Tutorial-1: Communication Circuit Design

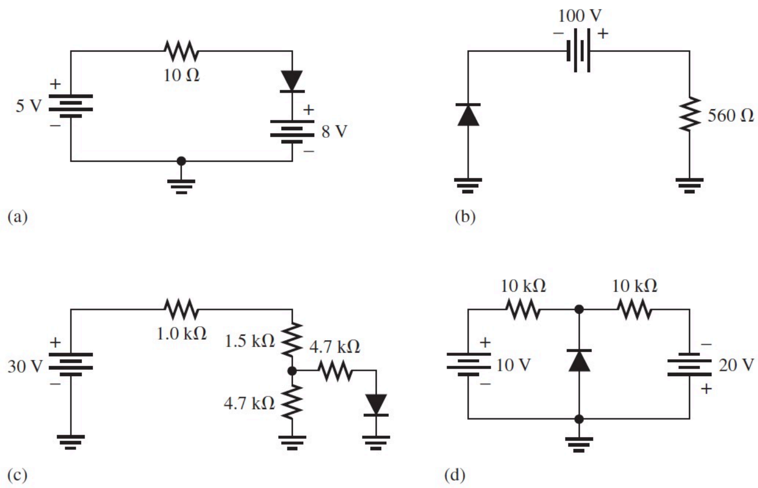
L3 - Semiconductors and PN Junction

Question 3.1: Determine whether each silicon diode in Figure below is forward-biased or reverse-biased.

Question 3.2: Determine the voltage across each diode in Figure below, assuming the practical model.

Question 3.3: Determine the voltage across each diode in Figure below, assuming an ideal diode.

Question 3.4: Determine the voltage across each diode in Figure below, using the complete diode model with
$r'_d = 10\ \Omega$ and $r'_R = 100\ \text{M}\Omega$



Answer 3.1:

(a) The diode is reverse-biased.
(b) The diode is forward-biased.
(c) The diode is forward-biased.
(d) The diode is forward-biased.

Answer 3.2:

(a) $V_R = 5\text{ V} - 8\text{ V} = \mathbf{-3\ V}$
(b) $V_F = \mathbf{0.7\ V}$
(c) $V_F = \mathbf{0.7\ V}$
(d) $V_F = \mathbf{0.7\ V}$

Answer 3.3:

(a) $V_R = 5\text{ V} - 8\text{ V} = \mathbf{-3\ V}$
(b) $V_F = \mathbf{0\ V}$
(c) $V_F = \mathbf{0\ V}$
(d) $V_F = \mathbf{0\ V}$

Answer 3.4:

Ignoring r'_R:

(a) $V_R \cong 5\text{ V} - 8\text{ V} = \mathbf{-3\ V}$

(b) $I_F = \dfrac{100\text{ V} - 0.7\text{ V}}{560\ \Omega + 10\ \Omega} = 174\text{ mA}$

$V_F = I_F r'_d + V_B = (174\text{ mA})(10\ \Omega) + 0.7\text{ V} = \mathbf{2.44\ V}$

(c) $I_{tot} = \dfrac{30\text{ V}}{R_{tot}} = \dfrac{30\text{ V}}{4.85\text{ k}\Omega} = 6.19\text{ mA}$

$I_F = \dfrac{6.19\text{ mA}}{2} = 3.1\text{ mA}$

$V_F = I_F r'_d + 0.7\text{ V} = (3.1\text{ mA})(10\ \Omega) + 0.7\text{ V} = \mathbf{0.731\ V}$

(d) Approximately all of the current from the 20 V source is through the diode. No current from the 10 V source is through the diode.

$I_F = \dfrac{20\text{ V} - 0.7\text{ V}}{10\text{ k}\Omega + 10\ \Omega} = 1.92\text{ mA}$

$V_F = (1.92\text{ mA})(10\ \Omega) + 0.7\text{ V} = \mathbf{0.719\ V}$

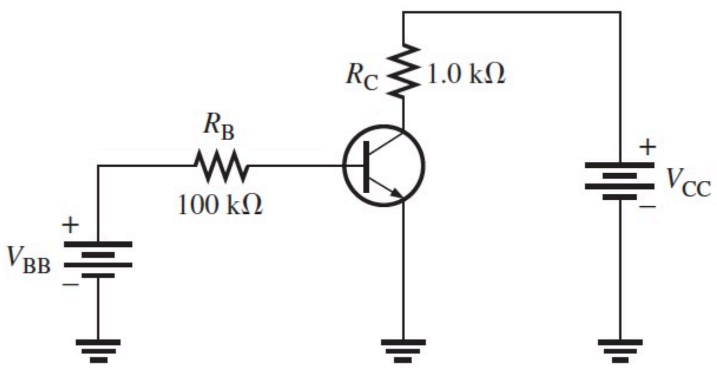
L4 - Bipolar Junction Transistor (BJT)

Question 4.1: A certain transistor has an I_C = 25 mA and an I_B = 200 mA. Determine the β_{DC}.

Question 4.2: What is the β_{DC} of a transistor if I_C = 20.3 mA and I_E = 20.5 mA.

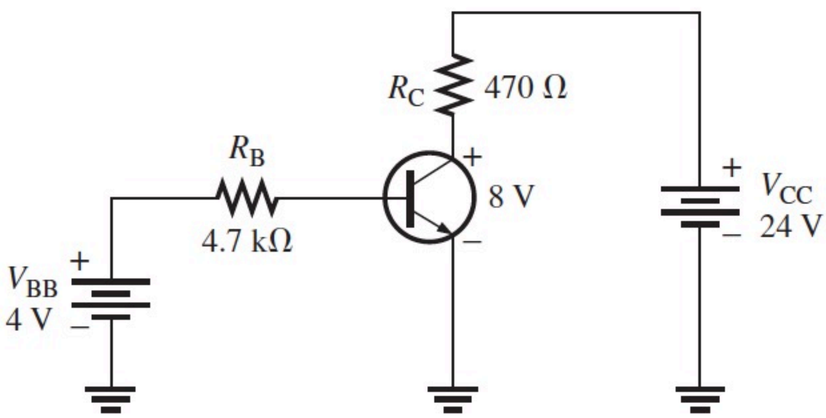
Question 4.3: What is the α_{DC} if I_C = 5.35 mA and I_B = 50 mA?

Question 4.4: A base current of 50 μA is applied to the transistor in Figure below, and a voltage of 5 V is dropped across R_C. Determine the β_{DC} of the transistor.

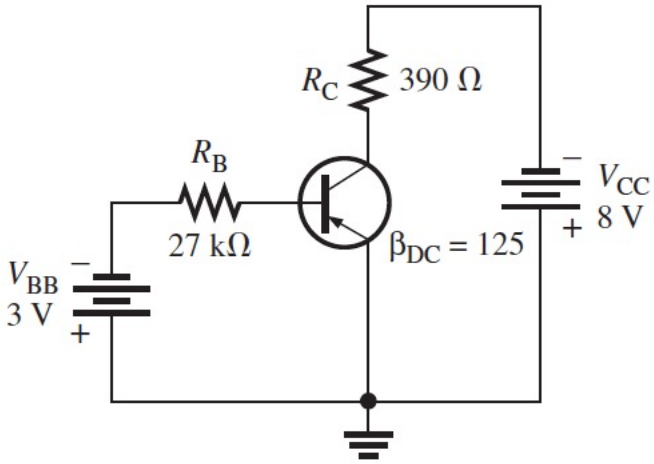


Question 4.5: Assume that the transistor in the circuit of Figure above is replaced with one having a β_{DC} of 200. Determine I_B, I_C, I_E, and V_{CE} given that V_{CC} = 10 V and V_{BB} = 3 V.

Question 4.6: Determine each current in Figure below. What is the β_{DC}?



Question 4.7: Find V_{CE}, V_{BE}, and V_{CB} in the circuits of Figure below.



Answer 4.1:

$$\beta_{DC} = \frac{I_C}{I_B} = \frac{25\text{ mA}}{200\ \mu\text{A}} = \mathbf{125}$$

Answer 4.2:

$$I_B = I_E - I_C = 20.5\text{ mA} - 20.3\text{ mA} = 0.2\text{ mA} = 200\ \mu\text{A}$$
$$\beta_{DC} = \frac{I_C}{I_B} = \frac{20.3\text{ mA}}{200\ \mu\text{A}} = \mathbf{101.5}$$

Answer 4.3:

$$I_E = I_C + I_B = 5.35\text{ mA} + 50\ \mu\text{A} = 5.40\text{ mA}$$
$$\alpha_{DC} = \frac{I_C}{I_E} = \frac{5.35\text{ mA}}{5.40\text{ mA}} = \mathbf{0.99}$$

Answer 4.4:

$$I_C = \frac{V_{R_C}}{R_C} = \frac{5\text{ V}}{1.0\text{ k}\Omega} = 5\text{ mA}$$
$$\beta_{DC} = \frac{I_C}{I_B} = \frac{5\text{ mA}}{50\ \mu\text{A}} = \mathbf{100}$$

Answer 4.5:

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{3\text{ V} - 0.7\text{ V}}{100\text{ k}\Omega} = \mathbf{23\ \mu A}$$

$$I_C = \beta_{DC} I_B = 200(23\ \mu\text{A}) = \mathbf{4.6\ mA}$$

$$I_E = I_C + I_B = 4.6\text{ mA} + 23\ \mu\text{A} = \mathbf{4.62\ mA}$$

$$V_{CE} = V_{CC} - I_C R_C = 10\text{ V} - (4.6\text{ mA})(1.0\text{ k}\Omega) = \mathbf{5.4\ V}$$

Answer 4.6:

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{4\text{ V} - 0.7\text{ V}}{4.7\text{ k}\Omega} = \frac{3.3\text{ V}}{4.7\text{ k}\Omega} = \mathbf{702\ \mu A}$$

$$I_C = \frac{V_{CC} - V_{CE}}{R_C} = \frac{24\text{ V} - 8\text{ V}}{470\ \Omega} = \mathbf{34\ mA}$$

$$I_E = I_C + I_B = 34\text{ mA} + 702\ \mu\text{A} = \mathbf{34.7\ mA}$$

$$\beta_{DC} = \frac{I_C}{I_B} = \frac{34\text{ mA}}{702\ \mu\text{A}} = \mathbf{48.4}$$

Answer 4.7:

$$V_{BE} = \mathbf{-0.7\ V}$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{-3\text{ V} - (-0.7\text{ V})}{27\text{ k}\Omega} = \frac{-2.3\text{ V}}{27\text{ k}\Omega} = -85.2\ \mu\text{A}$$

$$I_C = \beta_{DC} I_B = 125(-85.2\ \mu\text{A}) = -10.7\text{ mA}$$

$$V_{CE} = V_{CC} - I_C R_C = -8\text{ V} - (-10.7\text{ mA})(390\ \Omega) = \mathbf{-3.83\ V}$$

$$V_{CB} = V_{CE} - V_{BE} = -3.83\text{ V} - (-0.7\text{ V}) = \mathbf{-3.13\ V}$$

L5 - Field-Effect Transistor (FET)

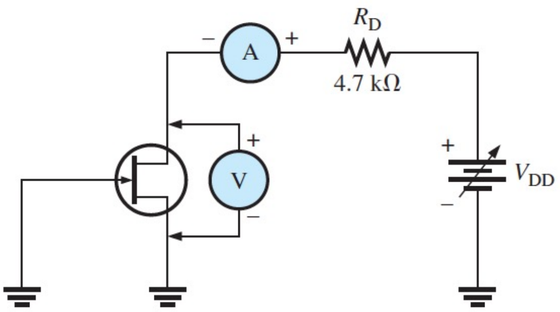
Question 5.1: A JFET has a specified pinch-off voltage of 5 V. When V_{GS} = 0, what is V_{DS} at the point where the drain current becomes constant?

vgs not Vgsoff

Question 5.2: A certain *n*-channel JFET is biased such that $V_{GS(off)}$ = -2 V. What is the value of $V_{GS(off)}$ if V_P is specified to be 6 V? Is the device on?

Question 5.3: A certain JFET datasheet gives When $V_{GS(off)}$ = -8 V and I_{DSS} = 10 mA. When V_{GS} = 0, what is I_D for values of V_{DS} above pinch off? V_{DD} = 15 V.

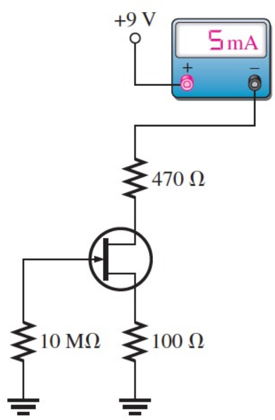
Question 5.4: The JFET in Figure below has a $V_{GS(off)}$ = -4 V. Assume that you increase the supply voltage, V_{DD}, beginning at zero until the ammeter reaches a steady value. What does the voltmeter read at this point?



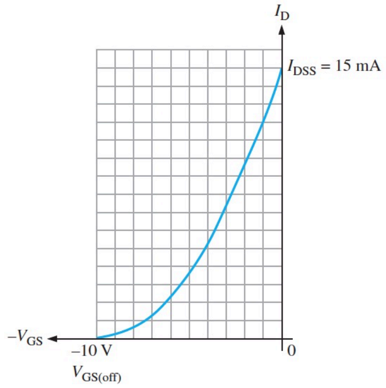
Question 5.5: For a particular JFET, g_{m0} = 3200 μS. What is g_m when VGS = -4 V given that $V_{GS(off)}$ = -8 V?

Question 5.6: A *p*-channel JFET datasheet shows that I_{GSS} = 5 nA at V_{GS} = 10 V. Determine the input resistance.

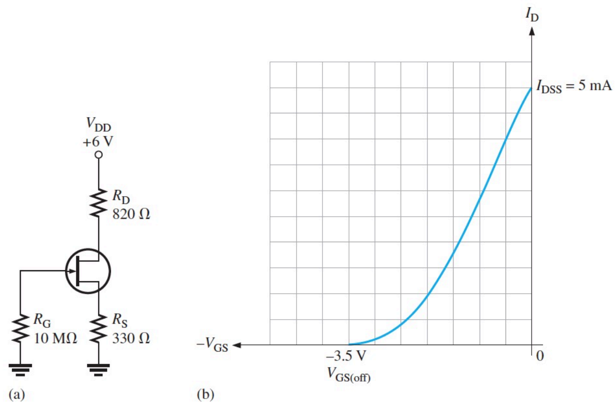
Question 5.7: For each circuit in Figure below, determine V_{DS} and V_{GS}.



Question 5.8: Using the curve in Figure below, determine the value of R_S required for a 9.5 mA drain current.



Question 5.9: Graphically determine the Q-point for the circuit in Figure (a) below using the transfer characteristic curve in Figure (b).



Question 5.10: The Q-point of a JFET is varied from V_{DS} = 0.4 V and I_D = 0.15 mA to V_{DS} = 0.6 V and I_D = 0.45 mA. Determine the range of R_{DS} values.

Answer 5.1:

$V_{DS} = V_P = \mathbf{5\ V}$ at point where I_D becomes constant.

Answer 5.2:

$V_{GS(off)} = -V_P = \mathbf{-6\ V}$
The device is **on**, because $V_{GS} = -2$ V.

Answer 5.3:

By definition, $I_D = I_{DSS}$ when $V_{GS} = 0$ V for values of $V_{DS} > V_P$. Therefore, $I_D = \mathbf{10\ mA}$.

Answer 5.4:

$V_P = -V_{GS(off)} = -(-4\text{ V}) = 4\text{ V}$
The voltmeter reads V_{DS}. As V_{DD} is increased, V_{DS} also increases. The point at which I_I reaches a constant value is $V_{DS} = V_P = \mathbf{4\ V}$.

Answer 5.5:

$$g_m = g_{m0}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right) = 3200\ \mu S\left(1 - \frac{-4\text{ V}}{-8\text{ V}}\right) = \mathbf{1600\ \mu S}$$

Answer 5.6:

$$R_{IN} = \frac{V_{GS}}{I_{GSS}} = \frac{10\text{ V}}{5\text{ nA}} = \mathbf{2000\ M\Omega}$$

Answer 5.7:

$V_S = (5\text{ mA})(100\ \Omega) = 0.5\text{ V}$
$V_D = 9\text{ V} - (5\text{ mA})(470\ \Omega) = 6.65\text{ V}$
$V_G = 0\text{ V}$
$V_{GS} = V_G - V_S = 0\text{ V} - 0.5\text{ V} = \mathbf{-0.5\ V}$
$V_{DS} = 6.65\text{ V} - 0.5\text{ V} = \mathbf{6.15\ V}$

Answer 5.8:

From the graph, $V_{GS} \cong -2$ V at $I_D = 9.5$ mA.

$$R_S = \left|\frac{V_{GS}}{I_D}\right| = \left|\frac{-2\text{ V}}{9.5\text{ mA}}\right| = \mathbf{211\ \Omega}$$

Answer 5.9:

For $I_D = 0$,
$V_{GS} = -I_D R_S = (0)(330\ \Omega) = 0\text{ V}$
For $I_D = I_{DSS} = 5$ mA
$V_{GS} = -I_D R_S = -(5\text{ mA})(330\ \Omega) = -1.65\text{ V}$
From the graph in Figure 8-69 in the textbook, the Q-point is
$V_{GS} \cong \mathbf{-0.95\ V}$ and $I_D \cong \mathbf{2.9\ mA}$

Answer 5.10:

$$R_{DS1} = \frac{0.4\text{ V}}{0.15\text{ mA}} = 2.67\text{ k}\Omega$$

$$R_{DS2} = \frac{0.6\text{ V}}{0.45\text{ mA}} = 1.33\text{ k}\Omega$$

$$\Delta R_{DS} = 2.67\text{ k}\Omega - 1.33\text{ k}\Omega = \mathbf{1.34\ k\Omega}$$