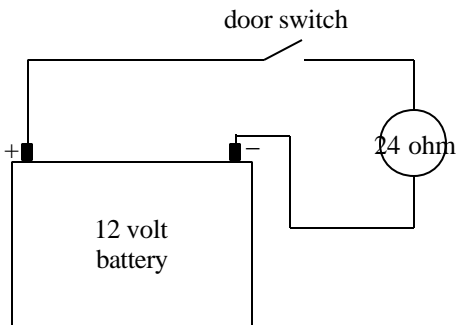


# Ohm's Law

Voltage causes current to flow in a closed circuit, and the components of the circuit offer resistance, or opposition to this flow of current. George Simon Ohm first determined this relationship between Voltage (**E**), Current (**I**), and Resistance (**R**), in the early 1800s. Ohm's Law is a statement of this relationship, and a valuable mathematical equation has been developed from his work. The equation states that in a given circuit; voltage, (expressed in volts), equals current in amps times resistance in ohms.  **$E = IR$** .

**Example;** If the dome light in a car has a resistance of 24 ohms, how many amps will flow when the switch is closed?

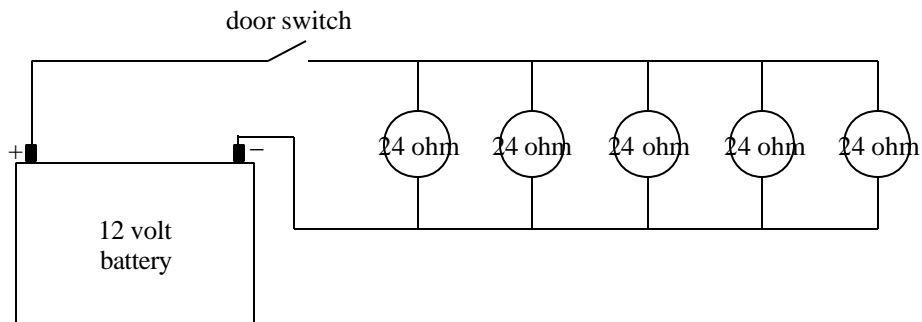


The answer is .5, or 1/2 amp. 12 volts (**E**) = .5 amps (**I**) times 24 ohms (**R**).

The rating of most circuit components, (light bulbs, heating elements, etc.), is expressed in watts, the unit of power, (**P**). The formula for power is an extension of the original equation, and it is even more valuable to the electrician.  **$P = IE$** . The power consumed in the above circuit can now be calculated as 6 watts. 6 watts (**P**) = .5 amps (**I**) times 12 volts (**E**). The lamp in this circuit is rated as a 6 watt lamp. This rating presumes that the applied voltage is 12 volts.

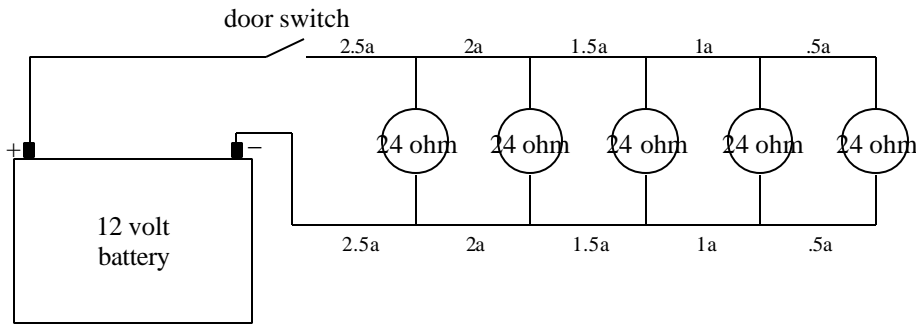
## Questions ;

- 1) If the same lamp was connected to a 24 volt battery, what would happen?
- 2) What would happen if a lamp with a 6 ohm resistance was used?
- 3) Four more lamps are connected in the circuit . . . what has happened to the current?

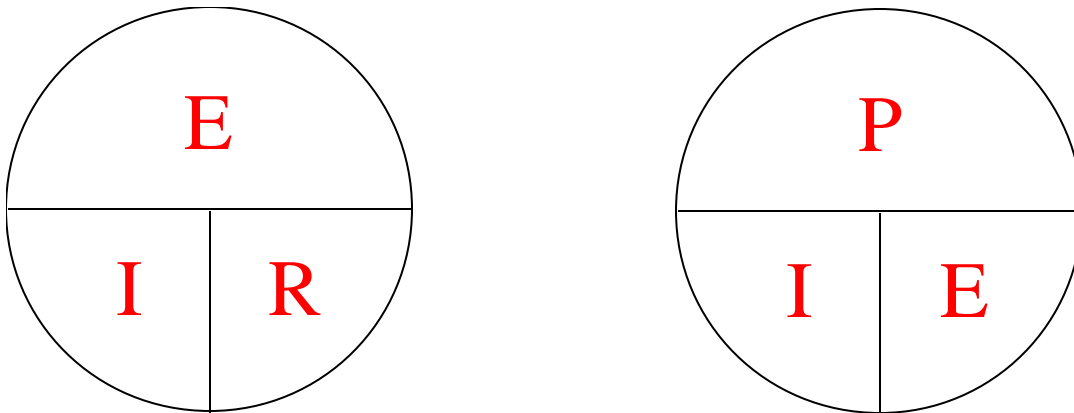


**Answers ;**

- 1) One amp would flow, and 12 watts of power would be consumed in the circuit. However, the lamp was designed to operate at 12 volts, and applying twice that voltage would burn out the filament.
- 2) The lower resistance of the new lamp would allow 2 amps to flow and the power consumed would be 24 watts. The light output would be 4 times that of the original lamp!
- 3) This is an example of a parallel circuit, and the current would increase in the circuit conductors as the loads each add the same current to the overall circuit.



Now look at this circuit and recognize that there are five - 24 ohm lamps in the circuit. This does not mean that there is a total of 120 ohms of resistance in the circuit! Change the lamp rating to watts, then add them up for total power consumed, (6 watts times 5, or 30 watts total). To find total resistance (**R**), divide voltage (**E**) by current (**I**),  $R = E/I$   $12/2.5 = 4.8$ . Adding more loads in parallel to an existing circuit lowers total resistance, increases current, and consumes more power.



Ohm's Law is a statement of proportion among the electrical characteristics of a circuit. The mathematical equations are used to determine sizes of conductors, and fuses or breakers needed in the circuits that feed different loads.

## Ohm's Law and Alternating Current

When Ohm's law is applied to AC circuits, total opposition to current flow needs to be considered. Alternating Current circuits have characteristics that oppose current in addition to the inherent resistance of the circuit components. These AC circuit elements are called induction and capacitance, and are covered in the section on AC Theory. The effect of these elements becomes significant in circuits containing motors, transformers, computer equipment, and extremely long circuit conductors or 'feeders'. In the following examples, the effect is unimportant.

Ohm's Law can be used to determine whether more lights can be added to an existing circuit. Let's say a lighting circuit in a barn feeds 12 light fixtures on a 20 amp circuit. Each fixture has a 100 watt lamp, for a total of 1200watts. The voltage is 120 volts, so the current is 10 amps. You might think that you could add 12 more fixtures, but the National Electrical Code requires that circuit loads be limited to not more than 80% of the rating of the breaker. Therefore, not more than seven fixtures could be added to the circuit safely. Could you put 150 watt lamps in the original 12 fixtures? Yes, that would increase the load to 1800 watts, or 15 amps.

By now you've done the math and you know that a 20 amp, 120 volt circuit can support a maximum of 2400 watts. Microwave ovens draw from 600 to 1200 watts, coffee pots run from 450 to 800 watts, and toasters draw from 500 to 1000 watts. Add a refrigerator compressor that draws 1000 watts and it's easy to see why the National Electrical Code requires at least two - 20 amp kitchen appliance circuits.

One more exercise and I'll leave you to do your own circuit calculations;

A 1500 watt baseboard heater is designed for operation at 240 volts, (typical, single phase residential service). A commercial building has a three phase, 120/208 service, (see article on transformer theory). What will happen when a 1500 watt baseboard heater is connected to a 208 volt source? The equation  $P = IE$  will give us the current flow in the original 240 volt circuit. 1500 watt (**P**) divided by 240 volt (**E**) equals 6.25 amps (**I**). Now use  $E = IR$  to find the resistance. 240 volt (**E**) divided by 6.25 amps (**I**) equals 38.4 ohms (**R**). **The resistance of the heating element stays constant and cannot be changed.** Now apply a voltage source of 208 volts. 208 volt (**E**) divided by 38.4 ohms (**R**) equals 5.4 amps (**I**). Notice that less voltage applied to the same resistance results in less current. **With less voltage and less current, the same baseboard heater is going to consume less power and produce less heat.** 208 volt (**E**) times 5.4 amps (**I**) equals 1123 watts (**P**). If you install baseboard heaters in a commercial building with a 120/208 volt service, you must take these calculations into consideration. Heat loss calculations require 12 watts per square feet in the climate of the Pacific Northwest. A 200 square foot office might need 2400 watts of heat. You might think that two 1500 watt heaters would be plenty, when the reality is that the 2246 watts actually produced by these heaters will be marginal. You won't find this information on the packaging from heater manufacturers, and I've yet to meet a sales representative that understands these principles of Ohm's Law.

**Be smart . . . be thorough . . . and provide your customer with an adequate and appropriate product!**