Name ______________________

Date ______________________

Instructor ______________________

EXPERIMENT 12

JFET Characteristics

OBJECTIVE

To obtain the output and transfer characteristics for a JFET transistor.

EQUIPMENT REQUIRED

Instruments

DMM
Curve tracer (if available)

Components

Resistors

(1) 100-Ω
(1) 1-kΩ
(1) 10-kΩ
(1) 5-kΩ potentiometer
(1) 1-MΩ potentiometer

Transistor

(1) 2N4416 (or equivalent)

Supplies

DC power supply
9 V battery with snap-on leads

EQUIPMENT ISSUED

Item	*Laboratory serial no.*
DMM	
DC power supply	

RÉSUMÉ OF THEORY

The junction field-effect transistor (JFET) is a unipolar conduction device. The current carriers are either electrons in an n-channel JFET or holes in a p-channel JFET. In the n-channel JFET the conduction path is an n-doped material, germanium or silicon, while in the p-channel the conduction path is p-doped germanium or silicon. Conduction through the channel is controlled by the depletion region established by oppositely doped regions in the channel. The channel is connected to two terminals, referred to as the drain and the source, respectively. For n-channel JFETs, the drain is connected to a positive voltage, and the source to a negative voltage, to establish a flow of conventional current in the channel. The polarities of the applied voltages for the p-channel JFET are opposite to those of the n-channel JFET.

A third terminal, referred to as the gate terminal, provides a mechanism for controlling the depletion region and thereby the width of the channel through which conventional flow can exist between the drain and source terminals. For an n-channel JFET, the more negative the gate-to-source voltage is, the smaller the channel width is and the less the drain-to-source current is.

This experiment will establish the relationships between the various voltages and currents flowing in a JFET. The nature of these relationships determines the range of JFET applications.

PROCEDURE

Part 1. Measurement of the Saturation Current I_{DSS} and Pinch-Off Voltage V_P

a. Construct the network of Fig. 12.1. Insert the measured value of R. The 10-kΩ resistor in the input circuit is included to protect the gate circuit if the 9 V battery is applied with the wrong polarity and the potentiometer is set on its maximum value.

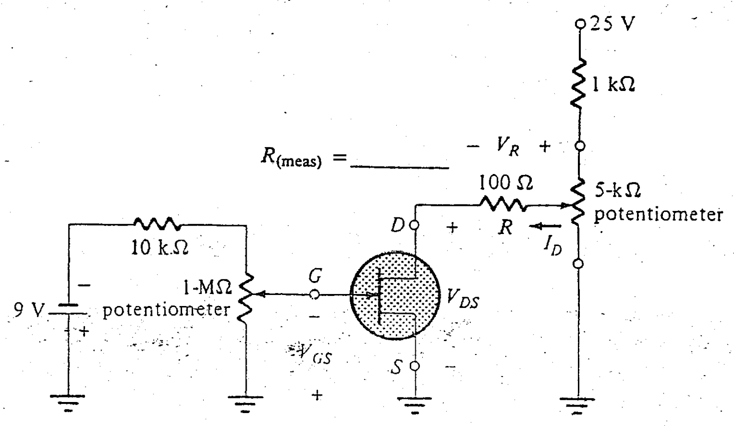

Figure 12-1

b. Vary the 1-MΩ potentiometer until V_{GS} = 0 V. Recall that I_D = I_{DSS} when V_{GS} = 0 V.

c. Set V_{DS} to 8 V by varying the 5-kΩ potentiometer. Measure the voltage V_R.

V_R (measured) = ____________

d. Calculate the saturation current from $I_{DSS} = I_D = V_R/R$ using the measured resistor value and record below.

I_{DSS} (from measured) = ____________

e. Maintain V_{DS} at about 8 V and reduce V_{GS} until V_R drops to 1 mV. At this level $I_D = V_R/R$ = 1 mV/100 Ω = 10 μA ≅ 0 mA. Recall that V_P is the voltage V_{GS} that results in I_D = 0 mA. Record the pinch-off voltage below:

V_P (measured) = ____________

f. Check with two other groups in your laboratory area and record their levels of I_{DSS} and V_P.

1. I_{DSS} = ____________ , V_P = ____________
2. I_{DSS} = ____________ , V_P = ____________

Based on the above, are I_{DSS} and V_P the same for all 2N4416 transistors?

g. Using the determined values of I_{DSS} and V_P, sketch the transfer characteristics for the device in Fig. 12.2 using Shockley's equation. Plot at least 5 points on the curve.

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \tag{12.1}$$

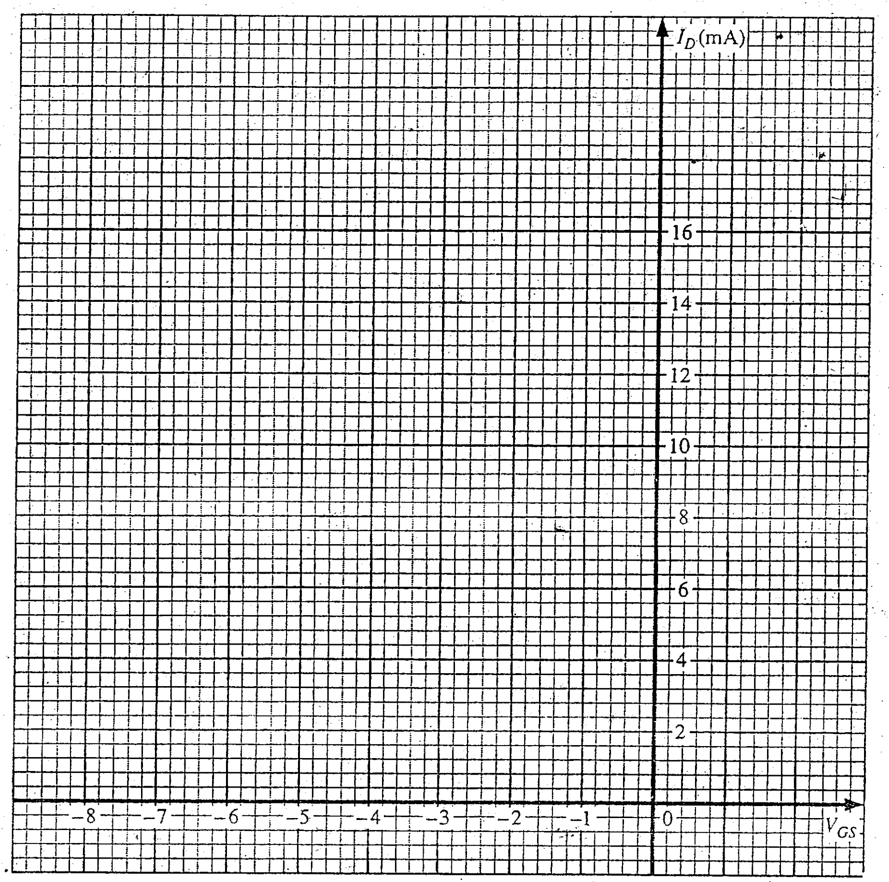

Figure 12-2 Transfer characteristics: 2N4416

Part 2. Output Characteristics

This part of the experiment will determine the I_D versus V_{DS} characteristics for an n-channel JFET.

a. Using the network of Fig. 12.1, vary the two potentiometers until $V_{GS} = 0$ V and $V_{DS} = 0$ V. Determine I_D from $I_D = V_R/R$ using the measured value of R and record in Table 12.1.

b. Maintain V_{GS} at 0 V and increase V_{DS} through 14 V (in 1 volt steps) and record the calculated value of I_D. Be sure to use the measured value of the 100-Ω resistance in your calculations.

c. Vary the 1-MΩ potentiometer until $V_{GS} = -1$ V. Maintaining V_{GS} at this level, vary V_{DS} through the levels of Table 12.1 and record the calculated value of I_D.

d. Repeat step 2(**c**) for the values of V_{GS} appearing in Table 12.1. Discontinue the process once V_{GS} exceeds V_P.

e. Plot the output characteristics for the JFET on the graph of Fig. 12.3.

f. Does the plot verify the conclusions of Part 1? That is, is the average value of I_D for $V_{GS} = 0$ V relatively close to I_{DSS}? Is the value of V_{GS} that results in $I_D = 0$ mA close to V_P?

TABLE 12.1

V_{GS} (V)	0	−1.0	−2.0	−3.0	−4.0	−5.0	−6.0
V_{DS} (V)	I_D (mA)	I_D (mA)	I_D (mA)	I_D (mA)	I_D (mA)	I_D (mA)	I_D (mA)
0.0							
1.0							
2.0							
3.0							
4.0							
5.0							
6.0							
7.0							
8.0							
9.0							
10.0							
11.0							
12.0							
13.0							
14.0							

I_{DSS} (Fig. 12.3) = ________

I_{DSS} (Part 1) = ________

V_P (Fig. 12.3) = ________

V_P (Part 1) = ________

Part 3. Transfer Characteristics

This part of the experiment will determine the I_D vs. V_{GS} transfer characteristics frequently used in the analysis of JFET networks. Ideally, the transfer characteristics as determined by Shockley's equation assume that the effect of V_{DS} can be ignored and the characteristic curves of Fig. 11.3 for a given V_{GS} are considered horizontal. The following will show that the transfer curve does vary slightly with V_{DS} but not to the point where concern should develop about using Shockley's equation.

For this part of the experiment all the data can be obtained from Table 12.1. There is no experimental work in this part.

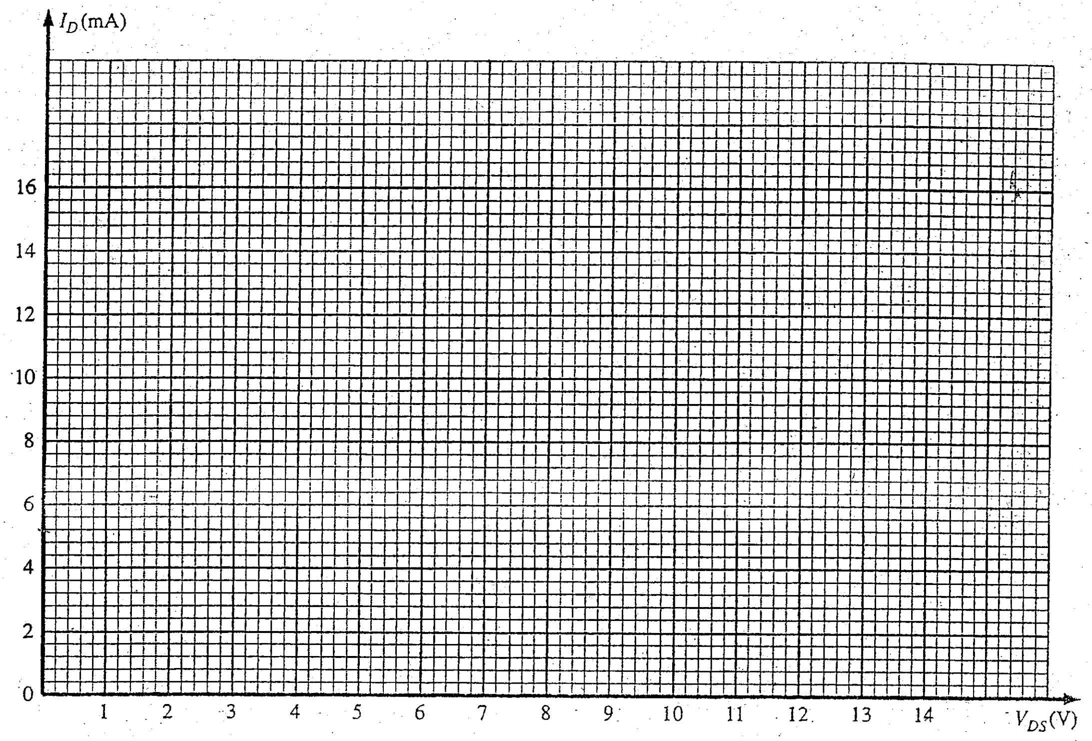

Figure 12-3 Drain-current curve: 2N4416.

a. At $V_{DS} = 3$ V record the values of I_D for the range of V_{GS} in Table 12.2 using the data of Table 12.1.

TABLE 12.2

V_{DS}	3 V	6 V	9 V	12 V
V_{GS}	I_D(mA)	I_D(mA)	I_D(mA)	I_D(mA)
0 V				
−1 V				
−2 V				
−3 V				
−4 V				
−5 V				
−6 V				

b. Repeat Part 3(a) for $V_{DS} = 6$ V, 9 V, and 12 V.

c. For each level of V_{DS} plot I_D vs. V_{GS} on the graph of Fig. 12.4. Plot each curve carefully and label each curve with the value of V_{DS}.

d. Is it reasonable (on an approximate basis) to assume the family of curves of Fig. 12.4 can be replaced by a single curve defined by Shockley's equation?

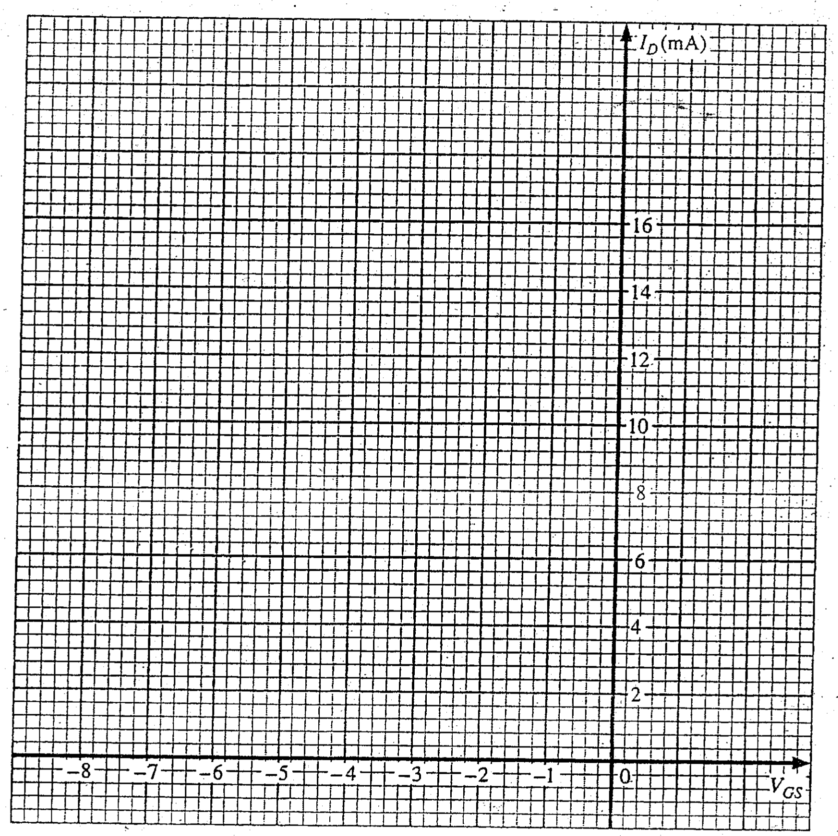

Figure 12-4 Pinch-off voltage curve: 2N4416.

Part 4. Determination of the JFET Characteristics Using a Commercial Curve Tracer

a. If available, use the curve tracer to obtain an output set (I_D vs. V_{DS}) of characteristics for the 2N4416 JFET.

b. Reproduce the characteristics on the graph of Fig. 12.5.

c. Compare the characteristics to those obtained in Part 2, Fig. 12.3. Note that the scales are the same to permit a direct com-parison.

d. From your data obtained in Fig. 12.5 draw the transfer characteristics in Fig. 12.6. Compare this graph with Fig. 12.4 in Part 3. Use as many data points from Fig. 12.5 as you feel are required to obtain the desired curves.

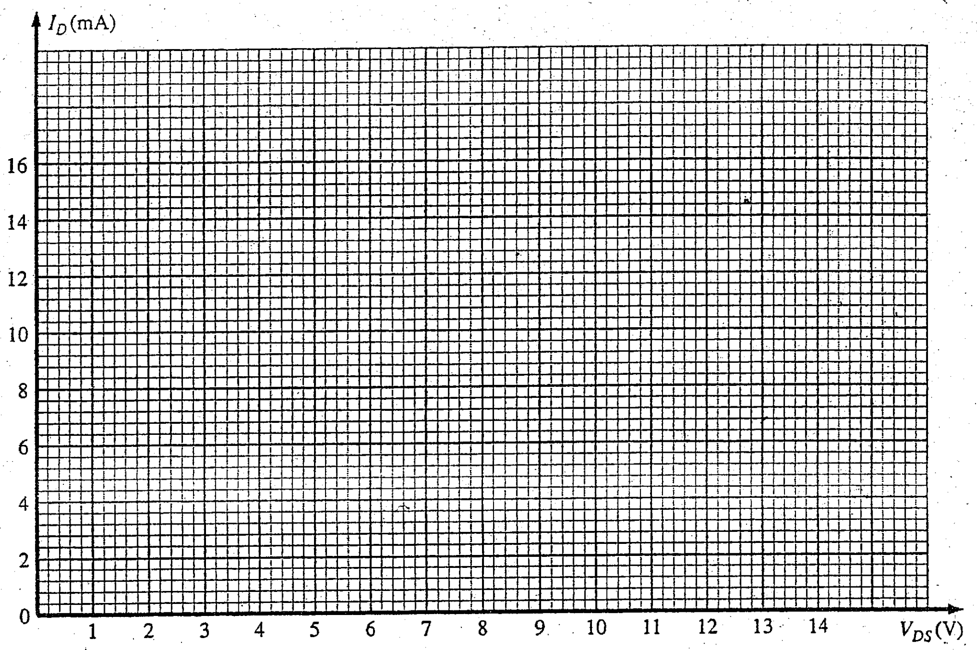

Figure 12-5 Drain-source characteristic: 2N4416.

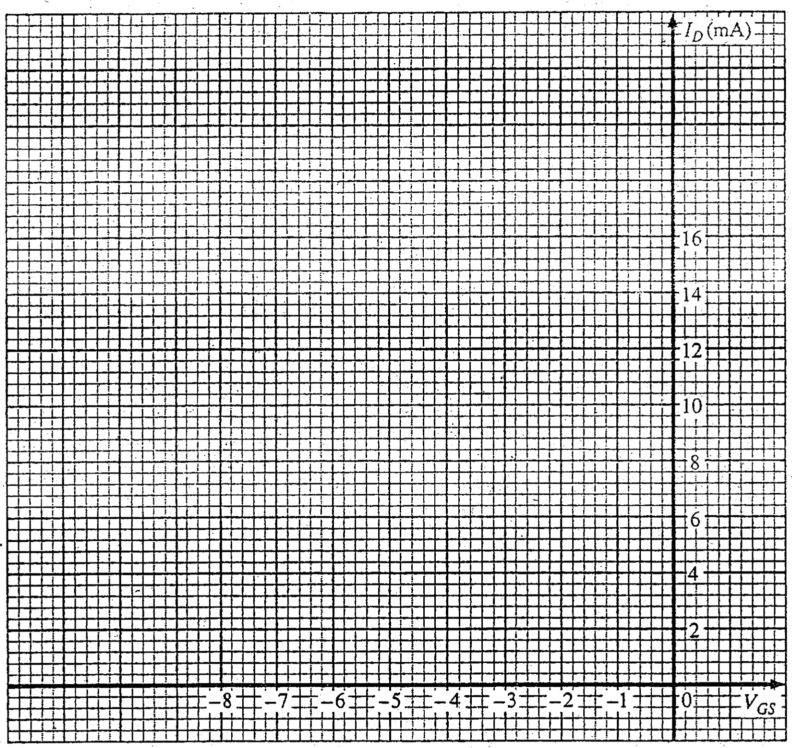

Figure 12-6 Transfer characteristic: 2N4416.

Problems and Exercises

1. Given I_D and V_{GS} at a particular point on Shockley's curve can the values of I_{DSS} and V_P be determined? If so, how? If not, why not?

2. **a. Write Shockley's equation in a form that will provide V_{GS} in terms of I_{DSS}, V_P, and I_D.**

   b. Given I_{DSS} = 10 mA, V_P = –5 V, and I_D = 4 mA, find the value of V_{GS}.

V_{GS} (calculated) = ____________

3. The transconductance, g_m, of a JFET is an important quantity in the AC analysis of JFET amplifiers. Its magnitude is defined by the slope of Shockley's equation at a point on the characteristics. The application of calculus techniques to Shockley's equation will result in the following equation for g_m:

$$g_m = g_{mo}(1 - V_{GS}/V_P) \tag{12.1}$$

with

$$g_{mo} = \frac{2\, I_{DSS}}{|V_P|} \tag{12.2}$$

which is the transconductance at V_{GS} = 0 V.

a. Using the experimental results of Part 1 determine g_{mo}.

g_{mo} (calculated) = __________

b. Referring to the transfer curve of Fig. 12.2, is the slope of Shockley's equation a maximum at $V_{GS} = 0$ V?

Based on the above, can we assume that g_{mo} calculated in Exercise 3(**a**) is the maximum value of g_m?

c. Determine g_m at $V_{GS} = V_P$.

g_m (calculated) = ________

Referring to the transfer curve of Fig. 12.2, is the slope of Shockley's equation a minimum at $V_{GS} = V_P$? In fact, what slope would you expect it to have exactly at $V_{GS} = V_P$?

d. Determine g_m at $V_{GS} = 1/4\ V_P$, $1/2\ V_P$, and $3/4\ V_P$, and plot the curve of g_m on Fig. 12.7.

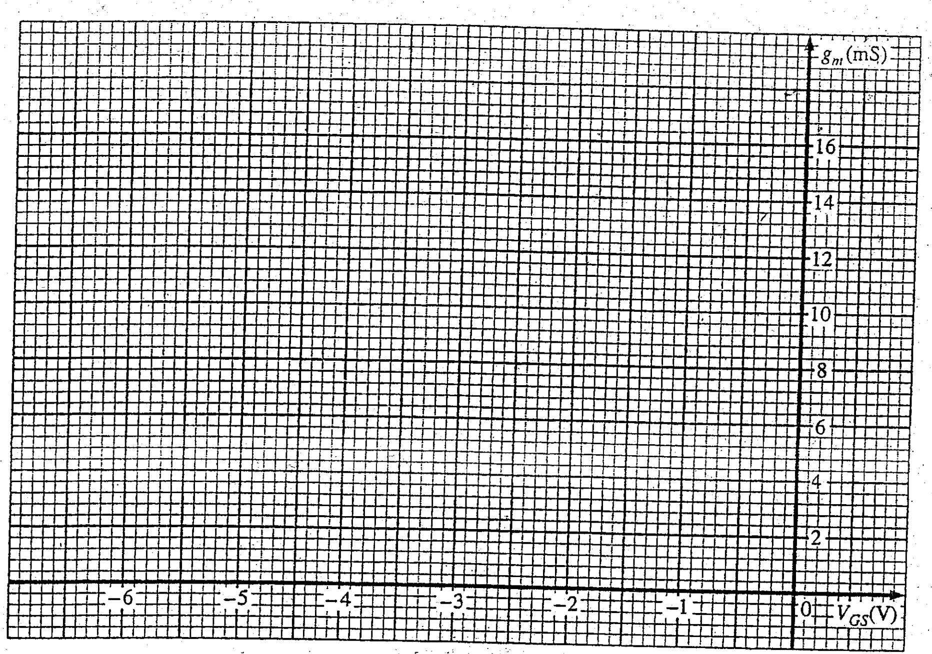

Figure 12-7 Transconductance versus V_{GS} of 2N4416.

e. Referring to the transfer curve of Fig. 12.2, does the slope increase with less negative values of V_{GS}? Is your conclusion verified by the plot of Fig. 12.7?

f. What does the fact that the graph of Fig. 12.7 is a straight line tell you about the curve resulting from Shockley's equation?