Plumbing science ebook Level 2

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How to get the most from this ebook

As you work your way through this ebook, you will come across **links to websites, videos and quizzes** to check on your learning. To get the most out of the content **watch** all of the videos and **visit** the websites. They really underpin the aims and objectives of the ebook content.

Keep attempting the quizzes until you **achieve 100%,** this will really prove that you have understood the content and are ready to begin the next section of the ebook. Using the full range of activities within the ebook will give you a fully rounded knowledge of the section you are studying.

These ebooks can be your companion throughout your plumbing studies, with a full suite of ebooks covering the full course content at all levels from 1 to 3. They are ideal to use for revision for module examinations or end of year synoptic tests.

An introduction

As a plumbing student you will cover a wide range of topics, these may all be delivered in an embedded way. Which is to say that you will learn many different things at the same time as let's say installing some guttering and rainwater pipes. This offers the opportunity to not only learn about the installation requirements of the rainwater system but also to look at some science, Health and Safety and communication techniques. The safety of working at heights, science looking at the coefficient of linear expansion and communication via working together and liaising with other trades/customers.

Having highlighted the method of possibly embedding the delivery of various topics/modules it is the mission of this ebook to allow you the learner the opportunity to separate all of the content of your plumbing course in smaller manageable chunks. This ebook will cover the scientific principles section of your course, even though you will not be assessed via a practical test on this subject it is very important to be able to understand the science that underpins the plumbing systems that you are currently studying.

It only remains for me to wish you the very best of luck in your studies and careers. Hopefully this ebook will assist you along the way.

Contents

Chapter 1 - properties of common plumbing materials

Metals are some of the main materials used in plumbing: pipes, fittings, boilers, radiators. Such as; Steel, Iron, Ferrous metals, Non-ferrous metals, Plastic and Alloys.

Ferrous

These are metals that contain iron. They are magnetic and will corrode easily if not treated (ferrous oxide or rust).

Non-ferrous metals
Any metal that does not contain iron (copper, lead, zinc, aluminium etc).

Alloys
A mixture of two or more metals, these are commonly used in the plumbing industry.

Brass – copper and zinc
Bronze – copper and tin
Gunmetal – copper, tin and zinc
Steel – iron and carbon.

Video explaining the difference

Plastics

Plastics

Common uses for plumbers when using plastics are for cold water, hot water, central heating, guttering, above ground drainage and below ground drainage. There are two main types known as;

Thermoplastic

Made from polymer resin; can be heated and re-shaped but become brittle when frozen, (guttering). These plastics are recyclable.There are many types of thermoplastics, which are suitable for different situations.

Thermosetting

These are rigid plastics that can cope with high temperatures, but are not recyclable.

Weight and how do we measure it?

We firstly need to clarify that our common use of the Kg as a weight unit is not exactly true, Weight is the force of gravity pulling on a mass:
1 kg = 10N (9.81N)- Watch this video for an explanation on how your mass affects your force (weight).

Video explaining how mass affects you

What is density?

We need to know that water has a density of 1 g/ml (1 gram per millilitre). As shown in the video anything with a density of less than 1 will float in water. Relative density is when we compare the mass of material.

Video explaining density relative to water

Heat transfer through differing materials can vary according to their density, like a heat exchanger.

Heated molecules pass on heat to the adjoining material, which in turn heats up. Some materials are better at conducting heat than others. Eg metal (copper) is a good conductor of heat but wood is not.

Strength of materials

The following terms are related to how a material will react in certain situations depending on its molecule make-up;
Strength
Hardness
Malleability
Ductility
Elasticity
Durability
Thermal expansion
Conductivity (thermal and electrical).

Video on tensile strength test

Video on compression strength test

Video on shear strength test

Video on malleability and ductility

As plumbers we use a lot of materials and some examples such as copper is very ductile ideal for our pipe bending without fracture and lead is very malleable which makes it ideal for bossing into shape without breaking.

Specific heat capacity

It is the amount of heat required to raise 1kg of a substance through 1 degree C.
Specific heat values change as the temperature increases. For plumbers, it may be important to work out how much heat is needed to heat a volume of water from one temperature to another.

Formula

Specific heat value x kg x temperature rise 1kg of water to rise 5 degree C.
4.186 x 1 x 5 = 20.93 KJ/kg/degree C
Kilojoules/kilogram/degrees centigrade

Water 4.186KJ/kg
Aluminium 0.887KJ/kg
Cast iron 0.554KJ/kg
Zinc 0.397KJ/kg
Copper 0.385KJ/kg
Lead 0.125KJ/kg
Mercury 0.125KJ/kg

Linear expansion

How much does a piece of material expand by when heated?
Plastic uPVC 0.00018

Lead	0.000029
Copper	0.000016
Steel	0.000011

Length of material x the temperature rise x the coefficient of expansion for that material.

How much will a 6 metre length of plastic guttering expand by, if the temperature rises by 10 degrees C?

6000mm x 10 x 0.00018 = 10.8mm

Video on linear expansion

Corrosion

Galvanic corrosion (also called bimetallic corrosion) is an electrochemical process in which one metal corrodes preferentially when it is in electrical contact with another, in the presence of an electrolyte.

Video on electrochemical series

Electrolytic corrosion: the further away metals are in the electromotive series, the quicker the electrolytic corrosion takes place. In a hot water cylinder, we install a sacrificial anode made of magnesium. For a central heating system, they can go in the boiler.

Prevention Pitting: after a solder joint is made, if flux is not cleaned off the outside of the tube and flushed out of the inside of the copper tube at the commissioning stage, the copper could be affected by: Type 1 pitting corrosion on the inside of the tube.
Plastics,Can be effected by:Heat: Thermal movement and distortion. UV: Sunlight degrading Oxygen: Degrading Light: Yellowing of plastic Chemicals: Degrading

Video on corrosion prevention

Quiz

Quiz on this chapter

Chapter 2 - Scientific properties and principles of water

Water is a substance that can be seen in three states, these states are as follows;

Solid - Ice

Liquid - Water

Gas - Steam

Video highlighting the three states

When water is heated it expands. For temperatures up to 100ºC, this expansion is usually up to 4% of the system contents at cold start up. When water exceeds 100ºC it can turn to steam and expand to almost 1,600 times its original volume.

As water falls as rainfall it travels through different surfaces and can pick up different substances that can make the water hard or soft.

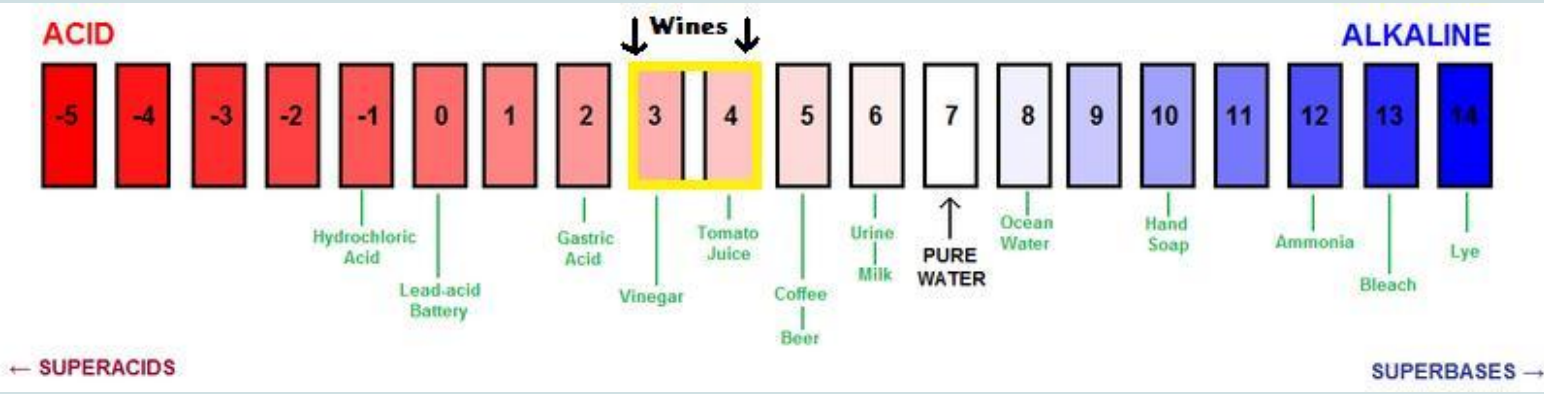
Given enough time it will: erode, corrode, absorb almost anything. Depending upon where water collects, it will absorb and contain a number of substances.

Video on hard and soft water

Scientific properties and principles of water

Depending upon what has been absorbed, water will either be acidic, neutral or alkaline. The amount of absorption is registered on the pH scale (potential hydrogen), depending on what strata water falls through.

[Video on the pH scale]



Scientific properties and principles of water

Definitions-

Plumbosolvency is the ability of a solvent, notably water, to dissolve lead. In the public supply of water this is an undesirable property. In (usually older) consumers' premises plumbosolvent water can attack lead pipes and any lead in solder used to join copper.

Classic cuprosolvency typically occurs in water that is relatively soft, low in pH, and high in dissolved gases. It generally is characterized by elevated levels of dissolved copper in the water.

Evaporate: when liquid turns into a gas (eg boiling at 100°C).

Freezing: when a liquid turns solid (eg water freezes at 0°C).

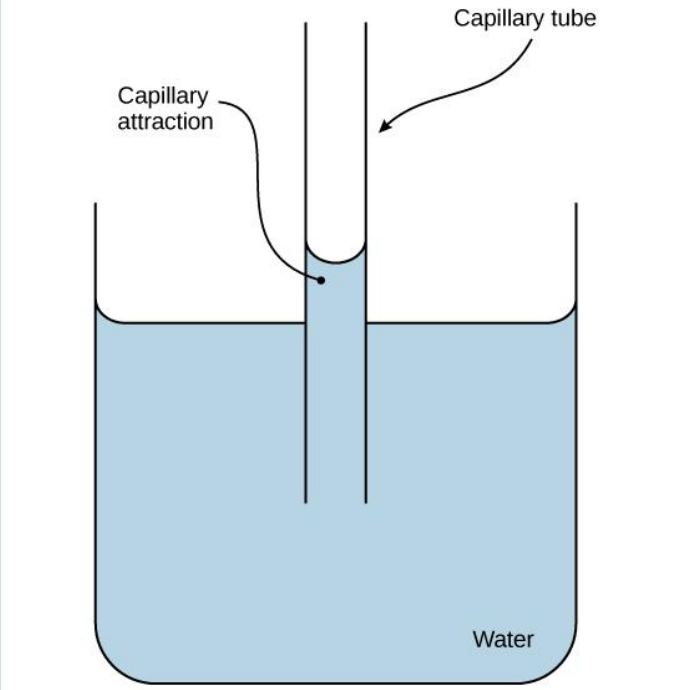
Condensation: when a gas turns into liquid – when it rains or when water droplets form on cold surfaces.

Scientific properties and principles of water

Capillary action of water-

Video demonstrating capillary action

This is when water can be drawn sideways or upwards between two close-fitting surfaces against gravity. The wider the gap, the less capillary action there is.
Plumbers will encounter this action during their workday both adventitious and as a disadvantage, for example;
Advantage- To make soldered joints on fittings: the solder can be drawn between the two close-fitting surfaces of the copper tube and fitting.
Disadvantage- loss of trap seal under an appliance (S trap) or under sheet lead weathering on a roof.



Scientific properties and principles of water

Key information to remember-

Chemical symbol for water = H₂O

Boiling point of water = 100°C (at sea level)

Increase the pressure = increase the boiling point of water
When boiling it expands by = 1,600 times

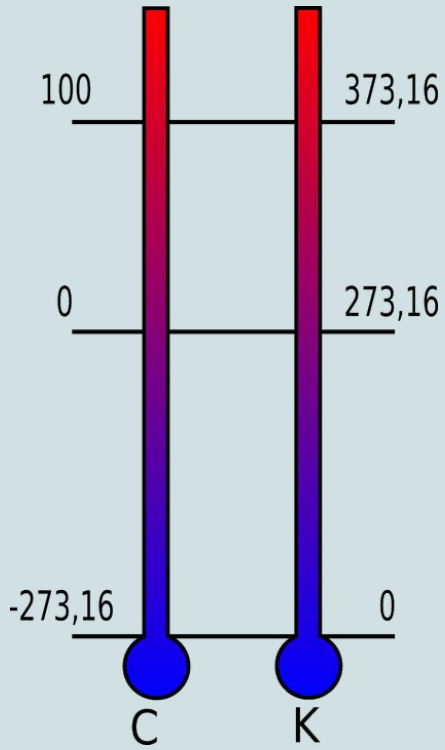
Maximum density of water = 4°C

Water freezes at = 0°C or 273°K

Add glycol (antifreeze) to water = Reduces freezing point

When frozen, water expands by = 10%

Relative density of water = 1
Water heating from 10-90°C expands by = 4%



Scientific properties and principles of water

Sensible and latent heat-

Sensible heat

When heat is applied to water the temperature will rise, but it remains water. It can then be cooled (a change in temperature without a change in state).

Latent heat

If you keep heating water, it will change from water to steam; this is a change in state.
Heat required to raise the temperature to 100 degrees C is sensible heat, heat required to keep it boiling is latent heat.

Video on sensible and latent heat

Scientific properties and principles of water

Water softeners-

The only way to fully remove hard water is to install a water softener.

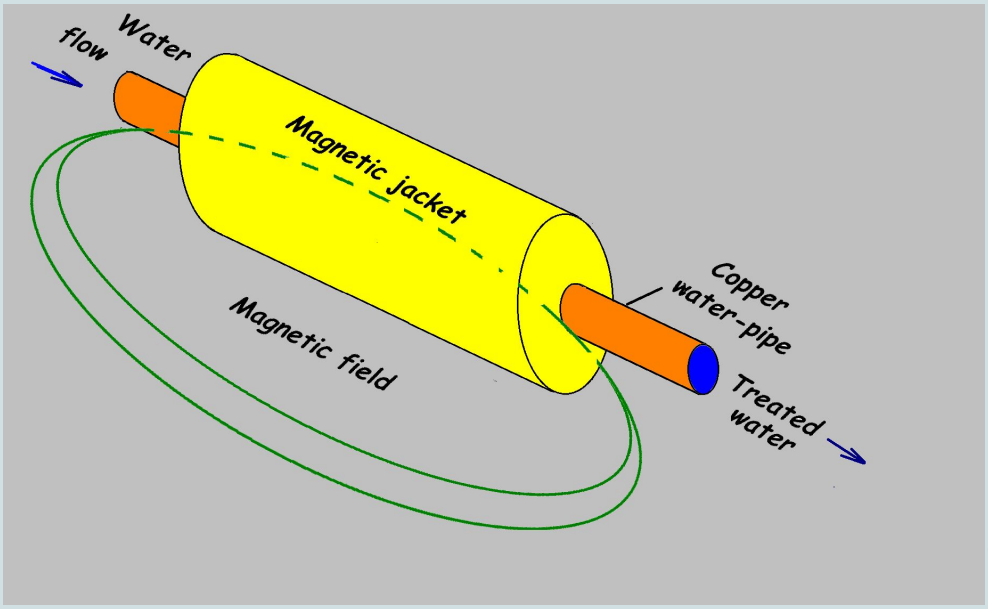
There are other methods such as;

Chemical-does not soften water they prevent scale.

Magnetic scale inhibitor - breaks crystals down so they can flush through, it alters the physical nature of the water

Electrical scale inhibitor - similar to the magnetic scale inhibitor

Video on softeners



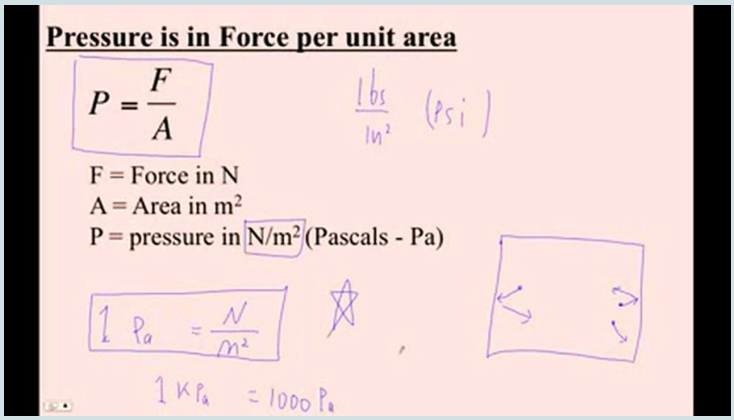
Quiz

Quiz-

Quiz on this chapter

Chapter 3 - Pressure, force and flow of water

SI units of pressure, force and flow.



Working out pressure

To work out pressure, we need to know two things:

1. the force or weight applied
2. the area over which the force or weight works

Example -
A force of 20 N acted over an area of 2 m2 (two square metres).
force ÷ area = pressure
20 ÷ 2 = 10 N/m2

Pascals and Newtons are measurements of pressure.
Notice that the unit of pressure here is N/m2 (newtons per square metre). Sometimes you will see another unit being used. This is called the pascal, Pa.
1 Pascal = 1 N/m2, so in the example above the pressure is 10 Pa.

Pressure, force and flow of water

Definitions-

Velocity The rate at which an object changes its position, taking into account speed and direction (m/s).

Acceleration The rate at which an object increases its velocity.

Acceleration due to gravity Gravitational pull of 9.81m/s (gravity is 9.81KN/m2).

Flow rate The amount of fluid that flows through a pipe at a given time.

Force An influence on an object that may cause it to move (N)+.

Pressure, force and flow of water

Head height x 9.81(gravity)= Intensity of Pressure N/m^2

Kilopascals/kPa	Bar	Meters head
10	0.1	1

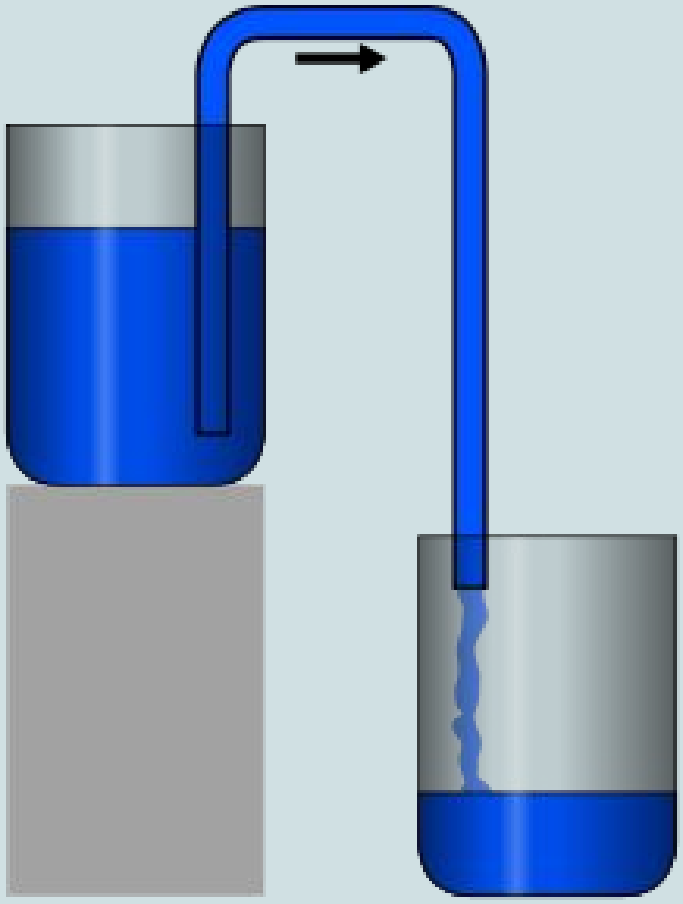
Static pressure is worked out when the water is stationary and dynamic pressure is worked out when the water is flowing.
Head refers to the height where the water comes from/stored.
Pressure: the greater the head, the greater the pressure
Video on pressure and flow

Pressure, force and flow of water

Siphon-

Definition- A pipe or tube in the form of an upside-down U, filled with liquid and arranged so that the pressure of the atmosphere forces liquid to flow upward from a container through the tube, over a barrier, and into a lower container.

Video on how a siphon works



Pressure, force and flow of water

Pressure and flow-

1 litre of water = 1kg
If a cistern holds 40 litres of water, you can work out the force of water leaving the tap.

40kg x 9.81m/s gravity = 392N

Force
If you reduce the pipe diameter,

like on this garden hose,

the speed increases and the

water shoots out further,

but the pressure and flow rate

have reduced.

Pressure, force and flow of water

What is flow rate?

The amount of fluid that flows through a pipe at a given time.

Flow rate can be affected by many factors:

Changes in direction
Pipe size
Pressure
Length of pipe
Frictional resistance
Constrictions.

Pressure, force and flow of water

Changes in pipework

If an appliance requires an increase in the flow rate, the elbows should be removed and replaced by machined bends, as this will ease the restriction.
The pipe diameter can be increased, to increase the velocity of the water, which is commonly the case for a bath feed compared to a basin feed. Resistance in pipes can be caused as you the plumber installs the system by the fittings you install. For every elbow, tee etc...will add resistance to the water. Notice the figures below highlights that the pulled bend adds less resistance than fittings, therefore whenever possible use a bend rather than a fitting.

Elbow	0.5m
Tee	0.6m
Stop valve	4.0m
Check valve	2.5m
Pulled bend	0.3m

Quiz

Quiz

Chapter 4 - Principles of heat in relation to plumbing systems

Transfer of heat-

Heat can be transferred in three ways which are as follows;

- Conduction
- Convection
- Radiation

Video on conduction

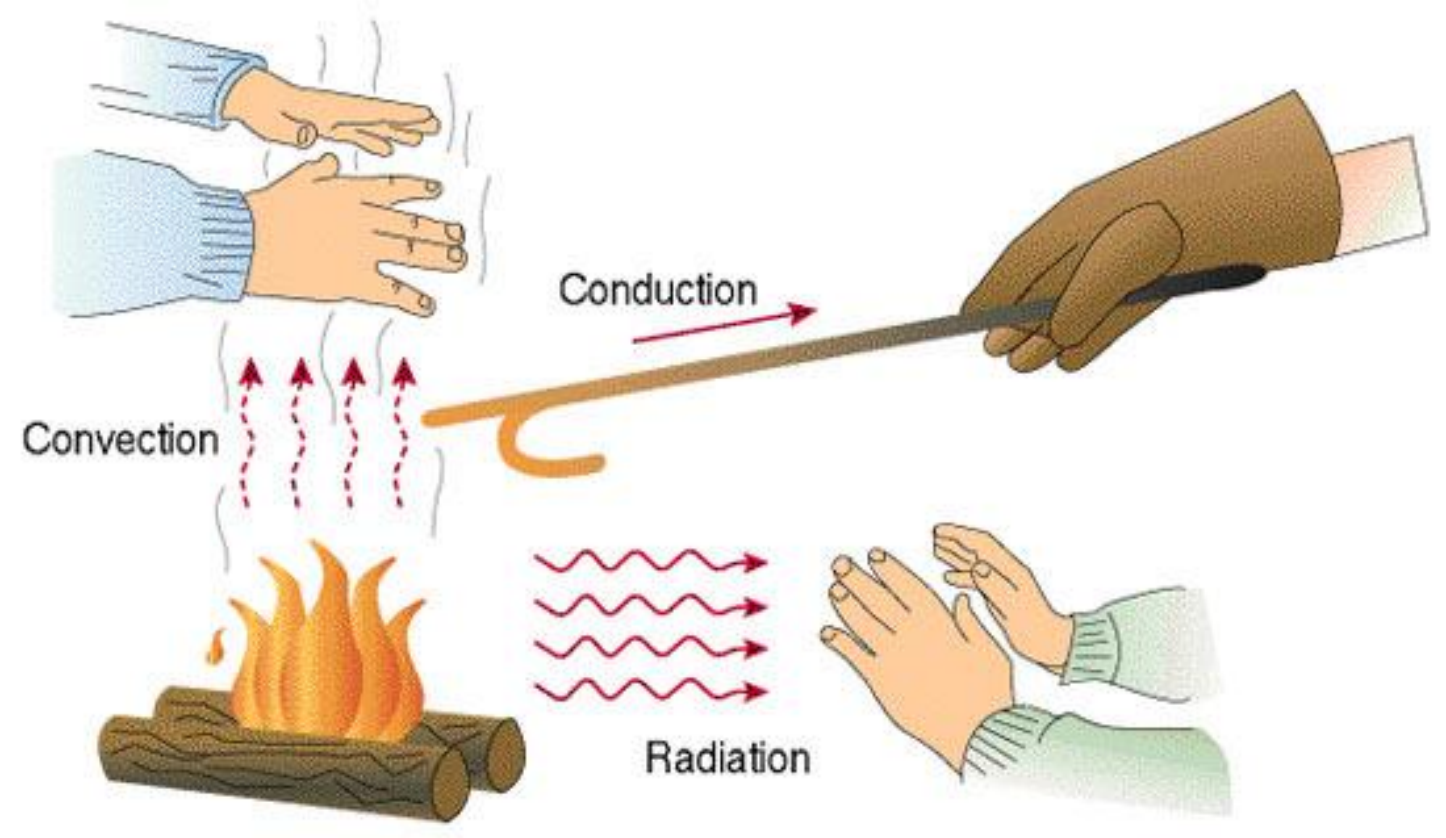
Video on convection

Video on radiation

Conduction

Conduction happens when heat travels through or along a material (one molecule to the next).
Heating copper tube to solder, or heating coil in a DHWC.
Copper is a very good thermal conductor. Plastics tend not to be good thermal conductors.

Principles of heat in relation to plumbing systems



Principles of heat in relation to plumbing systems

Convection

Can only take place in a fluid or gas.
Convection occurs because when molecules are heated, they heat and rise, and when they cool they fall. This is the main way a DHWC heats the water up by.

Radiation

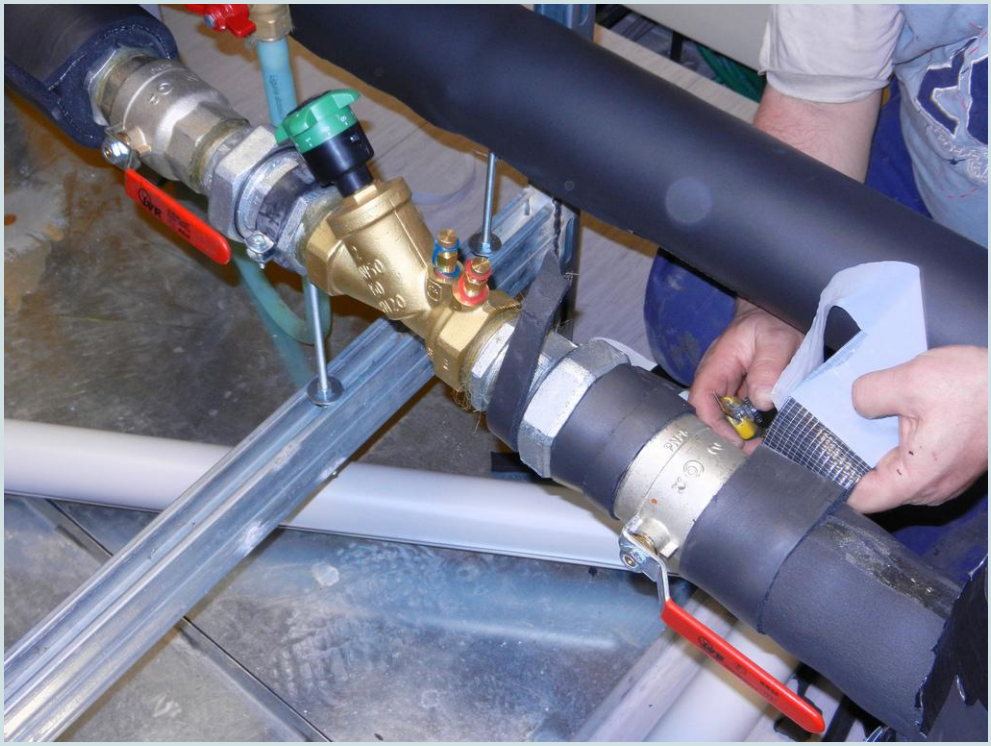
This is heat transfer via infrared light. It transfers heat from one body to another without heating the space in between.

Heat is measured in °C or scientifically in Kelvin (K).

Certain situations mean that heat needs to be retained – and at other times emitted – but always controlled. Hot water cylinder pipes need insulating to keep the heat in, so the hot water does not lose its temperature (efficiency).

Principles of heat in relation to plumbing systems

Cold water mains pipe needs to be insulated to stop condensation forming on the pipe. White cars are more common in hot countries, as white reflects the sun's heat. In solar panels, shiny surfaces are needed to absorb the heat from the sun.
Dark colours absorb heat – unpainted cast iron.
Light colours reflect heat – polished aluminium.
Heat remains in the pipework when it is insulated and therefore increases efficiency and reduces running costs.



Video on insulating pipes

Principles of heat in relation to plumbing systems

Heat transfer needs to be controlled: Building Regs part L.

Programmers – only on when needed.
Boiler stat – not too high (primary circuit).
Cylinder stat – not above 600C (secondary circuit).
Room stat – as low as possible.
TRVs – control individual rooms.
Zones – upstairs and downstairs.

Part L

Quiz-

Quiz on this chapter HERE

Chapter 5 - Principles of combustion and heating gases

When fuel or flammable materials are heated, the energy stored inside starts to react with oxygen in the air, giving off heat. This creates a vicious cycle, which causes the fire to spread. To stop the spread of a fire you have to remove one of these elements to break the triangle.

Remember- When working with heat producing equipment always use heat proof mats to protect the fabric of the building and also always have a fire extinguisher ready from your PPE kit.

Types of gases used in the plumbing industry-

- Propane
- Butane
- Natural gas

Gases used in blow torches-
Blowtorches can use different gases depending on the kind of work done. Professional gas torches use acetylene or MAPP gas to mix with oxygen, while smaller, home torches typically use either butane or propane

Principles of combustion and heating gases

Calorific values of gases used-

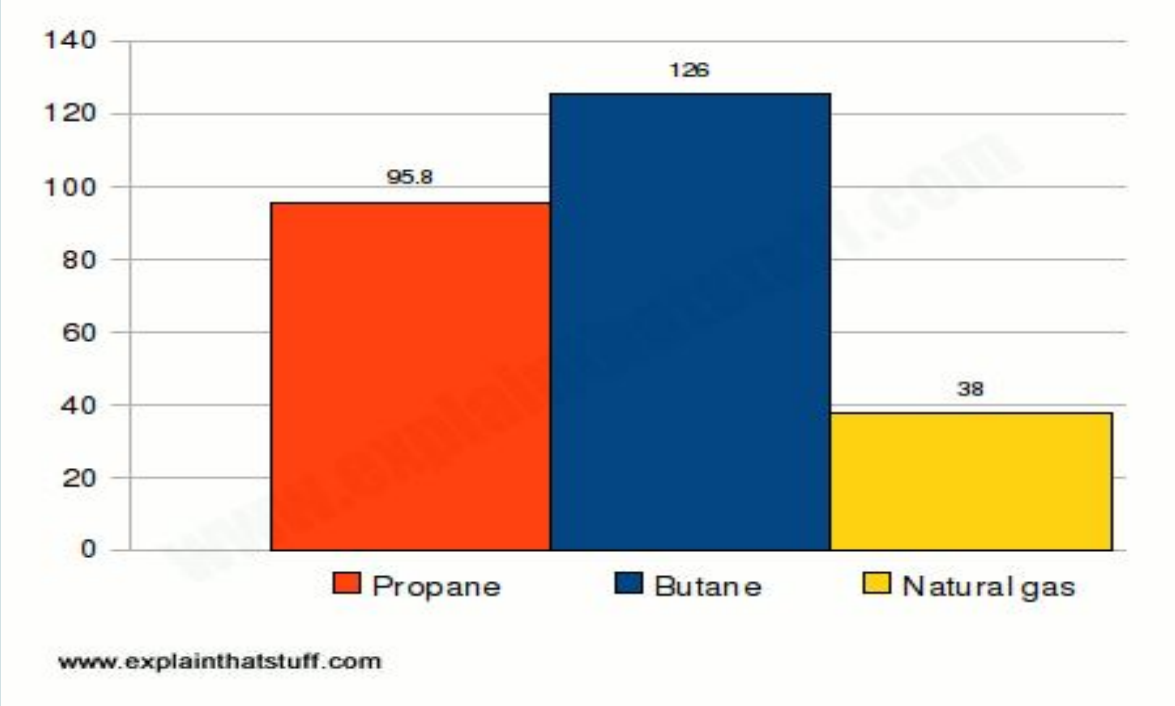


Chart: LPG packs more punch: both propane (red) and butane (blue) contain considerably more energy per cubic meter than natural gas (yellow); in other words, they're more calorific. Butane holds more energy than propane because a molecule of butane has three more atoms than a molecule of propane and three more chemical bonds holding it together. More bonds break when you burn butane, so more energy is released during combustion. Figures in megajoules per cubic meter.
Data from Calor Gas UK.

Principles of combustion and heating gases

Air to gas ratios-

Natural gas	Propane	Butane
10:1	24:1	30:1

In essence this means that for every cubic metre of gas used; for example natural gas then 10 cubic metres of air will be required to achieve complete combustion.

Natural gas: commonly used in domestic properties for boiler and cooker fuel. Ventilation is required in certain applications. Not hot enough for soldering.

Propane: commonly used for caravan boiler and cooking. Also used if mains gas is unavailable. Ventilation required.

Butane: commonly used in barbecues, due to high calorific value. Too hot for soldering. Ventilation required.

Principles of combustion and heating gases

Quiz-

Quiz for this chapter click HERE

Chapter 6 - Basic principles of electricity

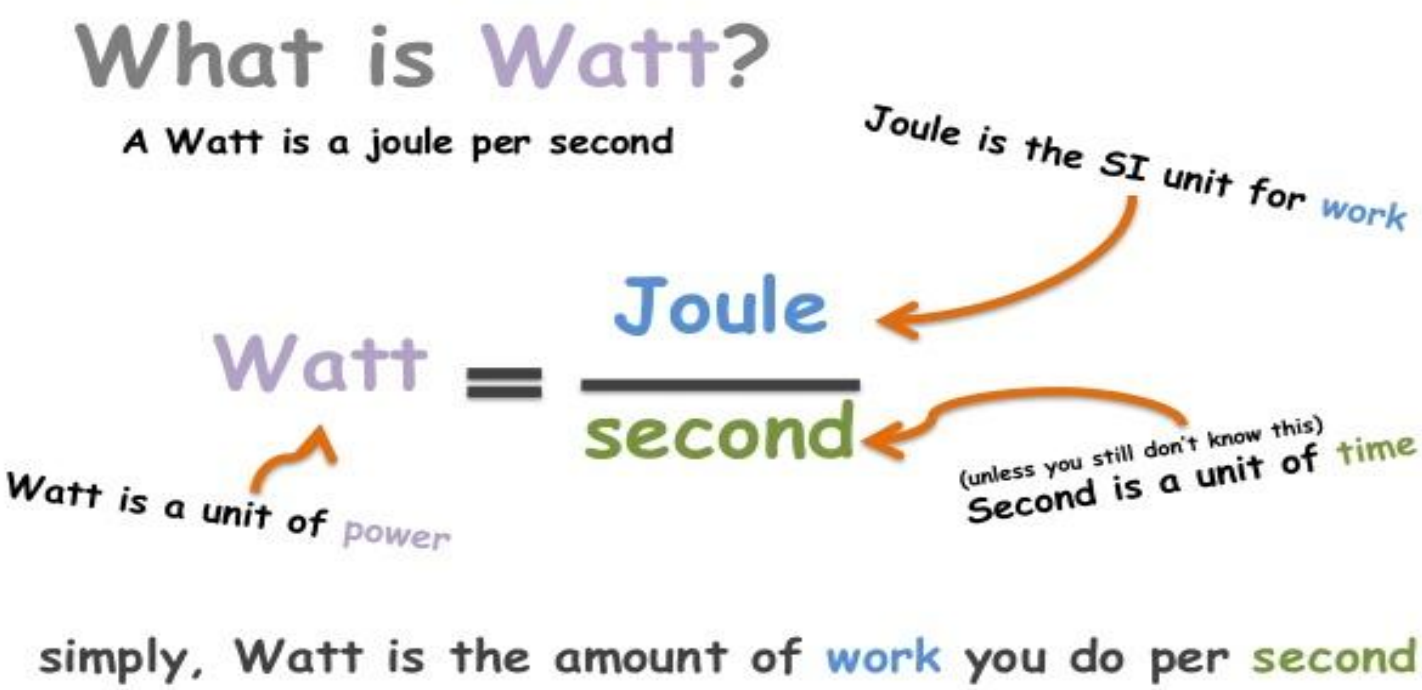
Principles of electricity-

Voltage = V
The unit for electromotive force (emf). The higher the voltage the greater the force is to cause electrons to flow along the conductor (eg 240v for domestic).
Current = I
The ampere is the unit of current, and can be defined as the unit of quantity or volume passing down a conductor. (eg 3 amp fuse).
Resistance = R
The ohm is the unit of resistance, which opposes the flow of current.

Quantity	Symbol	Unit of Measurement	Unit Abbreviation
Current	I	Ampere ("Amp")	A
Voltage	E *or* V	Volt	V
Resistance	R	Ohm	Ω

Basic principles of electricity

What is watt?



Watts = W

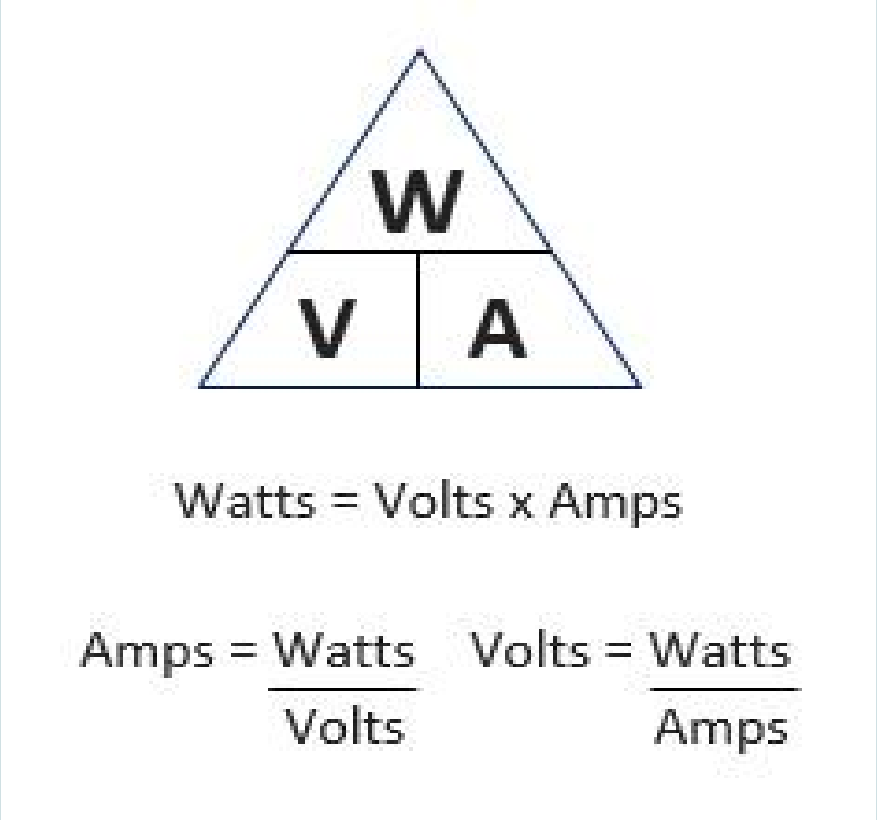
It is the unit of power for an appliance. Power is used to make an appliance work; as some power is absorbed, an appliance is never 100% efficient (e.g 3kW immersion heater).

Joules = J

The unit of electrical energy. As this is so small, it is not generally used. Today it would be measured in the kilowatt hour, which is how electricity bills are measured.

Basic principles of electricity

The relationship between amps-watts-volts

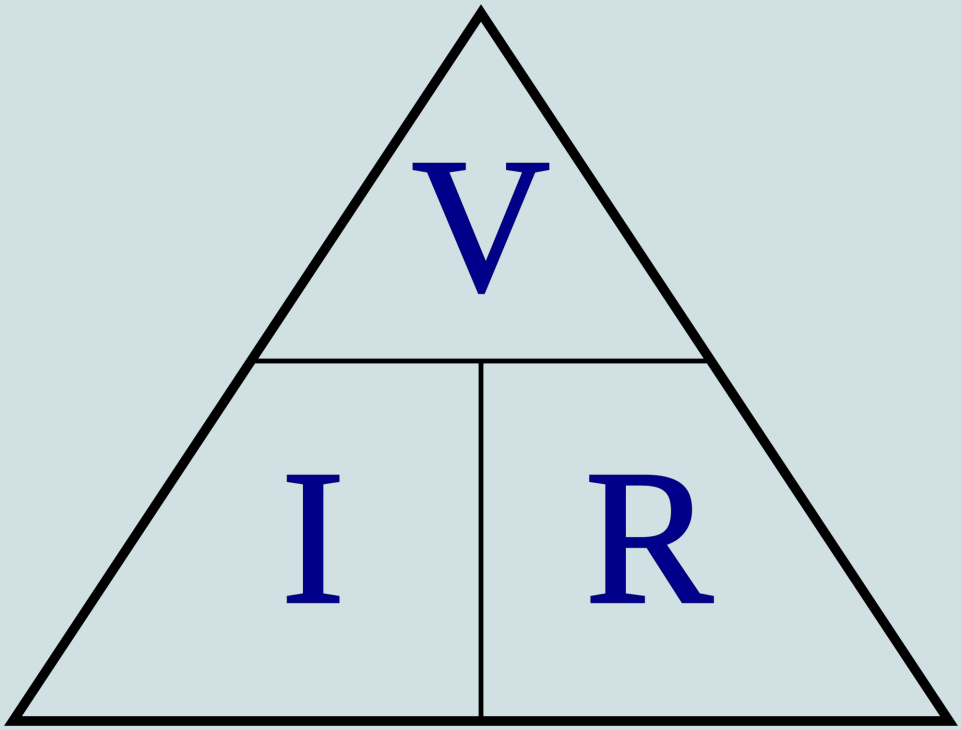


To use the power triangle just cover up what you are looking for; an example may be amps; so cover up the **A**, then because the **W** is on top and the **V** below divide the two. If you are looking for the watts, the V&A are on the bottom these would be multiplied to give you your answer in watts.

Basic principles of electricity

Ohms law-

Ohm's Law shows the relationship between: voltage – current – resistance. In a similar manner to the power triangle.



AC (alternating current) DC (direct current)

Video explaining AC and DC currents

Basic principles of electricity

Quiz-

Quiz on this chapter click HERE

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