Physics II

Resistance

$V = IR$ Ohm's law

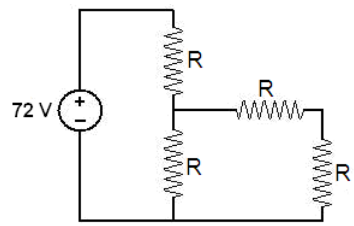
$R_{equivalent} = R_1 + R_2$ Equivalent for two resistors in series

$R_{equivalent} = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2}}$ Equivalent for two resistors in parallel

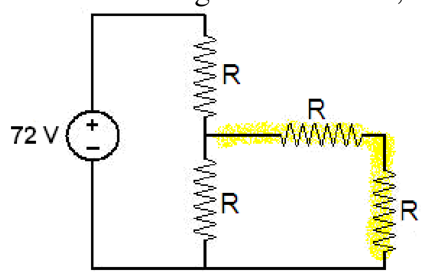
$\text{Power} = VI$ Power in general for electric devices

$\text{Power} = RI^2 = \dfrac{V^2}{R}$ Power in case of resistors

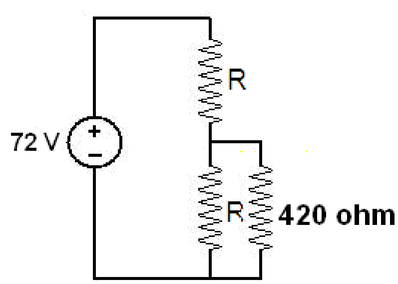
Problem 1.- Find the current passing through the voltage source if all the resistors shown in the circuit have the value R = 210 Ω.



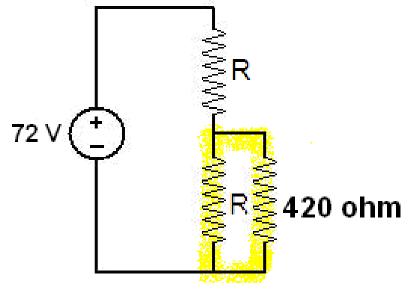
Solution: Notice that the two resistors on the right are in series,



so they can be replaced by an equivalent equal to
$R_{equivalent} = R + R = 420 \text{ohm}:$

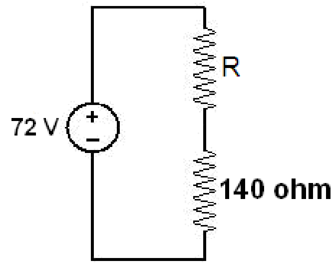


Now, the two resistors at the bottom are in parallel,



so the equivalent is:

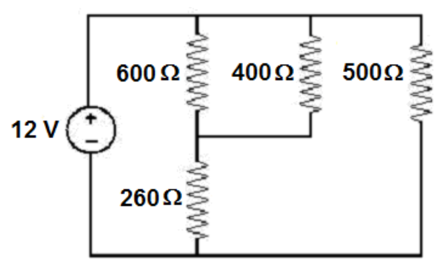
$$R_{equivalent} = \frac{1}{\frac{1}{R}+\frac{1}{420}} = \frac{1}{\frac{1}{210}+\frac{1}{420}} = 140\text{ohm}$$



Now, the last two resistors are in series, which means that the equivalent is 210+140=350 ohms and the current will be:

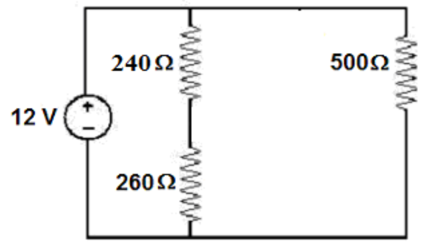
$$I = \frac{72}{350} = \mathbf{0.206\ A}$$

Problem 2.- Calculate the equivalent resistance from the point of view of the 12V voltage source.



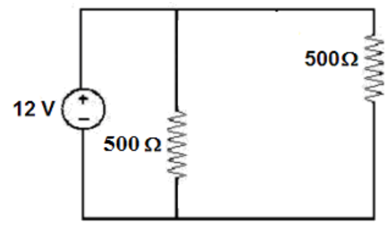
Solution: Notice that the 600-ohm resistor and the 400-ohm one are in parallel (they share the same voltage), so they can be replaced by an equivalent of:

$$R_{equivalent} = \frac{1}{\frac{1}{600}+\frac{1}{400}} = 240\Omega$$



Then this resistor is in series with the 260-ohm one, so they are equivalent to

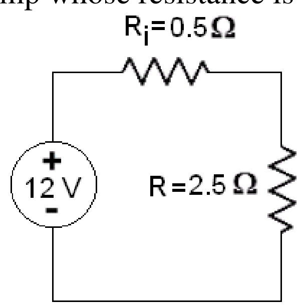
$$R_{equivalent} = 240 + 260 = 500\Omega$$



Finally, this is in parallel with the other 500-ohm resistor, so together they give:

$$R_{equivalent} = \frac{1}{\frac{1}{500} + \frac{1}{500}} = \mathbf{250\ \Omega}$$

Problem 3.- A model of a battery is represented by an ideal 12-V voltage source in series with an internal resistance of 0.5Ω
Calculate the power delivered to a lamp whose resistance is 2.5 Ω



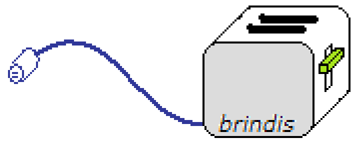
Solution: The current is: $I = \frac{V}{R} = \frac{12}{2.5 + 0.5} = 4A$
The power dissipated by the 2.5-ohm resistor is

$$P = I^2 R = 4^2 \times 2.5 = \mathbf{40\ W}$$

Problem 4.- A toaster draws 8.0A when plugged into a 115V line.

(a) What is the resistance of the toaster?

(b) How much charge passes through the resistance in 3 minutes (for this calculation assume that the current is DC)



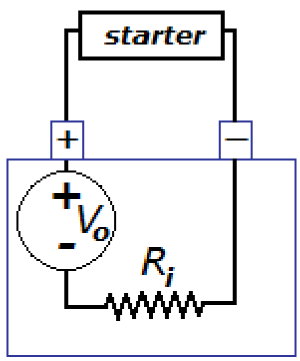
Solution: We can find the resistance using ohm's law:

$$R = \frac{V}{I} = \frac{115}{8} = \mathbf{14.4\ \Omega}$$

To find the charge we know the time: t=180 seconds and I=8A, so:

Q=180×8=**1,440 C**

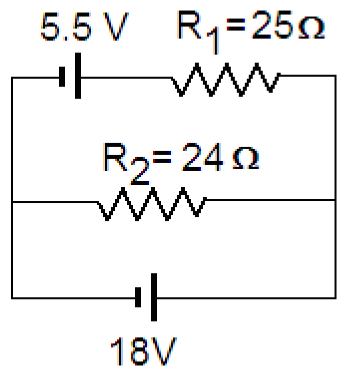
Problem 5.- What is the internal resistance of a 12 volt car battery if the terminal voltage is 9.5volts when the starter draws 125 amps?



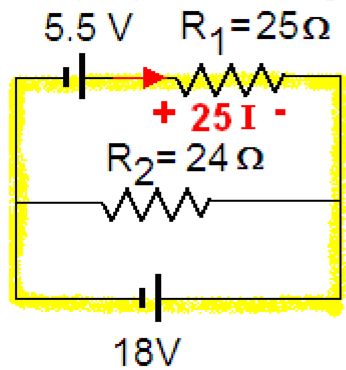
Solution: The internal ideal voltage source is 12 volts, but the terminal voltage is only 9.5 volts because there is a drop in voltage in the internal resistance (R_i) 12-9.5=2.5 volts.

Since we also know the current I=125 amps then $R_i = \frac{V}{I} = \frac{2.5V}{125A} = \mathbf{0.02\ \Omega}$

Problem 6.- Determine the magnitude and direction (to the left or to the right) of the current through R_1.



Solution: To solve the problem we are going to follow the path highlighted:



We can assume, initially that the current goes from left to right as shown above with the red arrow. Then there will be a drop of 25I across the 25-ohm resistor.
The Kirchhoff equation is then:

$$5.5 - 25I - 18 = 0 \rightarrow I = \frac{18-5.5}{-25} = \mathbf{-0.5\ A}$$

The minus sign tells us that the current goes from right to left.

Problem 7.- A 12V-battery has an internal resistance of 0.05Ω Calculate the power delivered to a starter motor that can be modeled as a resistance of 0.07Ω

Solution: To calculate the power we can use the equation $\text{Power} = RI^2$,
Where we already know the value of R=0.07 ohm.

All we need is the current. To find it, notice that the internal resistance and the external one are in series, so they together are equivalent to 0.05+0.07=0.12 ohm and then we can use ohm's law to solve the problem:

$$V = IR \rightarrow I = \frac{12V}{0.12\Omega} = 100A$$

So, the power is: $\text{Power} = 0.07 \times 100^2 =$ **700 watts.**

Problem 8.- A headlamp in a car is rated 75W at 12V.
Calculate:

(a) its resistance and
(b) the current when working at the nominal voltage of 12V.

Solution: Since $\text{Power} = \dfrac{V^2}{R}$,

$$\text{Then } R = \frac{V^2}{\text{Power}} = \frac{12^2}{75} = \mathbf{1.9\ \Omega}$$

$$\text{And: } I = \frac{V}{R} = \frac{12}{1.9} = \mathbf{6.3\ A}$$

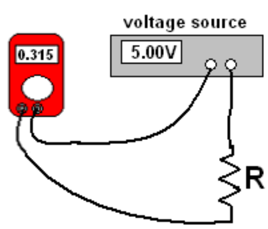
Problem 9.- Is it true that a good ammeter should have very high resistance?

Solution: A good ammeter should have very **low** resistance. The instruments we use in laboratories, for example, have typically only a fraction of an ohm.

Problem 9a.- Is it true that a good voltmeter should have very high resistance?

Solution: Voltmeters have **high** resistance. The higher the better, because then they do not perturb the circuit they are measuring too much. Typically, they are ~10Mohm.

Problem 10.- The fuse in a multimeter is rated 315mA. Calculate the minimum resistance that we need to connect in series with a voltage source of 5 volts if we don't want to blow the fuse. Consider the internal resistance of the instrument to be 1.5 Ω when used as an ammeter.



Solution: The current should not exceed 0.315 amps and the total resistance is R+1.5ohms so:

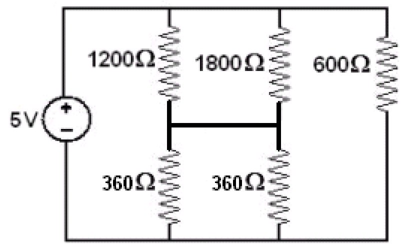
$$0.315A = \frac{5V}{R+1.5\Omega} \rightarrow R+1.5\Omega = \frac{5V}{0.315A} = 15.87\Omega \rightarrow R = 14.37\Omega$$

To be safe it better be more than **15Ω**

Problem 11.- Specify units used for resistance, electric field and current.

Solution: Resistance is measured in Ω, electric field is measured in N/C or V/m and current is measured in amps (A)

Problem 12.- Calculate the equivalent resistance from the point of view of the 5V voltage source.



Solution: Notice that the 1200Ω resistor is in parallel to the 1800Ω resistor, so together are equivalent to

$$R = \frac{1}{\frac{1}{1800} + \frac{1}{1200}} = 720\Omega$$

Notice also, that the 360Ω resistors are in parallel, which is equivalent to a 180Ω resistor.

Then the 720Ω resistor is in series with the 180Ω resistor, so together they are equivalent to 720Ω + 180Ω = 900Ω

Finally, this 900Ω resistor is in parallel with the 600Ω, so they are equivalent to:

$$R_{equivalent} = \frac{1}{\frac{1}{600} + \frac{1}{900}} = \mathbf{360\Omega}$$