Unit 305PH: Understand scientific principles

# Delivery guide

Unit information

This unit provides learning in the essential scientific principles that underpin the installation, commissioning and maintenance requirements of systems and components in the plumbing and heating Industry.

The unit also provides learning in a range of basic calculations.

Learners may be introduced to this unit by asking themselves questions such as:

* What are units of measurement and how are they used?
* What are the properties and applications of solid materials, liquids and gases?
* What do the terms energy, heat and power mean and what is their relationship with each other within the plumbing and heating industry?
* How do the principles of force and pressure apply within the plumbing and heating industry?
* What are mechanical principles?
* What are the principles of basic electron flow?

Learning outcomes

1. Understand the units of measurement used in the plumbing and heating industry
2. Understand the properties of materials
3. Understand the relationship between energy, heat and power
4. Understand the principles of force and pressure and their application in the plumbing and heating industry
5. Understand the mechanical principles in the plumbing and heating industry
6. Understand the principles of electricity in the plumbing and heating industry

Suggested resources

Textbook

Maskrey, M. (2009) *The City & Guilds Textbook: Plumbing Book 1 for the Level 3 Apprenticeship (9189), Level 2 Technical Certificate (8202) & Level 2 Diploma (6035) (City & Guilds Textbooks))*.London: Hodder Education. ISBN 978-1-5104-1648-2

Websites

* [BBC Bitesize | How an electric circuit works](https://www.bbc.co.uk/bitesize/clips/zq3fb9q)
* [BBC Bitesize | Material properties](https://d.docs.live.net/0654c38050dc99c9/Desktop/Just%20Content/C%5e0G%20Apprenticeship%20Delivery%20Guides/Apprenticeship%20-%20BSE/Plumbing%20and%20heating/2%20Edited%20units%20for%20review/Checked%20against%20HB%20and%20edited/BBC%20Bitesize%20|%20Material%20properties)
* [BBC Bitesize | Properties of water](https://www.bbc.co.uk/bitesize/guides/zt9887h/revision/10)
* [BBC Bitesize | Science](https://www.bbc.co.uk/bitesize/subjects/z7nygk7)
* [BBC Bitesize | SI Units](https://www.bbc.co.uk/bitesize/guides/z2mcfcw/revision/1)
* [BBC Bitesize | What is electricity?](https://www.bbc.co.uk/bitesize/topics/zgy39j6/articles/z8mxgdm)
* [Britannica | Composition and properties of natural gas](https://d.docs.live.net/0654c38050dc99c9/Desktop/Just%20Content/C%5e0G%20Apprenticeship%20Delivery%20Guides/Apprenticeship%20-%20BSE/Plumbing%20and%20heating/2%20Edited%20units%20for%20review/Britannica%20|%20Compostion%20and%20properties%20of%20natural%20gas)
* [Britannica | Corrosion](https://www.britannica.com/science/corrosion)
* [Calor | Calor LPG](https://d.docs.live.net/0654c38050dc99c9/Desktop/Just%20Content/C%5e0G%20Apprenticeship%20Delivery%20Guides/Apprenticeship%20-%20BSE/Plumbing%20and%20heating/2%20Edited%20units%20for%20review/Checked%20against%20HB%20and%20edited/Calor%20|%20Calor%20LPG)
* [eHow | Electrical calculations](https://www.ehow.co.uk/how_7605042_calculate-electrical-circuit-loads.html)
* [How Stuff Works | How electricity works](https://science.howstuffworks.com/electricity.htm)

| **Learning outcomes** | **Criteria** | **Delivery guidance** |
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| 1. Understand the units of measurement used in the plumbing and heating industry | * 1. The internationally recognised (SI) units of measurement | * Learners to have an understanding of the metric system of measurement and to know that it is an internationally recognised standard of measurement. * Learners to be able to identify and use in basic calculations the following internationally recognised (SI) units of measurement: * Metre (m) – unit of length * Kilograms (kg) – unit of mass * Second (s) – unit of time * Ampere (A) – unit of electrical current * Kelvin (K) – unit of temperature * Litres (l) – unit of the amount of substance * Pascals (Pa) – unit of pressure * Bar (bar) – unit of pressure. * Learners to be given examples of where these units are used in a practical setting, for example when marking out for system pipework or for positioning sanitary appliances. * Learners to be able to demonstrate how to use these SI units of measurements for calculating temperature, the contents of a cylinder and conversion of minutes into seconds. * Learners to be able to explain thermodynamic temperature and the unit of measurement Kelvin (K). |
| * 1. The application and use of SI derived units | * Learners to be able to state the application and use of the following SI derived units: * area (m2) (length x width) * volume (m3) (length x width x height) * density (kg/m3) (kilograms per cubic metre) * velocity (m/s) (metres per second) * acceleration (m/s2) (metres per second squared). * Learners to be able to calculate SI derived units. * Learners to be allowed to practice measuring the area of the classroom, the volume of the room and volume of cold-water storage cisterns. |
| * 1. The use of conversion tables for non-SI units | * Learners to be able to use conversion tables to complete calculations, for example imperial to metric conversion tables. * Learners to be allowed to calculate the volume of cold-water storage cisterns using imperial measurements and converting the figures to an SI unit. * Learners to be able to: * calculate area using imperial measurements then convert them to metric * convert lengths from imperial (inch) to metric (cm). |
| 1. Understand the properties of materials | * 1. The relative densities of common materials | * Learners to be aware of the densities of common gases in relation to air and common liquids and solids in relation to water. * Learners to be able to list the metals, plastics and fireclay and ceramic materials used in Mechanical Engineering Services (MES), giving examples of their applications. * Learners to understand the principles of Boyle’s and Charles’ Laws and how this applies in MES. * Learners to be able to compare relative densities of common materials including: * relative density to air (specific gravity) * relative density to water. * Learners to be able to calculate the relative densities of common materials including: * copper * steel * brass * polypropylene. * Example: Brass has a relative density of 8.4. * How much does 1m3 of copper weigh = 8400kg? |
| * 1. The properties and applications of solid materials | * Learners to be able to identify the properties and applications of solid materials used within the plumbing industry. * Materials include: * pure metals (copper, aluminium, lead) * ferrous metals (steel, cast iron, galvanised steel, stainless steel) * alloys including solders (brass, bronze, solder) * thermo plastics (polypropylene, PVC, nylon, polyethylene, polybutylene) * thermo-setting plastics (epoxy resin, polyurethane) * fireclays/ceramics. * Properties include: * hardness * tensile strength * compressive strength * shear strength * malleability * ductility * elasticity * conductivity. |
| * 1. The reasons why solid materials breakdown | * Learners to understand why solids breakdown, how corrosion affects them and how to apply protective coatings. * Learners to be able to explain reasons why solid materials breakdown due to: * atmospheric corrosion * oxidisation of metals * ultraviolet (UV) damage to plastics * heat damage to plastics * electrolytic corrosion * electromotive series * galvanic corrosion: dissimilar metals in the presence of an electrolyte (water) * erosion corrosion. |
| * 1. The methods of preventing corrosion | * Learners to be able to outline the methods used to prevent corrosion of plumbing systems and components including: * enamelling * painted coatings * galvanised coatings * inhibitors * sacrificial anodes * wrapping. * Learners to be able to describe specific protection methods for each type of plumbing and heating system, for example the use of inhibitors for central heating systems to prevent corrosion and the use of sacrificial anodes in hot water cylinders to prevent electrolytic corrosion. * Learners to be able to explain types of corrosion including: * de-zincification * pitting corrosion. |
| * 1. The applications of liquids and gases | * Learners to be aware of the liquids and gases used in MES and to be able to give examples of their applications. * Learners to be able to identify the applications of the following liquids and gases within the plumbing industry. * Liquids: * water * refrigerants (HFCs, isobutane, ammonia, carbon dioxide) * anti-freeze/glycol mixes * fuel oils (kerosene, heating oil, diesel) * lubricants/greases (natural, synthetic). * Gases: * air and steam * Liquid Petroleum Gas (LPG) * natural gas * carbon dioxide * refrigerant gases. |
| * 1. The basic properties of liquids | * Learners to be able to describe the basic properties of liquids (water) including: * boiling/freezing point * change of state and molecular changes * volume and pressure increases * density at differing temperatures * steam/super-heated steam * capillarity * adhesion and cohesion * acidity/alkalinity (pH value). * Learners to understand the principles and causes of water hardness, including: * soft * temporary hard * permanently hard. |
| * 1. The basic properties of gases | * Learners to be able to describe the basic properties of gases (natural gas/LPG/air) including: * pressure * volume * temperature of gases found within the industry * calorific value * flammability limits * flame speed * ignition temperature * specific gravity. * Learners to understand the scientific principles that relate to gases, including: * Charles’s Law * Boyle’s Law. |
| 1. Understand the relationship between energy, heat and power | * 1. The relationship between the Celsius and Kelvin temperature scales | * Learners to be able to identify the units of measurement for temperature, to be aware of the relationship between them and to be able to convert them for: * Celsius * Kelvin. * Learners to be able to discuss the equipment used for measuring temperature including: * glass thermometer * digital thermometer * infrared thermometer * differential thermometers. * Learners to be able to explain the use of each piece of equipment and what systems they would be used on, for example, a digital thermometer is used for taking temperatures at terminal fittings. |
| * 1. The principles associated with a change of state | * Learners to be able to describe the principles that are associated with a change of state: * melting (solid-liquid) * freezing (liquid-solid) * boiling (liquid-gas) * evaporating (liquid-gas) * condensing (gas-liquid). * Learners to be able to describe what causes a change in state. |
| * 1. How the terms latent and sensible heat apply to liquids and gases | * Learners to be able to describe the terms ‘latent’ and ‘sensible heat’ as they apply to liquids and gases. * Learners to know that latent heat is the amount of heat released or absorbed by a unit mass of substance during a change of state of the substance. * Learners to know that sensible heat is the amount of heat released or absorbed by a unit mass of substance without a change of state of the substance. |
| * 1. The methods of heat transfer | * Learners to be able to describe and provide examples of the following methods of heat transfer: * conduction * convection * radiation. * Example: * radiation (heat from the sun) * convection (gravity circulation in a hot water system) * conduction (heat travelling up a copper pipe). |
| * 1. How units of energy and heat are related and derived | * Learners to be aware that the unit of energy is a Joule and to understand that it derived from the units of power and time. * Learners to know the term ‘specific heat capacity of a substance’ is the amount of heat required to raise the temperature of one gram of a substance through one degree Celsius. * Learners to understand that specific heat capacity is a unit derived from the units for energy, mass and temperature. * Learners to be able to describe how the following units of energy and heat are related and derived: * energy – Joules (J) * specific heat capacity (kJ/kg/°C) * power – Watts (W) * maximum density * coefficient of linear expansion. * Learners to be able to explain how to calculate coefficient of linear expansion for a range of common plumbing materials, such as plastic guttering. * Learners to know increase in length (m) = original length (m) × temperature rise (°C) × coefficient of linear expansion. * Learners to be aware that the unit of power is a Watt and to understand that it is derived from the units of energy and time. |
| * 1. Heat, energy and power calculations | * Learners to be able to carry out the following heat, energy and power calculations: * quantity of heat energy required to raise the temperature of a substance: litres x temperature difference x specific heat capacity * the amount of power required to heat a substance: litres x temperature difference x specific heat capacity/time in seconds. |
| 1. Understand the principles of force and pressure and their application in the plumbing and heating industry | * 1. How units of force and pressure are derived from SI units | * Learners to be able to state how units of force and pressure used within plumbing and heating are derived from SI units: * Acceleration (m/s2) * Force due to gravity * Force – Newton (N) * Pressure (N/m2) * Atmospheric pressure * Flow rate (m3/s). |
| * 1. The pressure and flow rate units of measurements | * Learners to be able to identify and apply the following pressure and flow rate units of measurements. * Pressure: * bar/millibar * kPa * psi * metre head. * Flow rate: * m3/s * l/s * kg/s. |
| * 1. The application of pressure and flow rate measurements | * Learners to be able to describe and apply pressure and flow rate measurements on a range of plumbing systems. * Learners to be able to describe the effect of flow rate measurements on the system relating to good design to meet specifications and the reduction of noise and erosion in the system. |
| * 1. Simple force and pressure calculations | * Learners to be able to carry out simple force and pressure calculations. * Force calculations: * pressure head. * Pressure calculations: * static pressure * dynamic pressure * draught * forced draught. * Learners to understand the conversion between different pressure and flow rate units of measurements. |
| * 1. The relationship between velocity, pressure and flow rate in systems | * Learners to be able to explain the relationship between velocity, pressure and flow rate in systems including: * effects of increasing/reducing pressure * effects of increasing/reducing pipe size. * Learners to understand that there is a relationship between pressure in fluid systems and fluid velocity and flow rate. |
| * 1. How restrictions in the pipework affects the flow of liquids and gases | * Learners to understand that reducing or increasing pipe sizes alter the velocity and flow rate of fluids. * Learners to be able to identify how restrictions in the pipework affects the flow of liquids and gases: * changes of direction, bends and tees * pipe size * pipe reductions * roughness of material surface * constrictions such as valves. * Learners to understand the theory of laminar and turbulent flow in pipes and that there is a frictional resistance created when fluid moves in a pipe, and the diameter of a pipe determines the magnitude of frictional resistance. |
| * 1. The principles of a siphon | * Learners to be able to describe the applications and principles of a siphon (moving water from a high place to a low place using only atmospheric pressure and the cohesive properties of water). * Learners to know that this principle is used for the operation of a flushing cistern. |
| 1. Understand the mechanical principles in the plumbing and heating industry | * 1. The principles of simple machines | * Learner to be able to outline the working principles and applications of simple machines including: * levers * pulleys * Archimedes screws * wheels and axles. |
| * 1. The principles of basic mechanics | * Learners to be able to outline principles of basic mechanics including: * theory of moments * action and reaction * centre of gravity * equilibrium * velocity ratio * mechanical advantage. * Learners to understand the use of pulley systems for lifting heavy objects, moving onto wheels and axles. * Learners to know the principles of Archimedes screws and some of their applications with plumbing and heating. |
| 1. Understand the principles of electricity in the plumbing and heating industry | * 1. The basic principles of electron flow theory | * Learners to be able to identify basic principles of electron flow theory including: * measurements of electrical flow * material conductivity and resistance * the differences of alternating current (AC) and direct current (DC) currents * how AC and DC currents are generated. |
| * 1. The purpose and application of simple units of electrical measurement | * Learners to be able to describe the purpose and application of simple units of electrical measurement including: * current (amps) * voltage (volts) * resistance (ohms) * power (watts). |
| * 1. Simple electrical calculations | * Learners to know the simple units of electrical measurements and to be able to carry out simple electrical calculations including: * Ohm’s Law * power consumption of electrical circuits * basic over-current protection device size * voltage * current * resistance in series and parallel circuits. |
| * 1. The requirements for earthing of electrical circuits | * Learners to be able to describe the requirements including conductor sizes for earthing of electrical circuits for: * main equipotential bonding * supplementary bonding. * Learners to be able to identify the different types of earthing systems including: * Terre-terre (TT) system * TN system * Terrestrial neutral combined and separated (TN-CS) system. |