Equipment:
You must make up a complete equipment list and have your instructor review it before you start.

Components:
- \( Q_1 \) - 2N3904 NPN Transistor
- \( R_1 \) - 100 K\( \Omega \)

Objectives:
- To use an ohm meter to determine the forward and reverse resistance of transistor pn junctions
- To use the diode test function of the Keithley Model 175 to measure transistor pn junction characteristics
- To obtain several transistor characteristic curves by plotting the information taken from a transistor test circuit
- To obtain the IV Characteristic Curves for a transistor by using a Tektronix Model 571 Curve Tracer
- To verify manufacturer specifications
1. (HW) Transistor specifications, ratings and symbols

Refer to the specifications for the 2N3904 and find the following information:

(You will need to find the specification online for the 2N3904 fairchild NPN transistor)

a. transistor type
b. maximum power it can dissipate at 25°C
c. maximum collector current rating
d. maximum collector to emitter voltage rating
e. operating temperature range
f. minimum and maximum $h_{fe}$
g. the emitter to base breakdown voltage
h. $V_{BE} @ V_{CE} = 1.0$ V and $I_C = 5$ mA

- Place all this information in Data Table A - 2N3904 Specifications & Ratings.

- Identify the base, collector and emitter pins of the 2N3904. Draw a pin out diagram of this device and call it Figure A - Pin Out Diagram of 2N3904.

- Draw and label the electrical symbols for a NPN and PNP transistor. Place this information in Figure B - Types of Transistors & Their Electrical Symbols.
2.- Static Measurements

1. Set the ohm meter to the 200 kΩ scale.
   
   • Measure and record the forward biased resistance of the base-emitter junction and the base-collector junction in Q₁.
   • Set the ohm meter to its highest scale and measure and record the reverse bias resistance of both junctions in Q₁.
   • Place this information in Data Table B - 2N3904 Characteristics.

b. Test both pn junctions of Q₁ with the diode test feature found on the Keithley Model 175.
   
   • Measure and record the forward and reverse biased readings of Q₁ of both of these junctions.
   • Include this information in Data Table B.

c. (HW) Explain what your tests would indicate if either the base-emitter or base-collector pn junctions were good, open or shorted.

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Fig #0 – PSPICE Circuit setup for plotting IB vs. VBE
3.-(HW) \( I_B \) vs \( V_{BE} \) for different values of \( V_{CE} \) with SPICE

Plot \( I_B \) vs \( V_{BE} \) for different values of \( V_{CE} \) in SPICE, use the following method:

In Fig #0, we are going to vary the value of \( V_{BE} \) from 0 to 1V, we will also vary the value of \( V_{CE} \) from 0 to 20V

1) **Assemble** the circuit in Fig#0 using parts: GND, VDC (for the two sources), Q2N3904 (for the BJT)
2) **Name** the parts with exactly the same names as in Fig #0
3) **Set** the values of the two voltage sources (\( V_{BE} \) & \( V_{CE} \)) to 0V (you will sweep their values, so it doesn’t matter what value you set)
4) **Create** a “DC Sweep” simulation profile
   a. Under **Options**: check “Primary Sweep.” Under **Sweep Variable**: check “Voltage Source”. Set **Name**=\( V_{BE} \), Start Value=0, End Value = 1, Increment .1
   b. Under **Options**: check “Parametric Sweep.” Under **Sweep Variable**: check “Voltage Source”. Set **Name**=\( V_{CE} \), **Sweep Type**: Value List: 0,0.1,0.2,0.3,0.5,1,2,3,5,10
5) Place a AC “Current Probe” on the Base terminal of the BJT
6) Run the simulation.
7) Label this “Plot A” in your report

Things to notice:

1) The x-axis is your **primary** sweep variable.
2) The y-axis is your “current probe” in this case: \( I_B \).
3) The various curves are the different values of your **secondary** sweep variable.

Question:

Why do you only see 6 curves, although your value list has 10 values? (Hint: Does the value of \( V_{CE} \) matter, is there perhaps a minimum value)
4.- \textbf{I}_B \textit{vs} \textit{V}_{BE} \textit{Measurements Using a Test Circuit}

Assemble the circuit shown in Figure # 1.

- Set $V_{CE} = 1 \ \text{V}_{DC}$ and vary $I_B$ from 5 to 50 $\mu\text{A}$ in steps of 5 $\mu\text{A}$ and record the value of $V_{BE}$ for each step.
- Set $V_{CE} = 10 \ \text{V}_{DC}$ and once again vary $I_B$ from 5 to 50 $\mu\text{A}$ in steps of 5 $\mu\text{A}$ and record the value of $V_{BE}$ for each step.
- Place all this information in Data Table # 1 - Base Characteristics.
- Plot $I_B$ vs. $V_{BE}$ in Graph # 1 - 2N3904 Base Characteristics (be sure to annotate the $V_{CE}$ lines).
In Fig #2, we are going to vary the value of VCE from 0 to 10V, we will also vary the value of IB from 0 to 50uA

1) **Assemble** the circuit in Fig#2 using parts: GND, VDC, IDC, and Q2N3904 (for the BJT) (Note: ENSURE your IDC is in the right direction)

2) **Name** the parts with exactly the same names as in Fig #2

3) **Set** the values of the two sources (VCE & IDC) to 0V and 0A respectively (you will sweep their values, so it doesn’t matter what value you set)

4) **Create** a “DC Sweep” simulation profile
   a. Under **Options**: check “Primary Sweep.” Under **Sweep Variable**: check “Voltage Source”. Set Name=VCE, Start Value=0, End Value = 10, Increment .1
   b. Under **Options**: check “Secondary Sweep.” Under **Sweep Variable**: check “Current Source”. Set Name=IB, Start Value=0, End Value = 50u, Increment 5u

5) Place a AC “Current Probe” on the **Collector** terminal of the BJT

6) Run the simulation.

7) Label this “Plot B” in your report
Things to notice:

1) The x-axis is your *primary* sweep variable.
2) The y-axis is your “current probe” in this case: IC.
3) The various curves are the different values of your *secondary* sweep variable.

Question:

How many curves do you see? What does each curve represent?

*For your final report, NOT prelab, change the “Bf” parameter for Q2N3904, and repeat the simulation, label this “Plot C”. How to do this will be explained by your GTA in your lab. Compare your results with those in “Plot B.” Again, this is to be done in your final report, NOT prelab.*
6.- **I_C vs V_CE Measurements Using a Test Circuit**

- Set \( I_B = 20 \) \( \mu \)A and vary \( V_{CE} \) from 0 to 2 V in 0.2 V steps then step \( V_{CE} \) from 2 V to 10 V in 2.0 V steps.
- Set \( I_B = 40 \) \( \mu \)A and once again vary \( V_{CE} \) from 0 to 2 V in 0.2 V steps then step \( V_{CE} \) from 2 V to 10 V in 2.0 V steps.
- Place all this information in Data Table # 2 - IV Characteristic Data.
- Plot \( I_C \) vs. \( V_{CE} \) in Graph # 2 - 2N3904 Characteristic Curves (be sure to annotate the \( I_B \) lines).

7.- **I_C vs V_CE Measurements Using a Curve Tracer**

- Obtain a copy of a family of 10 curves for the 2N3904 from the Tektronix Model 571 Curve tracer.
- Set \( I_C \) to be no greater than 10 mA, \( V_{CE} \) to be no greater than 10 V and \( I_B \) to step 10 times in 5 \( \mu \)A steps (be sure to annotate the \( I_B \) lines).

8.- **Data Analysis**

a. Interpret and review all the data that you have taken.

b. Compare your results to the manufacturers’ specifications (examine the waveforms in the specifications; compare them to your waveforms)

c. Compare your results to your spice simulations, explain differences.

d. Determine the values of \( g_m \), \( r_\pi \), and \( r_e \) from the following formulas:

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\begin{align*}
g_m &= \frac{I_C}{V_T} \\
r_\pi &= \frac{V_T}{I_B} \\
r_e &= \frac{V_T}{I_E}
\end{align*}
\]