Department of Electrical Engineering

College of Engineering and Petroleum

Kuwait University

Lab Course Number and Section: 234/04A

Lab Course Title: ELECTRONICS LAB

Experiment Title: BJT (Bipolar Junction Transistor) Characteristics

Experiment Number: 6

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Introduction

A transistor is a semiconductor device that amplifies or switches electronic signals, typically made of silicon. It has three terminals: the emitter, base, and collector. BJT, or bipolar junction transistor, uses electrons and holes to conduct current, commonly used as amplifiers or switches. BJTs are divided into two main types: NPN and PNP. NPN transistors have an emitter, base, and collector doped with different semiconductor materials, with the emitter being N-type, the base being P-type, and the collector being N-type while the PNP BJT is the opposite. The BJT is widely used for amplification, where it boosts the strength of weak electrical signals in devices like audio amplifiers. It is also utilized in switching applications, acting as a fast on-off switch in digital circuits and power control systems. Alas, it represents the foundation of modern-day electrical circuits. BJTs have many types, in this report the types: 3904, 3906, and BC107 will be discussed [1].

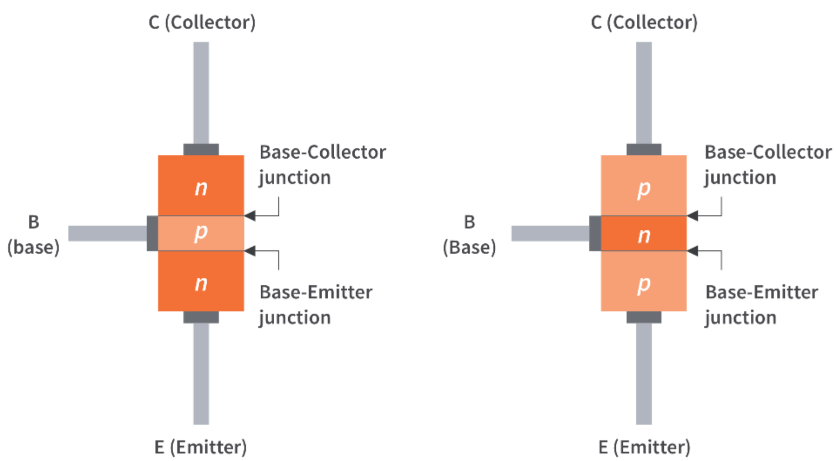

Figure 1 - Digital representation of BJT

Figure 2 - Physical representation of BJT types

The BJT can operate on 4 different modes as follows:

i. **FORWARD ACTIVE MODE:** In active mode, the BJT operates as an amplifier. The base-emitter junction is forward-biased, and the collector-base junction is reverse-biased, allowing a large current to flow from the collector to the emitter proportional to the base current.

ii. **SATURATION MODE:** In saturation mode, the BJT functions as a closed switch. Both the base-emitter and base-collector junctions are forward-biased, causing maximum current to flow from the collector to the emitter, with minimal voltage drop across the transistor.

iii. **CUT-OFF MODE:** In cut-off mode, the BJT acts as an open switch. Both the base-emitter and base-collector junctions are reverse-biased, resulting in no significant current flow through the transistor.

iv. **REVERSE ACTIVE MODE:** In reverse active mode, the roles of the collector and emitter are reversed. The base-emitter junction is reverse-biased, and the collector-base junction is forward-biased, resulting in a smaller current flow from the emitter to the collector, which is not typically used in standard applications.

Table 1 - BJT Modes

VBE	**VBC**	
	Reverse Bias	**Forward Bias**
Forward Bias	Forward Active Mode	Reverse Active Mode
Reverse Bias	Cut-Off Mode	Saturation Mode

Objectives

- Test and differentiate between BJT types: 3904, 3906, and BC107.
- Analyze the circuit behavior when a change in the DC power supply occurs.
- Analyze the BJT small-signal parameters: input resistance and output resistance

List of Equipment and components

- Oscilloscope (CRO)
- Breadboard
- Multiple resistors.
- BJT of type: 3904 (plastic), 3906 (plastic), and BC107 (metal).
- DDM
- Avometer

Experimental Method and Procedure

PART (A): Testing BJT Type (NPN or PNP)

1. Connect the (negative) lead of the Avometer with the mid lead terminals (Base 2) of the transistor and the other the (negative) lead of the Avometer to one end terminals (Emitter 1 or Collector 3) of the transistor (scale Rf*1).
2. Then measure the resistance (R), if we have a large reading
3. Then change and connect the (positive) lead of the Avometer with the mid lead terminal (Base 2) of the transistor.
4. Take the reading, if the value was small R12=R23, then the assumption is correct.
5. Check the polarity of the mid terminal of the transistor (Base 2) transistor, if its (positive) in this case, then its NPN transistor.
6. Repeat the same method for steps 1&2, then we check the polarity of the mid terminal of the transistor (Base 2) of the transistor if its (negative), then its PNP transistor [2].

PART (B): The BJT Characteristics

1. Using the Curve Tracer device the curve between the Ic and VCE can be obtained at different steps of Ib.
2. Analyze the graph and find whether the curve is the input or the output characteristics of the BJT.
3. The values for the h parameters, they can be found practically when analyzing the graph.
4. Using the following formulas the parameters can be calculated:

$$r_\pi = \frac{1}{slope} = \frac{\Delta VBE}{\Delta iB}\ for\ VCE = constant$$

5. Calculate the value of the Base emitter junction voltage (VBE).
6. Calculate the value of the AC output impedance (ro).

$$r_o = \frac{1}{slope} = \frac{\Delta VCE}{\Delta iC}\ for\ iB = constant$$

7. Calculate the value of AC current gains (β_{AC}).

$$\beta_{AC} = \frac{\Delta iC}{\Delta iB}\ for\ VCE = constant$$

8. Calculate the value of DC current gains (β_{DC} and α_{DC}).

$$\beta_{DC} = \frac{IC}{IB}, \qquad \alpha_{DC} = \frac{\beta_{DC}}{\beta_{DC} + 1} \leq 1$$

PART (C): DC analysis of the BJT circuit

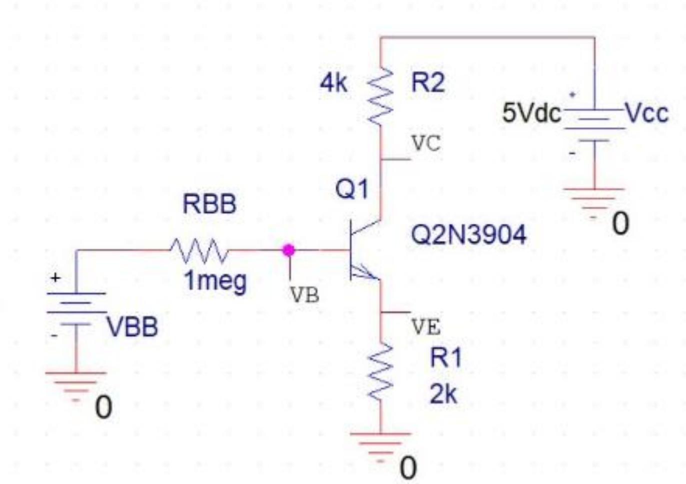

Figure 3 - BJT DC Circuit (NPN)

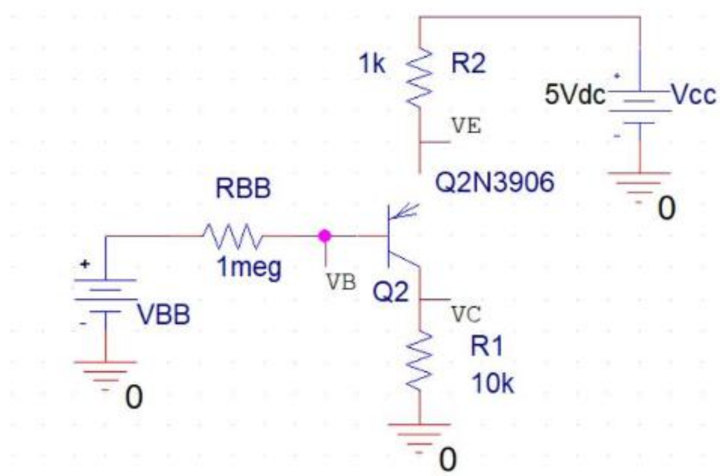

Figure 4 - BJT DC Circuit (PNP)

1. Set up circuit (NPN) in figure 3 on the breadboard.

2. Test all the resistors and their validity (1meg, 4k, 2k).

3. Set VCC initially to -5V.

4. Set VCC to 5V.
5. Measure VB, VE, and VC and write the data to a table.
6. Determine the region of operation of the transistor based on table (1).
7. Iterate the VBB to 2.5V then 10V and repeat the steps from 4 to 6.
8. Repeat the same steps for the PNP circuit in figure 4.
9. For analyzing the circuit in P-Spice use bias points simulation.

Observation and Results

PART (C): DC analysis of the BJT circuit – OrCAD simulation

i. Simulation for figure (3) – NPN circuit:

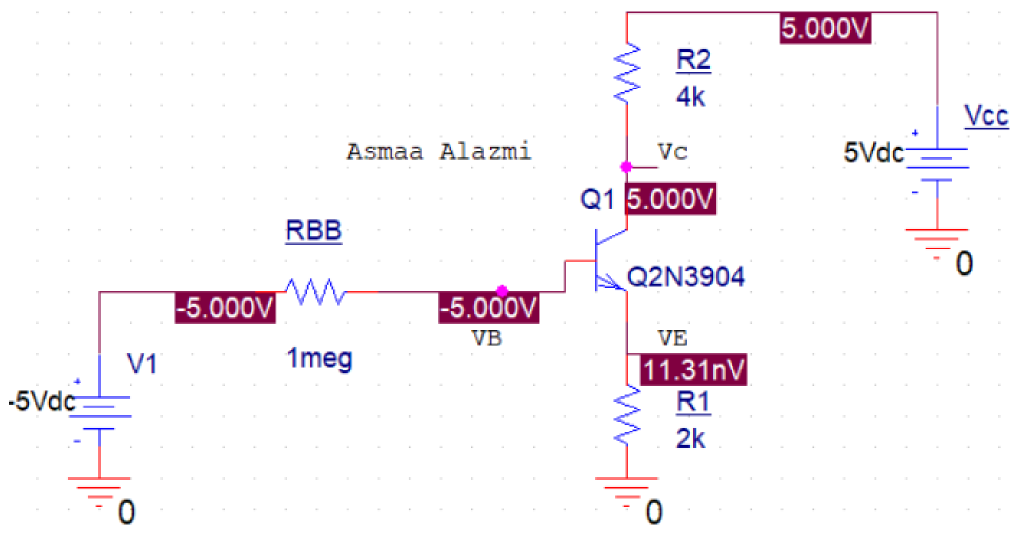

Figure 5 - NPN circuit VBB set to -5V

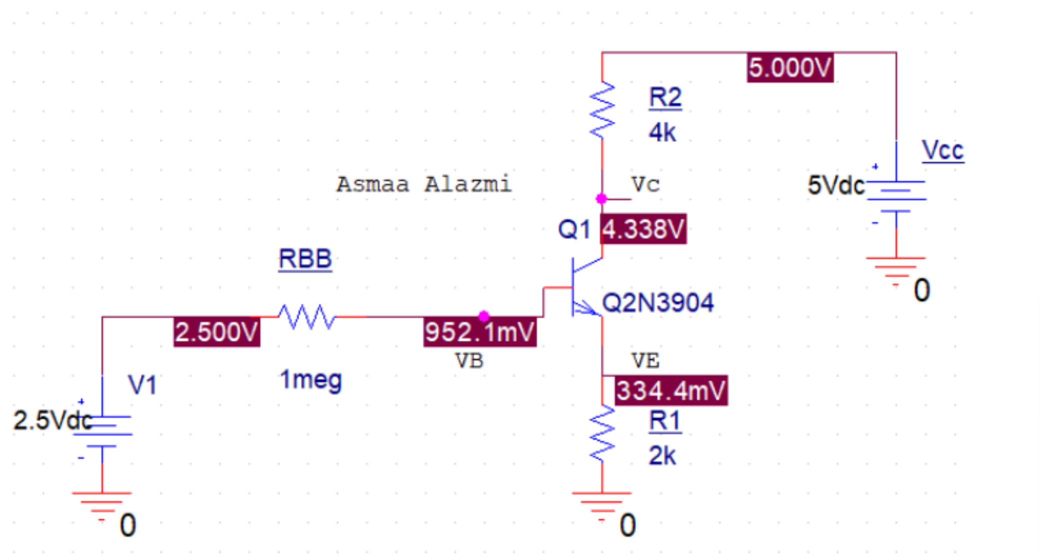

Figure 6 - NPN circuit VBB set to 2.5V

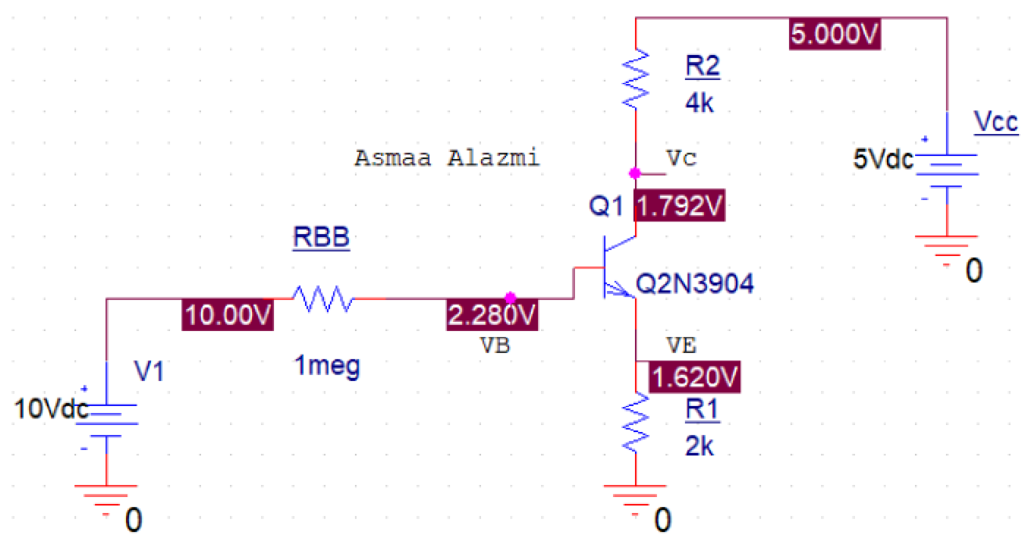

Figure 7- NPN circuit VBB set to 10V

Table 2 - NPN circuit OrCAD results

VBB	VC	VB	VE	MODE OF OPERATION	JUSTIFY YOUR ANSWER
-5V	5	-5	11.31n	**Cut-Off**	Vc > Vb < Ve
2.5V	4.338	0.952	0.334	**Forward Active**	Vc > Vb > Ve
10V	1.792	2.28	1.62	**Saturation**	Vc < Vb > Ve

i. **Simulation for figure (4) – PNP circuit:**

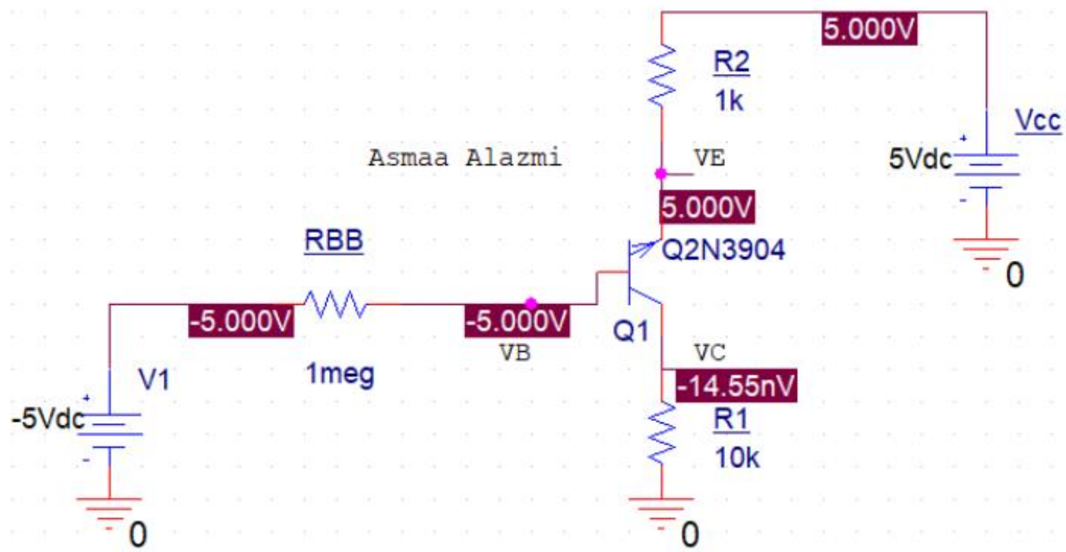

Figure 8 - PNP circuit VBB set to -5V

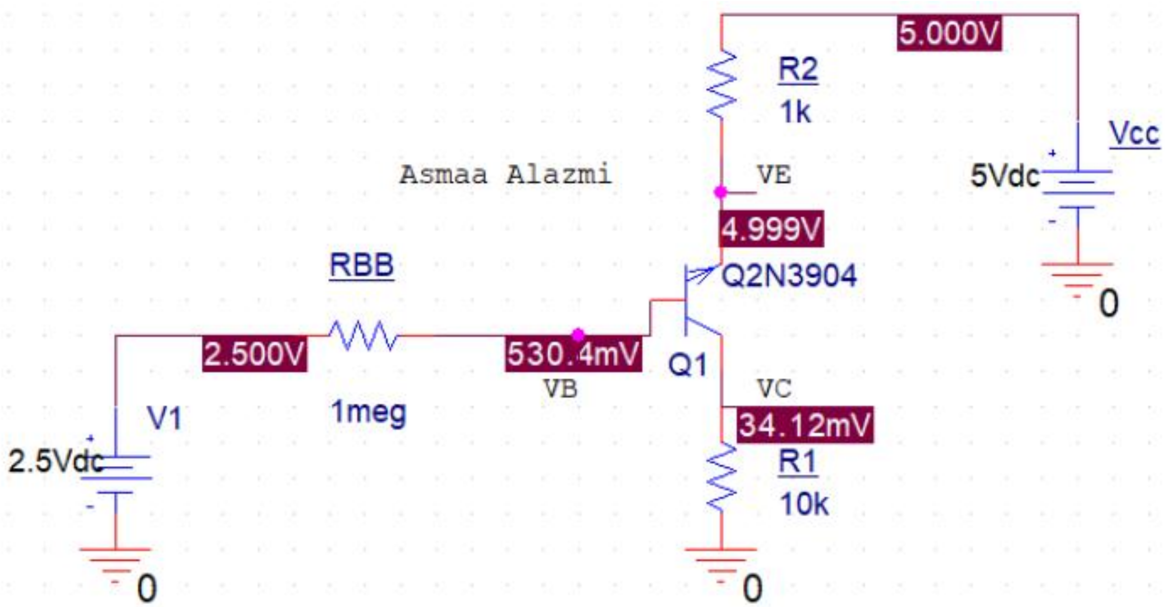

Figure 9 - PNP circuit VBB set to 2.5V

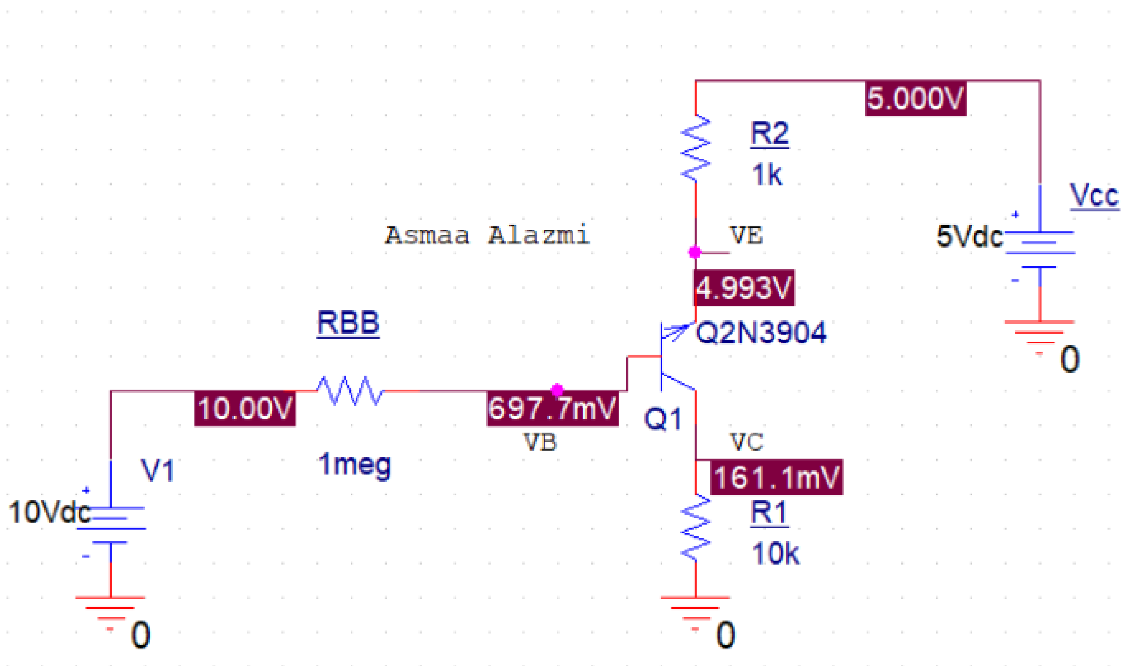

Figure 10 - PNP circuit VBB set to 10V

Table 3- PNP circuit OrCAD results

VBB	VC	VB	VE	MODE OF OPERATION	JUSTIFY YOUR ANSWER
-5V	-14.55	-5	5	**Saturation**	Vc < Vb > Ve
2.5V	0.034	0.53	4.999	**Forward Active**	Vc > Vb > Ve
10V	0.161	0.697	4.993	**Cut-Off**	Vc > Vb < Ve

Data and Results

PART (A): Testing BJT Type (NPN or PNP)

Table 4 - Practical PART (A) results

Type	3904(plastic)	3906(plastic)	BC107 (metal)
NPN or PNP	npn	pnp	npn

PART (B): The BJT Characteristics

PART (C): DC analysis of the BJT circuit

Table 5 - PART (B) Practical results for NPN

VBB	VC	VB	VE	Mode of operation	Justify your answer
-5V	5	-5	~0	cutoff	$V_C > V_B < V_E$
2.5V	4.5	0.8	0.23	Active	$V_C > V_B > V_E$
10V	3.3	1.5	0.8	Saturation	$V_C < V_B > V_E$

Table 6 - PART (B) Practical results for PNP

VBB	VC	VB	VE	Mode of operation	Justify your answer
-5V	4.53	3.29	5	saturation	$V_C > V_B < V_E$
2.5V	2.8	4.01	4.65	Active	$V_C > V_B > V_E$
10V	0	10	5	cut off	$V_C > V_B < V_E$

Discussion and Questions

Conclusion

1- Input Characteristics:

- The input characteristics curve indicates that the base current (IB) increases rapidly with a small increase in the base-emitter voltage (VBE).

- This behavior highlights the sensitivity of the BJT to small changes in VBE, which is crucial for its amplification capabilities.

2- Output Characteristics:

- The output characteristics curve shows that the collector current (IC) increases with an increase in the collector-emitter voltage (VCE) until it reaches saturation.
- This demonstrates the BJT's ability to control larger currents with small base current changes, essential for switching applications.
- Plots of the input and output characteristics curves reveal that transistor parameters such as IC and IB vary with VBE and VCE.

3- Region of Operation:

- The region of operation of the transistor is determined by the specific values of VBE, IB, and VCE.
- The BJT can operate in active (forward or reverse), saturation, or cut-off modes based on these values.
- By controlling the values of VBB, IB, and VCE, the transistor can be made to operate in different regions, enhancing its utility in various electronic circuits.

References

[1] Electrical Technology. (2020, May 7). Bipolar junction transistor (BJT) - Working, types & applications. Electrical Technology. https://www.electricaltechnology.org/2020/05/bipolar-junction-transistor-bjt.html

[2] D. M. Alsaif, "EXPERIMENT # 6: BJT (Bipolar Junction Transistor) Characteristics" Kuwait, 2024

[3] Sedra, A. S., Smith, K. C., Carusone, T. C., & Gaudet, V. (2020). Microelectronic Circuits. The Oxford Series in Electrical and Computer Engineering. Oxford University Press.

Kuwait University

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Lab Report Evaluation Form

Experiment: BJT (Bipolar Junction Transistor) Characteristics
Course Number and Title: EE 234 Electronics 1 Laboratory
Date: 21/7/2024
Student Name(s): Asmaa Alazmi, Fatma Alsuwaileh

Assign a weight (W) for each criterion to be evaluated. Sum of weights is 20.
Rank each criterion by assigning a numerical grade (G) from lowest 1 to highest 5.

	Weight (W)	Grade (G)	W*G
1. Experiment Title page with student Name and Due date	1	0 1 2 3 4 5	
2. Table of Contents	0.5	0 1 2 3 4 5	
2. Design and setup experiments, conduct and data analysis.			
a. Objectives.	1.5	0 1 2 3 4 5	
b. Theory of Experiment.	*3*	0 1 2 3 4 5	
c. Equipment and Components Used.	*1*	0 1 2 3 4 5	
d. Experimental procedures.	*1*	0 1 2 3 4 5	
e. Experimental Data and Results.	*4*	0 1 2 3 4 5	
f. Solving Discussion	*4*	0 1 2 3 4 5	
g. *Conclusion and Comments*	2	0 1 2 3 4 5	
4. Written Communication.			
a. Structure/Organization/plots.	1	0 1 2 3 4 5	
b. Grammar/Rhetoric.	1	0 1 2 3 4 5	

GRADE = Σ (W* G) = ________ %

Comments: