BRAC UNIVERSITY
Inspiring Excellence

BRAC UNIVERSITY
Dept. of Computer Science and Engineering

CSE250L
Circuits and Electronics Laboratory

Student ID:	22301184	**Lab Section:**	28
Name:	Pritom Mondal	**Lab Group:**	03

Experiment No. 4

Study of I-V Characteristics of Linear Circuits

Objective

The aim of this experiment is to acquaint students with the concept of I-V characteristics. They will find I-V characteristics of some linear components and some circuits consisting linear combinations of them.

Part 1: By Using Multimeter

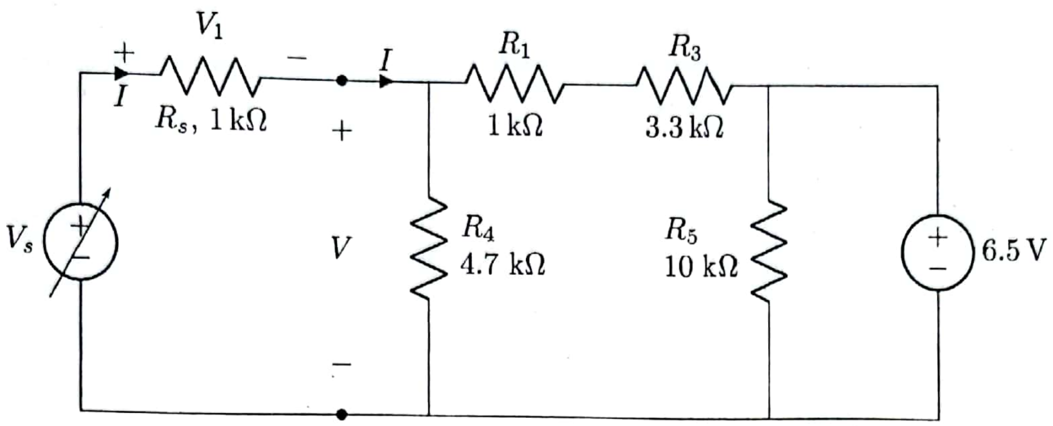
Theory

I-V characteristics, also known as current-voltage characteristics, describe the relationship between the current flowing through a device/circuitry and the corresponding potential difference (voltage) across it. This concept is commonly used in the field of electronics and electrical engineering to analyze the behavior of various components such as resistors, diodes, transistors, and in general, circuits.

I-V characteristics provide a way to understand how current and voltage interact in electrical and electronic components and circuits. By analyzing these characteristics, circuits/devices can be designed and optimized, appropriate components can be selected, and the behavior of devices under different operating conditions can be predicted.

In hardware labs, studying the I-V characteristics of an element/circuitry can be done in some simple steps. After building the circuit using hardware tools (such as Breadboards, Power Supply), a multimeter or other measuring instruments can be used to measure the voltage and current at specified terminals in the circuit. The multimeter probes can be placed across the component or along the desired path (specified by the terminals) to measure the voltage difference and current flow. To determine the I-V characteristics, the voltage or current across the circuit or specific components must be varied. This can be done by adjusting the power supply voltage, using variable resistors, or changing the values of other circuit parameters. As the voltage or current is varied and the corresponding values are measured, the data can be recorded in a table. The voltage and current values for each point of interest in the circuit should be noted.

Once we have the values of currents and voltages at various points in the circuit, the I-V characteristics can be plotted. Typically, this involves creating a graph with current (I) on the y-axis and voltage (V) on the x-axis.



Circuit 3

- For each of these circuits, apply the specified supply voltages (from the first column of their respective data tables) using the DC power supply.
- Measure the voltage, V_1 across the 1 kΩ resistor using the multimeter and use Ohm's law to calculate the current I through the two terminals (denoted by • in the circuits).
- Measure the voltage, V across the two terminals (denoted by • in the circuits) using the multimeter, and fill up the data tables.

Data Tables

Signature of Lab Faculty: [illegible] **Date:** 14.10.23

** ***<u>For all the data tables, take data up to three decimal places, round to two, then enter into the table.</u>***

Table 1: Resistance Data

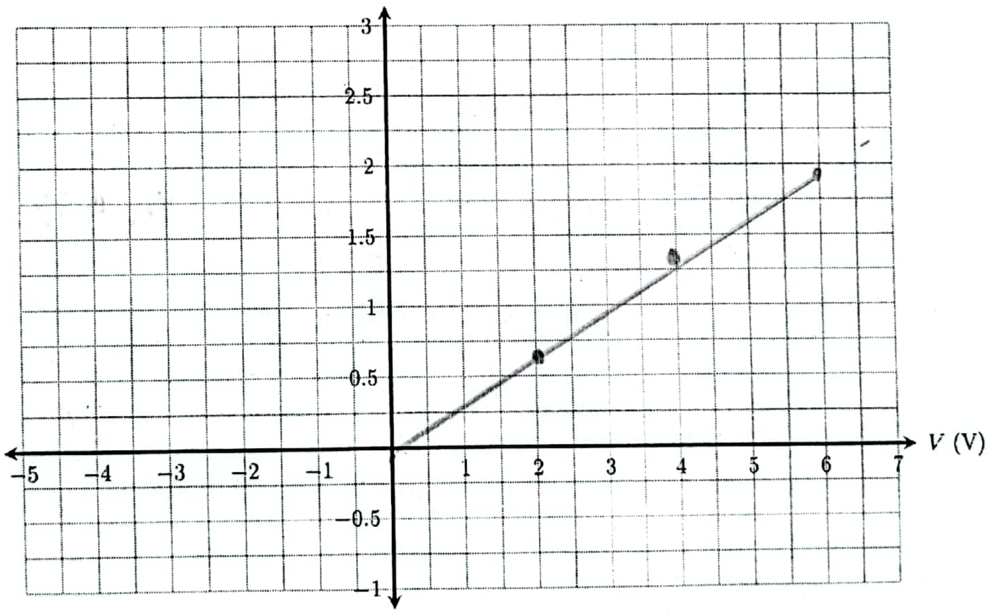
For all your future calculations, please use the observed values only **(even for theoretical calculations)**.

Notation	Expected Resistance	Observed Resistance (kΩ)	Notation	Expected Resistance	Observed Resistance (kΩ)
R_s	1 kΩ	0.988	R_3	3.3 kΩ	3.25
R_1	1 kΩ	0.987	R_4	4.7 kΩ	4.61
R_2	2.2 kΩ	2.168	R_5	10 kΩ	9.87

Table 2: Data from Circuit 1

V_S (V)			V_1 (V)		V (V)		$I = \frac{V_1}{R_s}$ (mA)	
Expected Voltage	From DC power supply	Using multi-meter	Experi-mental	Theo-retical	Experi-mental	Theo-retical	Experi-mental	Theo-retical
0.0	0.0	$-3'5\times10^{-3}$	-1'1mV	0	-2'5mV	0	$-1'11\times10^{-3}$	0
2.0	2.0	2'042	'639	0.6	1'40	1.2	0'69	0.6
4.0	4.0	4'09	1'27	1.2	2'796	2.4	1'28	1.2
6.0	6.0	6'03	1'879	1.8	4'14	3.6	1'902	1.8
8.0	8.0	8'09	2'521	2.4	5'56	4.8	2'552	2.4

Plot the values of I and V from the above table.



Draw the best-fitting straight line through all the data points.

Slope of the straight line, m = 0. 449 $k\Omega^{-1}$

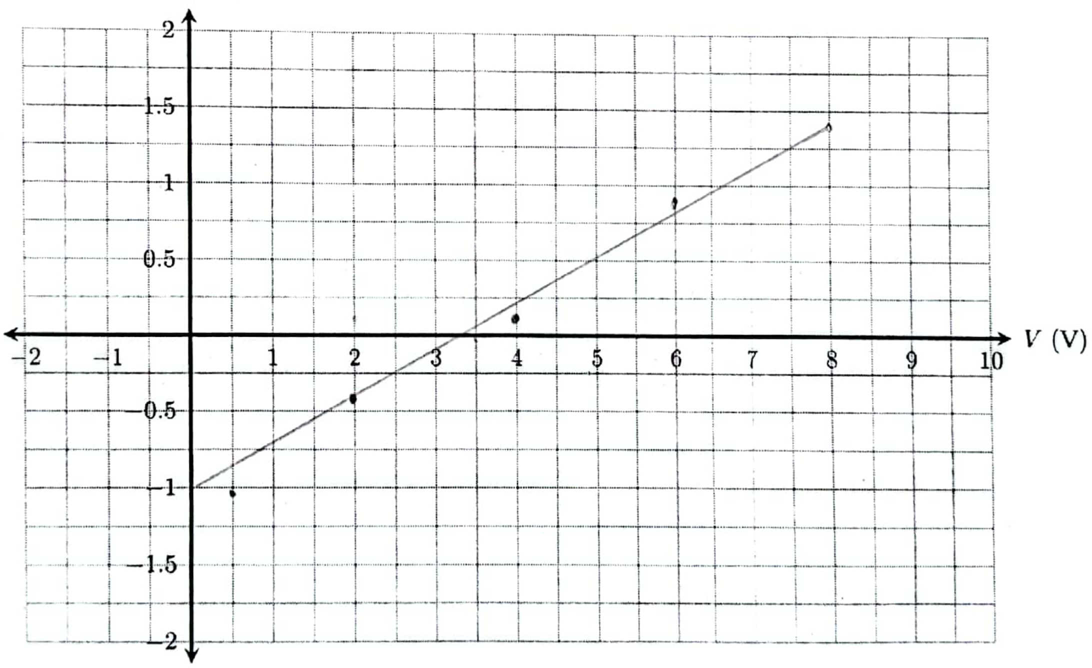
Resistance from the plot, $R_T = \frac{1}{m}$ = 2.225 $k\Omega$

Percentage of Error $= \left|\frac{R_2 - R_T}{R_2}\right| \times 100\%$ = 1. 14 %

Table 3: Data from Circuit 2

V_S (V)			V_1 (V)		V (V)		$I = \frac{V_1}{R_s}$ (mA)	
Expected Voltage	From DC power supply	Using multi-meter	Experi-mental	Theo-retical	Experi-mental	Theo-retical	Experi-mental	Theo-retical
0.0	0	0.0004	-1.09	-1.02	1.639	1.02	-1.053	-1.01
2.0	2.0	2.045	-.416	-0.42	2.462	2.42	-0.421	-0.42
4.0	4.0	4.04	0.193	0.18	3.827	3.82	0.195	0.18
6.0	6.0	6.11	0.837	0.78	5.26	5.22	0.847	0.77
8.0	8.0	8.09	1.453	1.38	6.63	6.62	1.47	1.37

Plot the values of I and V from the above table.



Draw the best-fitting straight line through all the data points.

Slope of the straight line, m = 0.213 $k\Omega^{-1}$

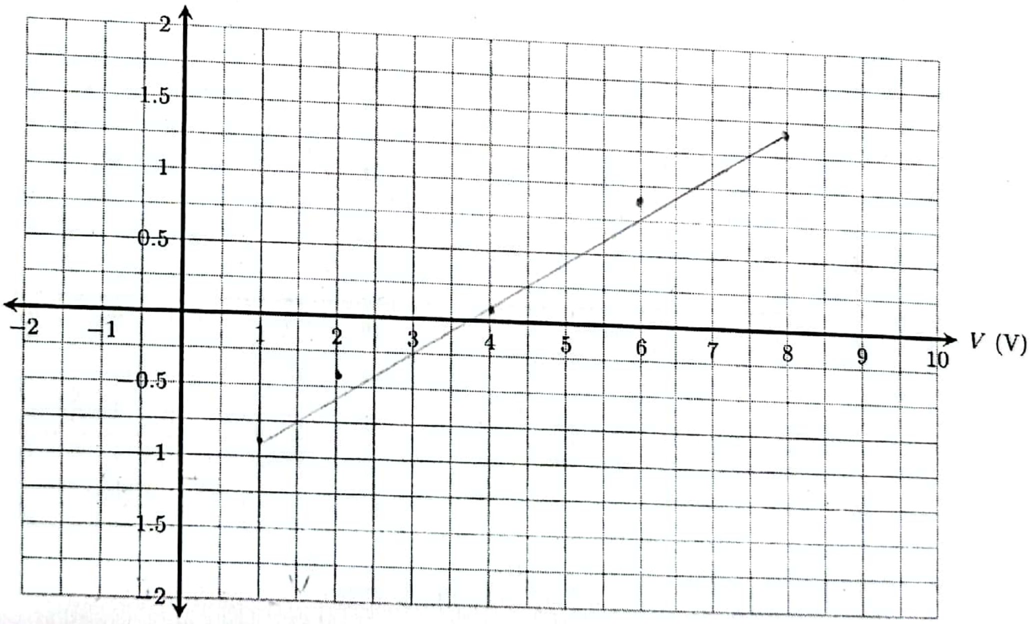
Resistance from the plot, $R_T = \frac{1}{m}$ = 4.69 $k\Omega$

The straight line intersects x-axis at, V_T = 3.4 V

Table 4: Data from Circuit 3

V_S (V)			V_1 (V)		V (V)		$I = \frac{V_1}{R_s}$ (mA)	
Expected Voltage	From DC power supply	Using multi-meter	Experi-mental	Theo-retical	Experi-mental	Theo-retical	Experi-mental	Theo-retical
0.0	0.07	0.773	-.806	-1.049	1.581	1.04	-.806	-1.036
2.0	2.0	2.098	-.413	-0.4298	2.46	2.42	-.413	-0.426
4.0	4.0	4.05	198.7 mV	0.168	3.87	3.81	0.198	0.184
6.0	6.0	6.0	0.799	0.80	5.19	5.1478	0.799	0.795
8.0	8.0	8.05	1.427	1.418	6.63	6.58	1.427	1.405

Plot the values of I and V from the above table.



Draw the best-fitting straight line through all the data points.

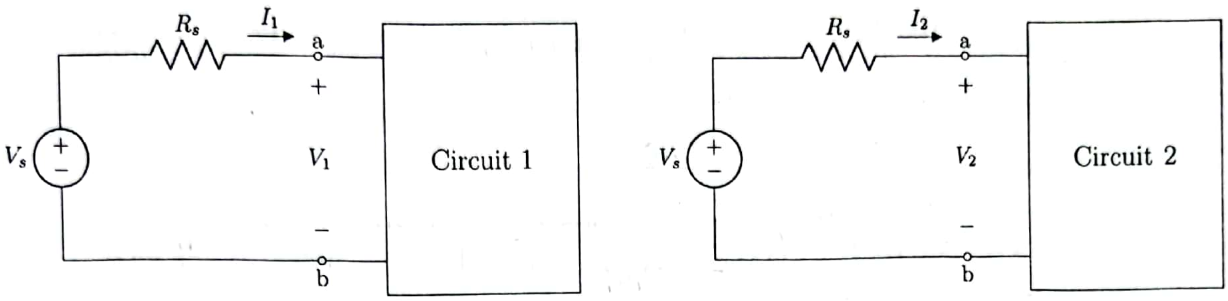
Slope of the straight line, m = 0.218 $k\Omega^{-1}$

Resistance from the plot, $R_T = \frac{1}{m}$ = 4.59 $k\Omega$

The straight line intersects x-axis at, V_T = 3.4 V

Questions

1. What conditions must exist for the following two circuits to be equivalent to each other with respect to terminals $a - b$?



The following two circuits will be equivalent to each other with respect to terminals a-b if they both have identical I-V characteristics.

2.

(a) For the **Circuit 2** you constructed in the laboratory, derive a relation between I and V.

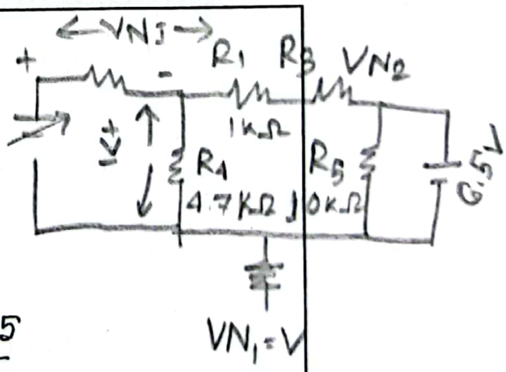
$$I = \frac{V}{R_s} = \frac{1}{R_s}(V_s - V \qquad V_1 = V_s - V$$

$$I = \frac{1}{R_s}(V_s - V) \qquad V = V_s - V_1$$

$$\therefore I \propto V$$

(b) For the **Circuit 3** you constructed in the laboratory, derive a relation between I and V.

At node-1



$$\frac{V_s - VN_1}{R_s} = \frac{VN_1}{R_4} + \frac{VN_1 - VN_2}{R_1 + R_3}$$

$$\Rightarrow \frac{V_s - V}{1} = \frac{V}{4.7} + \frac{V - 6.5}{4.3}$$

$$\Rightarrow V_s - V = \frac{4.3V + 4.7V - 30.55}{20.21}$$

$$\Rightarrow 20.21(V_s - V) = 9V - 30.55$$

$$\Rightarrow 20.21 V_s = 29.21 V - 30.55$$

$$\Rightarrow V = \frac{20.21 V_s + 30.55}{29.21}$$

$$\therefore V = 0.692\ V_s + 1.0459$$

$$I = \frac{V_1}{R_s} = \frac{1}{R_s}(V_s - V)$$

where, $V = 0.692\ V_s + 1.0459$

(c) Did you notice any similarity between the $I - V$ relationships in (a) and (b)?

☑ Yes ☐ No

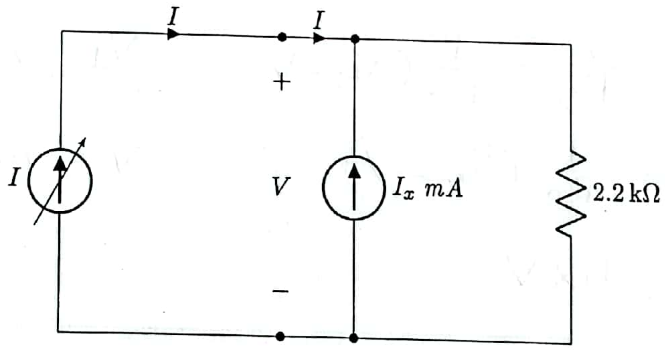
If yes, what are they?

In both circuits, current is proportionally increasing with change of voltage.

(d) Will it have any effect if one of these two circuits is replaced with the other? Why?

It won't have any effect if one of these two circuits is replaced with the other because from the graph we can see, that both have identical I-V characteristics which mean the circuits are equivalent.

(e) Now, for the following circuit, determine the value of I_x so that the $I - V$ relation matches with those you derived in (a) and (b). Is this circuit also equivalent to **Circuit 2** and **Circuit 3**?



$$I + I_x = \frac{V}{2.2}$$

$$\Rightarrow I_x = \frac{V}{2.2} - I$$

This circuit is also equivalent to circuit 2 and circuit 3 because they all have matches in I-V relation.

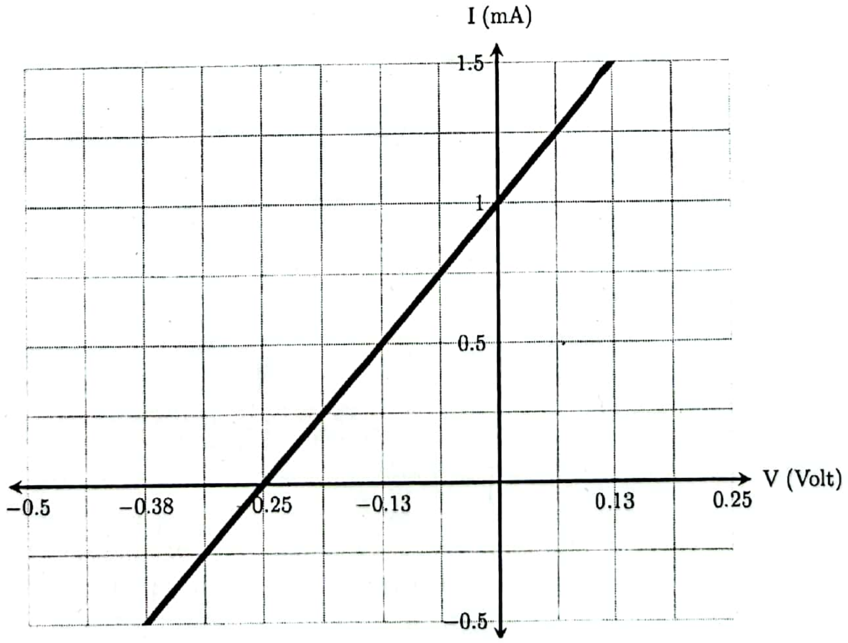
3. Can you think of any way where voltage-axis intersecting points (V_T) could be measured directly for Circuit **1** and **Circuit 2**?

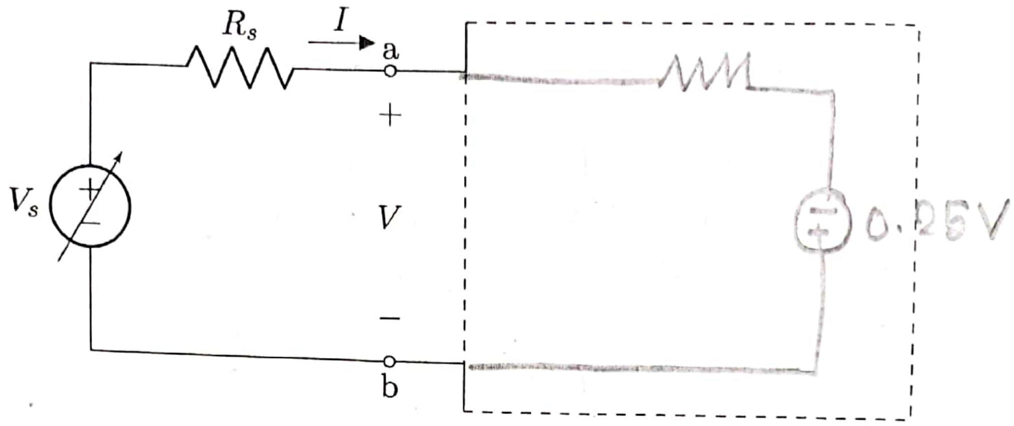
In circuit 1, there is no voltage source connected with load side(R_2). That's why the voltage axis intersection will be the origin. whereas in circuit 2, 3.4 V voltage source is connected with R_2. Hence, the voltage axis intersection will be 3.4 V.

4. In general, what is the simplest technique to derive the $I - V$ characteristics of any linear two terminal circuit? How many minimum data points are required?

In general the simplest technique to derive the I-V characteristics of any linear two terminal circuit will be determining the slope (1/R) and to do that we need at least two pairs of I-V value.

5. A linear two-terminal circuit has the following $I - V$ relationship at the terminals $a - b$ measured in a laboratory with the setup shown below. Draw (in the next page) a simplified version of the circuit that can give rise to the same $I - V$ as shown. Determine the corresponding parametric values of the circuit elements.





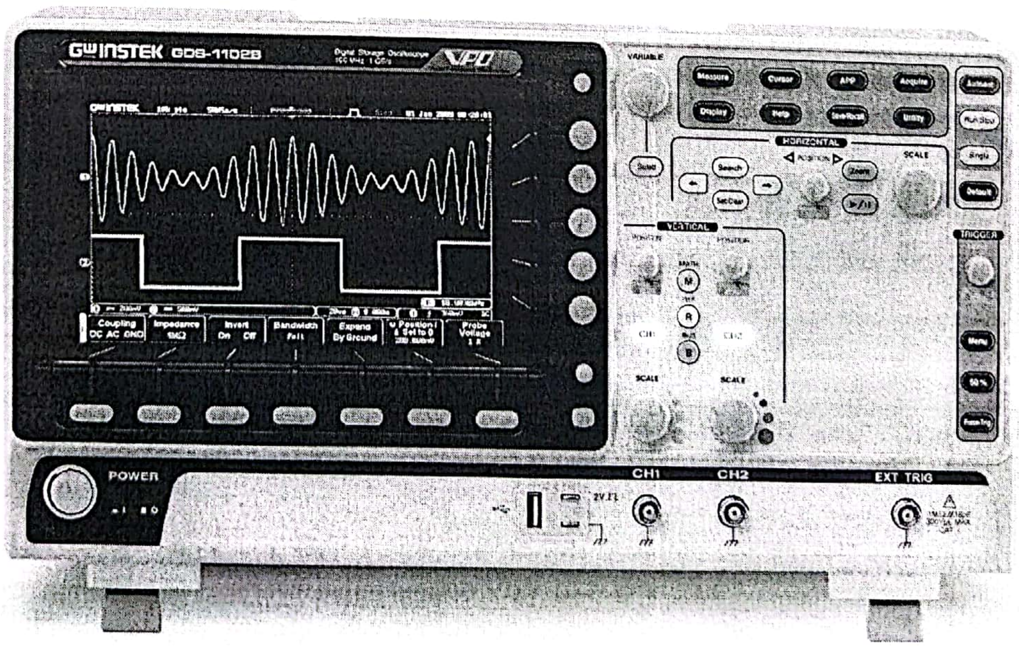
Draw inside the dashed box

Part 2: By Using Oscilloscope

Theory

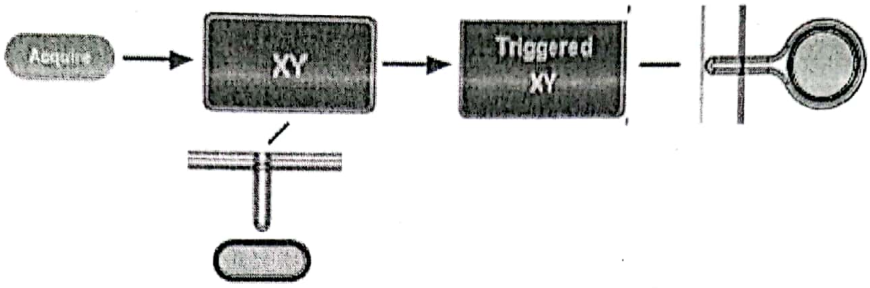
Oscilloscope

Oscilloscope is a device that can measure a sequence of voltages over time and can display that information by plotting them on a screen. In fact, oscilloscopes available at our labs are dual channel (**CH1** and **CH2**), meaning, they can simultaneously show voltage vs time graph across two separate set of nodes.

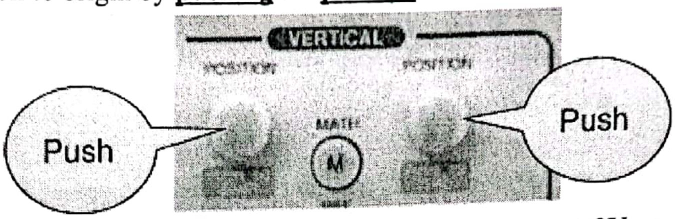


An oscilloscope

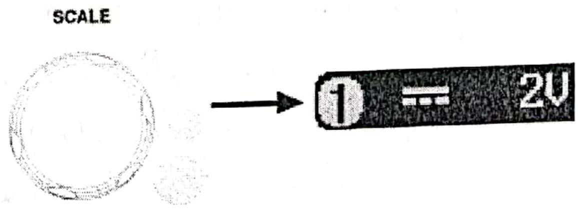
➢ Go to **XY** Mode:



➢ Set position to origin by **pushing** the **position knobs** on each channel.



➢ Turn both channel knobs so that the voltage resolutions are at **2V per division.**



Questions

6.

(a) In normal mode of operation, an oscilloscope always plots -

☑ voltage as a function of time ☐ current as a function of time

(b) In X-Y mode of operation, an oscilloscope plots Channel-1 along the -

☐ y-axis ☑ x-axis

(c) Is there any way to observe the one you haven't selected in (a)?

The oscilloscope is a high impedance voltage measuring device so it cannot measure current.

7. Put a checkmark beside the correct answers:

a. The I-V characteristics of the following circuits were **straight lines** -

☑ Circuit 4 ☑ Circuit 5 ☑ Circuit 6

b. The I-V characteristics of the following circuits went **through origin** -

☐ Circuit 4 ☑ Circuit 5 ☑ Circuit 6

c. The following circuits were **equivalent to a resistor** -

☐ Circuit 4 ☑ Circuit 5 ☑ Circuit 6

d. When the LDR was completely **in darkness**, the I-V characteristic line was -

☑ y-axis ☐ x-axis ☐ parallel to x-axis but shifted upwards

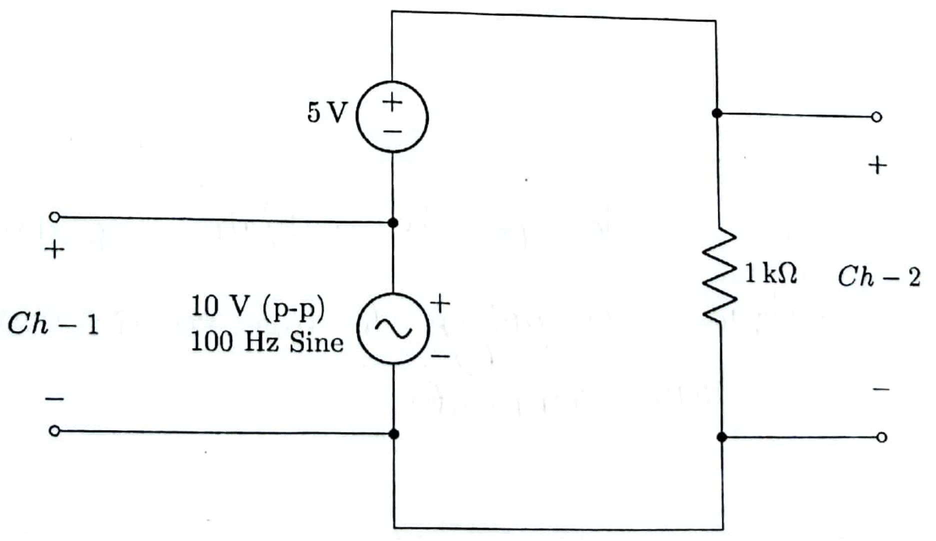
e. When the LDR was completely **in darkness**, it was equivalent to -

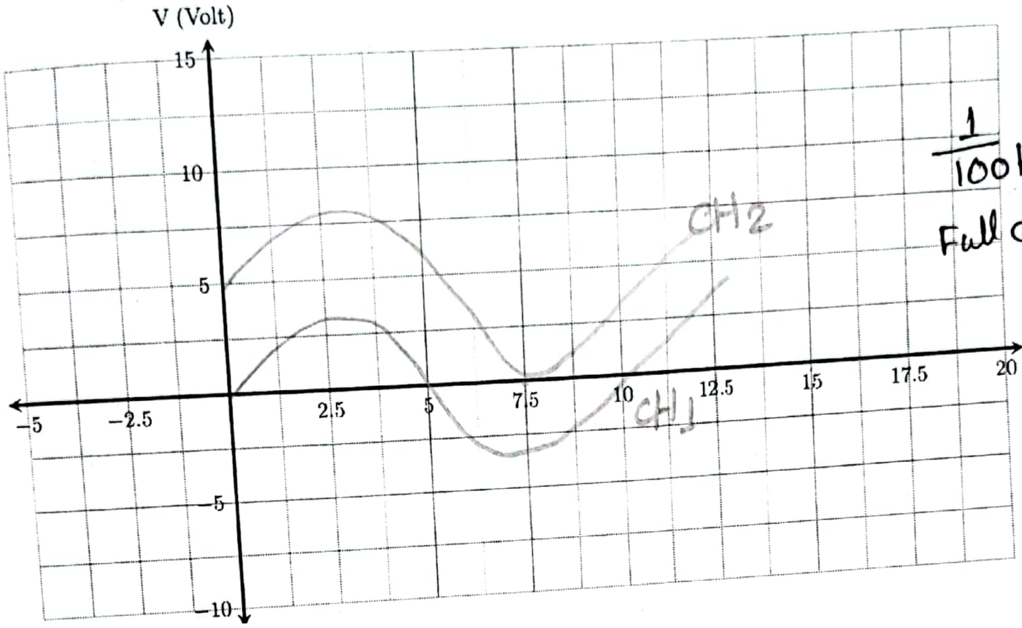
☑ short circuit ☑ open-circuit ☐ 1 kΩ resistor ☑ 0A current source

8. Why was it necessary to invert Channel-2 of the Oscilloscope in order to visualize the *I vs. V* plot of **Circuit 4, 5,** and **6**?

The 'invert' buttons are used to change the orientation of the signal voltage on a signal input connecter. Negative voltage become positive, Positive voltage become negative. To match with polarity we need to invert channel 2

9. Draw the waveforms that should be observed in Channel-1 and Channel-2 of an oscilloscope when both the channels are ON and are connected in a setup shown below. Draw both the plots in the same template given below. Mark the waveforms according to their visualizing channel.



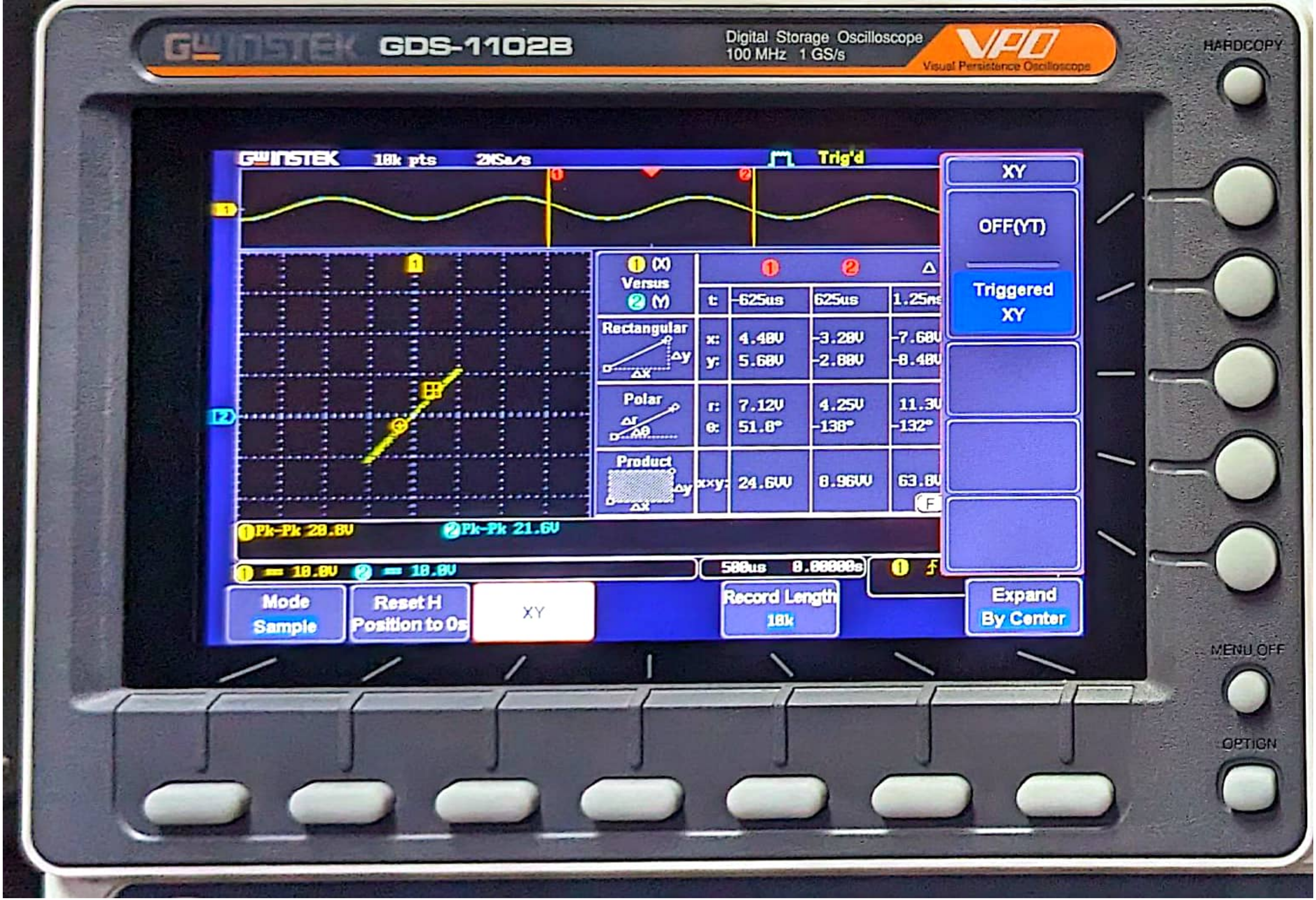


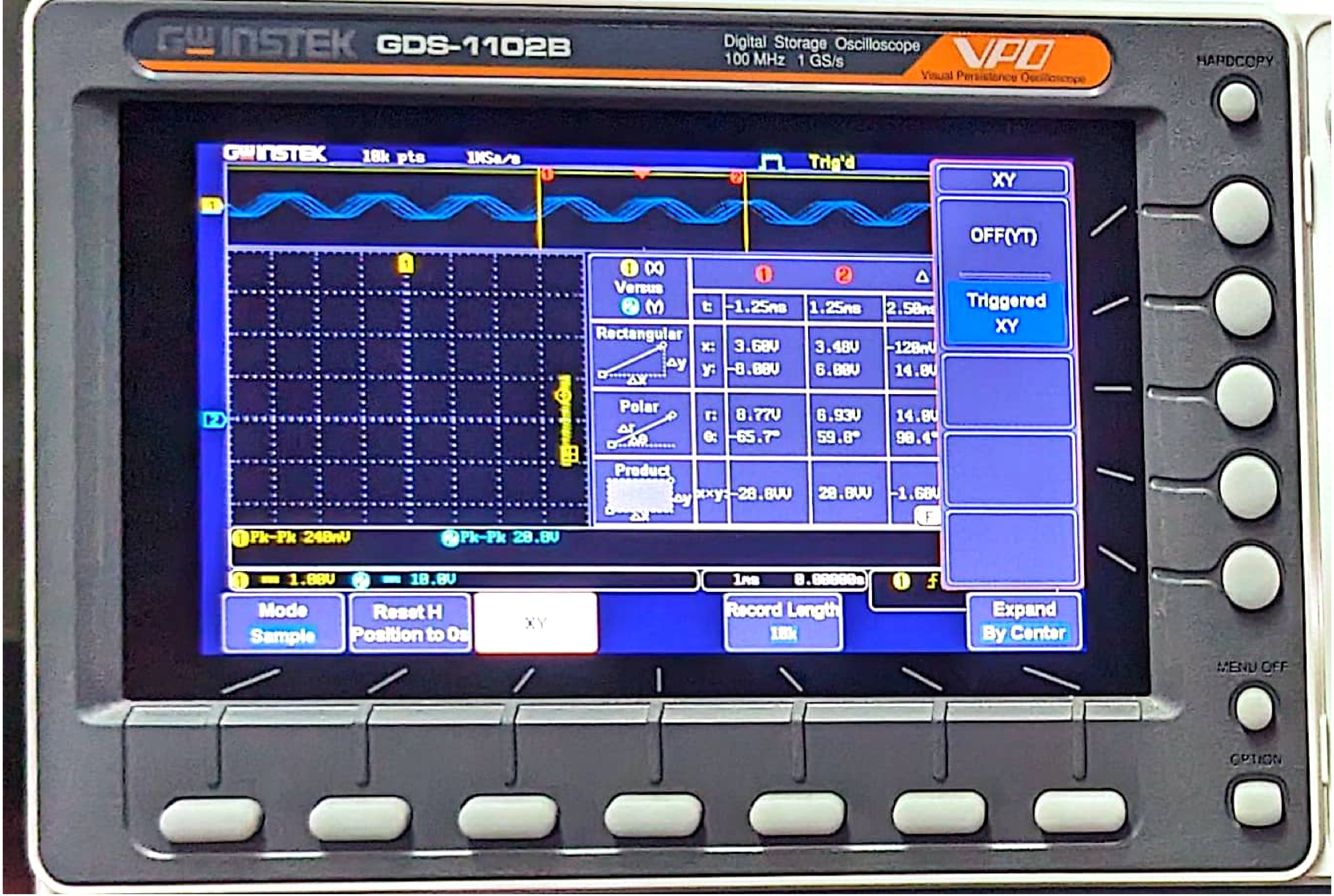
$\frac{1}{100\,Hz} = 10\,ms$

Full cyclye will be completed in 10 miliseco-nd

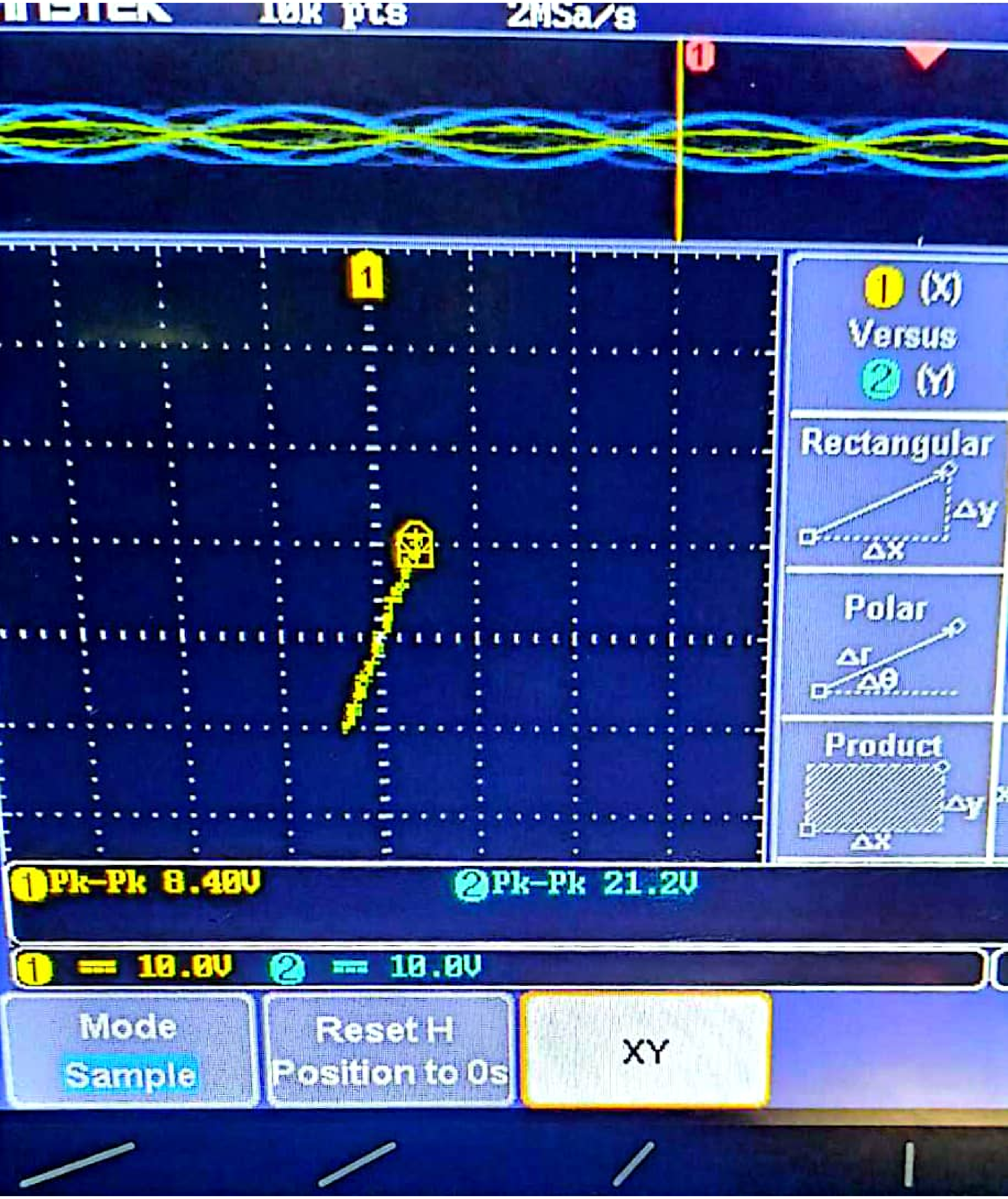
Report

1. Fill up the theoretical parts of all the data tables.
2. Answer to the questions.
3. Attach the captured images of the $I - V$ plot observed in oscilloscope for **Circuits 4, 5,** and **6**.
4. Discussion *[comment on the obtained results and discrepancies]*. Start writing from below the line.


GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
VPO
Visual Persistence Oscilloscope
HARDCOPY
10k pts
2MSa/s
Trig'd
XY
OFF(YT)
Triggered XY
1 (X) Versus 2 (Y)
Rectangular
Polar
Product
t: -625us 625us 1.25ms
x: 4.40V -3.20V -7.60V
y: 5.60V -2.80V -8.40V
r: 7.12V 4.25V 11.3V
θ: 51.8° -138° -132°
x×y: 24.6VV 8.96VV 63.8V
1 Pk-Pk 20.8V
2 Pk-Pk 21.6V
1 10.0V 2 10.0V
500us 0.00000s
Mode Sample
Reset H Position to 0s
XY
Record Length 10k
Expand By Center
MENU OFF
OPTION



GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
VPO
Visual Persistance Oscilloscope
HARDCOPY
10k pts
1MSa/s
Trig'd
XY
OFF(YT)
Triggered XY
Versus
Rectangular
Polar
Product
t: -1.25ns 1.25ns 2.50ns
x: 3.60V 3.48V -120mV
y: -8.00V 6.00V 14.0V
r: 8.77V 6.93V 14.0V
θ: -65.7° 59.8° 90.4°
xy: -28.8VV 20.8VV -1.68V
Pk-Pk 240mV
Pk-Pk 20.0V
1.00V
10.0V
1ms 0.00000s
Mode Sample
Reset H Position to 0s
XY
Record Length 10k
Expand By Center
MENU OFF
OPTION


10k pts
2MSa/s
1
1 (X)
Versus
2 (Y)
Rectangular
Δy
Δx
Polar
Δr
Δθ
Product
Δy
Δx
1 Pk-Pk 8.40V
2 Pk-Pk 21.2V
1 == 10.0V
2 == 10.0V
Mode
Sample
Reset H
Position to 0s
XY