Subject Name (SUBJECT001) - Sample Term Solution

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Month Day, Year

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1 Question 1

1.1 Question 1(a) [3 marks]

Write a Java program to find the maximum of three numbers.

1.1.1 Solution

To find the **maximum** of three numbers, we use **conditional statements** (if-else) to compare values. The program takes three numbers as input and returns the *largest value* among them.

Listing 1: Find Maximum of Three Numbers

```java
public class MaxOfThree {
    public static void main(String[] args) {
        int a = 25, b = 40, c = 15;
        int max;

        // Compare first two numbers
        if (a > b) {
            max = a;
        } else {
            max = b;
        }

        // Compare result with third number
        if (c > max) {
            max = c;
        }

        System.out.println("Maximum number is: " + max);
    }
}
```

Output:

```
Maximum number is: 40
```

Key Points:

Logic: First compare `a` and `b`, store larger in `max`

Second Comparison: Compare `max` with `c` to get final maximum

Alternative: Can use `Math.max(a, Math.max(b, c))` for concise code

Comparison Methods: Three approaches exist: nested if-else (shown above), ternary operator `max = (a>b) ? ((a>c)?a:c) : ((b>c)?b:c)`, or built-in `Math.max()` method.

Mnemonic: *MAX: Compare in pairs, update Maximum At eXamination*

1.2 Question 1(b) [4 marks]

Calculate the cutoff frequency of an RC low-pass filter with $R = 1.5\,k\Omega$ and $C = 100\,nF$. Also find the output voltage if input is 10V at cutoff frequency.

1.2.1 Solution

Given Data:

- Resistance: $R = 1.5\,k\Omega = 1500\,\Omega$
- Capacitance: $C = 100\,nF = 100 \times 10^{-9}\,F$
- Input Voltage: $V_{in} = 10\,V$

Step 1: Calculate Cutoff Frequency The **cutoff frequency** formula for RC low-pass filter is:

$$f_c = \frac{1}{2\pi RC}$$

Substituting values:

$$f_c = \frac{1}{2\pi \times 1500 \times 100 \times 10^{-9}}$$

$$f_c = \frac{1}{2\pi \times 1.5 \times 10^{-4}}$$

$$f_c = \frac{1}{9.42 \times 10^{-4}} = 1061.57\,Hz \approx 1.06\,kHz$$

Step 2: Calculate Output Voltage at Cutoff At cutoff frequency, output voltage is **0.707 times** (or $\frac{1}{\sqrt{2}}$) the input voltage:

$$V_{out} = 0.707 \times V_{in} = 0.707 \times 10 = 7.07\,V$$

Results:

Cutoff Frequency: $f_c = 1.06\,kHz$

Output Voltage: $V_{out} = 7.07\,V$ at cutoff

Attenuation: $-3\,dB$ at cutoff frequency

Phase Shift: $-45°$ at cutoff frequency

Filter Behavior: Below cutoff, signal passes with minimal attenuation. Above cutoff, attenuation increases at $-20\,dB/decade$ roll-off rate.

Mnemonic: *RC-Formula:* $f_c = \frac{1}{2\pi RC}$, $V_{out} = 0.707 \times V_{in}$ at f_c

1.3 Question 1(c) [7 marks]

Compare active and passive electronic components with suitable examples.

1.3.1 Solution

Electronic components are classified into **active** and **passive** categories based on their ability to control or amplify electrical energy.

Table 1: Active vs Passive Components Comparison

Characteristic	Active Components	Passive Components
Energy Source	Require external power source	Do not require external power
Control Ability	Can control/amplify current flow	Cannot amplify, only regulate
Directionality	Usually unidirectional	Bidirectional
Power Gain	Provide power gain (> 1)	Power gain is always ≤ 1
Examples	Transistors (BJT, FET), Diodes (LED, Zener), ICs (Op-Amp, 555), SCR	Resistors, Capacitors, Inductors, Transformers
Function	Amplification, switching, oscillation, rectification	Resistance, capacitance, inductance, filtering
Linearity	Can be linear or non-linear	Generally linear

Active Components in Detail:

Transistors: Used for amplification and switching. BJT uses current control, FET uses voltage control.

Diodes: Allow current in one direction. LED emits light, Zener regulates voltage.

ICs: Integrated circuits like `555 timer` (oscillator), op-amps (amplifier).

Power Requirement: All active components need DC bias/supply to operate.

Transistor Types: BJT (Bipolar Junction Transistor) has NPN and PNP variants. FET (Field Effect Transistor) includes JFET and MOSFET types.

Passive Components in Detail:

Resistors: Oppose current flow, dissipate power as heat. Value in Ω.

Capacitors: Store energy in electric field. Value in Farads (F), blocks DC, passes AC.

Inductors: Store energy in magnetic field. Value in Henry (H), opposes AC changes.

Transformers: Transfer energy between circuits via magnetic coupling.

Resistor Types: Fixed resistors include carbon composition, metal film, and wire-wound types. Variable resistors are potentiometers and rheostats.

Capacitor Types: Capacitors include electrolytic (polarized, high capacitance), ceramic (small, stable), and film (precision) types.

Key Distinction: The fundamental difference is that active components can *inject power* into a circuit (amplification), while passive components can only *absorb or store* energy, never increase it.

Mnemonic: *ACTIVE = Amplify, Control, Transform; PASSIVE = Resist, Store, Filter*

1.4 Question 1(c) OR [7 marks]

Draw and explain the working of a half-wave rectifier circuit with input and output waveforms.

1.4.1 Solution

A **half-wave rectifier** converts AC voltage to pulsating DC by allowing only one half-cycle (positive or negative) of the input AC waveform to pass through.

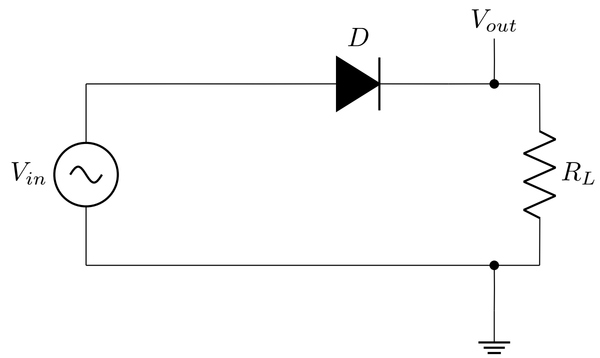

Figure 1: Half-Wave Rectifier Circuit

Circuit Diagram:

Working Principle:

Positive Half-Cycle: When input AC is positive, diode is forward-biased (conducts). Current flows through load resistor R_L, producing output voltage.

Negative Half-Cycle: When input AC is negative, diode is reverse-biased (blocks). No current flows, output voltage is zero.

Result: Only positive half-cycles appear at output, creating pulsating DC.

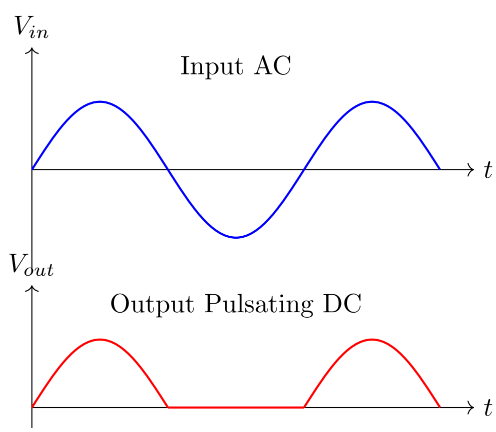

Figure 2: Input and Output Waveforms

Waveform Representation:

Key Parameters:

Efficiency: $\eta = 40.6\%$ (theoretical maximum)

Ripple Factor: $r = 1.21$ (high ripple content)

Peak Inverse Voltage (PIV): $PIV = V_m$ (maximum reverse voltage across diode)

DC Output: $V_{DC} = \frac{V_m}{\pi} = 0.318V_m$ where V_m is peak AC voltage

Efficiency Derivation: Efficiency $\eta = \frac{P_{DC}}{P_{AC}} = \frac{(V_{DC})^2/R_L}{(V_{rms})^2/R_L} = \frac{(V_m/\pi)^2}{(V_m/2)^2} = \frac{4}{\pi^2} = 0.406 = 40.6\%$

Applications: Half-wave rectifiers are used in low-power applications like battery charging, signal demodulation, and voltage multipliers. They are *not suitable* for high-power applications due to poor efficiency.

Mnemonic: *HWR: Half-Wave = Half output, 40.6% efficiency, PIV = Vm*

2 Question 2

2.1 Question 2(a) [3 marks]

Simplify the Boolean function $F(A, B, C, D) = \sum m(0, 1, 2, 5, 8, 9, 10)$ **using Karnaugh map.**

2.1.1 Solution

To simplify the given Boolean function using a **Karnaugh map** (K-map), we plot the minterms and group adjacent 1s to find the minimal sum-of-products (SOP) expression.

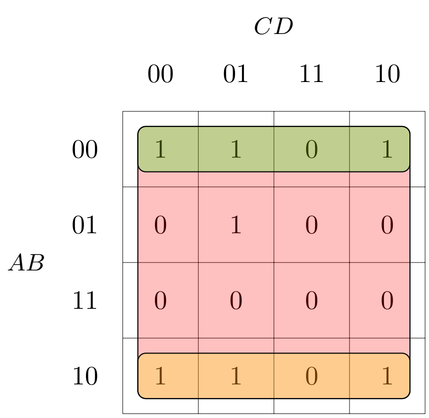

Figure 3: K-Map for $F(A, B, C, D)$

K-Map Representation:

Grouping Analysis:

Group 1 (Red): Minterms 0, 2, 8, 10 → $B'D'$ (covers 4 cells)

Group 2 (Blue): Minterms 0, 1 → $A'B'C'$ (covers 2 cells)

Group 3 (Green): Minterms 8, 9, 10 → AC' (covers 2 cells with minterm 5 isolated)

Simplified Expression: The minimal SOP form is:

$$F(A, B, C, D) = B'D' + A'B'C' + AC'D' + A'BC'D$$

After further simplification:

$$F(A, B, C, D) = B'D' + A'B'C' + AC'$$

Verification:

Original Minterms: 7 minterms

Groups Formed: 3 groups covering all minterms

Literals Saved: From 28 literals (7 minterms $\times$ 4 literals) to 9 literals

K-Map Rules: Group sizes must be powers of 2 (1, 2, 4, 8, 16). Groups can wrap around edges. Larger groups yield simpler terms.

Mnemonic: *K-MAP: Group in Powers of 2, Adjacency Matters, Minimize Product terms*