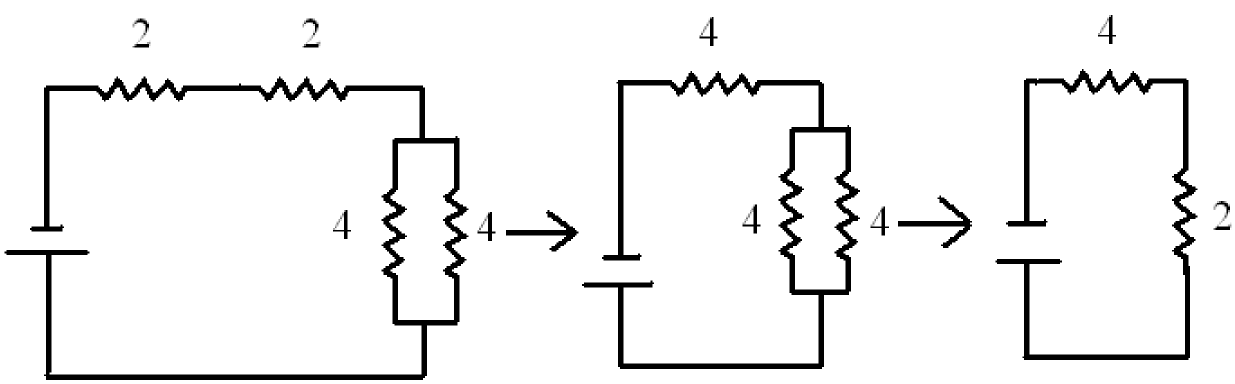
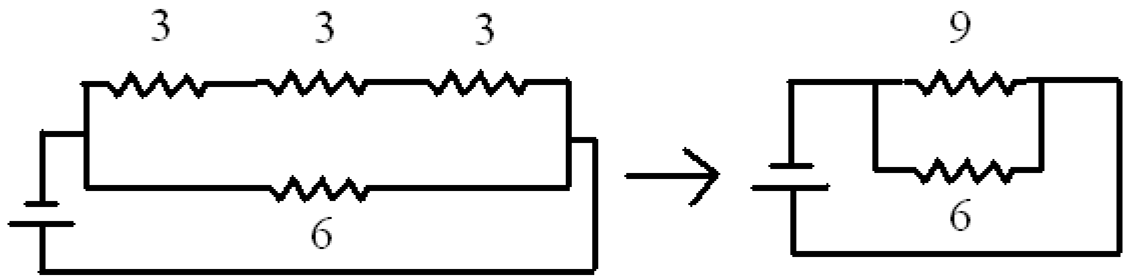
Complex Circuits, Effective Resistance, and Electrical Power: Physics 2

This lesson is to teach how to add resistors in series and parallel in order to determine an effective resistance. Why this resistance is important is then discussed. Finally, a demonstration was shown to show about power in series vs. parallel circuits.

- You've learned Ohm's Law: V = IR, now what do you do when you have more than 1 resistor in a circuit?
- You've also learned that resistors in series add as $R_{tot} = R_1+R_2+\ldots$
- In addition resistors in parallel add as $1/R_{tot} = 1/R_1+1/R_2+\ldots$
- But what do you do if you have a complex circuit with many different groups of resistors in both series and parallel?
- You want to find the effective resistance
  - Because that will tell you the current coming out of the battery
- How do you do this?
  - Start with a small simple chunk that you know how to work with that's either all series or all parallel.
  - Then keep redrawing circuit at each step as it simplifies.
  - This is easy
  - Do following examples: (all values in examples are in Ohms)



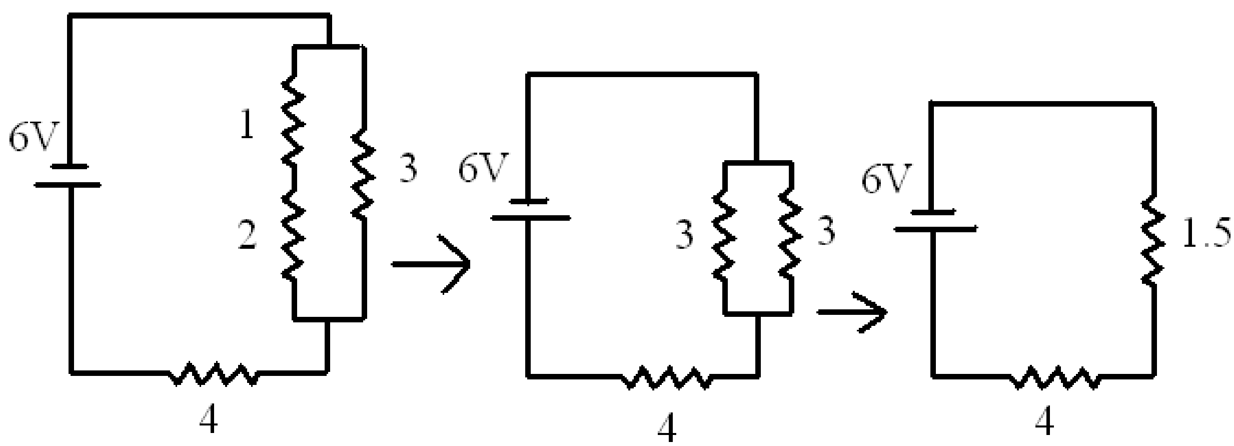
Reff = 6



Reff = 2.4

Practice Problem:

- Find the effective Resistance of the following circuit. Then find what the current is coming out of the battery.



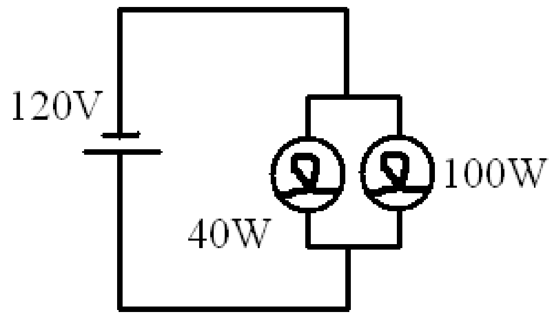
Reff = 5.5   I = 1.1 A

Electical Power: Series vs. Parallel

- Show demo of two lightbulbs: one 100 W and other 40 W. At first have them wired in parallel. This is how the students are used to seeing them wired in their house. They know that the 100W bulb is brighter than the 40 W bulb.
- Now tell them that you're going to wire them in series. Ask them what they think is going to happen. They'll usually say that the 100 will still be brighter.
- Turn them on: the 40W bulb is ridiculously brighter than the 100W bulb.
- Note: works best with clear bulbs, otherwise you can't see the 100W bulb light up at all.
- Ask them why that happened? They'll say they have no idea
- Tell them they already have all they need to know to figure it out except for a couple equations
- Electrical Power in a circuits is given by $P = IV$, or in the case of resistors such as lightbulbs, $P = I^2R$.
- Now, they can figure out what happened using the Power equations and the effective resistance that they just learned.

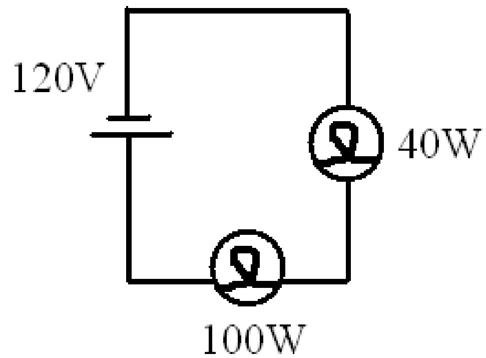
Here are what the two circuits look like:

Parallel



Voltage same across bulbs

Series



current constant
around circuit

Parallel Solution:

Known: $P = IV$ $\qquad P = I^2R$ $\qquad V = IR$

100W bulb:

$P_{100} = I_{100}V_{100}$

$I_{100} = 100W/120V$

$I_{100} = .833$ A

$V_{100} = I_{100}R_{100}$

$R_{100} = V_{100}/I_{100}$

$R_{100} = 120V/.833A$

$R_{100} = 144\ \Omega$

40W bulb:

$P_{40} = I_{40}V_{40}$

$I_{40} = 40W/120V$

$I_{40} = .33$ A

$V_{40} = I_{40}R_{40}$

$R_{40} = V_{40}/I_{40}$

$R_{40} = 120V/.33A$

$R_{40} = 360\ \Omega$

Now, find R_{eff} : $1/144 + 1/360 = 1/R_{eff}$

$R_{eff} = 102.9\Omega$

which means that I coming out of the battery is

$I = V/R_{eff} = 120V/102.9\Omega$ $\qquad I = 1.16$ A

Notice that current doesn’t split evenly between bulbs.

Now Series Solution:

Again, Known: $P = IV$ $P = I^2R$ $V = IR$
Now, we also know the resistance in each bulb.

So first find the $R_{eff} = R_{100} + R_{40}$
$R_{eff} = 144\Omega + 360\Omega = 504\Omega$

Therefore, you can find the current going through the circuit:
$V = IR$
$I = V/R$
$I_{tot} = 120V/504\Omega$
$I_{tot} = .24\ A$

Now, find the power in each light bulb:

$P_{40} = I^2R_{40}$
$P_{40} = .24^2*360\Omega = 20.7W$

$P_{100} = I^2R_{100}$
$P_{100} = .24^2*144\Omega = 8.3W$

WOW, the power in the 100W bulb is much less than the 40W bulb, that’s why it’s not as bright!

That’s pretty cool, huh, that you were able to solve this whole problem knowing what you know, which you didn’t think was much at first, but is actually very powerful!