Unit 33: Building Services Science

Unit code: T/600/0297

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to provide an understanding of heat transfer, thermodynamics, electricity, combustion and psychrometry for the building services industry.

Unit introduction

Building services is primarily concerned with creating comfortable working environments and environments that enable processes to be carried out effectively. It is, therefore, necessary to focus only on those areas of science that are useful in addressing these concerns. In other words, the science of building services is particular to building services and should not be thought of as general science.

The application of sound engineering principles to the design of building services requires a working knowledge of the appropriate supporting science. This includes an appreciation of its relevance and limitations, and the ability to use that science to underpin engineering decisions.

Good building services design is grounded in an understanding of what has led to the internal environmental conditions that exist in a working space. An understanding of what changes need to be made to improve or modify those internal environmental conditions is also required. In addition, a knowledge of how those changes can be accomplished in scientific terms is required, as is being aware of the impact on the wider environment of changing those conditions.

The focus of the unit is on linking scientific principles with practical applications and learners should have a basic understanding of science and analytical methods, or have begun studying the relevant units, before undertaking this unit.

Learning outcomes

On completion of this unit a learner should:

1 Understand the nature of energy in solids, liquids and gases, and the fundamental principles of heat transfer in building services applications

2 Understand the principles of electricity and combustion as they apply to the provision of electrical power, natural gas and other fossil fuel energy systems

3 Understand the thermodynamic properties of solids, liquids and gases as they apply to changes of state in heating, air conditioning and refrigeration installations

4 Understand the principles of psychrometry as they apply to air conditioning systems.

Unit content

1 Understand the nature of energy in solids, liquids and gases, and the fundamental principles of heat transfer in building services applications

Nature of energy: different forms of energy; units of energy; principle of the conservation of energy; absolute temperature scale; Kelvin and Celsius; specific heat capacity

Principles of heat transfer: types of heat transfer; applications and significance in building services systems; conduction transfer through single slab and composite structures; convection transfer due to free/natural convection in air from vertical and horizontal panels and horizontal cylindrical objects; radiation heat transfer from plane surfaces

2 Understand the principles of electricity and combustion as they apply to the provision of electrical power, natural gas and other fossil fuel energy systems

Electricity: electromagnetic induction; principles of alternating current (AC) generation; AC quantities; power in AC circuits; transformer principles; force on a current carrying conductor and its applications

Combustion of fuels: properties and characteristics of common solid, liquid and gaseous fuels; products of complete and partial combustion and their implications; minimum air requirements for stoichiometric combustion; requirements for excess air; need for control of excess air quantities; causes of incomplete combustion

3 Understand the thermodynamic properties of solids, liquids and gases as they apply to changes of state in heating, air conditioning and refrigeration installations

Thermodynamic properties and processes: relationship between pressure, saturation temperature and enthalpy; thermodynamic properties for water and refrigerants; use of tables and pH diagrams to solve problems; plotting processes and refrigeration cycles

Ideal gases: relationship between pressure, temperature, volume and mass; application of general gas law and characteristic gas equation; Dalton's Law

Change of state: kinetic theory of matter; reasons for change of state; sensible and latent heat; enthalpy change, problems incorporating latent heat of fusion and latent heat of vaporisation at constant pressure; examples within building services engineering where change of state occurs and latent heat is encountered

4 Understand the principles of psychrometry as they apply to air conditioning systems

Psychrometric principles: psychrometric terms and properties; psychrometric properties of air and water vapour mixtures by calculation, measurement, tables and charts

Air conditioning systems: air conditioning processes and cycles; psychrometric process lines for sensible heating and cooling, dehumidification and humidification (using different types of humidifiers); resulting condition from mixture of two air streams; plotting summer and winter psychrometric cycles for given arrangements of air conditioning plant and operating conditions; plant duties from psychrometric chart

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria					
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**		**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**	
P1	explain the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications [IE1, IE2, IE4, IE6, RL3, RL6, SM3]	**M1**	produce clear and accurate answers to four problems associated with heat transfer and the combustion of fossil fuels	**D1**	evaluate how the factors that affect heat transfer influence building services design
P2	discuss the essential characteristics of natural gas and other fossil fuel energy systems in terms of the principles of combustion [IE1, IE2, IE4, IE6, RL3, RL6, SM3]				
P3	discuss the essential characteristics of electrical energy systems in terms of the principles of electricity [IE1, IE2, IE4, IE6, CT1, CT2, CT4, RL3, RL6, SM3]	**M2**	produce clear and accurate answers to two problems associated with AC electrical supplies	**D2**	establish air conditioning and refrigeration plant and equipment duties.
P4	analyse sensible enthalpy, latent enthalpy and changes of state within building services engineering applications [IE1, IE2, IE4, IE6, CT1, CT2, CT4, RL3, RL6, SM3]	**M3**	produce clear and accurate answers to two problems relating to the gas laws and thermodynamic processes		

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P5 analyse the factors that determine pressure, saturation temperature and enthalpy for water and refrigerant gases [IE1, IE2, IE4, IE6, CT1, CT2, CT4, RL3, RL6, SM3]	**M4** plot psychrometric process lines associated with air conditioning plant and processes.	
P6 explain the psychrometric properties of air and water vapour mixtures. [IE1, IE2, IE4, IE6, RL3, RL6, SM3]		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills which are embedded in the assessment of this unit. By achieving the criteria, learners will have demonstrated effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, supervised practicals, research using the internet and/or library resources and use of personal and/or industrial experience are all suitable. Delivery should stimulate, motivate, educate and enthuse learners. Visiting expert speakers could add to the relevance of the subject.

The learning outcomes are all related in some way to energy. Although the main theme is thermal energy, each learning outcome deals with a different aspect of energy. This need not be in the order indicated by the unit content. It is logical that the first part of learning outcome 1 should be delivered before other thermal energy content and that some aspects of learning outcome 3 are dealt with before learning outcome 4. There is a degree of flexibility in the sequence of delivery and assessment.

The focus of this unit is on linking scientific principles with the practical applications of building services that can be found in other units. The delivery and assessment should either be integrated or coordinated with delivery of the appropriate sections of those more practical units. The sequence of delivery of this unit, and the design of assessment instruments, are likely to be influenced by the delivery and assessment of the related units.

Teaching and learning strategies designed to support delivery of the learning outcomes should take an integrated, learner-centred, investigative and supervised, hands-on, experiential learning approach. Practical activities should be used wherever possible. This will involve learners taking measurements, making observations, consulting standards, making decisions and suggesting alternatives.

Calculations are implicit in all learning outcomes but the unit should not be seen as a mathematical exercise and delivery should balance calculations, knowledge and understanding. Calculations used to support the delivery process should always reflect real-life and standard practice.

Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken before practical activities are taken. Centres are advised to read the *Delivery approach* section in the specification.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction by tutor Whole-class, tutor-led discussion on the basic principles of energy and heat transfer Individual research on specific items, compilation of information files; to be shared with the whole-class after comment, amendment and editing by the tutor Practical work and/or demonstrations of underpinning science where equipment is available. Use of audio-visual material and secondary sources where not Site visits to installations in progress, use of college workshops where available
Whole-class, tutor-led discussion on the basic principles of combustion Small group work on combustion of a specific fuel and compilation of information files. Each group to give a short presentation on 'their' fuel. Comment, amendment and editing by the tutor, followed by circulation of definitive handout Practical work and/or demonstrations of underpinning science where equipment is available. Use of audio-visual material and secondary sources where not Site visits to heating installations, use of college gas workshops where available
Assignment 1: Principles of Energy Conversion, Heat Transfer and Combustion
Whole-class, tutor-led discussion on the basic principles of electricity Practical work and/or demonstrations of underpinning electrical principles where equipment is available. Use of audio-visual material and secondary sources where not Visits to electrical installations, use of college electrical workshops where available
Whole-class, tutor-led discussion on the basic principles of thermodynamics Practical work and/or demonstrations of underpinning principles of thermodynamics where equipment is available. Use of audio-visual material/secondary sources where not
Assignment 2: Electricity and Thermodynamics
Whole-class, tutor-led discussion on the basic principles of psychrometry Practical work and/or demonstrations of underpinning principles of psychrometry where equipment is available. Use of audio-visual material and secondary sources where not Measurements of actual air temperature and relative humidity in classroom, use of charts to determine how to alter condition of air to that desired. Pressure/enthalpy considerations for water and refrigerant gases
Assignment 3: Pressure/Enthalpy and Psychrometry
Review of unit and assignment feedback

Assessment

Evidence for this unit may be gathered from a variety of sources, including well-planned investigative assignments, case studies or reports of practical assignments.

There are many suitable forms of assessment that could be used, and tutors are encouraged to consider and adopt these where appropriate. Some example assessment approaches are suggested below. However, these are not intended to be prescriptive or restrictive, and are provided as an illustration of the alternative forms of assessment evidence that would be acceptable.

Some criteria can be assessed directly by the tutor during practical activities. If this approach is used then suitable evidence would be observation records or witness statements. Guidance on the use of these is provided on the Pearson website.

The number of assignments needed to address this unit fully will depend on the extent to which they are integrated with assignments from other units, which is the preferred approach. Alternatively, if separate assignments are used, the structure of the unit suggests that the grading criteria could be addressed fully by using three assignments. The first of these would cover P1, P2, M1 and D1, the second would cover P3, P4, M2, M3 and D2 and the third P5, P6 and M4.

To achieve a pass grade learners must meet the six pass criteria listed in the grading grid.

For P1, learners must explain the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications. They must recognise how the principle of conservation of energy applies in heat transfer situations. Learners must be able to relate and illustrate these methods of heat transfer by reference to practical applications in their own field.

Although at this stage learners are not required to complete heat transfer calculations, they should identify the variables that affect the rate of heat transfer by conduction, free/natural convection and radiation. Correct and appropriate terms and units must be used throughout. Evidence could be in the form of a presentation, a report or through verbal questioning.

For P2, learners must discuss combustion principles, describing the essential characteristics of natural gas and other fossil fuel energy systems. They should identify the properties and constituents of a range of common solid, liquid and gaseous fuels and describe how these relate to the safe and efficient combustion of the fuel. Learners must identify the differences between complete and incomplete combustion, the causes and implications of incomplete combustion and the methods used to prevent it. They should relate the principles of good combustion, and the avoidance of incomplete combustion, to the design requirements for the provision of combustion air and the design of effective flue systems. Examples of suitable evidence approaches could be as for P1.

For P3, learners must discuss the essential characteristics of electrical energy systems. They should recognise the difference between the generation, transmission and distribution of electricity. Learners must understand that all power stations generate electrical energy using electromagnetic induction. They should also illustrate how basic electromagnetic induction is used in generators to produce an alternating emf. Learners do not need a more advanced understanding of basic physics such as Faraday's Laws or Lenz's Law. Learners should know that the difference between coal-fired, oil-fired, gas-fired and nuclear power stations is how the heat needed to drive the turbines is obtained. Learners must indicate how and why transformers are used in the distribution of electrical power from generator to consumer, and the principles on which transformers operate. They must produce a diagram to illustrate the distribution and supply systems from power station to a variety of premises with different load requirements, indicating typical voltages at each stage. Learners must also produce a diagram of a typical alternating current output and use this to support an explanation of AC quantities, the units involved and how power is derived in AC circuits. They must use correct terms and units throughout. Examples of suitable evidence approaches could be as for P1, supported by data, drawings and images as appropriate.

For P4, learners must analyse sensible enthalpy, latent enthalpy and changes of state within building services engineering applications. They must explain clearly the concepts of the kinetic theory of matter and how and why a material may change state if energy is added or removed. Learners must recognise that the increase or reduction of the internal energy of a substance can cause either a temperature or state change, or both. Learners are expected to illustrate these concepts by recognising building services engineering applications where a change of state occurs or where latent heat is encountered that may have to be quantified. They must apply these principles to solve basic enthalpy change problems incorporating the latent heat of fusion and the latent heat of vaporisation at constant pressure. Examples of suitable evidence approaches could be as for P3, supported by appropriate calculations.

For P5, learners must analyse the factors that determine pressure, saturation temperature and enthalpy for water and refrigerant gases. They should include thermodynamic properties, including how the values for saturation temperature and enthalpy at saturation vary with pressure. Learners must obtain strategic values, accurately and confidently, from tables of thermodynamic properties for water and refrigerant gases. They should obtain accurate values for a range of specified conditions such as the saturation temperature and enthalpy of dry saturated vapour at 'n' bar pressure, or the enthalpy at 'n' bar pressure with 'x' degrees of superheat. Learners are expected to recognise and explain that pressure/enthalpy diagrams are graphical representations of thermodynamic tables. Learners should also be able to identify and explain the various zones of a p/h diagram, for example sub-cooled liquid, latent heat, dryness fraction, super-heated vapour, saturated liquid and saturated vapour. Learners are expected to use p/h diagrams to obtain values confidently, and with an acceptable degree of accuracy, for a range of specified conditions. A report supported by tables, charts, calculations and graphs would be appropriate evidence.

For P6, learners must explain psychrometric properties of air and water vapour mixtures. Learners must explain the use of strategic values from tables of psychrometric properties accurately and confidently, and accurate values for a range of specified conditions when given two known conditions. They should recognise, and be able to explain, that psychrometric charts are graphical representations of psychrometric tables. Learners must also identify and explain the various values that can be obtained from a psychrometric chart. They must use these charts to obtain a range of values confidently, with an acceptable degree of accuracy, for the full range of different conditions. Examples of suitable evidence approaches could be as for P5.

To achieve a merit grade learners must meet all of the pass grade criteria and the four merit grade criteria.

For M1, learners must produce clear and accurate answers to four problems associated with heat transfer and the combustion of fossil fuels as applied to building services engineering. For heat transfer, the calculations could involve supporting the basic principles and practices of heat transfer by conduction through homogeneous and composite structures, natural convection from plane and cylindrical, horizontal and vertical surfaces and radiation from plane surfaces. For combustion, the calculations could involve establishing the stoichiometric air/fuel ratio for various solid, liquid and gaseous fuels. The answers to the calculations should be substantially correct, but small errors in calculations are acceptable if they are corrected after feedback from the tutor. This could be a natural extension of the work completed for P1 and P2.

For M2, learners must produce clear and accurate answers to two problems associated with AC electrical supplies. This implies a clear understanding of the relationship between volts, amperes, ohms, joules and watts. This could be a natural extension of the work completed for P3.

For M3, learners must produce clear and accurate answers to calculations relating to gas laws and simple thermodynamic processes using thermodynamic tables and/or p-h charts. They must also provide calculations involving change of enthalpy across items of plant, or across thermodynamic processes, through the use of values obtained from thermodynamic tables or pressure enthalpy diagrams. Where p/h diagrams are used, learners should plot simple thermodynamic processes or cycles of processes and use these as the basis for calculations, for example isothermal evaporation, adiabatic compression or simple vapour compression refrigeration cycles. The answers to the calculations for M3 should be substantially correct, but small errors in calculations or in interpolating values from diagrams and charts are acceptable if they are corrected after feedback from the tutor. This could be a natural extension of the work completed for P4.

For M4, learners must plot psychrometric process lines associated with various air conditioning plant and processes. They should provide calculations using psychrometric formulae to determine the psychrometric properties of air/vapour mixtures from two other properties such as wet and dry bulb temperatures. Learners should use psychrometric charts to plot the process lines for a range of air conditioning plant and typical combinations of plant used for summer and winter air conditioning cycles. This could include heater batteries, cooler batteries (operating in sensible cooling and de-humidification mode), humidification (steam and adiabatic), and air mixing applications. The answers to the calculations for M4 should be substantially correct, but small errors in calculations or in interpolating values from diagrams and charts are acceptable if they are corrected after feedback from the tutor. This could be a natural extension of the work completed for P6.

To achieve a distinction grade learners must meet all of the pass and merit grade criteria and the two distinction grade criteria.

For D1, learners must evaluate how the factors affecting heat transfer influence building services design. This evaluation should be more than illustrations of where different heat transfer mechanisms can be used. It must also evaluate how heat transfer mechanisms influence the design and performance of installations and equipment. Learners could evaluate why one design solution for a heating or cooling installation might be more effective than another. They could also evaluate how heat exchange equipment has evolved to be more effective or how it might be improved, how heat transfer mechanisms from the human body influence comfort and design solutions or how insulation levels influence design solutions. It is strongly recommended that evaluations are contextualised by use of realistic practical applications taken from learners' own fields of building services engineering. Suitable evidence could be a report supported by drawings, tables and calculations as appropriate.

For D2, learners must establish air conditioning and refrigeration plant and equipment duties using tables and p-h/psychrometric charts. Learners are expected to support the calculations with clear explanations showing an understanding of the underlying scientific principles used in establishing these duties.

Programme of suggested assignments

The following table shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, M1, D1	Principles of Energy Conversion, Heat Transfer and Combustion	A client is keen to understand the principles behind energy conversion, heat transfer and combustion. As a trainee building services engineer, you have been given the job of compiling a short presentation to address the client's request.	A presentation supported by a report to include text, calculations, diagrams, charts, graphs and tables as appropriate.
P3, P4, M2, M3, D2	Electricity and Thermodynamics	As a trainee building services engineer, you have been asked to produce a report to be distributed to designers and craftspersons explaining the principles that underpin their work.	A report to include text, diagrams, sketches, drawings, p/h charts and graphs as appropriate.
P5, P6, M4	Pressure/Enthalpy and Psychrometry	As a trainee building services engineer, you have been asked to produce a report to be distributed to designers and craftspersons explaining the principles that underpin their work.	A report to include a text, diagrams, p/h charts, psychrometric charts and graphs as appropriate.

Links to other BTEC units

This unit forms part of the BTEC Construction and the Built Environment sector suite. This unit has particular links with the following unit titles in the Construction and the Built Environment suite:

Level 1	Level 2	Level 3
		Unit 4: Science and Materials in Construction and the Built Environment

Essential resources

Learners will need access to equipment in order to measure factors associated with psychrometric properties of air, including thermometers and hygrometers. Equipment which gives learners 'hands-on' experience of observing and measuring processes, such as heat transfer, electromagnetic induction and generation, electrical quantities in circuits, transformer principles, latent heat of fusion and vaporisation, gas laws, refrigeration cycles and processes, air conditioning cycles, is not essential but would be advantageous. Centres are encouraged to use as much practical science as possible. Health, safety and welfare issues must be considered at all times and risk assessments should be undertaken for all demonstrations and experiments used in the delivery or assessment of the unit.

Employer Engagement and Vocational Contexts

Support to enable centres to initiate and establish links to industry, and to networks arranging visits to industry and from property practitioners is given below:

- Learning and Skills Network
- National Education and Business Partnership Network
- The Royal Institution of Chartered Surveyors

Delivery of personal, learning and thinking skills (PLTS)

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying questions to answer and problems to resolve, planning and carrying out research, analysing and evaluating information and supporting conclusions using reasoned arguments and evidence, as they: • explain the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications • discuss the essential characteristics of natural gas and other fossil fuel energy systems in terms of the principles of combustion • discuss the essential characteristics of electrical energy systems in terms of the principles of electricity • analyse sensible enthalpy, latent enthalpy and changes of state within building services engineering applications • analyse the factors that determine pressure, saturation temperature and enthalpy for water and refrigerant gases • explain the psychrometric properties of air and water vapour mixtures
Creative thinkers	generating ideas and exploring possibilities, asking questions to extend their thinking and adapting ideas as circumstances change, as they: • discuss the essential characteristics of electrical energy systems in terms of the principles of electricity • analyse sensible enthalpy, latent enthalpy and changes of state within building services engineering applications • analyse the factors that determine pressure, saturation temperature and enthalpy for water and refrigerant gases

Skill	When learners are ...
Reflective learners	reviewing progress, acting on the outcomes and communicating their learning in relevant ways for different audiences, as they: • explain the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications • discuss the essential characteristics of natural gas and other fossil fuel energy systems in terms of the principles of combustion • discuss the essential characteristics of electrical energy systems in terms of the principles of electricity • analyse sensible enthalpy, latent enthalpy and changes of state within building services engineering applications • analyse the factors that determine pressure, saturation temperature and enthalpy for water and refrigerant gases • explain the psychrometric properties of air and water vapour mixtures
Self-managers	organising time and resources and prioritising actions, as they: • explain the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications • discuss the essential characteristics of natural gas and other fossil fuel energy systems in terms of the principles of combustion • discuss the essential characteristics of electrical energy systems in terms of the principles of electricity • analyse sensible enthalpy, latent enthalpy and changes of state within building services engineering applications • analyse the factors that determine pressure, saturation temperature and enthalpy for water and refrigerant gases • explain the psychrometric properties of air and water vapour mixtures.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using the internet to research heat transfer, thermodynamics, electricity, combustion and psychrometry saving material electronically using email to communicate with the tutor and other learners
Manage information storage to enable efficient retrieval	downloading and saving internet files and their own work electronically
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	using the internet to research heat transfer, thermodynamics, electricity, combustion and psychrometry saving material electronically using email to communicate with the tutor and other learners
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including:	producing reports and presentations for both formative and summative assessment purposes
Present information in ways that are fit for purpose and audience	
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	using email to communicate with the tutor and other learners
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	performing calculations relating to heat transfer, thermodynamics, electricity, combustion and psychrometry
Select and apply a range of skills to find solutions	
Use appropriate checking procedures and evaluate their effectiveness at each stage	
Draw conclusions and provide mathematical justifications	
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	discussing the principles of heat transfer, thermodynamics, electricity, combustion and psychrometry
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching heat transfer, thermodynamics, electricity, combustion and psychrometric principles and practices in books, journals, CD ROMs and websites
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing reports for assessment purposes.