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I have worked over the years as an electrical expert in jury trials involving personal injury and death cases. The jury mainly consists of persons from all walks of life and generally they need the invisible force of electricity explained in a way that is simple and easy to understand.

Electricity and Water Analogy

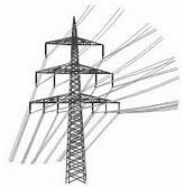
In 1827, Georg Simon Ohm discovered some laws relating to the strength of a current in a wire. Ohm found that electricity acts like *water* in a pipe.

We must first understand how the electrical system functions and then mathematical analysis can follow.

Since you cannot visually *see* the flow of electrons, current, etc. and you need to see the relationship between voltage, current, and resistance, let's do it with some terms which you are more familiar with, using *water*.

WATER
PUMP
PIPE
PRESSURE
FLOW OF GALLONS
RESTRICTION

ELECTRICITY
GENERATOR
CONDUCTOR
VOLTAGE
AMPERES
RESISTANCE

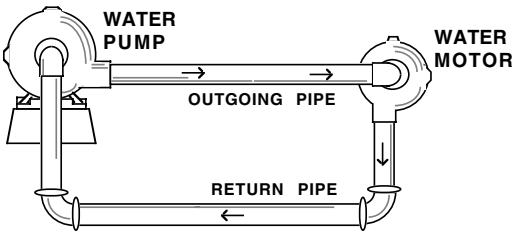


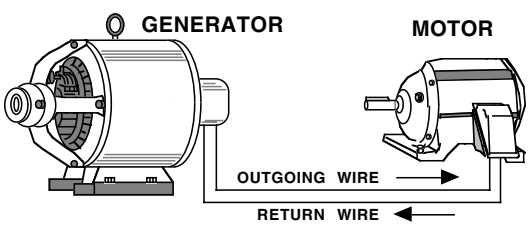
The electric circuit is a path in which an electric current flows. A water circuit is a path in which water flows.

Before water can flow in a pipe, some means must be used to force the water to move. A water pump is used to provide the pressure to force the water to move through the pipes. The pipes offer resistance to the flow of water. The water motor is the **load**. This motor may be used to drive equipment.

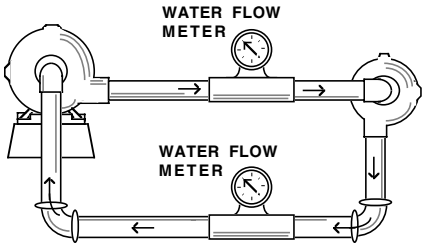
In an electric circuit, the current must flow through a set of wires called conductors. These wires act just the same in an electric circuit as pipes do in a water circuit.

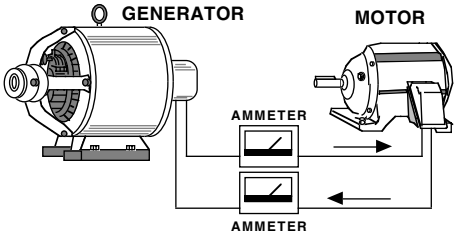
In the water circuit all of the water which leaves the pump must return to the pump. No water is lost in the circuit. The same holds true in the electric circuit. The current which leaves one terminal of the generator, returns to the other terminal and is pumped out into the circuit again.





The rate at which water flows through a pipe is measured in gallons per minute, but in the electric circuit, the current flow is measured in amperes.





The water flow meters will both read the same, as the water on the outgoing pipe will be the same on the return pipe.

The ammeters will both read the same, as the current on the outgoing wire will be the same on the return wire.

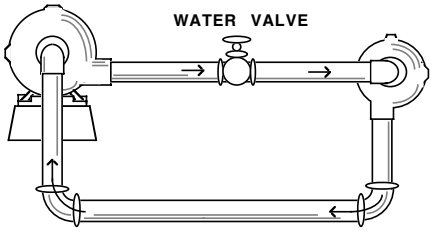
Resistance is opposition to the flow of current in a wire. All wires have resistance. The more resistance a conductor has, the more difficult it will be for current to flow through it. Resistances are measured in ohms. *There is no term or unit to measure the resistance of a water pipe.*

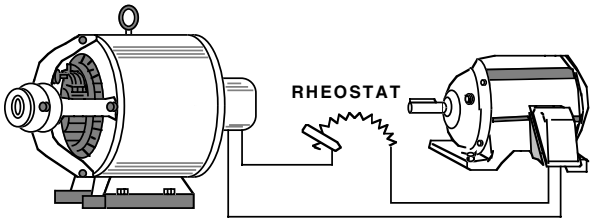
In a water circuit the valve is used to govern the flow of water. By closing the valve it will add more resistance to the flow of water.

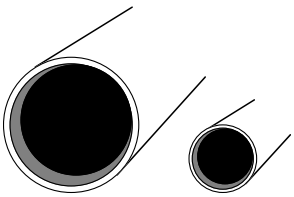
A rheostat (adjustable resistor) will govern the flow of current in an electrical circuit by changing the resistance.

The rheostat has a movable arm which makes contact with the resistance wire. As the arm is moved to the left, the current must flow through more of this wire which adds resistance and less current will flow in the circuit.

The water valve does the same thing in a water circuit. Since it will be difficult for water to flow through the small opening in the valve, pressure will be lost and the amount of water flowing will be cut down.

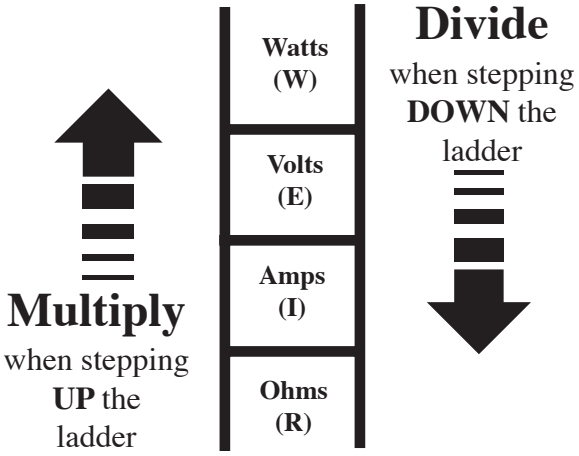






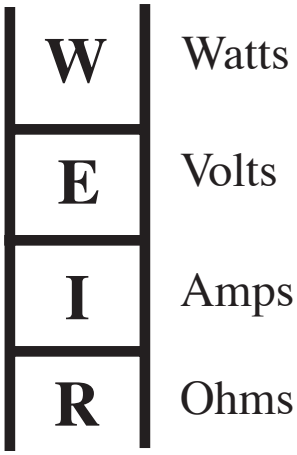
It's easier for water to flow through a big pipe than a smaller one. It's the same with electrical conductors. The larger the wire, the less resistance it has.

Next, I'll introduce you to the ***Ohm's Law Ladder*** which some find as an easier way to store the formulas in your head.

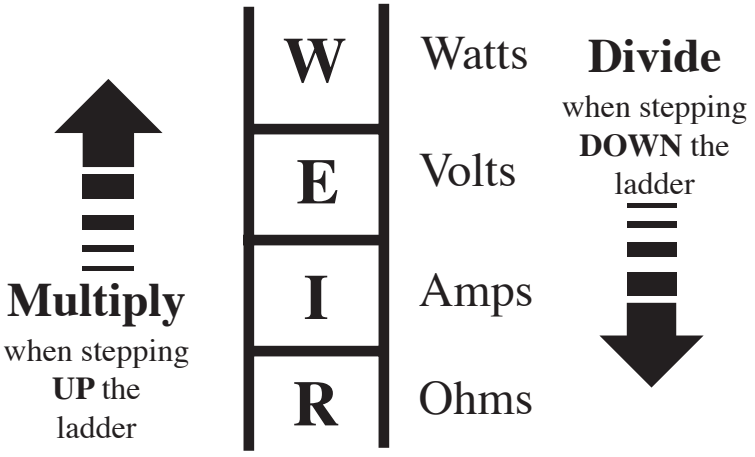


There's a simple alternative to using the Ohm's Law Wheel and trying to memorize all of those formulas. All you have to do is learn the elements of Ohm's Law; in the order above (top to bottom)....Watts (W) Volts (E) Amps (I) Ohms (R).

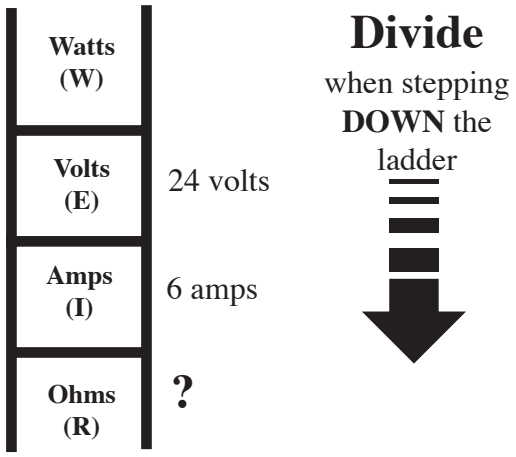
Or, you can try to remember which is W.I.R.E. spelled wrong (**W.E.I.R**)! It can be more easily thought of as steps in a ladder. In order to use the ladder, just put the known values next to each item.



Then **multiply the value below by the value above**, stepping UP the ladder, or divide the **value above by the value below** stepping DOWN the ladder.

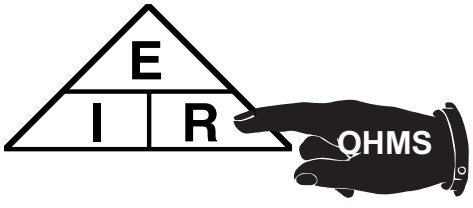


Example: What is the **resistance** in the circuit? The knowns are 24 volts and 6 amps.
_____ ohms.

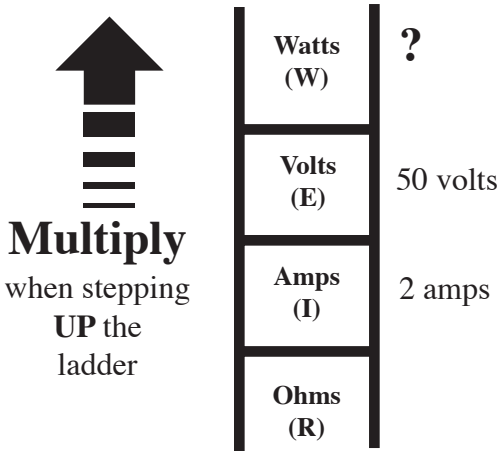


Solution: The "**?**" is on the bottom of the ladder with the numbers above, so you are going DOWN and you DIVIDE, 24 volts ÷ 6 amps = **4 ohms.**

•Using the triangle to check your answer: R = E ÷ I 24v ÷ 6a = 4 Ω.



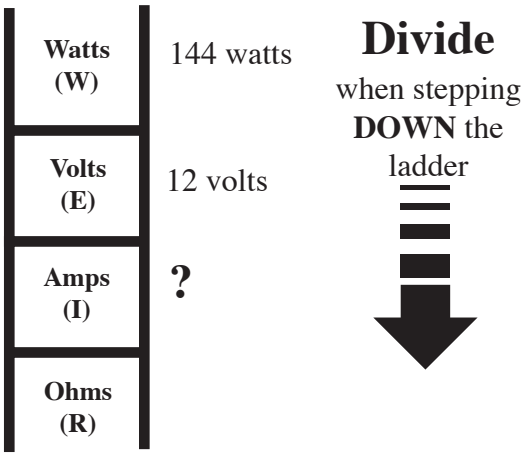
Example: What is the **wattage** in the circuit? The knowns are 50 volts and 2 amps.
_____ watts.



Solution: The "**?**" is on the top of the ladder with the numbers below, so you are going UP and you MULTIPLY, 50 volts x 2 amps = **100 watts.**

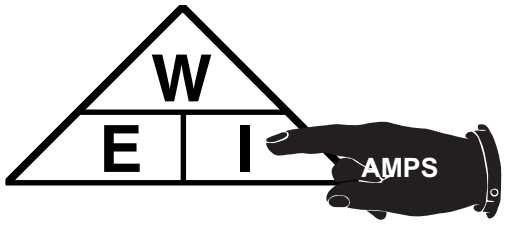
•Using the triangle to check your answer: W = E x I 50v x 2a = 100 watts.

Example: What is the **amperage** in the circuit? The knowns are 144 watts and 12 volts.
_____ amps.

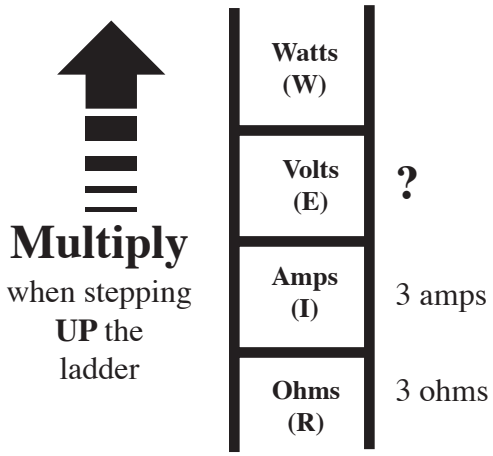


Solution: The "**?**" is below the numbers above, so you are going DOWN and you DIVIDE, 144 watts ÷ 12 volts = **12 amps.**

•Using the triangle to check your answer: I = 144w ÷ 12v = 12 amps.

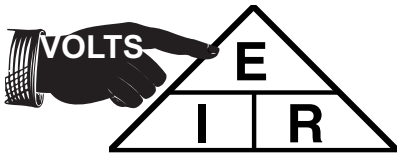


Example: What is the battery **voltage**? The knowns are 3 amps and 3 ohms of resistance.
_____ volts.

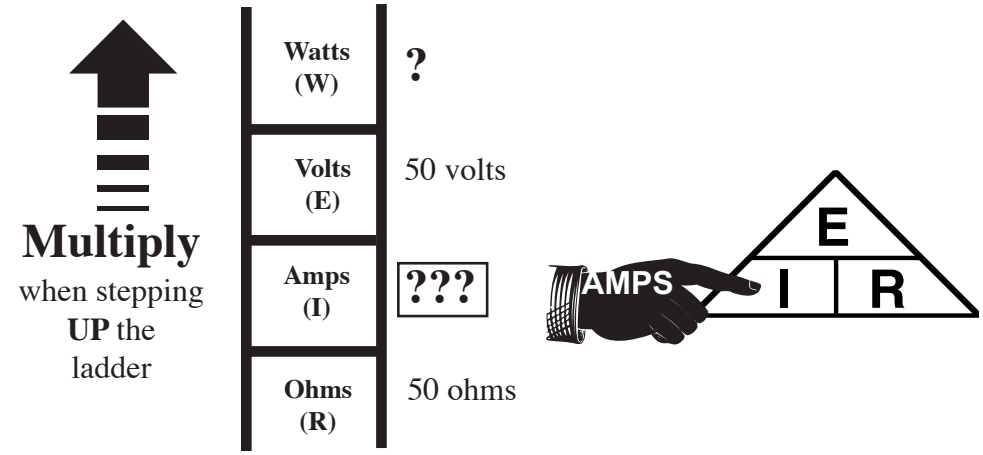


Solution: The "**?**" is above the numbers below, so you are going UP and you MULTIPLY, 3 ohms x 3 amps = **9 volts.**

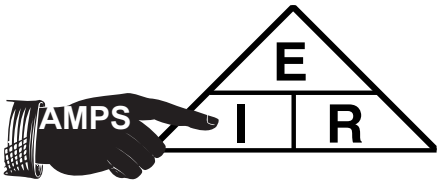
•Using the triangle to check your answer: E = 3a x 3Ω = 9 volts.



Example: What is the **wattage** in the circuit? The knowns are 50 **volts** and **50 ohms**.
_____ watts.

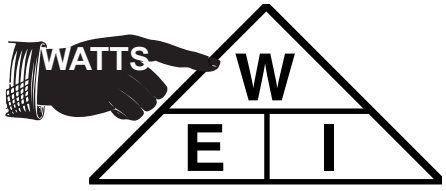


Solution: This question is requiring to skip a STEP (amps) to find watts with ohms and volts. With a ladder it is not safe to skip a step, so the first step is to find **amps** using the triangle.



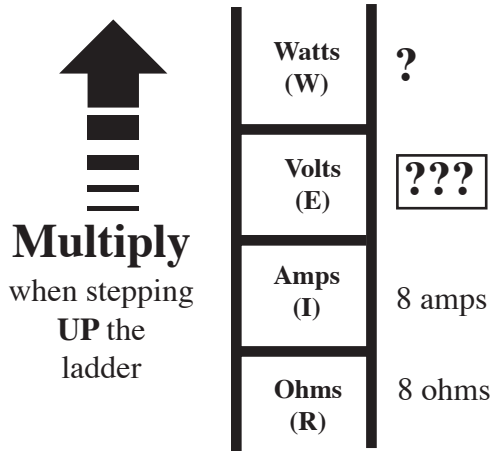
$I = E \div R$ $50v \div 50\Omega = 1$ amp.

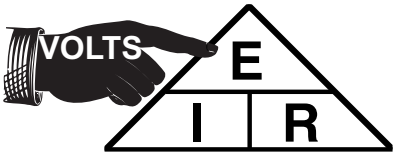
Now you can step UP to find the watts.



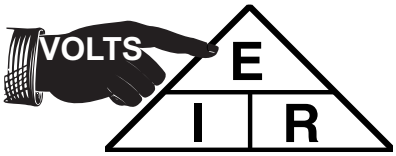
$W = E \times I$ $50v \times 1a =$ **50 watts**.

Example: What is the **wattage** in the circuit? The knowns are 8 **amps** and 8 **ohms**.
_____ watts.



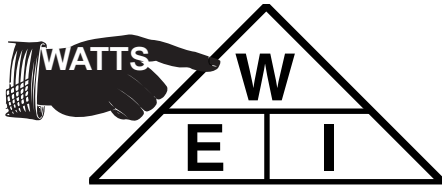


Solution: This question is requiring to skip a STEP (volts) to find watts with amps and ohms. With a ladder it is not safe to skip a step, so the first step is to find **volts** using the triangle.



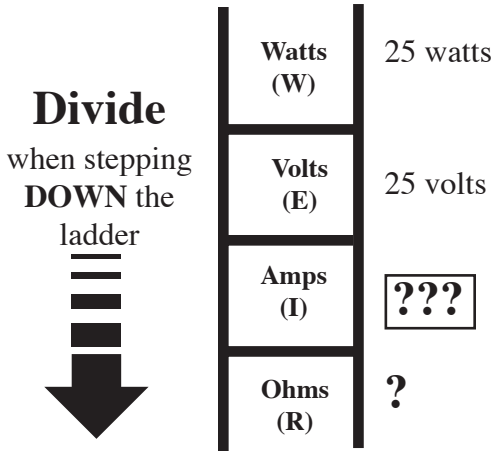
E = I x R 8a x 8Ω = 64 volts.

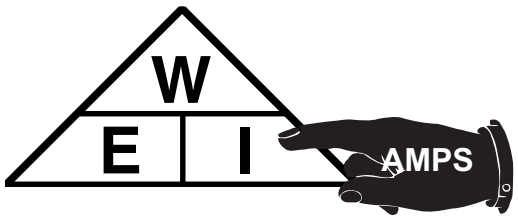
Now you can step UP to find the watts.



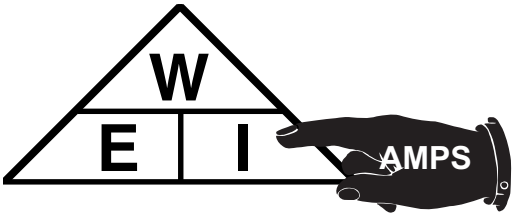
W = E x I 64v x 8a = **512 watts**.

Example: What is the **resistance** in the circuit? The knowns are 25 **watts** and 25 **volts**.
_____ ohms.





Solution: This question is requiring to skip a STEP (amps) to find ohms with watts and volts. With a ladder it is not safe to skip a step, so the first step is to find **amps** using the triangle.



I = W ÷E 25w ÷ 25v = 1 amp.

Now you can step DOWN to find the ohms.

R = E ÷ I 25v ÷ 1a = **25 watts**.

SQUARE ROOT

When the questions ask for the **voltage or current** and the knowns are **wattage and resistance,** you must use the *square root formula* from the ladder.

Example: What is the **voltage** in the circuit? The knowns are 81 **watts** and 9 **ohms**.
_____ ohms.

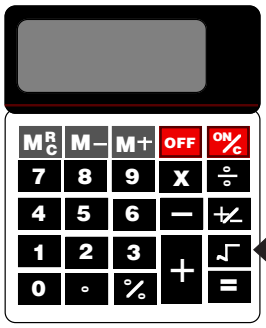
SQUARE ROOT
when stepping **DOWN** the ladder

Watts (W)	81 watts
Volts (E) $\sqrt{WxR}$	**? = 27v** $\sqrt{\quad}$
Amps (I) $\sqrt{\frac{W}{R}}$	**??? = 3a** $\sqrt{\quad}$
Ohms (R)	9 ohms

Solution: This question is requiring to step DOWN to find **voltage** with watts and ohms. Applying the squre root formula for volts which is 27 volts, but to make sure its the correct answer, you need to find the amps using the square root formula for amps and it is 3 amps.

ONE STEP DOWN VOLTAGE

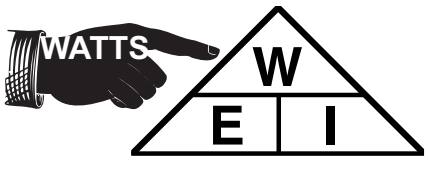
$\sqrt{\quad}$ •First work inside the square root symbol W x R 81w x 9Ω = 729 then press the square root button on your calculator = **27 volts**.



TWO STEPS DOWN AMPERAGE

$\sqrt{\quad}$ •First work inside the square root symbol W ÷ R 81w ÷ 9Ω = 9 then press the square root button on your calculator = **3 amps**.

By having found BOTH volts and amps, you can check to see if your answer of 27 volts is correct.



W = E x I 27v x 3a = 81 watts

R = E ÷ I 27v ÷ 3a = 9 ohms