AEC LAB REPORT-1

BY- Chanda Akshay Kumar

ROLL NO2024102014

TEAM MEMBER- S V Santhosh

ROLL NO-2024102054

Lab-1 RC Circuits and diode characterization

Materials required:

1. Lab Notebook
2. USB Drive/Camera
3. Calculator
4. Digital Multimeter
5. Breadboard
6. Connecting Wires
7. Oscilloscope (Keysight EDUX1052G DSO)
8. Function Generator
9. Resistors (R = 1 MOhm, R1 = 100 KOhm)
10. Capacitors (C = 10 pF, C1 = 1 uF, C2 = 1 uF)
11. Diodes
12. Power Supply
13. Probes (1x, 10x)
14. Load Resistor (RV)

1. Know Your Equipment

a) Familiarizing with Equipment

- Breadboard
- Power Supply

- Multimeter

b) Oscilloscope and Function Generator Specifications

1. **Oscilloscope Probe Specifications**
    - **10:1 Mode:**
        - Bandwidth: 75 MHz
        - Impedance: 10 MΩ,15pF
    - **1:1 Mode:**
        - Bandwidth: 6 MHz
        - Impedance: 1 MΩ,100pF

2. **Observation of Demo Signal**
    - **Signal Type:** Square Wave
    - **Amplitude (Peak-to-Peak):** 1 V
    - **Frequency:** 1000 Hz

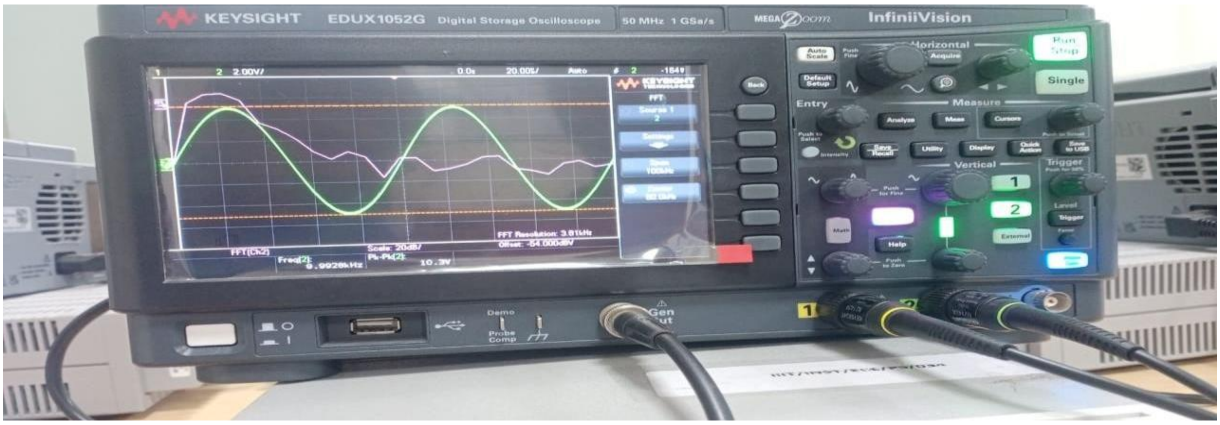
3. Generating and Observing Sinusoidal Wave , Probe-factor , Oscilloscope-factor

Signal Type	Amplitude (Vin)	Frequency	Probe Factor	Oscilloscope Factor	Measured V(OSC) (mV)	Calculated V(OSC)
Sinusoidal	5 V	25 kHz	1	1	5.19 V	5 V
Sinusoidal	5 V	25 kHz	1	10	51.9 V	50 V
Sinusoidal	5 V	25 kHz	10	1	550 mV	500 mV
Sinusoidal	5 V	25 kHz	10	10	5.5 V	5 V

4. Frequency Spectrum Using FFT

1. **Sine Wave**
   - **Frequency:** 10 kHz
   - **Span:** 100 kHz
   - **Centre Frequency:** 50 kHz
   - **Harmonics:**

        - First Harmonic (x1): 11.2 kHz
        - Second Harmonic (x2): 22 kHz -----

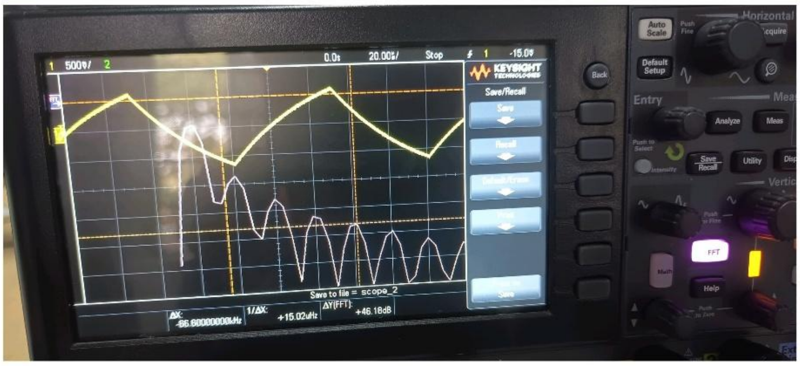


2. **Square Wave**
    - **Frequency:** 10 kHz
    - **Span:** 100 kHz
  - **Centre Frequency:** 50 kHz
  - **Harmonics:**
      - First Harmonic (x1): 10 kHz
      - Second Harmonic (x3): 30.2 kHz
      - Third Harmonic (x5): 50 kHz
      - Fourth Harmonic (x7): 70 kHz
      - Fifth Harmonic (x9): 90 kHz

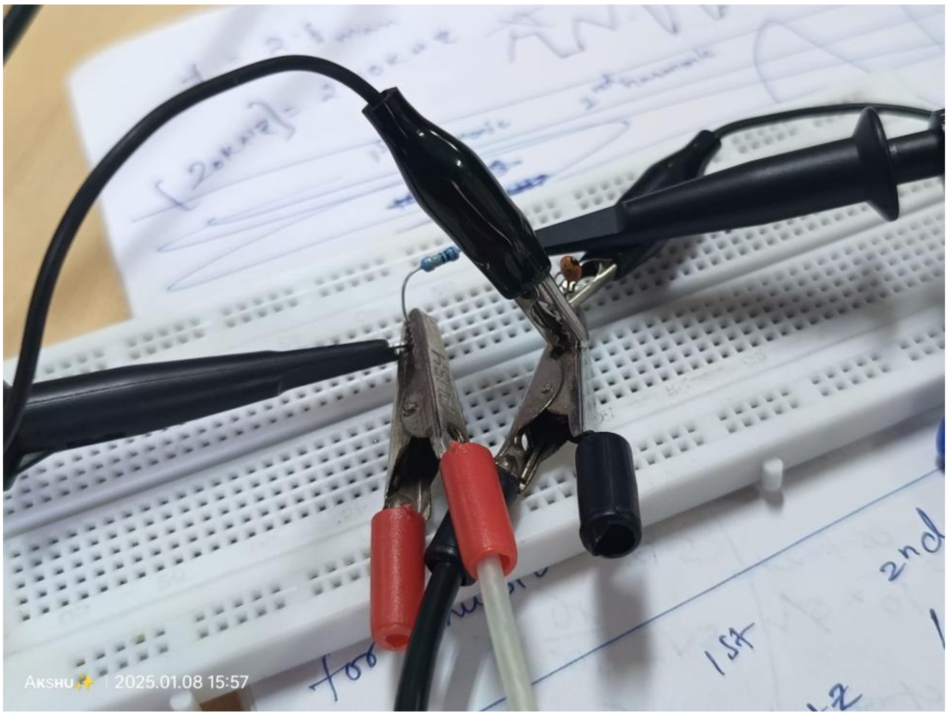
Observations

- Sine waves produce harmonics at frequencies f,2f,3f, while square waves generate harmonics at f,3f,5f,7f,....
- The **cutoff frequency** for filtering high frequencies is calculated as: $f_c=1/(2\pi RC)$
- Frequencies above the cutoff are attenuated.

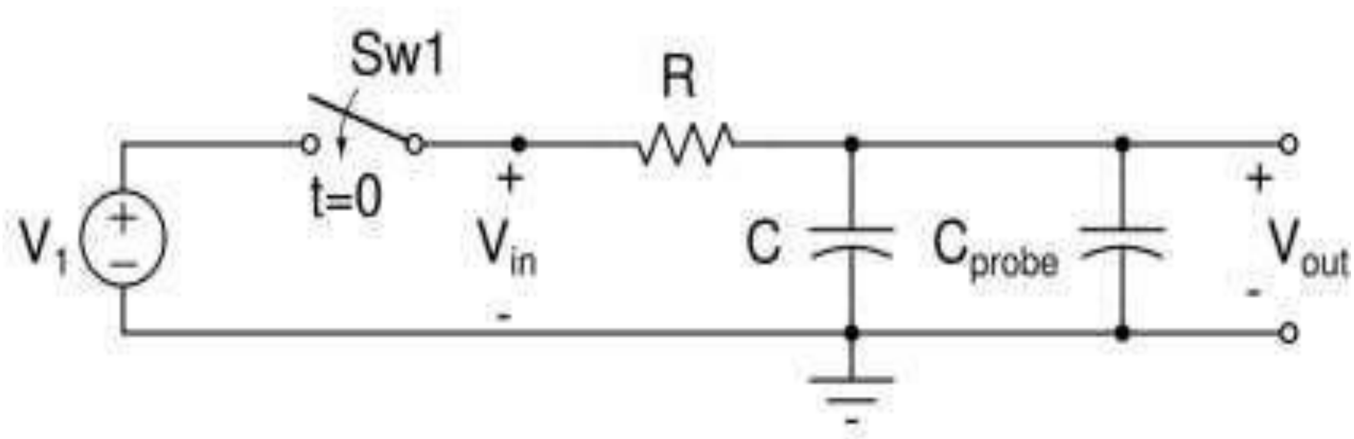
Harmonic	Without Filter (dB)	With Filter (dB)
First	6.70	-10
Second	-2.5	-28
Third	-7	-35.99
Fourth	-10.29	-42.9
Fifth	-12.5	-46.1



The low-pass filter with R=1 MΩ and C=10 pF has a calculated cutoff frequency of fc=15.9 kHz fc=15.9kHz, but the presence of probe capacitance lowers this fc, resulting in increased attenuation of higher harmonics. This effect is observed as a reduction in the amplitude of the harmonic peaks (measured in dB) in the frequency spectrum after the filter. The attenuation confirms that while the fundamental frequency remains relatively unaffected, higher harmonics are strongly suppressed, illustrating the practical impact of parasitic capacitances in real-world filtering.



2. Estimate the effective probe-capacitance



Procedure

1. **Circuit Setup**
   - Components: Resistor R=1 MΩ, Capacitor C=10 pF.
   - Equipment: Digital Storage Oscilloscope (DSO) in 10x mode.
2. **Experimental Steps**
   - Apply a square wave input signal to the RC circuit.
   - Monitor the input (Vin) and output (Vout) voltages using two DSO channels.
   - Record the time constant (τ) of the circuit by measuring the time for Vout to rise to 63.2% of Vin.
3. **Time Constant Calculation**
   - **Theoretical Time Constant:**
     τ(theo)=R·C.
   - **Measured Time Constant:**
     τ(meas) obtained from the DSO.

4. Probe Capacitance Estimation

- If τ(meas)>τ(theo), additional capacitances (e.g., probe, wire, breadboard) are present.
- Estimate the effective probe capacitance (Cprobe): Cprobe=(τ(meas)−τ(theo))/R

5. Data Table

Cload (pF)	Probe Factor	Calculated Time Constant (µs)	Measured Time Constant (µs)	Estimated Cprobe(pF)
10	1x	10	50.2	40
10	10x	10	24.2	14.2
27	1x	27	62.0	35
27	10x	27	46.0	19

Observations

- Measured time constants were consistently longer than theoretical values across all cases.
- Higher Cload and probe factors resulted in increased effective probe capacitance.

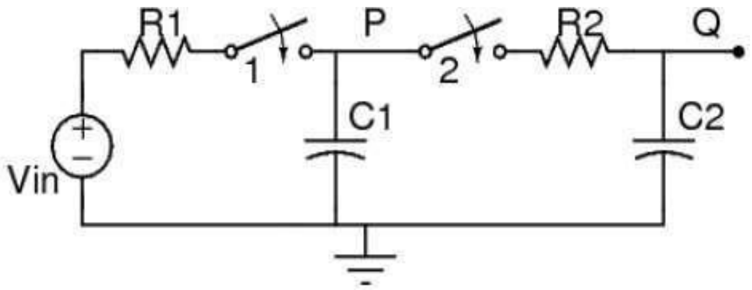
Conclusion

- The presence of additional capacitances (probe, wires, and breadboard) in the circuit was evident, as shown by the measured τ.
- Effective probe capacitance increased with Cload and probe factor.

- The calculated probe capacitance aligns with expectations, verifying the experimental procedure.

3. Two Capacitor Experiment:

In this experiment we will be observing the switching behaviour (charging and dis-charging) of the two capacitor network



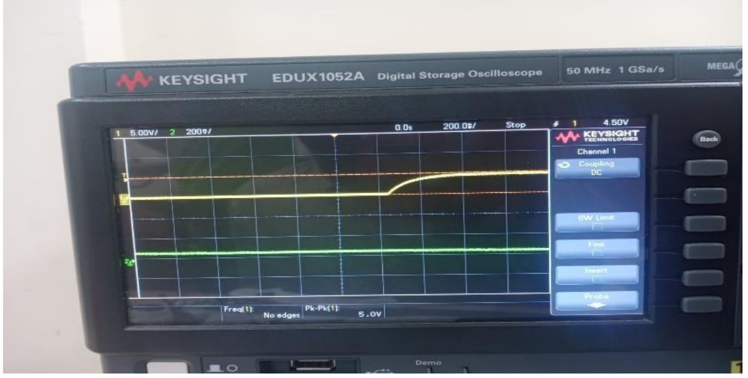
Connect the circuit a shown above.

1. **Charging Phase:**

- Close S1 and keep S2 open.
- Allow C1 to charge to 1 V.
- Measure the voltage at node P using the oscilloscope.
- Record VP (initial), VP (final), and the time taken to reach steady state in **Table 1**.

2. **Discharging Phase:**

- Open S1 and close S2.
- Observe the voltage across nodes P and Q using the oscilloscope.
- Record VP, VQ (initial and final), and the time taken to reach steady state in **Table 2**.



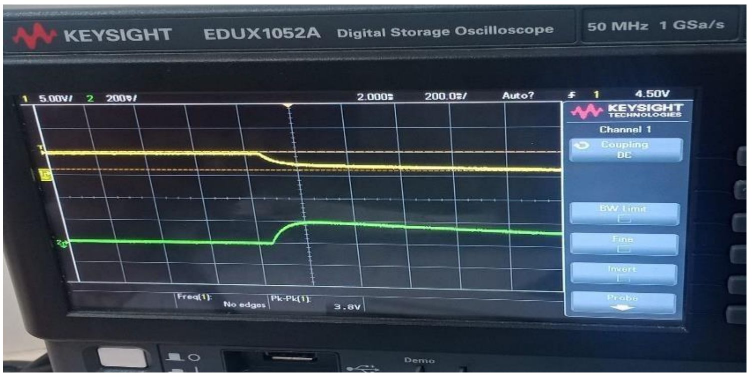


Table 1: Charging Phase (C1)

Resistance (R1)	Capacitance (C1)	VP (initial)	VP (final)	Time Taken (ms)
100 kΩ	1 µF	0 V	1 V	580.6 ms

Table 2: Discharging Phase (C2)

Resistance (R2)	Capacitance (C2)	VP (initial)	VP (final)	VQ (initial)	VQ (final)	Time Taken(ms)
100 kΩ	1 µF	1 V	0.5 V	0 V	0.5 V	224.6 ms

Explanation:

1. Charging Behavior:

- The time taken to charge C1 to steady state is proportional to the time constant $\tau = R1C1$.

2. Discharging Behavior:

- The voltage at Q reflects the transfer of charge between C1 and C2.

3. Intuitive Explanation:

- Voltage stabilization at Q to 0.5 V confirms charge redistribution between C1 and C2.

Conclusion

- The experiment demonstrated the time-dependent charging and discharging behavior of capacitors in a two-capacitor network. The observed results validate the relationship between resistance, capacitance, and the time constant.

4. Diode Characteristics

To study the I-V characteristics of a diode in forward and reverse bias configurations and determine the diode's cut-in voltage.

1. **Setup:**
    - Connect the diode in forward bias as shown in **Figure 3**.
    - Apply a sinusoidal input signal (Vin) with an amplitude of 1V.

2. **Observations:**
    - Observe the output signal (Vout) using the oscilloscope.
    - Record the behavior of the waveform.
3. **I-V Characteristics:**
    - Use the oscilloscope in **X-Y mode** to plot Vout (proportional to ID) vs. Vin.
    - Determine the **cut-in voltage** from the I-V plot using the cursor option.
    - Calculate the current (ID) at the cut-in voltage: ID=Vout/R

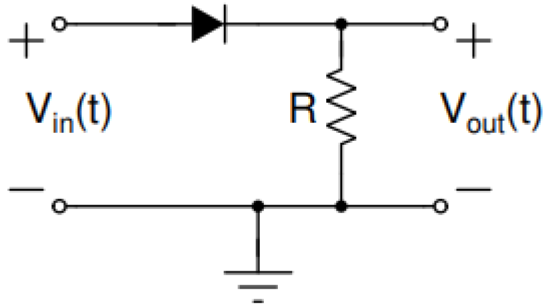
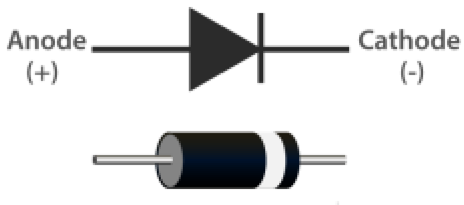


Figure 3: Forward Biased



Reverse Bias Configuration

1. **Setup:**
    - Connect the diode in reverse bias as shown in **Figure 4**.

- Apply the same sinusoidal input signal (Vin).

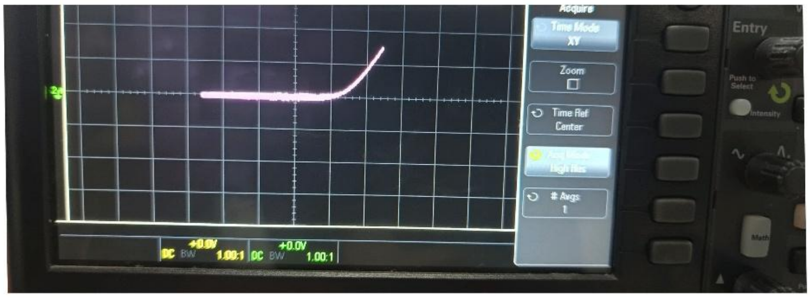
2. **Observations:**
   - Observe the output signal (Vout) using the oscilloscope.
   - Note any clipping, saturation, or significant changes in the waveform.
3. **I-V Characteristics:**
   - Plot Vout vs. Vin using X-Y mode on the oscilloscope.
   - Analyze the I-V characteristics in reverse bias and note the breakdown voltage if observable.

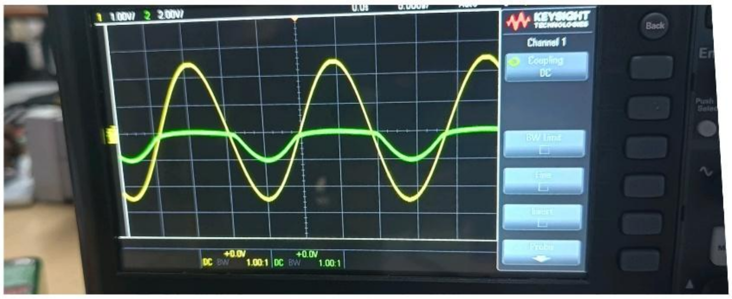
Forward Bias Observations

Parameter	Value
Input Signal (Vin)	Sinusoidal, Amplitude = 1Vpp
Output Signal (Vout)	0.17 Vpp
Cut-in Voltage (Vcut-in)	0.33 Vpp
Current at Cut-in Voltage (ID)	ID = Vout / R = 3.3 micro A(uA)

Reverse Bias Observations

Parameter	Value
Input Signal (Vin)	Sinusoidal, Amplitude = 1Vpp
Output Signal (Vout)	negligible current/voltage





1. **Forward Bias:**
   - The diode conducts when the input voltage exceeds the cut-in voltage (Vcut-in).
   - The output signal shows clipping at low input voltages, indicating the diode's threshold behavior.
2. **Reverse Bias:**
   - Negligible current flows until the breakdown voltage (if observable).

    - The output signal remains flat for most of the reverse-biased region.
3. **Comparison:**
    - Forward bias demonstrates exponential growth in current beyond Vcut-in.
    - Reverse bias highlights the diode's blocking behavior, with a small leakage current.

Conclusion

- The diode's forward and reverse bias behavior conforms to its I-V characteristics.
- The cut-in voltage was determined as ~ *(Insert cut-in voltage value)*.
- Reverse bias characteristics show minimal current flow until breakdown conditions.

08-01-25

Probe: 75MHz 10:1 1:1 6MHz

$10M\Omega \parallel 15pF$ $1M\Omega \parallel 100pF$

10:1 300 V_{rms}

1:1 150 V_{rms}.

1) Demo signal.

$T = 40\,\mu s$

$V_{pp} = 5V$

$V_{amplitude} = 2.5V$

square wave.

1X probe

$\cancel{5}V = \frac{osc\text{-}factor}{1} \times \cancel{5}V$

Osc-factor = 1

5.19V

(2) $T = 40\,\mu s$.

$V_{pp} = 500\,mV$

$V_{amp} = 250\,mV$

Sq. wave

10 X probe

$\cancel{500} \times \cancel{10}V = \frac{os\text{-}facto}{10} \times \cancel{5}V$

os-factor = 1

550mV

(3) $50 = \frac{10}{1} \times 5$.

51.9V

(4) 5.2V

$5V = \frac{10}{10} \times 5V$

square	5	25KHz	1 x	1	5.19V	5
"	5	"	1 x	10	51.9V	50
"	5	"	10 x	1	550mV	500mV
"	5	"	10x	10	5.5V	5V

greenprobe 10 KHz ~~[illegible]~~ ~~R~~ ~~[illegible]~~ Cprobe

Capacitance	Probe factor	Calculated τ (Time constant " RC)		Cprobe
10pF	1X	~~1×10^{-5}~~ ~~[illegible]~~	+50.2µs	$\frac{4\times10^{-5}}{10^{6}}$ = 40PF
10PF	10X	1×10^{-5}	~~60.2µs~~ 24.2µs ~~50.2µs~~	~~[illegible]~~ 14.2PF
27PF	1X	~~[illegible]~~ $27\times10^{-12}\times1\times10^{6}$ 27×10^{-6} s	62.0µs	~~[illegible]~~ 35PF
27PF	10X	27×10^{-6} s	46.0µs	19PF

Span 200KHZ
center 50.0KHZ

1^{st} harmonic ~~[illegible]~~ ~~[illegible]~~ +11.2KHZ

2^{nd} Harmonic 66KHZ

for Sinusoid

For squarewave

y in dBV
x in KHZ

	1st	2nd	3rd	4th	5th
without Filter	6.70/10KHZ	-2.5/30KHZ	-7.00/50 KHZ	-10.29/70KHZ	-12.5/90KHZ
with filter	-10dBV/10KHZ	-28/30KHZ	-35.99/50KHZ	-42.9/70KHZ	-46.1/90KHZ

Band width of Low-pass filter is lesser than the (1st peak) fundamental frequency of signal

$R = 1\,M\Omega$, $C = 10pF$ $f_c = 1.59\,KHZ = \frac{1}{2\pi RC}$

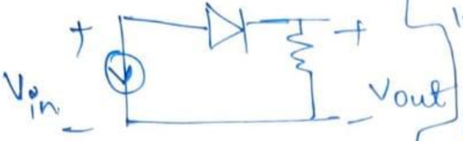
$f_{fundamental} = 10\,KHZ$ (Amplitude) [So, there decrease in strength of signal]

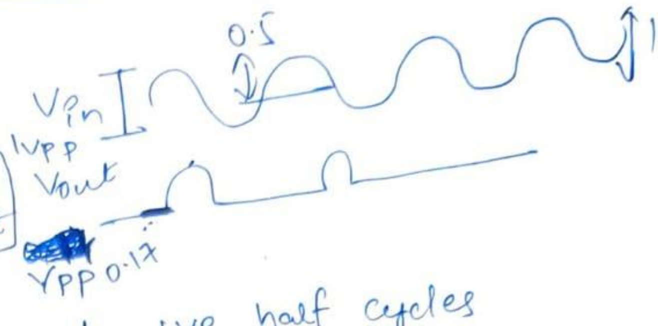
So, $f_c < f_{fundamental}$

f_c will be more Lesser bcz Probe cap's also added.

4

(a)



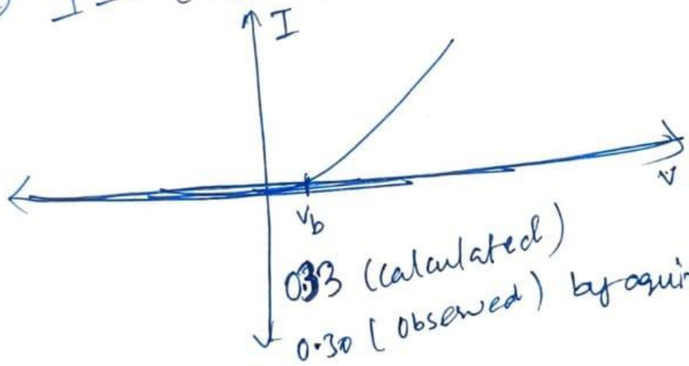


1)

1. The diode allowing only +ve half cycles
2. The diode blocks -ve half cycles
3. A small voltage drop (0.8mv) can be noticed due to diode in forward bias

Hence, Amplitude of +ve half-cycle reduced and -ve rests at zero.

2) I-V (aquire)



0.33 (calculated)

0.30 (observed) by aquire graph

(3) Cut-in vol:

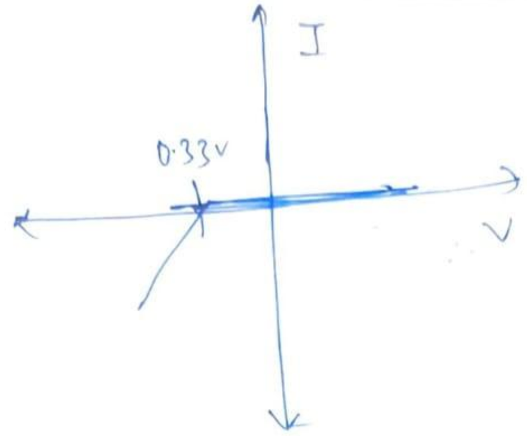
(4) $\frac{0.33}{100 \times 10^3} = 3.3 \times 10^{-6} A = 3.3 \mu A$

(5) (i) allows only -ve half cycles

(ii) the diode blocks +ve half cycles in Reverse bias

(iii) Voltage drop for -ve half cycle

(6)



(7)(i) minimal current flow in reverse bias

(ii) forward bias allows current when

$V_{in} > V_{breakdown}$

(iii) Voltage of V_b is there in +ve half cycles of Sinusoid in forward bias as well as voltage drop in -ve half cycles in reverse bias.

(3) Two-capacitor.

→ open S-2 close S-1

R	Capacitance(c_1)	$V_{P(i)}$	$V_{P(f)}$	Time taken
R_1 100KΩ	1μF	0	1	580.6ms

→ Open S-1 close S-2

R2	(cap) C_2	$V_{P(i)}$	$V_{P(f)}$	$V_{Q(i)}$	$V_{Q(f)}$	Time taken
100KΩ	1μF	1V	0.5V	0V	0.5	224.6 ms

Sooner both discharges.