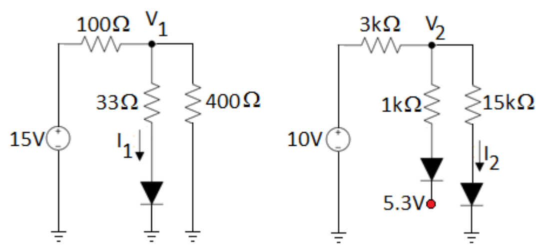
Electronics

Diodes, simple circuits

Problem 1.- In the circuits shown below, the diodes are silicon ones. Calculate the voltages and currents V_1, V_2, I_1 and I_2



Solution:

For the first circuit we can replace the voltage source and the 100 ohm and 400 ohm resistors by their Thevenin equivalent:

$$Vth = 15V \frac{400\Omega}{400\Omega + 100\Omega} = 12V$$

$$Rth = \frac{400\Omega \times 100\Omega}{400\Omega + 100\Omega} = 80\Omega$$

Then, this circuit would be in series with the diode and the 33 ohm resistor, hence the current will be:

$$I_1 = \frac{12V - 0.7V}{80\Omega + 33\Omega} = 100mA$$

And we can calculate V_1

$$V_1 = 0.7V + 33\Omega \times 100mA = 4.00V$$

For the second circuit we can start by assuming that the diode on the left is conducting (to be confirmed afterwards). This would mean that its anode would be at a voltage of 5.3V+0.7V=6V.

Then, the network formed by the 10V source, the 3kohm and 1kohm resistors, and the diode can be replaced by a Thevenin equivalent:

$$Vth = 6V \frac{3k\Omega}{1k\Omega + 3k\Omega} + 10V \frac{1k\Omega}{1k\Omega + 3k\Omega} = 7V$$

$$Rth = \frac{1k\Omega \times 3k\Omega}{3k\Omega + 1k\Omega} = 750\Omega$$

Then, this circuit will be in series with the diode on the right and the 15kohm resistor. The current will be:

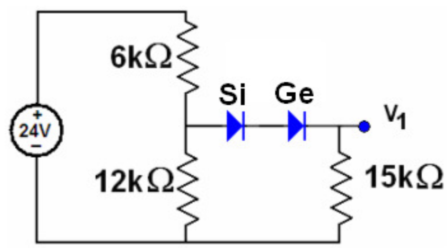
$$I_2 = \frac{7V - 0.7V}{15k\Omega + 750\Omega} = 400\mu A$$

And knowing the current we can calculate the voltage V_2

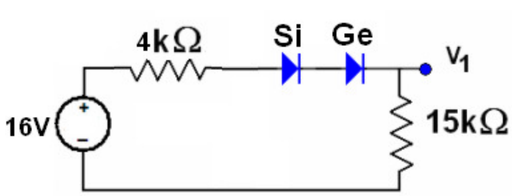
$$V_2 = 0.7V + 15k\Omega \times 400\mu A = 6.7V$$

This confirms that the first transistor is indeed in conduction.

Problem 2.- In the following circuit calculate the load voltage V_1. Use the second approximation for the diodes.



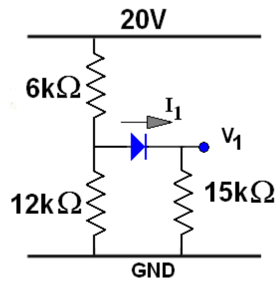
Solution: First, let us find a Thevenin equivalent of the circuit to the left:



Now the two diodes, which are forward biased, behave as 0.7V and 0.3 voltage sources, so they produce a drop of 1 volt. That means we have 15V shared by the 4kohm resistor and the load resistor, so:

$$V_1 = 15\left(\frac{15k\Omega}{15k\Omega + 4k\Omega}\right) = \mathbf{11.8\ V}$$

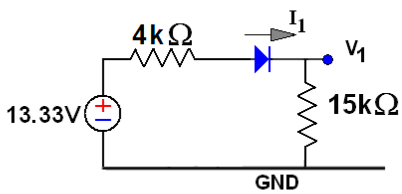
Problem 3.- For the circuit shown in the figure, find the values of the voltage and current indicated (V_1 and I_1) using the constant voltage drop model (2nd approximation, silicon diode).



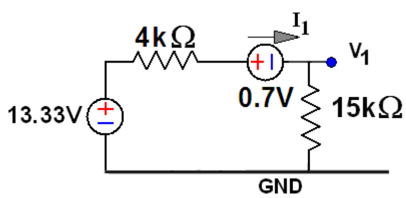
Solution: We can replace the 20V voltage source and the 6kohm and 12kohm resistors by their Thevenin equivalent:

$$V_{Thevenin} = 20V\left(\frac{12k\Omega}{12k\Omega + 6k\Omega}\right) = 13.33V \qquad R_{Thevenin} = \frac{1}{\frac{1}{12k\Omega} + \frac{1}{6k\Omega}} = 4k\Omega$$

So the circuit will look like this:



The diode is forward biased, so using the constant voltage drop model we will replace it with a 0.7V source:



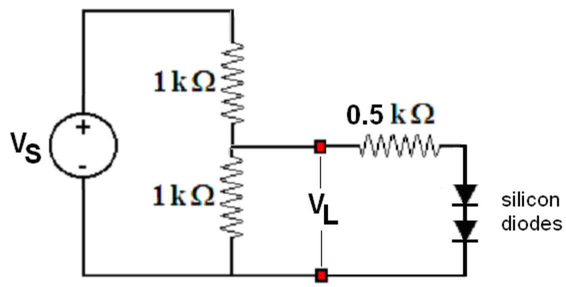
One loop equation will give us the current:

$$13.33V - 4k\Omega I_1 - 0.7V - 15k\Omega I_1 = 0 \rightarrow I_1 = \frac{13.33V - 0.7V}{4k\Omega + 15k\Omega} = \mathbf{0.66\ mA}$$

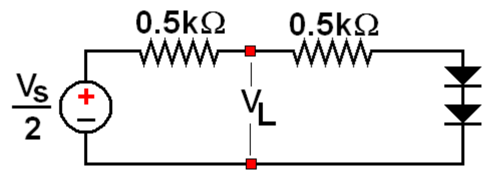
To get the voltage we multiply I_1 times 15k-ohm:

$$V_1 = 15k\Omega(0.66mA) = \mathbf{9.95\ V}$$

Problem 4.- In the following circuit calculate the load voltage V_L for source voltages V_S of 1V, 2V, 3V, 4V and 5V. Make a sketch of V_L as a function of V_S. Use the second approximation for the diodes.

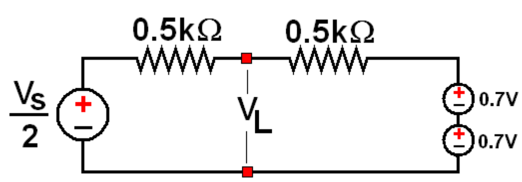


Solution: Notice that the voltage source together with the two 1-kohm resistors can be replaced by a Thevenin equivalent as shown below:



In the second approximation of the diodes they need 0.7V to start conducting electricity. So, for voltages V_S of 1V and 2V there won't be enough (there are two diodes so we need 1.4V and the Thevenin voltage is $V_S/2$).

In these two cases the diodes will behave like open circuits and so, the voltage of the load will be 0.5V and 1.0V, respectively.
For a voltage of the source greater than 2.8V the diodes will start conducting and will behave like voltage sources with values of 0.7V, as shown:

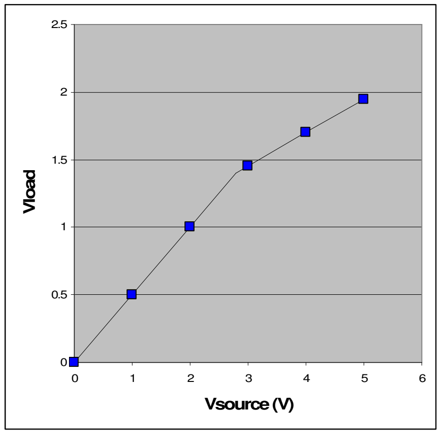


In this case the voltage of the load will be:

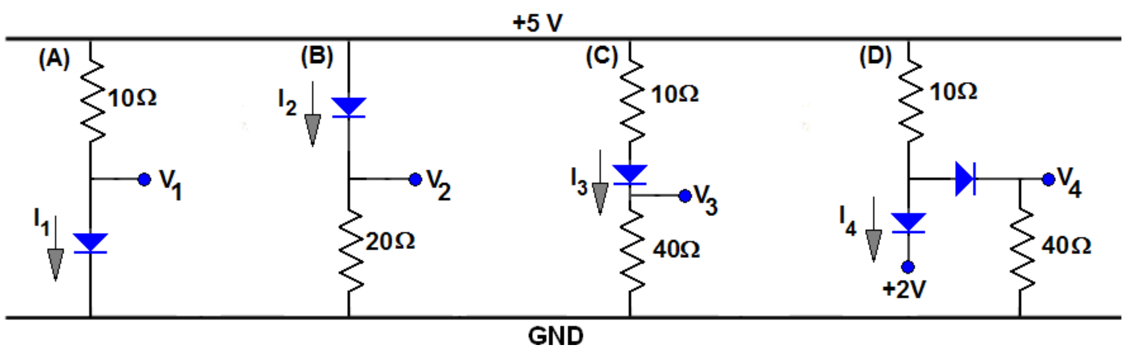
$$V_L = 1.4\text{V} + 0.5\text{k}\Omega\left(\frac{V_S/2 - 1.4\text{V}}{1\text{k}\Omega}\right) = V_S/4 + 0.7\text{V}$$

Summarizing:

V_S	1	2	3	4	5
V_L	0.5	1	1.45	1.7	1.95

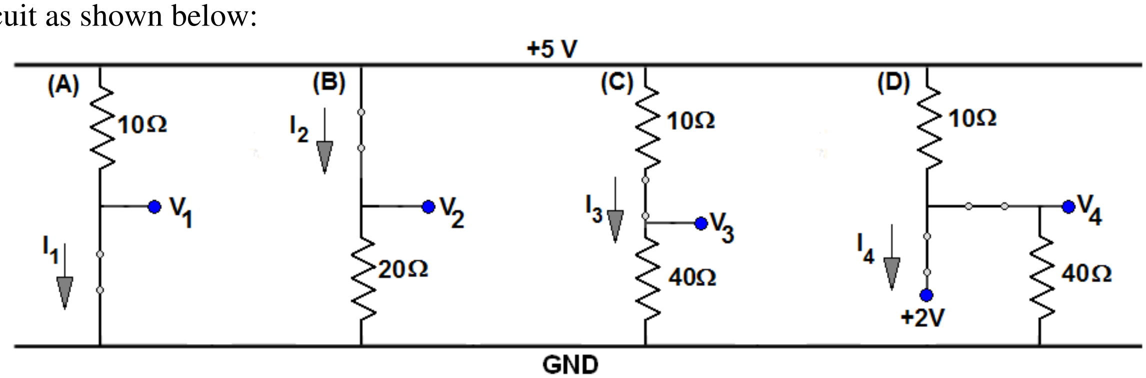


Problem 5.- For the circuits shown in the figure, find the values of the voltages and currents indicated using the ideal diode model (1st approximation) and the constant voltage drop model (2nd approximation, silicon diodes).



Solution:

Using the first approximation to the diode, every forward biased diode will behave like a short circuit as shown below:



So the voltages are:

$V_1=0$

$V_2=5V$

$$V_3=5V\left(\frac{40}{40+10}\right)=4V$$

$V_4=2V$

And the currents:

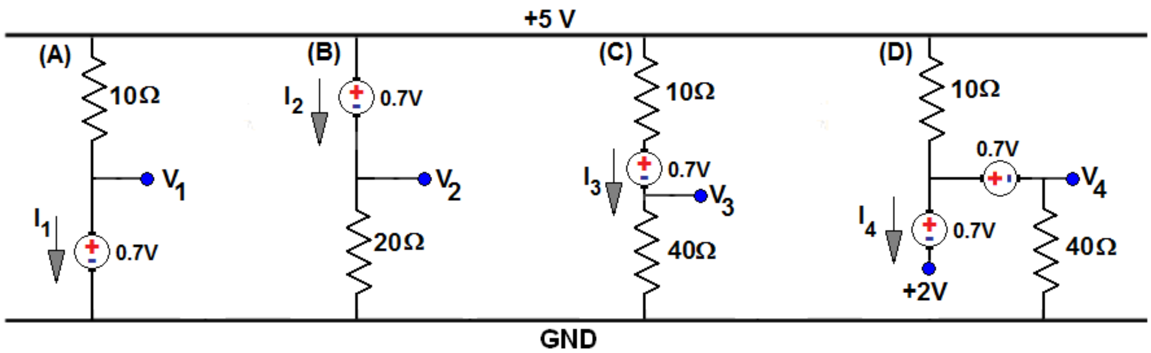
I_1=5V/10Ω=0.5A

I_2=5V/20Ω=0.25A

I_3=5V/50Ω=0.1A

I_4=$\left(\frac{5V-2V}{10\Omega}\right)-\left(\frac{2V}{40\Omega}\right)$=0.25A

Using the second approximation instead, we replace forward biased diodes with 0.7V-sources:



So the voltages are:

V_1=0.7V

V_2=5V-0.7V=4.3V

V_3= $(5V - 0.7V)\left(\frac{40}{40+10}\right) = 3.44V$

V_4=2V

And the currents:

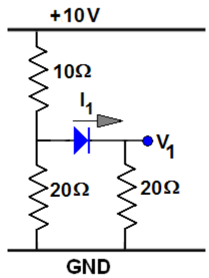
I_1=4.3V/10Ω=0.43A

I_2=4.3V/20Ω=0.215A

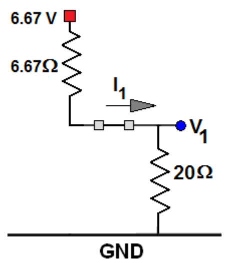
I_3=4.3V/50Ω=0.086A

I_4=$\left(\frac{5V-2.7V}{10\Omega}\right)-\left(\frac{2V}{40\Omega}\right)$=0.18A

Problem 6.- For the circuit shown in the figure, find the values of the voltage and current indicated using the ideal diode model (1st approximation) and the constant voltage drop model (2nd approximation, silicon diode).



Solution: Using the first approximation we replace the diode by a short circuit. The circuit to the left of the diode can be replaced by a Thevenin equivalent:

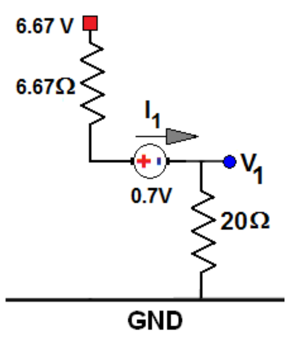


So, in this approximation:

$$V_1 = 6.67\text{V}\frac{20}{20+6.67} = 5.0\text{ V}$$

$$I_1 = \frac{6.67V}{26.67\Omega} = 0.25\text{A}$$

In the second approximation, the circuit looks as follows:



This time:

$$V_1 = (6.67\text{V} - 0.7)\frac{20}{20+6.67} = 4.45\text{ V}$$

$$I_1 = \frac{5.93V}{26.67\Omega} = 0.22\text{A}$$