Fundamentals of Electronics (4311102) - Summer 2023 Solution

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Question 1(a) [3 marks]

Define Active and Passive components.

Solution

Answer:

Table 1. Active vs Passive Components

Active Components	**Passive Components**
Require external power source to operate.	Do not need external power source.
Can amplify and process electrical signals.	Cannot amplify or process signals.
Examples: transistors, diodes, ICs.	**Examples**: resistors, capacitors, inductors.

Mnemonic

"APE: Active needs Power to Enhance signals"

Question 1(b) [4 marks]

State types of capacitors based on materials used.

Solution

Answer:

Table 2. Types of Capacitors Based on Materials

Material Type	**Capacitor Type**	**Typical Applications**
Ceramic	Ceramic disc, multilayer	Bypass, coupling, high frequency
Plastic Film	Polyester, Polypropylene, Teflon	Timing, filtering, precision
Electrolytic	Aluminum, Tantalum	Power supply, DC blocking, high capacitance
Paper	Paper dielectric	Old equipment, not common now
Mica	Silvered mica	High precision RF circuits
Glass	Glass dielectric	High voltage applications

Mnemonic

"CEPPMG: Ceramic Electrolytic Paper Plastic Mica Glass"

Question 1(c) [7 marks]

Explain resistor color coding technique with example.

Solution

Answer:
The resistor color code uses colored bands to indicate resistance value, tolerance, and reliability.

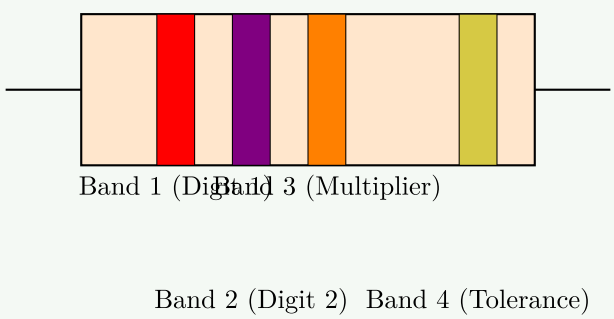
Table 3. Standard Resistor Color Code

Color	Digit	Multiplier	Tolerance
Black	0	$\times 10^0$ (1)	-
Brown	1	$\times 10^1$ (10)	$\pm 1\%$
Red	2	$\times 10^2$ (100)	$\pm 2\%$
Orange	3	$\times 10^3$ (1k)	-
Yellow	4	$\times 10^4$ (10k)	-
Green	5	$\times 10^5$ (100k)	$\pm 0.5\%$
Blue	6	$\times 10^6$ (1M)	$\pm 0.25\%$
Violet	7	$\times 10^7$ (10M)	$\pm 0.1\%$
Grey	8	$\times 10^8$	$\pm 0.05\%$
White	9	$\times 10^9$	-
Gold	-	$\times 0.1$	$\pm 5\%$
Silver	-	$\times 0.01$	$\pm 10\%$

Figure 1. Resistor Color Bands

Example 1: Red-Violet-Orange-Gold

$27 \times 10^3 \Omega \pm 5\% = 27k\Omega$



Example 1: Red-Violet-Orange-Gold
- 1st (Red) = 2, 2nd (Violet) = 7, 3rd (Orange) = $\times 1k$, 4th (Gold) = $\pm 5\%$
- Value: $27k\Omega \pm 5\%$

Example 2: Brown-Black-Yellow-Silver
- 1st (Brown) = 1, 2nd (Black) = 0, 3rd (Yellow) = $\times 10k$, 4th (Silver) = $\pm 10\%$
- Value: $100k\Omega \pm 10\%$

Mnemonic

"BBROY: BBROY Great Britain Very Good Wife (Black Brown Red Orange Yellow Green Blue Violet Gray White)"

Question 1(c) OR [7 marks]

Explain construction, working Characteristic and application of LDR.

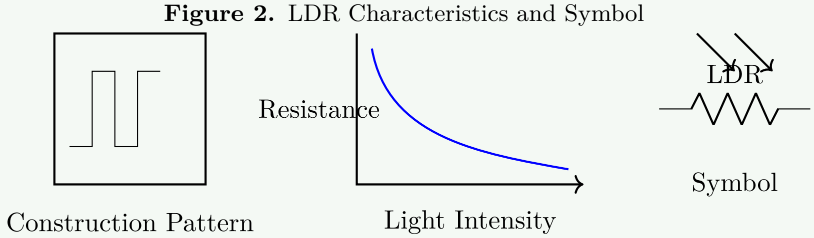
Solution

Answer:
Light Dependent Resistor (LDR)

Table 4. LDR Details

Aspect	Description
Construction	Semiconductor material (cadmium sulfide) deposited in zigzag pattern on ceramic substrate. Packaged in transparent case with two terminals.
Working Principle	Photoconductivity: When light falls on material, photons release electron-hole pairs, increasing conductivity and decreasing resistance.
Characteristics	High resistance in dark (MΩ). Low resistance in light (100-5000Ω). Inverse non-linear relationship. Slow response time.
Applications	Automatic street lights, camera light meters, burglar alarms, display brightness control.

Figure 2. LDR Characteristics and Symbol



Mnemonic

"MOLD: More light On, Less resistance Down"

Question 2(a) [3 marks]

Classify Resistors based on materials.

Solution

Answer:

Table 5. Resistor Classification

Material Type	Characteristics	Examples
Carbon Composition	Low cost, noisy, poor tolerance.	General purpose.
Carbon Film	Better stability than composition.	Audio, general circuits.
Metal Film	Excellent stability, low noise.	Precision circuits.
Metal Oxide	Heat resistant, high stability.	Power supplies.
Wire Wound	High power, inductive.	Heating elements.
Thick/Thin Film	Small size (SMD).	Surface mount.

Mnemonic

"CMMWTF: Carbon Makes Much Wire To Form resistors"

Question 2(b) [4 marks]

Calculate value of resistor for a given color code. – (i) Brown, Black, Yellow, Golden (ii) Yellow, Violet, Red, Silver

Solution

Answer:

Part (i): Brown, Black, Yellow, Golden
- Brown (1), Black (0), Yellow ($\times 10^4$), Golden ($\pm 5\%$)
- $10 \times 10,000 = 100,000\Omega = 100k\Omega \pm 5\%$

Part (ii): Yellow, Violet, Red, Silver
- Yellow (4), Violet (7), Red ($\times 10^2$), Silver ($\pm 10\%$)
- $47 \times 100 = 4,700\Omega = 4.7k\Omega \pm 10\%$

Question 2(c) [7 marks]

Illustrate construction and operation of Electrolytic capacitors.

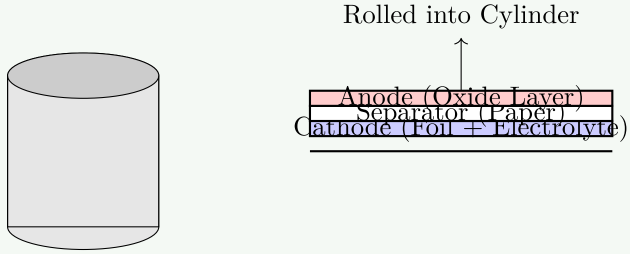
Solution

Answer:

Table 6. Electrolytic Capacitor

Component	Description
Anode	Aluminum foil with oxide layer (dielectric).
Cathode	Electrolyte (liquid/paste) and metal foil.
Separator	Paper soaked in electrolyte.
Operation	Oxide layer gives high capacitance ($C \propto A/d$) due to extreme thinness. Polarized (must connect correct +/-).

Figure 3. Electrolytic Capacitor Construction



Mnemonic

"PAVE: Polarized Aluminum with Very high capacitance and Electrolyte"

Question 2(a) OR [3 marks]

State the importance of filter circuit in rectifier.

Solution

Answer:
- **Smoothing**: Converts pulsating DC from rectifier into steady DC.
- **Ripple Reduction**: Removes unwanted AC components (ripples).
- **Voltage Stabilization**: Maintains average output voltage.
- **device Protection**: Prevents damage to sensitive electronic components.

Mnemonic

"SVRL: Smoothens Voltage by Reducing ripples for Load"

Question 2(b) OR [4 marks]

Differentiate between P type semiconductor and N type semiconductor.

Solution

Answer:

Table 7. P-type vs N-type

Feature	P-type	N-type
Dopant	Trivalent (B, Al, Ga)	Pentavalent (P, As, Sb)
Majority Carriers	Holes (+)	Electrons (-)
Minority Carriers	Electrons (-)	Holes (+)
Energy Level	Acceptor level near Valence band	Donor level near Conduction band

Mnemonic

"HELP-NED: Holes Exist Large in P, Negative Electrons Dominate N"

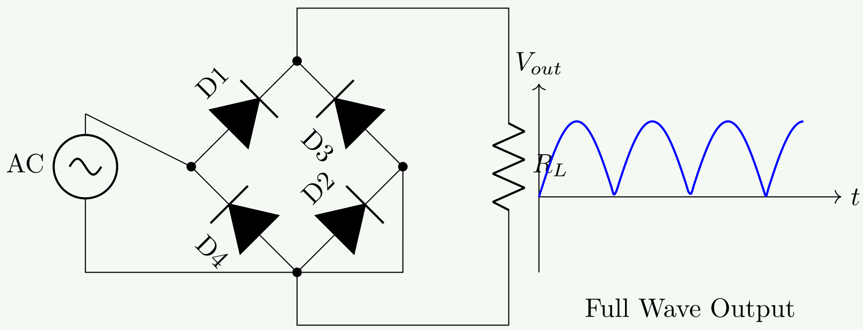
Question 2(c) OR [7 marks]

Illustrate working of Bridge Rectifier with waveforms.

Solution

Answer:
Operation:
- **Positive Half**: D1, D3 conduct. Current flows through load.
- **Negative Half**: D2, D4 conduct. Current flows through load in same direction.
- **Result**: Full wave rectification without center-tap transformer.

Figure 4. Bridge Rectifier Circuit and Waveforms



Mnemonic

"FBRO: Four diodes, Both cycles, Rectified Output"

Question 3(a) [3 marks]

Define (1) PIV (2) Ripple Factor.

Solution

Answer:

Table 8. PIV and Ripple Factor

Term	Definition
PIV (Peak Inverse Voltage)	Maximum voltage a diode can withstand in reverse bias. Must be higher than circuit's max reverse voltage to prevent breakdown.
Ripple Factor (r)	Ratio of RMS value of AC component to DC component in output. Lower r means better filtering.

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

Mnemonic

"PIR: Peak Inverse voltage Restricts, Ripple indicates Rectification quality"

Question 3(b) [4 marks]

Illustrate VI characteristics of PN junction diode.

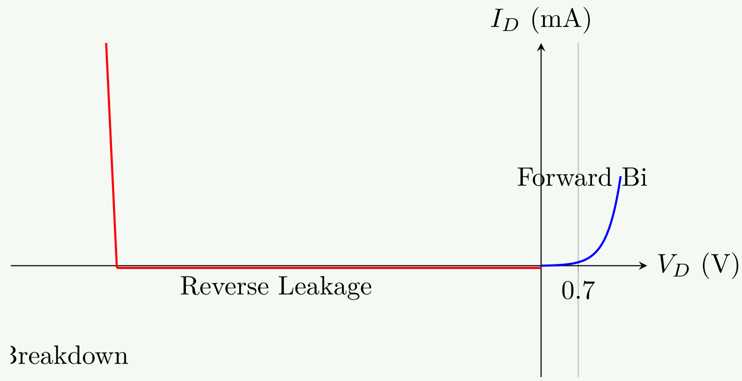
Solution

Answer:

Table 9. PN Junction Characteristics

Region	Behavior
Forward Bias	Conducts current easily after threshold (0.7V Si, 0.3V Ge). Exponential current rise.
Reverse Bias	Blocks current. Very small leakage (μA). Breakdown at high reverse voltage.

Figure 5. VI Characteristics of PN Diode



Mnemonic

"FBRL: Forward Bias Resists Little, reverse blocks lots"

Question 3(c) [7 marks]

Explain the working of capacitor input and choke input filter with waveforms.

Solution

Answer:

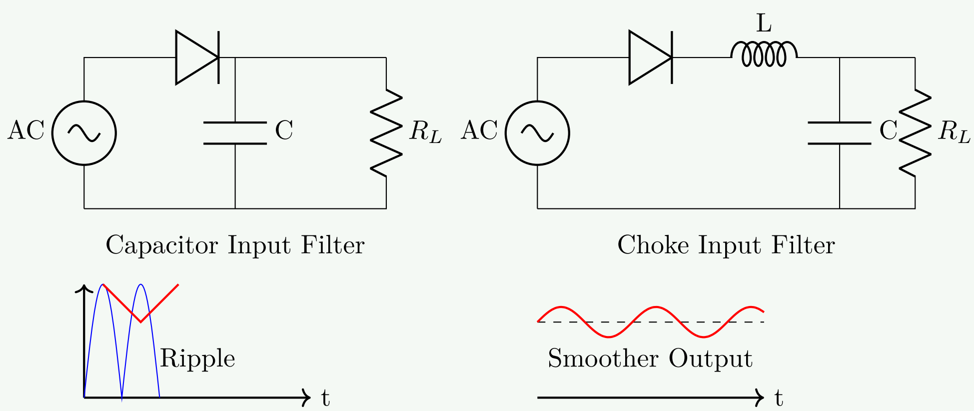
1. Capacitor Input Filter

- Capacitor connected in parallel with load.
- Charges to peak, discharges slowly during dips.
- High DC voltage, but poor regulation.

2. Choke Input Filter

- Inductor (choke) in series, capacitor in parallel.
- Inductor opposes current change, smoothing current.
- Better regulation, lower DC voltage.

Figure 6. Filter Circuits and Waveforms



Mnemonic

"VOICE: Voltage Output Is Constant with Either filter, but choke gives better regulation"

Question 3(a) OR [3 marks]

State the function and importance of Zener diode.

Solution

Answer:

Table 10. Zener Diode Functions

Function	Description
Voltage Regulation	Maintains constant output voltage.
Voltage Reference	Provides precise reference voltage.
Protection	Prevents voltage spikes from damaging circuits.
Usage	Operates in breakdown region.

Mnemonic

"VPRVW: Voltage Protection, Regulation, and Voltage Waveform control"

Question 3(b) OR [4 marks]

Describe Light emitting diode (LED) with its characteristic.

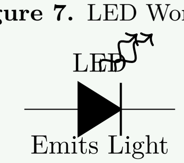
Solution

Answer:

Table 11. LED Characteristics

Aspect	Description
Principle	Electroluminescence. Recombination of holes and electrons releases photons.
Material	Direct bandgap semiconductors (GaAs, GaP).
Forward Voltage	Red: 2V, Blue/White: 3V.
Operation	Works only in Forward Bias. Damaged by reverse bias ($> 5V$).

Figure 7. LED Working



Mnemonic

"CRAVE: Current Regulated And Voltage Emits light"

Question 3(c) OR [7 marks]

Illustrate the working of capacitor input and choke input filter.

Solution

Answer:
(Refer to Question 3(c) for detailed waveforms and diagrams. This section provides component breakdown.)

Table 12. Capacitor vs Choke Filter

Parameter	Capacitor Input	Choke Input
Components	Capacitor in parallel.	Choke (series) + Cap (parallel).
Output V	Higher ($\approx V_m$).	Lower ($\approx 0.9V_m$).
Regulation	Poor (V drops with load).	Good (L opposes change).
Diode Current	High peak surges.	Continuous, lower peak.
Cost/Size	Low cost, small.	Heavy, bulky, expensive.

Mnemonic

"CHEER: Capacitor Holds Energy, inductor Ensures Regulated current"

Question 4(a) [3 marks]

Discuss characteristics of PN junction diode.

Solution

Answer:

- **Forward Bias**: Low resistance, current flows after knee voltage.
- **Reverse Bias**: High resistance, only leakage current.
- **Breakdown**: Rapid current increase at Zener/Avalanche voltage.
- **Temp Effect**: V_f drops with heat, I_r doubles every 10°C.

Mnemonic

"FRBCT: Forward conducts, Reverse blocks, Breakdown destroys"

Question 4(b) [4 marks]

Compare between P-N junction diode and Zener diode.

Solution

Answer:

Table 13. General Diode vs Zener Diode

Feature	PN Diode	Zener Diode
Symbol	Standard arrow	Arrow with 'Z' ends
Doping	Moderate	Heavy
Breakdown	Destructive	Non-destructive (Operating region)
Main Use	Rectification	Voltage Regulation

Mnemonic

"FORBAR: Forward Operation is Regular, Breakdown Application is Real difference"

Question 4(c) [7 marks]

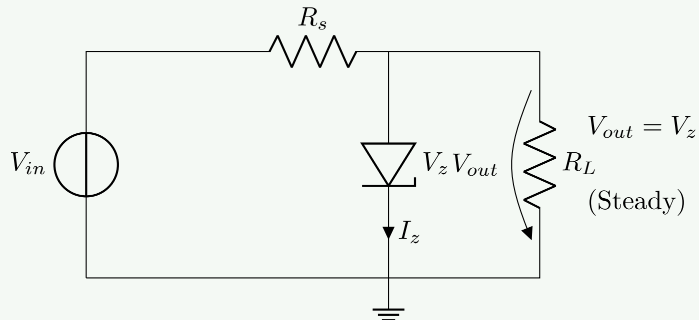
Illustrate the function of Zener diode as a voltage regulator.

Solution

Answer:
Circuit Operation:

- Zener diode connected in **Reverse Bias**.
- When $V_{in} > V_z$, Zener conducts and holds $V_{out} = V_z$.
- Series resistor R_s drops the excess voltage $(V_{in} - V_z)$.
- Changes in load current or input voltage are compensated by changing Zener current, keeping V_{out} steady.

Figure 8. Zener Regulator



Mnemonic

"VISOR: Voltage In Stays Out Regulated"

Question 4(a) OR [3 marks]

Discuss transistor in brief.

Solution

Answer:

- **Definition**: 3-terminal semiconductor device (Emitter, Base, Collector).
- **Types**: BJT (NPN, PNP), FET (JFET, MOSFET).
- **Function**: Amplifies weak signals, acts as a switch.
- **Control**: Current controlled (BJT) or Voltage controlled (FET).

Mnemonic

"TAWAI: Transistors Amplify, Work As switches, and are Integral"

Question 4(b) OR [4 marks]

Derive relation between α and β for transistor amplifier.

Solution

Answer:
Definitions:

- $\alpha = \frac{I_C}{I_E}$ (Common Base current gain)
- $\beta = \frac{I_C}{I_B}$ (Common Emitter current gain)

Derivation:

1. Fundamental Equation: $I_E = I_B + I_C$
2. Divide by I_C: $\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$
3. Substitute definitions: $\frac{1}{\alpha} = \frac{1}{\beta} + 1$
4. Rearrange: $\frac{1}{\alpha} = \frac{1+\beta}{\beta}$
5. Therefore: $\alpha = \frac{\beta}{1+\beta}$
6. Solving for β: $\beta = \frac{\alpha}{1-\alpha}$

Example: If $\alpha = 0.99$, $\beta = \frac{0.99}{1-0.99} = 99$.

Mnemonic

"ABR: Alpha and Beta are Related"

Question 4(c) OR [7 marks]

Explain in detail the construction of NPN and PNP transistor.

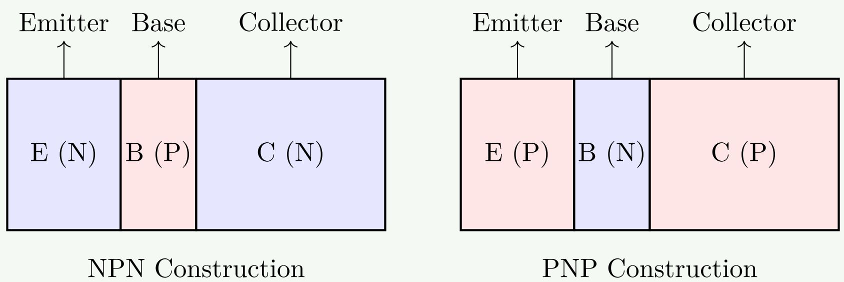
Solution

Answer:

Table 14. NPN vs PNP Construction

Aspect	NPN	PNP
Layers	N-P-N	P-N-P
Majority	Electrons	Holes
Doping	Emitter (Heavy), Base (Light), Collector (Moderate)	Same
Width	Base is very thin ($< 10\mu m$) to reduce recombination	Same

Figure 9. Transistor Construction



Mnemonic

"ENB-CPM: Emitter has N in NPN, Collector is Proportionally Medium-doped"

Question 5(a) [3 marks]

Explain e-waste in brief.

Solution

Answer:
E-Waste (Electronic Waste): Discarded electronic devices (phones, PCs, TVs).

- **Hazards**: Contains toxic lead, mercury, cadmium.
- **Value**: Contains recoverable gold, silver, copper.
- **Impact**: Environmental pollution if ended in landfill.
- **Need**: Proper recycling and disposal management.

Mnemonic

"TECH: Toxic Electronics Create Hazards"

Question 5(b) [4 marks]

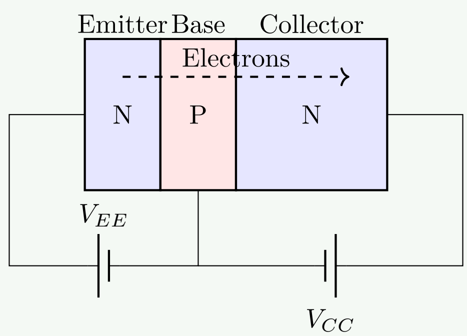
Illustrate operation of NPN transistor with figure.

Solution

Answer:
Working Principle:

- **Forward Biased** Base-Emitter: Electrons injected from Emitter to Base.
- **Reverse Biased** Base-Collector: Electrons swept from Base to Collector.
- Small Base current (I_B) controls large Collector current (I_C).
- Equation: $I_E = I_B + I_C$.

Figure 10. NPN Operation



Mnemonic

"BECAN: Base current Enables Collector Amplification in NPN"

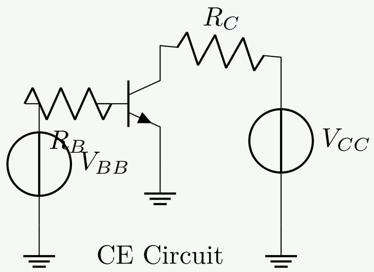
Question 5(c) [7 marks]

Illustrate common emitter (CE) configuration of Transistor with input and output characteristics.

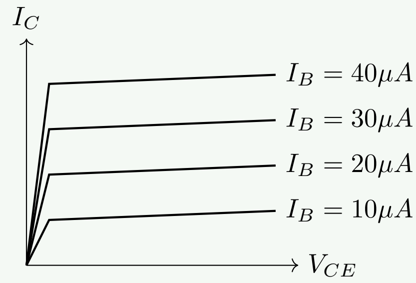
Solution

Answer:
CE Configuration: Emitter is grounded (common). Input at Base, Output at Collector. High Gain.

Figure 11. CE Circuit and Characteristics



CE Circuit



Output Characteristics

- **Input Char**: I_B vs V_{BE}. Like a diode.
- **Output Char**: I_C vs V_{CE}. Saturation (steep rise), Active (flat), Cutoff (zero).

Mnemonic

"CASIO: Common emitter Amplifies Signals with Inverted Output"

Question 5(a) OR [3 marks]

State types of e-waste.

Solution

Answer:

- **IT & Telecom**: Computers, phones, printers.
- **Consumer**: TVs, audio sets, cameras.
- **Appliances**: Fridges, washing machines.
- **Lighting**: Bulbs, LEDs.
- **Medical**: Scanners, monitors.

Mnemonic

"CLIMATE: Computing, Lighting, Industrial, Medical, Appliances, Telecom, Electronic components"

Question 5(b) OR [4 marks]

Illustrate different categories of Electronics waste.

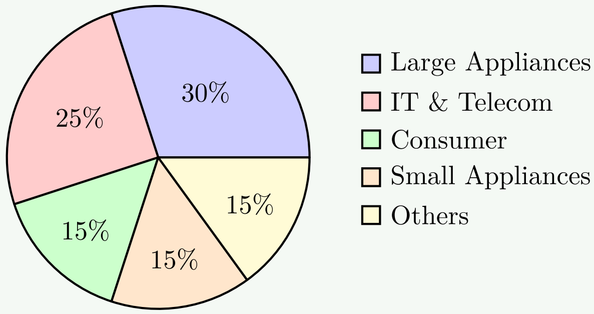
Solution

Answer:

Table 15. E-Waste Categories

Category	Examples
Large Appliances	Washing machines, AC units
Small Appliances	Toasters, Irons
IT Equipment	PCs, Laptops, Mobile phones
Consumer Electronics	TVs, Stereos, Game consoles
Lighting	Fluorescent tubes
Tools	Drills, Saws

Figure 12. E-Waste Composition



Mnemonic

"LIMCEST: Large, IT, Medical, Consumer, Electronic tools, Small, Telecom"

Question 5(c) OR [7 marks]

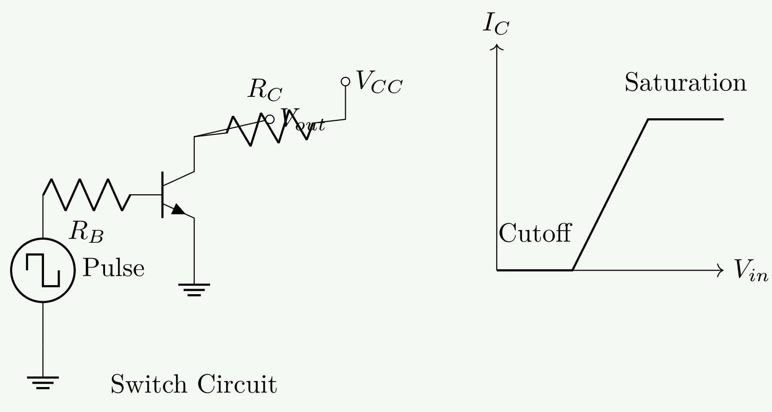
Explain transistor as a switch in cutoff and saturation region.

Solution

Answer:
Transistor Switch States:

State	Region	Conditions
OFF (Open)	**Cutoff**	$V_{in} < 0.7V$, $I_B = 0$, $I_C = 0$, $V_{CE} = V_{CC}$.
ON (Closed)	**Saturation**	$V_{in} > 0.7V$, I_B max, I_C max, $V_{CE} \approx 0.2V$.

Figure 13. Transistor Switching



Mnemonic

"COSVL: Cutoff means Off State with Vce Large"