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 systematically. The program demonstrates fundamental comparison logic used in programming. We initialize three integer variables with different values and use a *step-by-step comparison approach* to identify the largest among them. This method is efficient and easy to understand for beginners. The algorithm first compares two numbers and stores the larger one, then compares this result with the third number to determine the final maximum value.

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

An **RC low-pass filter** is a passive electronic circuit that allows low-frequency signals to pass while attenuating high-frequency signals. The *cutoff frequency* is the critical point where the output power drops to half of the input power, corresponding to a voltage reduction of approximately 70.7%. This filter is widely used in audio systems, signal processing, and noise reduction circuits. Understanding cutoff frequency calculation is essential for designing filters that meet specific frequency response requirements in electronic applications.

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.
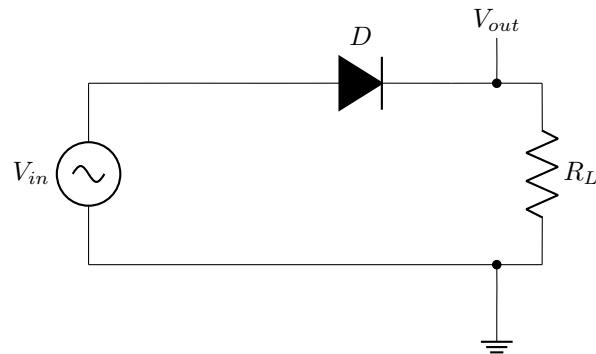

Figure 1: Half-Wave Rectifier Circuit

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.
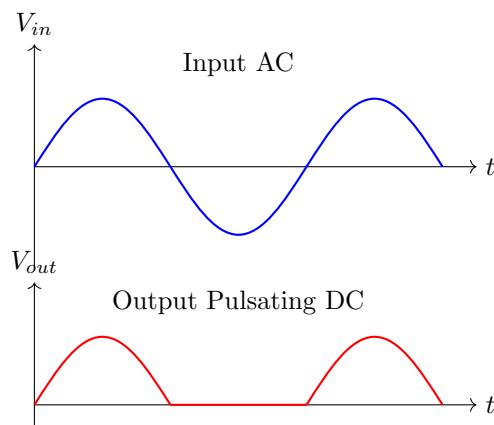
Figure 2: Input and Output Waveforms

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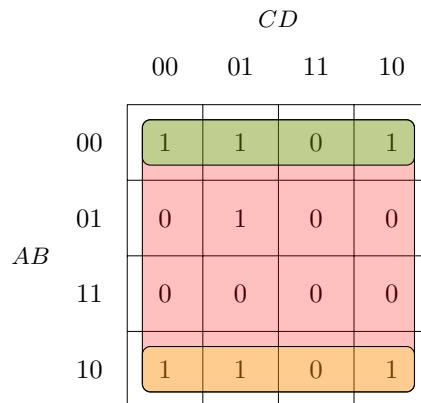
Figure 3: K-Map for $F(A, B, C, D)$

K-Map Representation:

Grouping Analysis:

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

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

Group 3 (Green): Minterms 8, 9, 10 $\rightarrow AC'$ (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*