



Unit 21: Building Services Science

Delivery guidance

This unit focuses on the theory that underpins building services science, including principles that relate to electricity, heat transfer, thermodynamics, combustion and psychrometry.

Approaching the unit

There is a range of approaches that you could adopt when delivering this unit, including lectures, discussions, presentations, supervised practical investigations, independent research using a variety of resources and using personal and/or industrial experience. This variety will give you many ways to engage and inspire your learners.

There are also opportunities to carry out site visits and to invite visiting expert speakers to share current practices from industry. This will enhance the relevance of the subject while motivating learners who may be considering a career in this sector, whether through employment or by following higher education studies.

This is an optional unit for the Diploma in Building Services Engineering as well as the Extended Diploma in Building Services Engineering.

Delivering the learning aims

There are many opportunities for learners to carry out paired or small group investigations, using presentations and discussions to feed back their findings to the wider group. Throughout your delivery of the topics covered, learners will benefit from being given scenarios that relate to realistic construction problems. You will find that some of the topics also lend themselves to practical investigation tasks and/or demonstrations of underpinning science. The use of experiments, site visits and audio-visual materials would also be appropriate methods to reinforce learning.

Introduce **learning aim A** by leading a group discussion on the basic principles relating to energy, such as conservation of energy. This will allow you to gauge any prior knowledge and understanding. You could then set learners tasks to investigate methods of heat transfer along with associated calculations.

Following this, learners could work in small groups to carry out investigations into the properties of and the complete and incomplete combustion of a specific fuel. Each small group could give a short presentation on their findings to the rest of the group. Notes from this activity could then be compiled and made available for the whole group. If resources are available, learners could carry out supervised practical work to investigate combustion or they could be shown such processes using online resources.

Moving on to **learning aim B**, introduce the principles of both direct current (DC) and alternating current (AC). Where appropriate, you could use practical demonstrations and set practical investigations for learners to carry out readings and related calculations for voltage, power, current and other related quantities. You could also give learners a range of circuits to analyse either practically or virtually.



The delivery of electricity generation, transmission and distribution presents a good opportunity to carry out site visits, which would provide some background context to the learning aim. These could include visits to a power station, a small-scale wind or solar installation or similar. The topic of the transmission and distribution of energy and the voltages in each part of the network can form the basis of a learner-led research activity. As part of this, learners will need to be able to produce a diagram showing the energy supply and its component parts.

Give presentations to explain the conversions required for domestic installations from the local distribution transformer. You could discuss why different voltages are used for different settings, including commercial, domestic and portable equipment. Develop task sheets that require learners to calculate AC voltages and currents during generation, transmission and distribution.

Learning aim C covers the basic principles of thermodynamics. You could lead discussions about, set group practical activities about or conduct demonstrations of the principles of thermodynamics. You could also use appropriate video resources. Introduce the general gas law, making appropriate use of demonstrations or simulations to allow learners to visualise the relationship between pressure, volume and temperature.

Once learners have a good understanding of the fundamental parameters of thermodynamics, build on this knowledge by introducing pressure–enthalpy (P-H) diagrams, graphical representations of thermodynamic processes and a combination of these in order to solve thermodynamic problems. To further prepare learners for investigating air conditioning systems, introduce the kinetic theory of matter and the reasons for changes in state. This then leads into discussions relating to sensible and latent heat, which again provides the opportunity for learners to carry out investigations or demonstrations to support theoretical knowledge.

Enhance any tutor-led discussions on the basic principles of psychrometry with hands-on practical work and/or demonstrations. For example, learners could carry out practical investigations by taking measurements of actual air temperature and relative humidity in their classroom or working areas. They could then use charts to determine how to alter the condition of the air to the desired conditions.

It would be appropriate to carry out site visits to observe the operation of suitable installations as well as using the expertise of external speakers to explain the interaction of factors when designing building services systems.



Assessment model

Learning aim	Key content areas	Recommended assessment approach
A Understand the principles of energy, heat transfer and combustion applicable to building services systems	A1 Energy A2 Heat transfer A3 Combustion of fuels	Analysis of a given a client brief in relation to the heat transfer and combustion system applicable to the context.
B Explore the characteristics of electrical supply systems applicable to building services systems	B1 Electrical principles B2 Generation, transmission and distribution of electricity	A report for a given project scenario that covers the different transmission methods that can be used to provide electricity to a particular site, including the use of appropriate transformers.
C Examine the thermodynamic properties for heating, air conditioning and refrigeration	C1 Ideal gases and application to building services engineering applications C2 Thermodynamic properties and processes C3 Change of state C4 Air conditioning systems and refrigeration	A report for a given project scenario that covers the evaluation and interpretation of a P-H diagram.

Assessment guidance

There is a maximum of three summative assignments for this unit, one for each of the learning aims. There is flexibility in the forms of evidence that are acceptable: for example, you could use a report and a presentation, as long as the work submitted fulfils the necessary requirements of the assessment criteria and the essential information for assessment decisions and is individual to each learner. However, each learner must include line drawings and diagrams as part of their submission.

Evidence for **learning aim A** is most likely to be in the form of an illustrated written report that will include line drawings and diagrams to support the text. Learners should support their judgements by providing clear links to the required installation and the information provided in the client brief.

The evidence for **learning aim B** is also likely to be in the form of a report for the given project scenario. Again, it should include detailed and comprehensive line drawings that support learners' evaluation of the advantages and disadvantages of alternative electrical distribution systems.



Finally, for **learning aim C**, learners should present a report that provides at least two solutions to thermodynamic and psychrometric problems relating to heating, air conditioning and refrigeration systems, using tables and diagrams. The report should include an evaluation of the advantages and disadvantages of alternative systems and include detailed and comprehensive line drawings.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 21: Building Services Science

Introduction

Good building services design requires an understanding of a range of underpinning scientific principles that allow internal environmental conditions to be examined and changes made to improve or modify those conditions.

Give learners the background knowledge that they will need to understand the nature of energy, heat transfer mechanisms, thermodynamics and the theory of combustion of fuels. Ensure that learners have the opportunity to gain an understanding of the principles of electrical generation, transmission and distribution. Finally, demonstrate the skills required to use psychrometric charts and P-H diagrams to solve a variety of problems relating to building services.

Learning aim A – Understand the principles of energy, heat transfer and combustion applicable to building services systems

- Introduce the unit and **learning aim A1** by leading a discussion on building services installation. This could form the basis of a discussion into the nature of energy, including electrical and thermal energy, and its use within building services installations. This discussion could then be expanded to include the units that are used to measure energy and power, with learners considering the uses of each and applying conversions between them.
- Learners carry out either paired or small group investigations into the application of conservation of energy within building services contexts. This could be in the form of case studies or through scenario-based problems.
- Moving on, organise learners into small groups to research and produce presentations explaining the different temperature scales used in building services science. They should give examples of conversions between scales and typical applications of each.
- Introduce the principles and theory of specific heat capacity, reflecting on learners' prior knowledge of materials and their properties. Learners could complete activities related to the selection of materials and components for given situations.
- As a lead-in to **learning aim A2**, revisit the principles of conservation of energy and expand upon this with an overview of how these principles can be applied in heat transfer situations. Outline how this in turn impacts on the design and performance of installations and equipment.
- Follow this with a paired investigation into methods of heat transfer. Ask learners to produce illustrated reports that explain the processes of conduction, convection and radiation through structures and materials. They need to demonstrate the ways in which calculations can be carried out.
- Set learners a range of scenario-based problems so that they can independently carry out further calculations relating to conduction, convection and radiation. This could be accompanied by individual research and investigation into the factors that affect the rate of heat transfer.
- Once learners have a good understanding of types of energy and methods of heat transfer, introduce **learning aim A3**. Introduce the types of fuel that can be used in installations, then ask learners to investigate a range of different fuels before investigating combustion in more



detail. You could divide the group into three sub-groups and allocate a fuel type (solid, liquid and gas) to each group. The groups could then produce information booklets for their peers about the properties and constituents of the different fuels.

- Once learners have a sound understanding of different types of fuel, introduce them to the principles of combustion. A number of approaches could be used, including demonstrations, animations or video clips relating to combustion processes. For example, you could use animations or video to demonstrate the requirements for safe and efficient combustion and the differences between complete and incomplete combustion. Learners could then work individually or in pairs to complete scenario-based worksheets that ask them to research the causes and implications of incomplete combustion in domestic heating systems, along with methods to prevent this from occurring.
- To conclude the learning aim, introduce learners to the products of complete and incomplete combustion. This could form part of an extended investigation to be carried out by learners, which could also consider air requirements and the need to control excess air quantities.
- At this point, you could assess learners for learning aim A. This assessment is likely to be in the form of a report that addresses a given client brief and installation scenario.

Learning aim B – Explore the characteristics of electrical supply systems applicable to building services systems

- Begin **learning aim B1** by leading a discussion to determine learners' prior knowledge and understanding of direct current theory. Use this opportunity to also introduce learners to alternating current (AC) theory, referring to the similarities between some of the concepts, such as impedance and resistance.
- Ask learners to work in pairs to investigate the relationships between volts, amperes, ohms, joules and watts, including the SI units used for each, and the measurements that are taken for each in a building services application.
- Once learners understand each of the principles, demonstrate how to complete calculations for voltage, current, resistance, energy and power. Learners could then complete calculations based on given information.
- Give learners the opportunity to carry out some practical investigations into the concepts covered in this learning aim. You could do this by giving learners electronic kits to construct direct current circuits, from which they can take measurements of values such as voltage, current and resistance. Learners could compare these to the theoretical values found in earlier calculations. Alternatively, use online video resources to demonstrate how readings and measurements are taken.
- Introduce learning aim B2 by showing video clips or animations that illustrate the operation and principles of the three phase generator. When learners understand the relationship between the phases, give them a basic description of the process of generation in a conventional power station, where heat is used to produce steam that powers the turbine and then drives the generator. Divide learners into small groups to investigate how each specific type of power station generates electricity, with each groups investigating one of the following: nuclear, coal, gas, oil, wind, tidal or hydroelectric power stations.
- Introduce local methods of generation, with learners working in pairs to investigate and produce research notes about solar, wind and biomass used for small-scale electricity generation.



- Learners would benefit from visits to sites where small-scale generation is used, as this would allow you to introduce them to various components of the system. If this is not possible, you could achieve the same level of understanding using video resources.
- Once the principles of electricity generation are established, move on to the transmission and distribution of this electrical supply, looking at the processes from the power station to the consumer. This will include transformer principles and the concepts that relate to both step-up and step-down transformers. Check learners' understanding by setting tasks that require them to do calculations to determine voltage and current values.
- Learners could then move on to consider the application of transformers in the transmission and distribution of electrical power. This could include a case study covering power distribution, starting at the power station and including national transmission via various grids and distribution to local transformers.
- This could lead on to a learner-led research project, which should include information about the extent, make-up and components of the grid and the local supply. Learners could research the various voltages and the hierarchy of grid system up to the local supply. They could produce a suitable diagram showing the elements and voltages that make up the network of transmission and distribution.
- Finally, introduce theory relating to the function and processes of a local transformer, which converts an incoming supply of high voltage to a low voltage. Learners could investigate the different types of supply provided by a local transformer, including the supply of single phase voltage to domestic installation from the three-phase mains and three-phase commercial supply. This could also include the need for a lower supply voltage for portable workshop equipment.

Learning aim C – Examine the thermodynamic properties for heating, air conditioning and refrigeration

- Introduce **learning aim C1** by refreshing learners' understanding of pressure, temperature, volume and mass. Follow this with individual learner investigations into the relationships between these quantities, the units of measurement and how they impact on the design and performance of installations.
- Introduce learners to the general gas law, giving them individual research tasks that require them to investigate the application of the general gas law to systems under pressure. This could be expanded upon by introducing the characteristic gas equations. Following the completion of worked examples, give learners some scenario-based problems relating to building services science in order to test their understanding of the concepts of general gas law.
- Introduce learners to systems where a number of different pressures are found and demonstrate the application of Dalton's law. Learners' understanding of this concept could be assessed using a number of activities that require learners to solve problems involving multiple pressures.
- Once learners have a good understanding of the principles of ideal gases and their applications, you could introduce them to the thermodynamic properties and processes covered in **learning aim C2**. Initially, discuss the concepts of saturation temperature and enthalpy, then set learners an individual study task to investigate the relationships between pressure, saturation temperature and enthalpy.
- Once learners understand pressure and enthalpy, introduce them to P-H diagrams. They should be able to identify various zones of the diagram and to interpret the information that is presented.



Demonstrate graphical methods of representing the thermodynamic processes of isothermal evaporation, adiabatic compression, simple vapour compression and refrigeration cycles.

- Introduce other methods of identifying values to solve problems, such as using tables. Follow this by giving learners a range of scenario-based activities that require them to determine values such as saturation temperatures, enthalpy for given conditions and problems relating to refrigeration plant and equipment.
- Begin **learning aim C3** by moving on to the kinetic theory of matter. Learners could conduct individual or paired investigations into the reasons for changes of state of matter. Develop their understanding of this by looking at concepts of sensible and latent heat, then link the theory of enthalpy to problems relating to changes of state of matter.
- Set learners some investigatory activities that consider latent heat, changes of state and also enthalpy, using the theory of enthalpy to arrive at solutions.
- Within the delivery of **learning aim C4**, there are opportunities to make effective use of guest speakers, such as members of an air conditioning company's sales team or an installation sub-contractor.
- Initially, focus on the principles of air conditioning processes and cycles and introduce learners to psychrometric terms and properties of air and water vapour. Following this, set tasks for learners to complete that require them to use calculations, measurements, use of tables and charts to arrive at solutions.
- Moving on, consider psychrometric process lines for a range of different conditions and ask learners to produce their own line drawings for given situations, such as dehumidification. Demonstrate to learners how to derive the resulting conditions for a mixture of two air streams, with learners practising and developing their skills in the production of such diagrams.
- Introduce summer and winter psychrometric cycles and a range of operating conditions and arrangements of plant. Learners could then carry out paired activities to plot summer and winter cycles based on the provided information and explain the information that is represented by the diagrams.
- To conclude this learning aim, introduce the approaches that learners will need to take to determine plant duties from given psychrometric charts, then ask learners to work individually to complete exercises based on these charts.
- In preparation for assessment, give learners scenarios for installations. They consider alternative approaches to meet the needs of the scenario and compare proposals. They could develop supporting documentation, such as line drawings, and the confidence to refer to tables and diagrams when making or evaluating proposals.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit has links to

- *Unit 11: Management of a Construction Project*
- *Unit 14: Low Temperature Hot Water Systems in Building Services Engineering*
- *Unit 16: Provision of Primary Services in Buildings*
- *Unit 19: Projects in Construction*
- *Unit 24: Conversion, Adaptation and Maintenance of Buildings.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Internationals in Construction and the Built Environment. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Bird J., *Electrical Circuit: Theory and Technology* (5th edition), Routledge, 2013, ISBN 9780415662864

Includes AC theory, DC theory, electromagnetism, transformers.

Grimwood, T. and Jeffery, A., *Levels 2 and 3 Diploma in Electrical Installations (Buildings and Structures)*, Pearson Education, 2013, ISBN 9781447940258

Gives a thorough grounding in all electrical principles and processes, with a comprehensive chapter on electrical science.

McMullan, R., *Environmental Science in Building* (7th edition), Palgrave Macmillan, 2012, ISBN 9780230290808

Covers a wide range of principles and theories relating to building services science.

Moss, K., *Heat and Mass Transfer in Buildings* (2nd edition), Routledge, 2007, ISBN 9780415409070

Includes chapters on heat transfer, heat exchangers, heat transfer, ventilation and other principles covered in learning aim C.

Sherwin, K. and Horsley, M., *Thermofluids*, Chapman and Hall, 1996, ISBN 9780412598005

Covers temperature, measurements, pressure, ideal gas laws, psychrometry and combustion as well as other topics covered in this unit.

Journals

Building Services & Environmental Engineer (Datateam Publishing Ltd) – relevant to all learning aims and includes current practices and developments in the industry.

CIBSE Journal (Chartered Institution of Building Services Engineers) – relevant to all learning aims, including current practices.

Heating and Ventilating Review (Datateam Business Media) – relates to learning aim C.



Videos

Search YouTube™ for the following videos:

- 'L11 1 Three Phase Power Generation' – an animation and presentation that covers both single-phase and three-phase generators
- 'Basics of Rooftop Solar PV' – a walkthrough of a solar photovoltaic installation
- 'Complete & Incomplete Combustion | Environmental Chemistry | Chemistry | FuseSchool' – complete and incomplete combustion explained.

Websites

Visit the Building Engineering Services Association (BESA) website.

Visit the Building Services & Environmental Engineer website. This is an industry magazine for building services and environmental engineering.

Visit the Chartered Institution of Building Services Engineers (CIBSE) website.

Visit the "Docircuits" website – an online simulator for electronic circuits.

Visit the Energy Networks Association website for more on local distribution design.

Search for the 'Electricity' page for more on how the transmission grid works.

Visit the Heating & Ventilating magazine for heating and ventilation contractors.

Visit the Learn About Electronics website. This covers both AC and DC theory

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling learners to access them through the school/college intranet.