Watt's Law

OBJECTIVES

- Define Watt's Law
- Discuss an Ohm's Law Chart with Watt's Law included
- Calculate It, Rt, Vt, and Pt using the New Ohm's Law Chart

INTRODUCTION

In this lesson work will be defined and the unit of measure given. Power will also be defined and how it relates to the other electrical parameters discussed so far, Voltage, Current, and Resistance. This lesson will add Watt's Law to the Ohm's Law chart from a prior lesson and will show how to use this New Ohm's Law chart.

Work (Energy)

Work is said to be done (or energy used) anytime a force causes any kind of motion. A force that does not cause motion is not doing work. How can work be done in an electrical circuit that looks like it is not moving? Well, if you could see individual electrons in a conductor you would be able to see the electrical pressure (Voltage) moving the individual Electrons (Current). The English unit of measure for work is the foot-pound, but usually in the study of electricity the metric unit of measure called the joule is used. A joule equals about 3/4 of a foot-pound.

Power

Power is the rate at which work is being done. Another way of saying this is Power is the rate at which energy is used. The unit of measure for electrical power is called the Watt, named after James Watt whose improvements to the steam engine is said to have helped lead the way for the Industrial Revolution. James Watt also introduced the concept of horsepower. (746 Watts = 1 Horsepower)

Power is measured in Watts and is symbolized by the letter P. Power (Watts) equals Energy (joules) divided by time (seconds). (See Figure 1)

$$\boxed{P = \frac{W}{t}} = \frac{\text{energy}}{\text{time}} = \frac{1 \text{ joule}}{1 \text{ second}} = 1 \text{ Watt or } 1 \text{ W}$$

Figure 1

If Figure 1, the confusing thing is that W is used for two different variables. It is what it is, so lets discuss it and move on.

The W in the shaded equation stand for energy (Work) and in this equation energy is expressed as joules (J). The P in the shaded equation stands for Power and in this equation power is expressed as Watts (W). The t in the shaded equation stands for time and in this equation time is expressed as seconds (s). The second W stands for the amount of power or Watts the equation equals, 1 Watt or 1 W. So if we are talking about power in general we use P, and if we are talking a value for power we use Watts or W.

Power is how much energy is used over time, so it can be said power used over time is how much energy is consumed. So if we multiply power and time together we get energy. (See Figure 2)

$$t \cdot \boxed{P = \frac{W}{\cancel{t}}} \cdot \cancel{t} \quad \text{So,} \quad W = P\,t$$

Figure 2

In Figure 2, if the shaded equation from Figure 1 is multiplied by time (t) on both sides, time can be canceled from the right side of the equation leaving just Energy (W). We can then see that Energy (W) equals Power (P) multiplied by time (t). This explains the unit of measure used to charge consumers for the energy used in their homes. The kilowatt-hour (kWh). The “electric bill” charges for how many kilowatt-hours used or how much energy used. A 100 Watt light bulb turned on for 10 hours uses 1 kWh of energy.

Power in an Electric Circuit

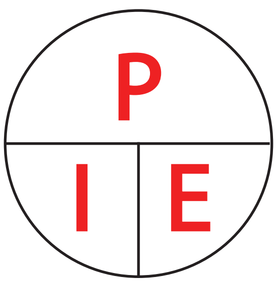
When one Volt (electrical pressure) is used to move one Amp (flow = 1 Coulomb per second) through a circuit, the work accomplished is equal to one Watt of power. (See Figure 3)

$$\mathbf{P = V \bullet I}$$

Watt’s Law

Figure 3

Watt’s Law can be put into a chart the same as Ohm’s Law was. (See Figure 4)



Remember: Power is symbolized by P or W
Current is symbolized by I or A
Voltage is symbolized by E or V

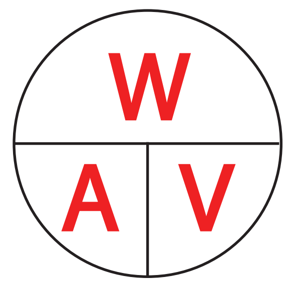
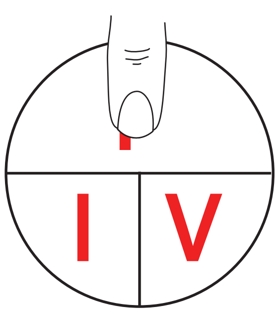


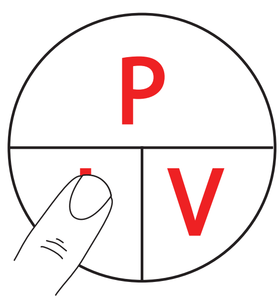
Figure 4

And three equations can be shown for Power. (See Figure 5, 6, and 7)



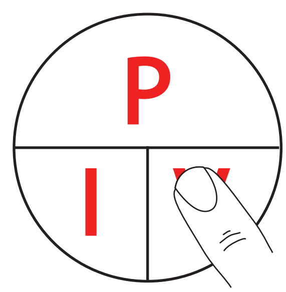
$P = I \bullet V$

Figure 5



$I = P \div V$

Figure 6



$V = P \div I$

Figure 7

To conform with the Ohm’s Law lesson the charts in Figures 5, 6, and 7 substitute V for E. Remember place your finger over the electrical property that you are trying to solve for and what you have left showing will indicate the equation to use.

When electrons flow through a resistance in an electrical circuit, the electrons will collide with each other and the atoms that make up the resistance. These collisions give off heat and result in a loss of energy. This power loss can be shown in the equation in Figure 8. It will be shown in the next section where we get this equation.

$$\mathbf{P = I^2 \bullet R}$$

Variation of Watt’s Law

Figure 8

Ohm's Law and Watt's Law combined

Because Ohm's Law and Watt's Law use the same electrical variables they can be combined to come up with some useful equations. (Figure 8 is an example of a combined equation.)

In Figure 9, a combined Ohm's Law and Watt's Law chart is shown.

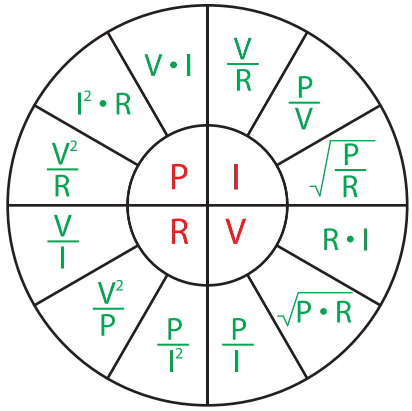
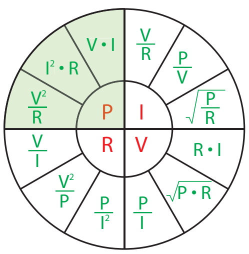
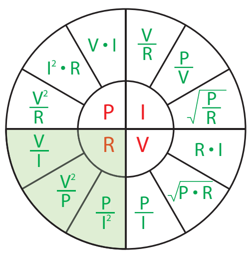


Figure 9

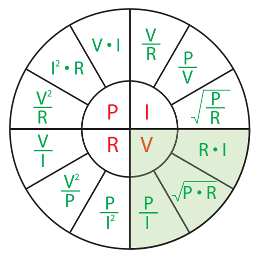
Figure 10, shows how to use the chart. There are four quarter pie slices, one for each of the electrical properties; P, R, V, and I. Each Quarter slice identifies three equations for solving the shaded electrical property.



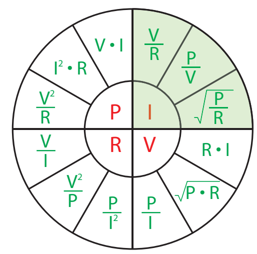
3 Equations for Power



3 Equations for Resistance



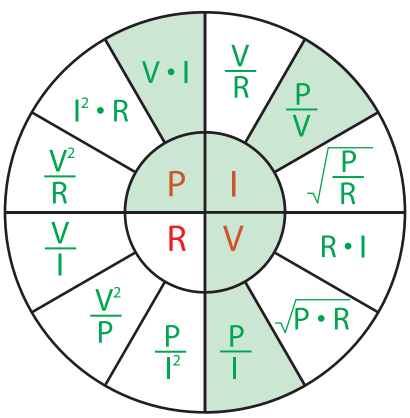
3 Equations for Voltage

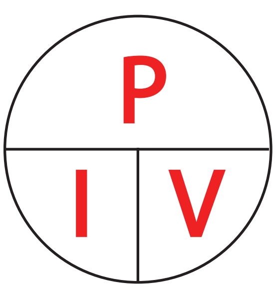


3 Equations for Current

Figure 10

Figure 11, shows Ohm's Law and Watt's Law identified in the combined chart.



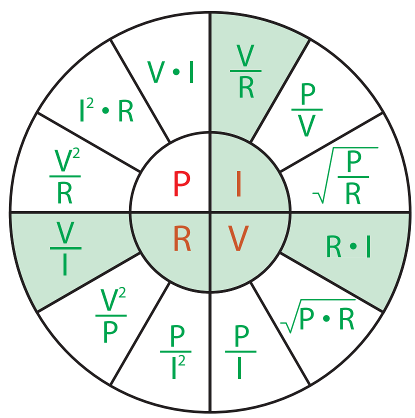


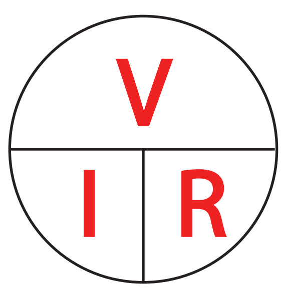
$P = V \cdot I$

$I = P \div V$

$V = P \div I$

Watt's Law Identified





$V = R \cdot I$

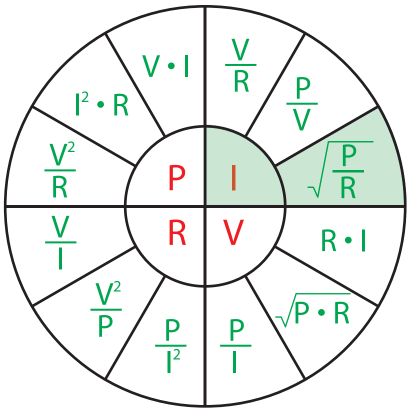
$I = V \div R$

$R = V \div I$

Ohm's Law Identified

Figure 11

Notice Watt's Law and Ohm's Law gives you six (half of the twelve) of the equations on the chart, using simple equation manipulations it will be shown where the other six come from.



Start with: $I = \frac{P}{V}$ Watt's Law

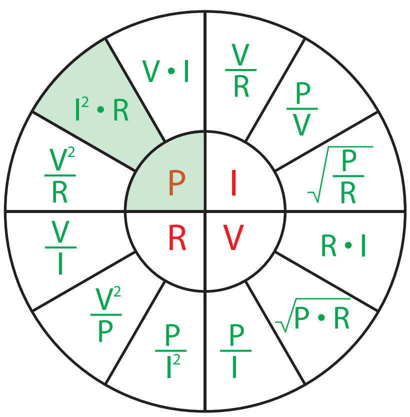
Substitute: $V = R \cdot I \longrightarrow I = \frac{P}{R \cdot I}$ Ohm's Law

Multiply both sides of equation by I: $I \cdot I = \frac{P}{R \cdot I} \cdot I$

Simplfy Equation by Muliplying Left side and Cancelling Right side: $I^2 = \frac{P}{R \cdot \cancel{I}} \cdot \cancel{I} = \frac{P}{R}$

Square Root both sides: $\sqrt{I^2} = \sqrt{\frac{P}{R}}$

Ending equation: $I = \sqrt{\frac{P}{R}}$

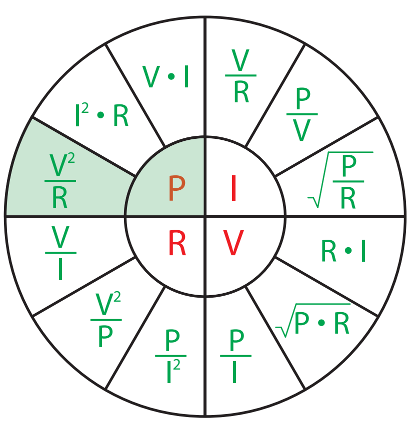


Start with: $P = V \cdot I$ Watt's Law

Substitute: $V = R \cdot I \longrightarrow P = R \cdot I \cdot I$ Ohm's Law

Group I's together and symplify: $P = R \cdot (I \cdot I) \longrightarrow P = R \cdot I^2$

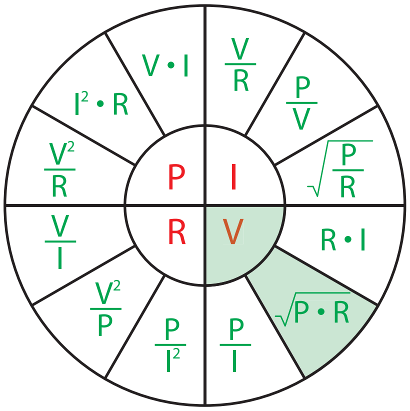
Ending equation: $P = I^2 \cdot R$



Start with: $P = V \cdot I$ Watt's Law

Substitute: $I = \frac{V}{R} \longrightarrow P = V \cdot \frac{V}{R}$ Ohm's Law

Multiply equation and ending equation: $P = \frac{V^2}{R}$



Start with: $V = R \cdot I$

Ohm's Law

Substitute: $I = \frac{P}{V} \longrightarrow V = R \cdot \frac{P}{V}$

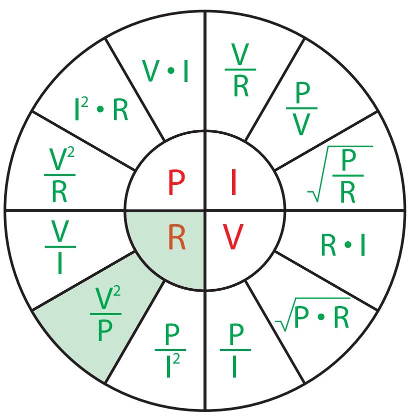
Watt's Law

Multiply both sides of equation by V: $V \cdot V = R \cdot \frac{P}{V} \cdot V$

Simplfy Equation by Muliplying Left side and Cancelling Right side: $V^2 = R \cdot \frac{P}{\cancel{V}} \cdot \cancel{V} = R \cdot P$

Square Root both sides: $\sqrt{V^2} = \sqrt{R \cdot P}$

Ending equation: $V = \sqrt{R \cdot P}$



Start with: $R = \frac{V}{I}$

Ohm's Law

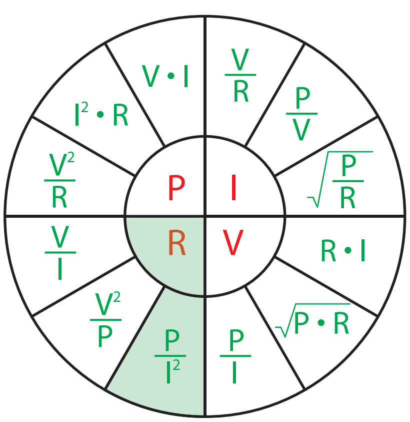
Substitute: $I = \frac{P}{V} \longrightarrow R = \frac{V}{\left(\frac{P}{V}\right)}$

Watt's Law

Multiply right side by $\frac{V}{V}$ or 1: $R = \frac{V}{\left(\frac{P}{V}\right)} \cdot \frac{V}{V} = \frac{V \cdot V}{\frac{P \cdot V}{V}}$

Simplfy Equation by Muliplying Top and Cancelling Bottom: $R = \frac{V \cdot V}{\frac{P \cdot \cancel{V}}{\cancel{V}}} = \frac{V^2}{P}$

Ending equation: $R = \frac{V^2}{P}$



Start with: $R = \frac{V}{I}$

Ohm's Law

Substitute: $V = \frac{P}{I} \longrightarrow R = \frac{\left(\frac{P}{I}\right)}{I}$

Watt's Law

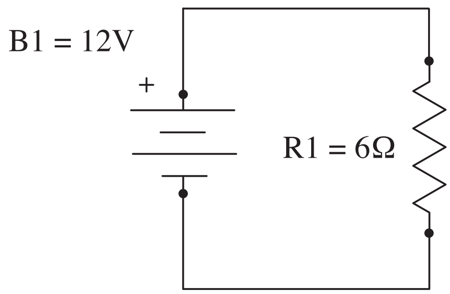
Multiply right side by $\frac{I}{I}$ or 1: $R = \frac{\left(\frac{P}{I}\right)}{I} \cdot \frac{I}{I} = \frac{\frac{P}{I} \cdot I}{I \cdot I}$

Simplfy Equation by Muliplying Bottom and Cancelling Top: $R = \frac{\frac{P}{\cancel{I}} \cdot \cancel{I}}{I \cdot I} = \frac{P}{I^2}$

Ending equation: $R = \frac{P}{I^2}$

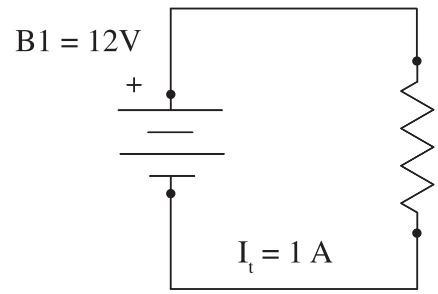
Practice Problems:

1.



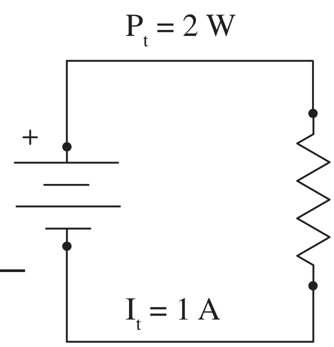
P_t = ____________

2.



P_t = ____________

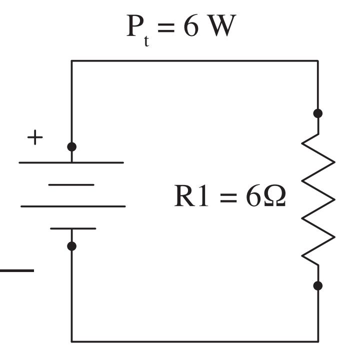
3.



R_t = ____________

V_t = ____________

4.



I_t = ____________

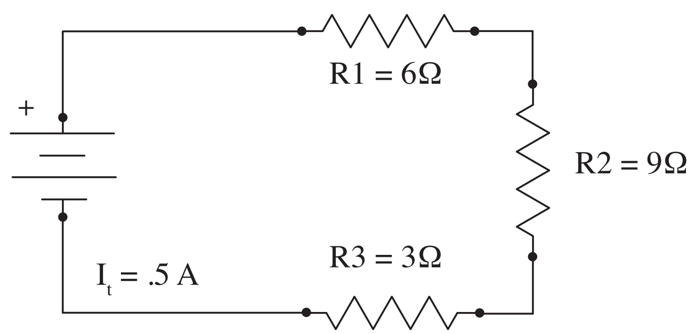
V_t = ____________

5.

P_t = ____________

R_t = ____________

V_t = ____________



6.

P_t = ____________

R_t = ____________

I_t = ____________