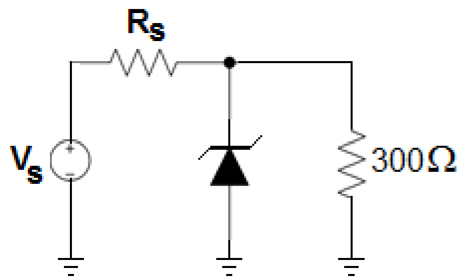
Electronics

Zener diode

Problem 1.- A typical voltage regulating circuit based on a Zener diode is shown in the figure with V_Z=5.1V. The source gives a voltage in the range between 8.5V and 11.5V and the diode can only withstand 240mW. Calculate the range of values that R_s can have to maintain the load at 5.1V and do not exceed the maximum power in the diode.



Solution: To maintain the voltage stable in the load it should be 5.1V even with the minimum source voltage. We can find the maximum R_s by assuming that the current in the diode is zero in this condition, so:

$$R_s(\max) = 300\Omega \frac{8.5V - 5.1V}{5.1V} = 200\Omega$$

The condition of maximum power implies that the maximum current in the diode is:

$$I_D(\max) = \frac{P}{V_D} = \frac{240mW}{5.1V} = 47.1mA$$

But, the current in the load resistance is always

$$I_L = \frac{5.1V}{300\Omega} = 17.0mA$$

Then, the current in the resistance R_s must not exceed

47.1mA+17mA=64.1mA

Given this current we can calculate the minimum value of R_s in the extreme case when the source voltage is 11.5V

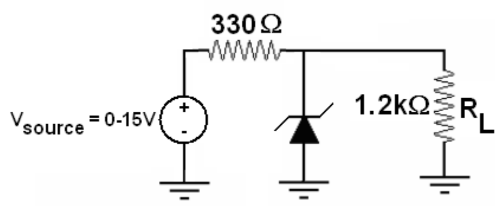
$$R_s(\min) = \frac{11.5V - 5.1V}{64.1mA} = 100\Omega$$

In conclusion, the resistance R_s must be between 100ohm and 200ohm

Problem 2.- The Zener diode shown in the figure has a reverse breakdown voltage $V_Z = 6.8$ V. Calculate:

a) The minimum source voltage so it starts regulating the load voltage

b) The maximum current through the diode



Solution: The minimum source voltage for regulation to start can be calculated assuming the current through the diode is zero, but with a voltage equal to its breakdown. Then, the source voltage can be calculated using the voltage divider equation:

$$6.8V = V_{source}\left(\frac{1.2k\Omega}{1.2k\Omega + 330\Omega}\right) \rightarrow V_{source} = 6.8V\left(\frac{1.2k\Omega + 330\Omega}{1.2k\Omega}\right) = \mathbf{8.67\ V}$$

The maximum current can be calculated assuming source voltage is 15 volts, the current through the load resistor is:

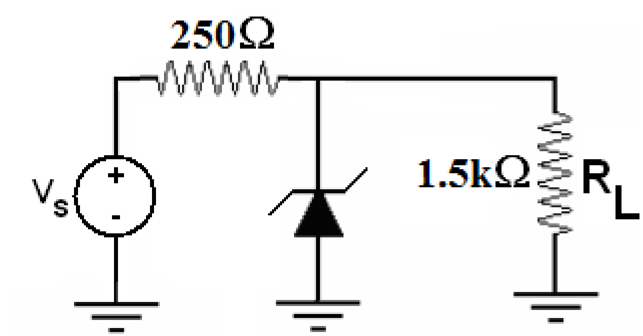
$$I_{source} = \frac{6.8V}{1.2k\Omega} = 5.66\text{mA}$$

And the current through the 330ohm resistor is:

$$I_{330\Omega} = \frac{15V - 6.8V}{330\Omega} = 24.84\text{mA}$$

So the current though the diode is: 24.84mA-5.66mA=**19.2mA**

Problem 3.- If the diode in the circuit shown has a Zener voltage of 4.8V, what is the minimum source voltage Vs so the load voltage in R_L is regulated?



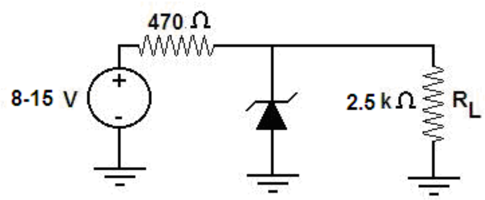
Solution: Consider that we increase the source voltage from zero. If the voltage in the node that connects the two resistances together is less than 4.8V, there will not be any current through the diode and the network will behave as a simple voltage divider. In this case, the voltage in the load will be

$$V_L = \frac{1.5k\Omega}{1.5k\Omega + 250\Omega} V_S$$

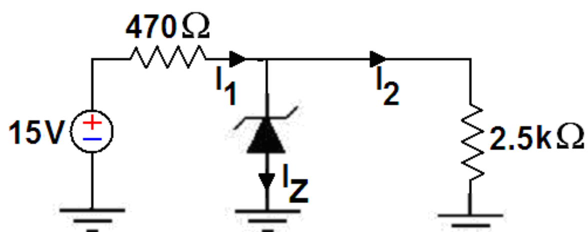
When this voltage reaches 4.8V the diode will start conducing current and the voltage in the load will stay at 4.8V, fulfilling its function as a regulator. This threshold will occur when

$$4.8V = \frac{1.5k\Omega}{1.5k\Omega + 250\Omega} V_S \rightarrow V_S = \frac{1.5k\Omega + 250\Omega}{1.5k\Omega} 4.8V = \mathbf{5.6V}$$

Problem 4.- The Zener diode shown has V_Z = 7.2 V. Calculate the maximum and minimum current through the diode.



Solution: To get the maximum current through the diode, let assume the maximum voltage across the source is present (15V). Then the circuit would look like this:



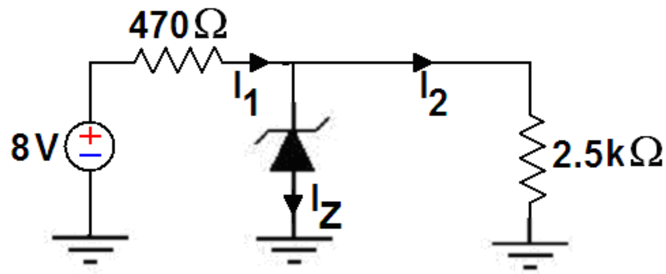
If the Zener voltage is 7.2V, the current I_2 will be: $I_2 = \frac{7.2V}{2500\Omega} = 2.88mA$. We can also calculate the current through the 470-ohm resistor: $I_1 = \frac{15V - 7.2V}{470\Omega} = 16.60mA$

The difference between these two currents is the current through the diode:

$$I_Z = 16.60mA - 2.88mA = \mathbf{13.72\ mA}$$

This is the maximum current.

Let's see what happens when the source is at its minimum voltage:



If the Zener voltage is 7.2V, the current I_2 will be: $I_2 = \frac{7.2V}{2200\Omega} = 2.88mA$, like before, and the current through the 470-ohm resistor would be: $I_1 = \frac{8V - 7.2V}{470\Omega} = 1.7mA$

Since I_2 is larger than I_1, the diode does not conduct in this case, so its actual current is **zero** and it is not regulating the load voltage. The current through the load resistor is not 2.88mA but:

$$I_1 = I_2 = \frac{8V}{470\Omega + 2.5k\Omega} = 2.69mA$$