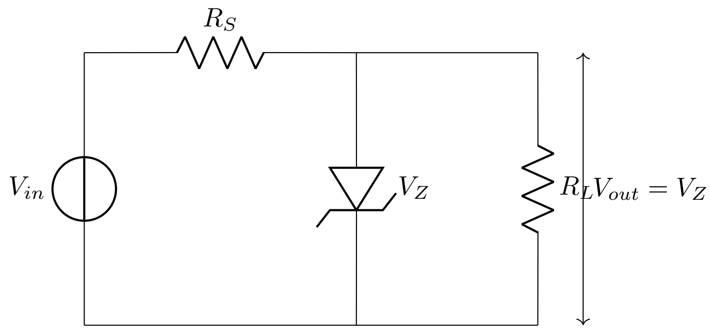


Figure 19: Zener Voltage Regulator

Circuit:

Working: R_S drops excess voltage. Zener maintains $V_{out} = V_Z$. Changes in V_{in} or I_L are absorbed by varying I_Z.

$$I_S = I_Z + I_L = \frac{V_{in} - V_Z}{R_S}$$

Design Condition: For proper regulation, the Zener diode must remain in breakdown region. The current through Zener (I_Z) must be between $I_{Z(\text{min})}$ and $I_{Z(\text{max})}$ under all load conditions.

Regulation Factor: The quality of regulation is measured by line regulation (input change) and load regulation (load change). Zener provides acceptable regulation for low cost applications.

Doping: The doping level in a Zener diode is much higher than in a normal diode.

Mnemonic: *"Zener Zaps excess, maintains constant voltage"!*

4.4 Question 4(b) OR [4 marks]

Give limitations of zener voltage regulator.

4.4.1 Solution

Limitations:

1. Limited current capacity (few mA to few A)
2. Poor efficiency (power dissipated as heat)
3. Output voltage not adjustable (fixed by Zener)
4. Limited ripple rejection
5. Not suitable for high power applications
6. Requires minimum load current

Temperature Dependence: Zener voltage changes with temperature. Zener breakdown has negative temperature coefficient, while Avalanche breakdown has positive coefficient. This can affect stability in precision circuits.

Noise: Zener diodes generate significant noise in the avalanche breakdown region. This noise can interfere with sensitive signal processing circuits, requiring additional bypass capacitors.

Stability: For very high precision voltage references, standard Zener diodes are often replaced by bandgap reference circuits which offer much better temperature stability and lower noise performance.

Mnemonic: *"Zener limits: Low current, Fixed voltage, Heat loss"!*

4.5 Question 4(c) [7 marks]

Discuss the necessity of filter circuit in rectifier. List various types of filter circuits used in rectifier and explain any one with neat diagram.

4.5.1 Solution

Necessity of Filter Circuit: Rectifier output is pulsating DC with significant AC ripple. Filters smooth this into steady DC for:

- Protecting sensitive electronic components
- Reducing ripple factor
- Improving voltage regulation
- Minimizing electrical noise

Types of Filter Circuits:

1. Capacitor filter (C)
2. Inductor filter (L)
3. LC filter
4. CLC filter (π-filter)
5. RC filter

Explanation: Capacitor Filter

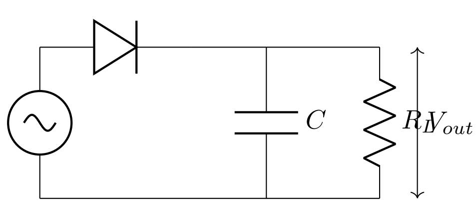


Figure 20: Capacitor Filter Circuit

Circuit:

Working: Capacitor charges to peak during conduction, discharges through load when diode is OFF. Provides relatively smooth DC with small ripple.

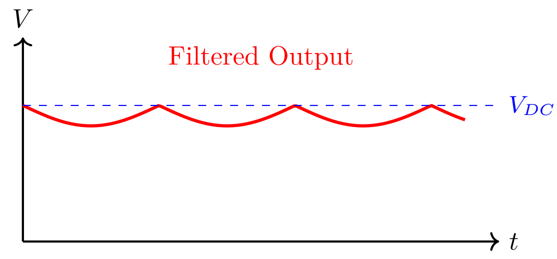


Figure 21: Capacitor Filter Output Waveform

Waveform:

Specifications: Ripple: $V_{ripple} \approx \frac{I_{DC}}{fC}$ Good for low current loads.

Comparison: L-filter is good for heavy loads/low resistance. C-filter is good for light loads/high resistance. Pi-filter provides best smoothing but is bulky. Selection depends on load and cost constraints.

Additional Info: Without filter circuits, noise (hum) occurs in electronic devices. A combination of capacitor and inductor gives the best filtering.

Mnemonic: *"Filter Flattens pulsating DC to smooth DC"!*

5 Question 5

5.1 Question 5(a) [3 marks]

Define e-waste. List common e-waste items.

5.1.1 Solution

Definition: **E-waste (Electronic Waste)** refers to discarded electrical or electronic devices and their components. It includes obsolete, broken, or end-of-life electronic products.

Common E-waste Items:

- Computers, laptops, tablets
- Mobile phones, chargers
- TVs, monitors
- Printers, scanners
- Batteries (lithium, lead-acid)
- Circuit boards, cables
- Home appliances (refrigerators, washing machines)

Environmental Impact: E-waste usually contains hazardous substances like Lead (Pb), Cadmium (Cd), Mercury (Hg), and Brominated Flame Retardants (BFR) which contaminate soil and water if dumped.

Sources: Major sources include IT equipment (servers, PCs), consumer electronics (TVs, cameras), large household appliances, and toys. Rapid technology upgrades increase waste volume.

Warning: E-waste should not be thrown with normal trash. Toxic substances in it need to be recycled.

Mnemonic: *"E-waste: Electronics discarded after use"!*

5.2 Question 5(b) [3 marks]

State and explain various strategies of e-waste management.

5.2.1 Solution

E-waste Management Strategies:

Reduce: Extend product lifespan through repair and maintenance. Buy durable products.

Reuse: Donate or sell working devices. Repurpose components.

Recycle: Extract valuable materials (gold, copper, rare metals) through proper recycling facilities.

Proper Disposal: Use authorized e-waste collection centers. Never dump in landfills.

Awareness: Educate public about hazards and proper disposal methods.

Legislation: Governments implement EPR (Extended Producer Responsibility) laws, making manufacturers responsible for the entire lifecycle of electronic products, encouraging eco-friendly design.

Benefit: Precious metals like gold, silver, and copper can be recovered from E-waste recycling.

Mnemonic: *"3R+: Reduce, Reuse, Recycle, Right disposal"!*

5.3 Question 5(c) [4 marks]

Explain transistor as switch.

5.3.1 Solution

A transistor operates as an electronic switch with two states: ON (saturation) and OFF (cutoff).

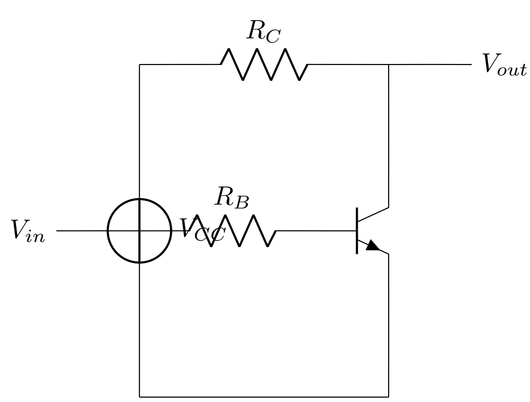


Figure 22: Transistor as Switch

Circuit:

States:

OFF (Cutoff): $V_{in} = 0V$, base current $I_B = 0$, $I_C \approx 0$, $V_{out} = V_{CC}$ (Switch OPEN)

ON (Saturation): $V_{in} = High$, I_B sufficient, $I_C = I_{C(sat)}$, $V_{out} \approx 0V$ (Switch CLOSED)

Applications: Digital circuits, relay drivers, LED drivers, motor control.

Ideal vs Real: Ideally, a switch has zero resistance when ON and infinite when OFF. Transistors have small saturation voltage ($V_{CE(sat)} \approx 0.2V$) when ON and small leakage current when OFF.

State: In saturation region transistor acts as ON switch and in cut-off as OFF switch.

Mnemonic: *"Transistor Switch: Base controls Collector current"!*

5.4 Question 5(d) [4 marks]

Derive relation between α and β for CE configuration of transistor.

5.4.1 Solution

For a transistor in Common Emitter configuration:

Definitions:

$$\alpha = \frac{I_C}{I_E} \quad \text{(Common Base gain)}$$

$$\beta = \frac{I_C}{I_B} \quad \text{(Common Emitter gain)}$$

Derivation: From Kirchhoff's Current Law:

$$I_E = I_B + I_C$$

From definition of α:

$$I_C = \alpha I_E = \alpha(I_B + I_C)$$

Expanding:

$$I_C = \alpha I_B + \alpha I_C$$

Rearranging:

$$I_C(1 - \alpha) = \alpha I_B$$

$$\frac{I_C}{I_B} = \frac{\alpha}{1 - \alpha}$$

Since $\beta = \frac{I_C}{I_B}$:

$$\boxed{\beta = \frac{\alpha}{1 - \alpha}}$$

Similarly, solving for α:

$$\boxed{\alpha = \frac{\beta}{1 + \beta}}$$

Example: If $\alpha = 0.98$: $\beta = \frac{0.98}{1-0.98} = 49$
If $\beta = 100$: $\alpha = \frac{100}{1+100} = 0.99$

Significance: Value of α is always slightly less than 1 (0.95 to 0.99) as $I_C < I_E$. Value of β is much greater than 1 (typically 50-300), showing high current gain capability of CE configuration.

Application: High beta allows transistors to act as amplifiers. A small base current variation causes a large collector current variation, amplifying the input signal.

Remember: Always $\beta > \alpha$. The value of α is close to 1, while β can be from 20 to 500.

Mnemonic: *"Alpha over one-minus-alpha equals Beta"!*