Jules' Workshop ADVANCED

Lesson 2

Power and Units

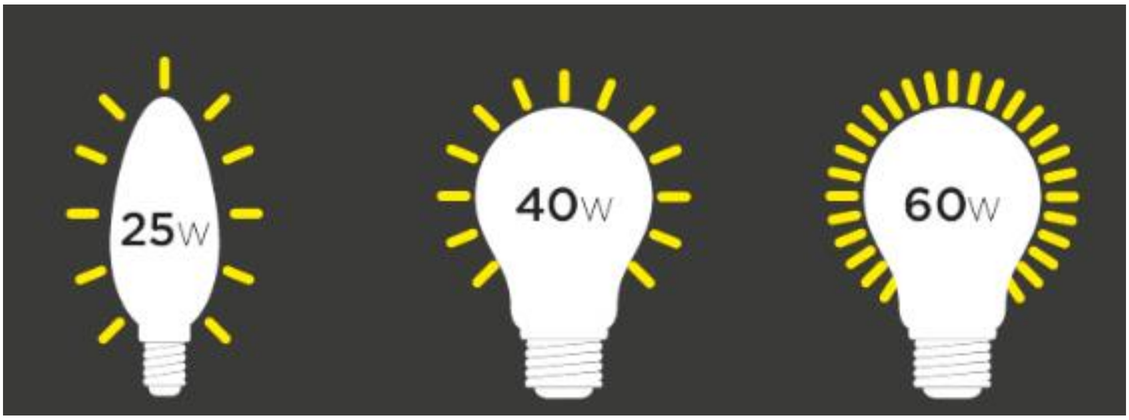
ACMA Syllabus February 2024 Chapters 1.1 and 1.2

Contents

Electric Power

The rate of doing work in an electrical circuit is termed *electrical power* and is measured in watts. A common misconception is that electric power is supplied to your house. In reality "electrical energy" is traded and delivered to your house. Electrical energy will be addressed later.

The first place you probably encounter watts is in light bulbs. Brake lights in cars are around 20 watts and taillights are around 10 watts. From this we now know that the higher the wattage of the bulb, the brighter it is.

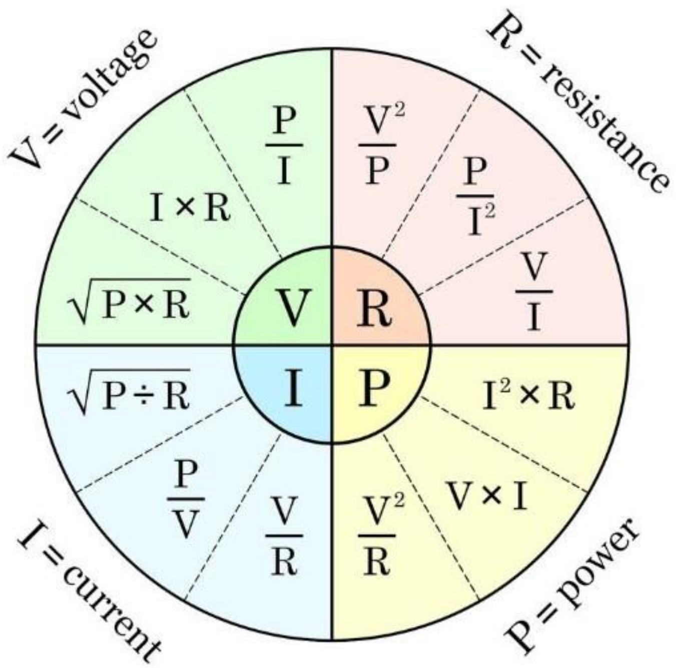


The formula for electrical power in a resistive circuit is shown below.

$$P = I \times E \qquad P = I^2 \times R \qquad P = \frac{E^2}{R}$$

P = electrical power in watts
I = current in amperes
E = electromotive force in volts
R = resistance in ohms

Ohm's law tied I, E and R together. So now if we know two of the quantities, we can calculate the other two. This relationship is depicted in the formula circle below.



Examples: What power is dissipated when 12 V is applied across a load with 0.5 A flowing?

$$P = I \times E = 0.5 \times 12 = 6\ W$$

What power is dissipated when 2 A flows through a 10 Ω load?

$$P = I^2 \times R = 2^2 \times 10 = 4 \times 10 = 40\ W$$

What power is dissipated when 12 V is applied to a 10 Ω load?

$$P = E^2 \div R = 12^2 \div 10 = 144 \div 10 = 14.4\ W$$

Electric Energy

Distinction between kW (power) and kWh (energy)

A kilowatt is a unit of power.

A kilowatt hour is a unit of energy.

Work is the amount of energy transferred to a system; power is the rate of delivery of energy. Energy is measured in joules, or watt-seconds. Power is measured in watts, or joules per second.

For example, a battery stores energy. When the battery delivers its energy, it does so at a certain power, that is, the rate of delivery of the energy. The higher the power, the quicker the battery's stored energy is delivered. A higher power output will cause the battery's stored energy to be depleted in a shorter period.

Example: A 100 Amp Hour battery can discharge 100 A for 1 hour or 10 A for 10 hours or 2 A for 50 hours.

Electrical energy for public consumption is generated by central power stations and is usually provided through a grid system. Electrical energy is measured in the unit kilowatt-hour (kWh). One kilowatt of power for one hour and this is the common billing unit for electrical energy.

Electrical energy is usually sold by the kilowatt hour (1 kWh = 3.6 MJ) which is the product of the power in kilowatts multiplied by running time in hours. Electric utilities measure energy using an electricity meter, which keeps a running total of the electric energy delivered to a customer.

Energy = Power / Time

Example: A unit uses 1 MW of power a day, the energy consumed is 1,000,000 / 24 or 41.66 kW per hour.

Understanding the units

We have used the units of volt, ampere, resistance and watt but what is the basis of these units? How are these units the same here in Australia as they are anywhere else in the world? These units are defined as SI (Système International) units or International Standard units.

Volt

Voltage is the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conductor.

1 volt = energy ÷ charge

1 volt = 1 Joule (J) ÷ 1 Coulomb (Q)

1v = J ÷ Q

*A **joule (J)** is the work unit of energy in the International System of Units. A joule is the heat dissipated when an electric current of one ampere passes through a resistance of one ohm for one second.*

*A **coulomb** (**Q** as C is used for capacitance) is the unit of electric charge in the International System of Units equal to the electric charge delivered by a 1 ampere at a constant current in 1 second.*

Example: What voltage is required to push 10 Q while dissipating 7 joules?

V = J÷Q

V = 7 ÷ 10

V = 0.7 V

Ampere

Ampere relates to the intensity or quantity of electrons flowing. An ampere equals 1 coulomb per second.

1 Ampere = 1 coulomb (Q) ÷ 1 second (t)

1 A = Q ÷ t

Example: What current is flowing in a circuit if 10 Q passes a point in 5 seconds?

A = Q ÷ t

A = 10 ÷ 5

A= 2 A

Coulombs (Q) and Amperes (A) **are not the same**.
Coulomb is the total electric charge (quantity of electrons).
Ampere measures the rate of charge flow (rate of electron flow).
A coulomb is like gallons (total water). An ampere is like gallons per second (flow rate)

Watt

The watt relates to power.

1 watt = 1 joule per second (J/s)

$$W = J \div t$$

Example: What power is dissipated in a circuit if 20 joules are expended in 5 seconds?

$$W = J \div t$$

$$W = 20 \div 5$$

$$W = 4\ W$$

Joules (J) and watts (W) **are not the same**.
Joules measure total energy (quantity).
Watts measure the rate of energy use (rate)
Using water analogy, joules as the total water in a bucket, and watts as the speed of the tap filling the bucket.

Resistance

Resistance is defined as the resistance equals one ohm when one amp of current flows and the electromotive force is one volt. (Ohm's Law)

1 ohm = 1 volt ÷ 1 ampere

Example: What is the resistance of a circuit with 2 A flowing and an EMF of 16 V?

$$\Omega = E \div A$$

$$R = 16 \div 2$$

$$R = 8\ \Omega$$

Electrical energy

Electrical energy is measured in kW per hour (kWh). One watt is equal to 1 Joule per second.

Example

What is the total energy electrical energy dissipated from 3.6MJ (3,600,000 joules).

kW = joules per hour

kW = joules ÷ 3600 seconds (1 hour)

kW = 3600000 ÷ 3600

= 1 kW

One kilowatt-hour (kWh) can be defined as 3.6 megajoules (MJ).

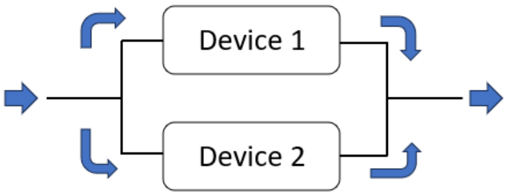
Series and Parallel Voltage Sources

Voltage sources, e.g. batteries, can be connected in series or parallel depending on the system requirements.

Series is defined as the configuration where current flows through one device then the then the second device.

Parallel is defined as the configuration where current splits and goes through two devices at the same time.

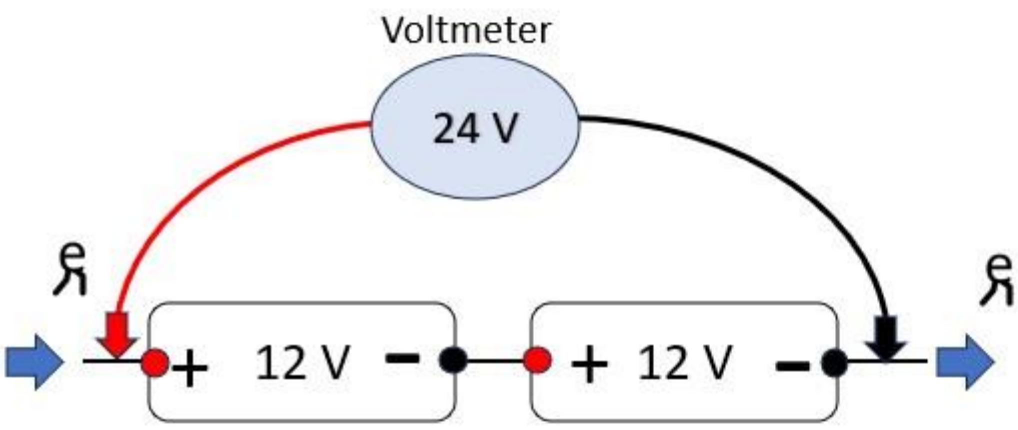
Series Connection



Parallel Connection

Connecting two or more voltage sources in series will increase the voltage or EMF across the devices.

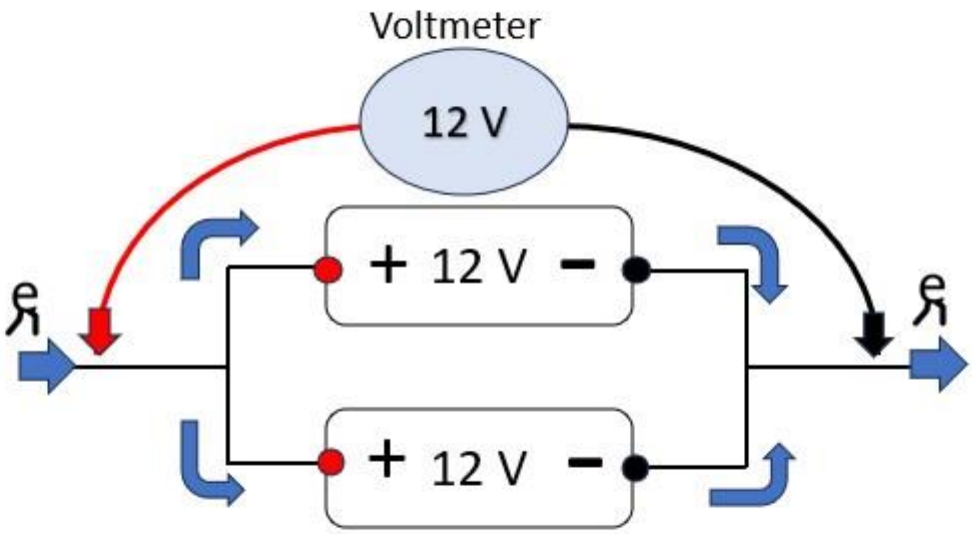
In the case of a series connection, the voltage potential across the devices is the sum of the voltage sources.



Series Connection

Voltage doubles but current same as one device

For a parallel connection the voltage potential across the devices does not change but the current can increase.



Parallel Connection

Voltage remains the same, but this combination can deliver double the current.

Go to Lesson 2 questions.