Unit 33: Building Services Science

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

Building services is primarily concerned with creating a comfortable working environment for building occupants and environments that enable processes to be carried out effectively. Therefore, it is 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 programme.

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 the engineering decisions made.

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. Also required is a knowledge of how those changes can be accomplished in scientific terms and 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 therefore have achieved a basic understanding of science and analytical methods, or have begun studying these, before undertaking it.

Learning outcomes

On completion of this unit a learner should:

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

2 Understand and apply electrical and combustion principles to describe the essential characteristics of electricity, natural gas and other fossil fuel energy systems

3 Understand the thermal properties of solids, liquids and gases in order to explain the changes of state taking place in heating, air-conditioning and refrigeration installations

4 Understand and apply the principles of psychrometry in air conditioning systems.

Unit content

1 **Understand the nature of energy in solids, liquids and gases, and be able to apply the fundamental principles of heat transfer in building services applications**

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

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 and apply electrical and combustion principles to describe the essential characteristics of electricity, natural gas and other fossil fuel energy systems**

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 and need for control of excess air quantities; causes of incomplete combustion

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

3 **Understand the thermal properties of solids, liquids and gases in order to explain the changes of state taking place in heating, air-conditioning, and refrigeration installations**

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

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 for ideal gases; application of general gas law and characteristic gas equation; Dalton's Law

4 **Understand and apply the principles of psychrometry in air conditioning systems**

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

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

Grading grid

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

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 identify the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications	M1 produce clear and accurate answers to a range of problems associated with heat transfer as applied to building services engineering applications	D1 evaluate how the factors affecting heat transfer influence building services design
P2 apply combustion principles to describe the essential characteristics of natural gas and other fossil fuel energy systems P3 apply electrical principles to describe the essential characteristics of electrical energy systems	M2 produce clear and accurate answers to a range of problems associated with combustion of fossil fuels M3 produce clear and accurate answers to a range of problems associated with AC electrical supplies	

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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:**
P4 apply the important concepts relating to sensible and latent enthalpy and changes of state within building services engineering applications P5 define the important concepts and factors relating to pressure, saturation temperature and enthalpy for water and refrigerant gases	M4 produce clear and accurate answers to calculations relating to gas laws and simple thermodynamic processes using thermodynamic tables and/or p-h charts	
P6 define and describe the important psychrometric properties of air and water vapour mixtures.	M5 determine psychrometric properties of air and plot psychrometric process lines associated with various air conditioning plant and processes.	D2 establish air conditioning and refrigeration plant and equipment duties using tables and p-h/psychrometric charts.

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 the 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 related in some way to energy. Although the main theme is thermal energy, each learning outcome deals with a different aspect of energy that, within reason, does not necessarily have to be dealt with in any specific order. 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. It implies 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 in a variety of other units. The delivery and assessment should be either integrated or co-ordinated with the delivery of the appropriate sections of those practical units. The sequence of delivery of this unit, and the design of the 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 whenever possible. This would involve learners taking measurements, making observations, consulting standards, making decisions and suggesting alternatives.

Calculations are implicit in all learning outcomes, the unit should not, however, be seen as a mathematical exercise and delivery should provide a balance between 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 are provided with equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be strictly reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken prior to practical activities. Centres are advised to read the *Delivery approach* section on page 24, and *Annexe G: Provision and Use of Work Equipment Regulations 1998 (PUWER)*.

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 employed, and tutors are encouraged to consider and adopt these where appropriate. Some examples of possible 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. General guidance on the design of suitable assignments is available on page 19 of this specification.

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 Edexcel website.

The number of assignments needed to fully address this unit will depend on the extent to which these 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 may be fully addressed by using four assignments. The first of these would cover criteria P1, M1 and D1, the second would cover P2, P3, M2 and M3, the third would cover P4, P5 and M4, and the fourth would cover P6, M5 and D2.

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

For P1, learners must identify the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications. They must show recognition of 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 of building services engineering.

Although at this stage learners are not required to complete heat transfer calculations, they should identify the variables that will 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 apply combustion principles to describe 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 apply electrical principles to describe 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 electro-magnetic induction. They should also illustrate how basic electro-magnetic 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 the way in which 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 for P3 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 other images as appropriate. Learners must apply the important concepts relating to sensible and latent enthalpy and changes of state within building services engineering applications. They must clearly explain the concepts of the kinetic theory of matter and how and why a material may change state by adding or removing energy. 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 whereby a change of state occurs or where latent heat is encountered and 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 a constant pressure. Examples of suitable evidence approaches could be as for P3, supported by appropriate calculations.

For P5, learners must define the important concepts and factors relating to pressure, saturation temperature and enthalpy for water and refrigerant gases. They should be able to explain that thermodynamic properties, including 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, for example 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 also 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, 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 define and describe the important psychrometric properties of air and water vapour mixtures. Learners must obtain strategic values, accurately and confidently, from tables of psychrometric properties and accurate values for a range of specified conditions when given two known conditions. They should also recognise and 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 are as for P5.

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

For M1, learners must produce clear and accurate answers to a range of problems associated with heat transfer as applied to building services engineering applications. They must provide a range of calculations to support 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. The answers to the calculations should be substantially correct, but small errors in calculation are acceptable, if they are corrected after feedback from the tutor. This could be a natural extension of the work completed for P1.

For M2, learners must produce clear and accurate answers to a range of problems associated with combustion of fossil fuels. They must provide a range of calculations to support the basic principles of combustion and establish 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 calculation are acceptable, if they are corrected after feedback from the tutor. This could be a natural extension of the work completed for P2.

For M3 learners must produce clear and accurate answers to a range of 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 M4, 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 a range of 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 process 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 M4 should be substantially correct but small errors in calculation 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 and P5.

For M5, learners must determine psychrometric properties of air and plot psychrometric process lines associated with various air conditioning plant and processes. They should provide a range of 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 M5 should be substantially correct, but small errors in calculation 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 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 might be improved, how heat transfer mechanisms from the human body influences comfort and design solutions or how insulation levels influence design solutions. It is strongly recommended that the evaluations should be contextualised by use of realistic practical applications taken from learners' own field of building services engineering. Examples of suitable evidence approaches could be in the form of 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 understanding of the underlying scientific principles used in establishing these duties.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

The learning outcomes in this unit are closely linked with, for example, *Unit 34: Heating in Building Services Engineering, Unit 35: Ventilation and Air Conditioning in Building Services Engineering, Unit 37: Refrigeration Technology in Building Services Engineering, Unit 38: Plumbing Technology in Building Services Engineering* and *Unit 40: Electrical Installations Standards and Components in Building Services Engineering* together with similar units at Higher National and degree level.

This unit may have links to the Edexcel Level 3 Technical and Professional NVQs for Construction and the Built Environment. Updated information on this, and a summary mapping of the unit to the CIC Occupational Standards, is available from Edexcel. See *Annexe D: National Occupational Standards/mapping with NVQs.*

This unit presents opportunities to demonstrate key skills in application of number and communication. Opportunities for satisfying requirements for Wider Curriculum Mapping are summarised in *Annexe F: Wider curriculum mapping*.

Essential resources

Learners will need access to the necessary equipment to measure factors associated with psychrometric properties of air, including thermometers and hygrometers.

Equipment which provides learners with 'hands-on' experience of observing and measuring processes such as heat transfer, electro-magnetic 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 highly 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.

Indicative reading for learners

Textbooks

Floyd T — *Electric Circuit Fundamentals, 7th Edition* (Prentice Hall, 2006) ISBN 0132047349

McMullan R — *Environmental Science in Building, 5th Edition* (Palgrave Macmillan, 2001) ISBN 0333947711

Moss K — *Heat and Mass Transfer in Building Services Design* (Spon Press, 1998) ISBN 0419226508

Rogers G and Mayhew Y — *Thermodynamics and Transport Properties of Fluids, 5th Edition* (Basil Blackwell, 1994) ISBN 0631197036

Saxon F — *Tolley's Basic Science and Practice of Gas Service* (LexisNexis, 2001) ISBN 0754514358

Sherwin K and Horsley M — *Thermofluids* (Spoon Press, 1995) ISBN 0412598000

Smith B, Phillips B and Sweeney M — *Environmental Science* (Longman, 1983) ISBN 0582416205

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• producing clear and accurate answers to a range of problems associated with heat transfer as applied to building services engineering applications; or, • applying the important concepts relating sensible and latent enthalpy and changes of state within building services engineering applications; or, • determining psychrometric properties of air and plot psychrometric process lines associated with various air conditioning plant and processes, for example.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use your information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae. N3.3 Interpret the results of your calculations, present your findings and justify your methods.

Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• identifying the fundamental principles of energy conversion and heat transfer as applied to building services engineering applications; or, • applying combustion principles to describe the essential characteristics of natural gas and other fossil fuel energy systems; or, • defining the important concepts and factors relating to pressure, saturation temperature, and enthalpy for water and refrigerant gases; or, • evaluating how the factors affecting heat transfer influence building services design, for example.	C3.1a Take part in a group discussion. C3.1b Give a talk of at least eight minutes using an image or other support material. C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. C3.3 Write **two** different types of documents each one giving different information about complex subjects. One document must be at least 1000 words long.