Student Number & Name: ______________________________

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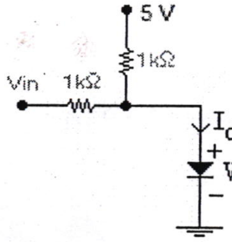
ES232 Midterm Exam

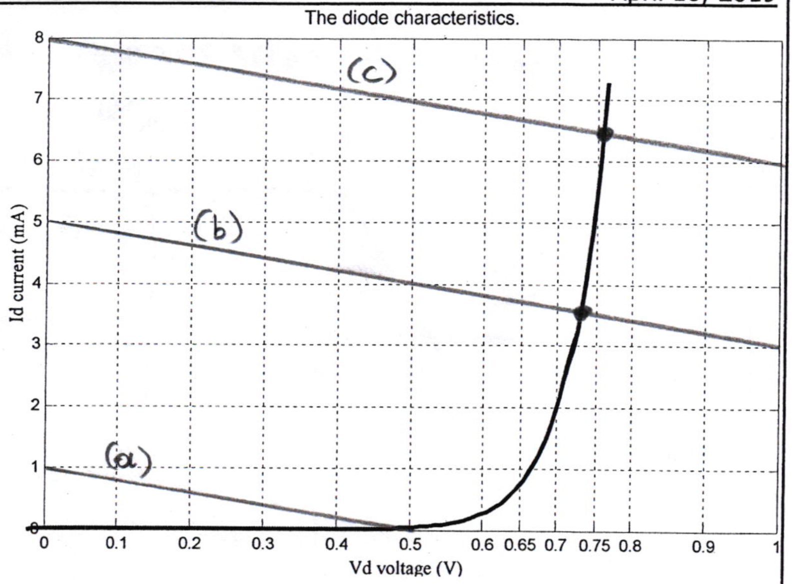
April 10, 2019

(15 pts.) **1)** The diode used in the following circuit has the characteristics shown by the graph. Draw the *load line* (V_d and I_d relationship from the circuit) on the graph and find V_d and I_d values (within ±5% range) for each of the following input voltages:

a) $V_{in} = -4$,
b) $V_{in} = 0$,
c) $V_{in} = 3$.



Hint: To find the load line write a KCL equation involving V_{in}, V_d and I_d from the circuit.



$$\frac{V_d - V_{in}}{1K} + \frac{V_d - 5}{1K} + I_D = 0 \quad \Rightarrow 2 \cdot V_d + 1K \cdot I_d = V_{in} + 5$$

The load line passes from the points: $V_d = 0$ & $I_d = \frac{V_{in}+5}{1K}$, and, $I_d = 0$ & $V_d = \frac{V_{in}+5}{2}$

These are:

	$V_d = 0$	$I_d = 0$
a)	$I_d = 1mA$	$V_d = 0.5\ V$
b)	$I_d = 5mA$	$V_d = 2.5\ V$
c)	$I_d = 8mA$	$V_d = 4\ V$

After we draw these lines on the figure we find that:

a) V_d = 0.5 V I_d = 0 mA	b) V_d = 0.73 V I_d = 3.5 mA	c) V_d = 0.76 V I_d = 6.5 mA

(10 pts.) **2)** For Question 1, find the required values assuming that the diode is (0.7 Volt) ideal.

The corner point $V_d = 0.7V$ & $I_d = 0mA$ is operational when

$$2 \cdot (0.7) + 1K \cdot 0 = V_{in} + 5 \Rightarrow V_{in} = -3.6V$$

Therefore: For $V_{in} \leq -3.6 \Rightarrow$ Diode is off

$V_d = \frac{V_{in}+5}{2}$, $I_d = 0$

For $V_{in} > -3.6 \Rightarrow$ Diode is on

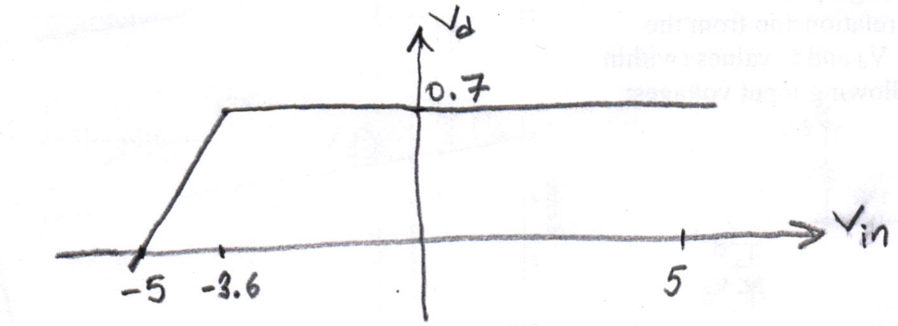
$V_d = 0.7$, $I_d = \frac{V_{in}+3.6}{1K}$

We, then obtain that:

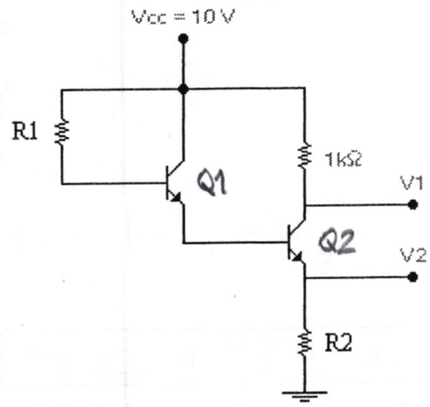
a) V_d = 0.5V I_d = 0 mA	b) V_d = 0.7 V I_d = 3.6mA	c) V_d = 0.7V I_d = 6.6mA

(15 pts.) **3)** For the circuit in Question 1, find and draw $V_d = f(V_{in})$ relationship assuming that the diode is (0.7 Volt) ideal. (When drawing the figure, use [-5 to 5] for the input voltage range.)

From the relationship obtained in Question 2 we find:



(25 pts) **4)** For the circuit given, we would like to obtain V1=5 Volts and V2=3 Volts. Transistors have β=20. Find the requried R1 and R2 values.



$$I_{c2} = \frac{V_{cc} - V_1}{1K} = 5\,mA$$

$$I_{e2} = \frac{\beta+1}{\beta} \cdot I_{c2} = 5.25\,mA$$

$$R_2 = \frac{V_2}{I_{e2}} = 571\,\Omega$$

$$I_{e1} = I_{b2} = \frac{I_{c2}}{\beta} = 0.25\,mA$$

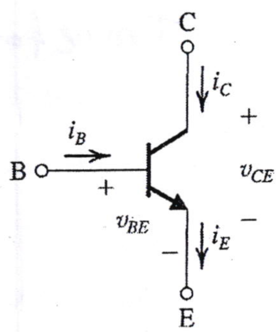
$$I_{b1} = \frac{I_{e1}}{\beta+1} = 11.9\,\mu A$$

$$V_{b1} = 0.7 + 0.7 + V_2 = 4.4\,V$$

$$R_1 = \frac{V_{cc} - V_{b1}}{I_{b1}} = 470\,K\Omega$$

Hint: npn transistor equations in active mode are:

$i_C = \beta i_B$ $\quad$ V_{BE}=0.7

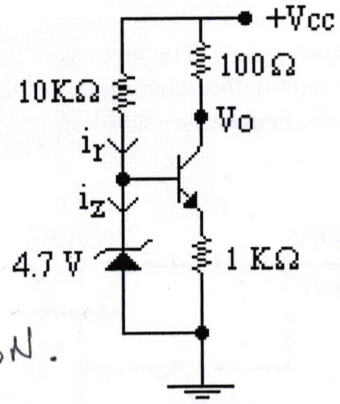


R1 = 470 KΩ

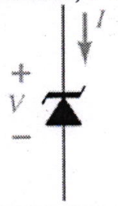
R2 = 571 Ω

5) For the circuit in the figure, the transistor has β=100 and $V_{CE(sat)}$= 0.2 V.
Find the currents i_r ,i_z ,i_c and the voltage Vo for these cases:

(15) a) Vcc= 10 V.



Hint:
A zener diode is '**on**' when I>0, and in this case, the voltage on it is kept constant at the rating voltage, V=V_Z.
It is '**off**' when V<V_Z, and in this case, the current on it is zero, I=0.



The zener diode will be ON.

$$i_r = \frac{10-4.7}{10K} = 0.53\ mA$$

$$i_e = \frac{4.7-0.7}{1K} = 4\ mA \Rightarrow i_c \cong 4mA\ ,\ i_b = 0.04\ mA$$

$$\Rightarrow i_z = i_r - i_b = 0.49\ mA$$

$$\Rightarrow V_o = V_{cc} - 100 \cdot i_c = 10 - 0.4 = 9.6\ V$$

$$V_{ce} = V_o - V_e = 9.6 - (4.7-0.7) = 5.6\ V > V_{CE(sat)}\ ✓$$

i_r = 0.53 mA	i_z = 0.49 mA	i_c = 4 mA	Vo = 9.6 V

(15) b) Vcc= 4 V.

The zener diode will be OFF. $\Rightarrow i_z = 0\ ,\ i_r = i_b$

$$V_{cc} = 10K \cdot i_b + 0.7 + 1K \cdot (\beta+1) \cdot i_b$$

$$4 = 10K \cdot i_b + 0.7 + 101K \cdot i_b \Rightarrow i_b = 29.7\ \mu A$$

$$\Rightarrow i_c = \beta \cdot i_b = 2.97\ mA$$

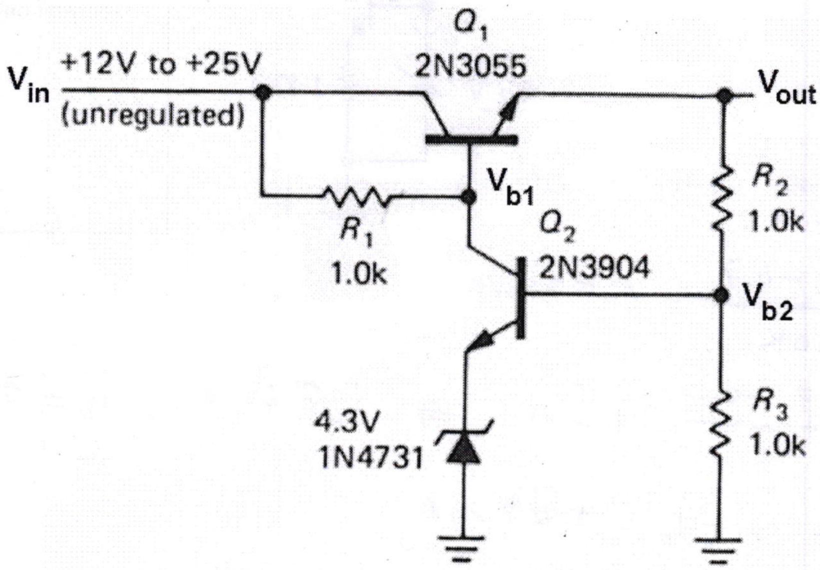
$$\Rightarrow V_o = V_{cc} - 100 \cdot i_c = 3.7\ V$$

$$\Rightarrow V_e = 1K \cdot i_e \cong 3V$$

$$\Rightarrow V_{ce} = V_o - V_e \cong 0.7V > V_{CE(sat)}\ ✓$$

i_r = 29.7 μA	i_z = 0 mA	i_c = 2.97 mA	Vo = 3.7 V

(15 pts.) **6)** A voltage regulator circuit is shown below. The input voltage can be between 12V to 25 V. Assume the transistors operate in the active region, the zener diode is ON, and the base currents can be neglected in your calculations. Find $\mathbf{V_{b2}}$, $\mathbf{V_{out}}$ (when finding this, neglect I_{b2}), and $\mathbf{V_{b1}}$.



$V_{b2} = 4.3 + 0.7 = 5\text{ V}$

$V_{out} = \frac{V_{b2}}{1K} \cdot (1K + 1K) = 10V$

$V_{b1} = V_{out} + 0.7 = 10.7\text{ V}$