SQA Advanced Unit specification

General information

Unit title: Heat Transfer Theory and Practical Skills (SCQF level 7)

Unit code: HV09 47

Superclass: RC

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Version: 01

Unit purpose

This Unit will provide learners with a practical introduction to and understanding of the theory and practical skills of heat transfer. This Unit is intended for learners studying at SQA Advanced level. This Unit will provide the necessary underpinning knowledge and skills to enable progression to further study of chemical engineering or to seek employment in the chemical, oil or allied industries.

Outcomes

On successful completion of the Unit the learner will be able to:

1 Apply the principles of heat transfer individually to conduction, convection and radiation.
2 Apply the principles of heat transfer to the combined mechanisms of conduction, convection and radiation.
3 Perform practical experiments using heat transfer equipment.

Credit points and level

1 SQA Credit at SCQF level 7: (8 SCQF credit points at SCQF level 7)

Recommended entry to the Unit

Entry is at the discretion of the centre; however it is recommended that learners should have completed Mathematics at SCQF level 6 or equivalent.

Core Skills

Achievement of this Unit gives automatic certification of the following Core Skills component:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Using Number at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of this Unit specification.

Context for delivery

This Unit is intended for learners at SQA Advanced level.

Equality and inclusion

This Unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**.

SQA Advanced Unit specification: Statement of standards

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Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Apply the principles of heat transfer individually to conduction, convection and radiation.

Knowledge and/or Skills

- Conduction
- Convection
- Thermal conductivity, thermal resistance
- Fourier equation to plane walls
- Fourier equation to cylinders and spheres
- Overall Heat transfer
- Heat transfer in films
- Black body radiation, emissivity
- Stefan-Boltzmann Law

Outcome 2

Apply the principles of heat transfer to the combined mechanisms of conduction, convection and radiation.

Knowledge and/or Skills

- Steady state heat transfer
- Surface temperature by graph or iteration
- Heat loss to surroundings
- Interface temperatures

Outcome 3

Perform practical experiments using heat transfer equipment.

Knowledge and/or Skills

- Heat exchange experiments
- Current health and safety regulations
- Recording observations and results
- Evaluation skills
- Result analysis and conclusions

Evidence Requirements for this Unit

Written and/or oral recorded evidence for Outcomes 1 and 2 should be assessed using an holistic closed-book assessment under supervised conditions. It is recommended that the assessment be completed within 90 minutes. Learners can only have access to non-programmable calculators when sitting the assessment.

Written and/or oral recorded evidence for Outcome 3 should be assessed by production of one full laboratory report, and by completion of one appropriate pro forma. An assessor's observation checklist should be used to record performance evidence of practical experiments.

Outcome 1

The assessment will sample six of the nine Knowledge and/or Skills items. The whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

A learners' response will be judged satisfactory where the evidence shows that for those knowledge or skills sampled, the learner can:

- describe the terms used in conduction heat transfer.
- describe the terms used in natural convection, forced convection heat transfer.
- define the terms thermal conductivity and thermal resistance.
- apply the Fourier equation to solve problems involving either single or composite plane walls.
- apply the Fourier equation to solve problems involving thick walled or composite cylinders or hollow spheres.
- calculate heat transfer loads, log mean temperature differences, and heat transfer area.
- calculate film and heat transfer coefficients and fouling factors and natural convection from a surface to air.
- define black body radiation and define or calculate emissivity.
- apply the Stefan Boltzmann law to solve radiation problems.

Calculations must:

- apply appropriate formulae.
- apply the principles of the calculation.
- show workings through a calculation.
- provide reasonable answers to the questions asked. The answer should derive from the application of the formulae and correct application of the principles of the calculation.

Outcome 2

The assessment will sample a minimum of three of the four Knowledge and/or Skills items. The whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

A learners response will be judged satisfactory where the evidence shows that for those knowledge or skills sampled, the learner can:

- apply two out of the three of the following equations, the Fourier equation, natural convection equation and Stefan Boltzmann equation, to simultaneous conduction, convection and radiation problem.
- determine graphically or by an iterative calculation, the surface temperature of a pipe or wall.
- perform at least one calculation for heat loss rate to surroundings.
- perform at least one calculation for interface temperature.

Calculations must:

- apply appropriate formulae.
- apply the principles of the calculation.
- show workings through a calculation.
- provide reasonable answers to the questions asked. The answer should derive from the application of the formulae and correct application of the principles of the calculation.

Outcome 3

Learners will be required to perform at least two experiments. The reports must include experimental results, calculations and conclusions drawn. A learner's response will be judged satisfactory where the evidence shows that the learner can achieve all of the following:

- Follow instruction to perform experiments related to heat exchangers, work in a safe manner in accordance with current health and safety regulations.
- Achieve and record accurate results and observations.
- Identify possible experimental errors.
- Analyse results correctly and state valid conclusions.

Where calculations are performed, the learner must:

- apply appropriate formulae.
- apply the principles of the calculation.
- show workings through a calculation.
- provide reasonable answers to the questions asked. The answer should derive from the application of the formulae and correct application of the principles of the calculation.

Learners may report results by production of one full laboratory report and completion of an appropriate pro forma for the other experiment. Where a pro forma approach is deployed, the pro forma will not present information or assistance to the learners on how to correctly perform calculations or analyse experimental results. Learners will be expected to perform such activities independently on the basis of the experimental data.

SQA Advanced Unit Support Notes

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Unit Support Notes are offered as guidance and are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

This Unit may form part of a group award or be completed as a free-standing Unit. It is intended to provide learners with a practical introduction to and the understanding of the theory and practical skills of heat transfer.

Outcome 1

In Outcome 1, learners are given an overview, using industrial examples, of the basic heat transfer mechanisms of conduction, natural and forced convection and radiation.

Learners should be given a description of the term ‘thermal conductivity’ in regard to heat transfer rate, area and temperature gradient. Learners will learn to solve problems using the Fourier equation particularly with respect to plane walls, composite walls, cylindrical (lagged) pipes and Horton spheres.

Learners will learn to calculate heat transfer loads, log mean temperature differences, film and overall heat transfer coefficients. Using these values, heat transfer areas can be determined and hence “number of tubes” for heat exchange evaluated.

‘Black body radiation’ and ‘emissivity’ should be defined, and learners will learn to apply the Stefan-Boltzmann equation to solve radiation problems.

Outcome 2

Learners will learn to apply acquired knowledge to solve a more complex problem involving simultaneous conduction, natural convection and radiation. Numerical data can be provided to allow the learner to determine, both graphically and by iterative calculations, the surface temperature of a pipe or wall. This temperature value will now permit calculation of both heat loss rate to the surroundings and interface temperatures.

Outcome 3

This Outcome is the practical element of the Unit where learners will follow both verbal and written instructions to perform experiments on heat exchangers. Learners are expected to work safely in accordance with current health and safety regulations. Learners should obtain accurate results and report these clearly in a full laboratory report and completed pro forma report.

Guidance on approaches to delivery of this Unit

Whilst this could be delivered as a stand-alone Unit, it may form part of a group award. The Unit requires the learner to be familiar with the fundamental concepts of heat transfer. Independent study should be encouraged by the use of learner centred learning material, although it is envisaged that learners will require a significant amount of planned instruction.

Outcomes 1 and 2 should be assessed using a holistic closed-book assessment.

It is envisaged that Outcome 1 is delivered prior to Outcome 2.

It is envisaged that Outcome 1 delivery will commence with the study of conduction heat transfer, followed by convection heat transfer and finally heat transfer via radiation.

Conduction heat transfer learning could commence with the introduction of the description of the basic mechanism supported by practical examples of conduction heat transfer. Learners would then be given a description of the term 'thermal conductivity' in regard to heat transfer rate, area and temperature gradient. Learners will learn to solve problems using the Fourier equation for heat transfer through plane walls and composite walls incorporating insulation materials. Learner's knowledge would then be extended to perform heat transfer calculations involving different geometries of cylindrical (lagged) pipes and Horton spheres for single and multiple layers. For all geometries, learners will learn to calculate the interfacial temperature at the boundaries between adjacent layers in composite walls.

Convection heat transfer learning could commence with the description of the both natural and forced convection heat transfer supported by practical examples of each. Learners should also be introduced to basic heat transfer equipment designs that are in common industrial use, which could also be used for the practical based calculations in Outcomes 1 and 2. Learners could then learn to calculate heat transfer loads based on mass flowrates and mean heat transfer coefficients. Learners would then learn how to calculate log mean temperature difference. Using these values, heat transfer areas could be determined and hence 'number of tubes' for heat exchange evaluated. Learners' knowledge and skills should then be developed to calculate overall heat transfer coefficients based on film coefficients in both clean and fouled heat transfer duties.

Radiation heat transfer learning could commence with the description of the mechanism supported by practical examples. 'Black body radiation' and 'emissivity' should be defined, and learners would learn to calculate the absorptivity, reflectivity and transmissivity of 'grey bodies'. Learners would learn to apply the Stefan-Boltzmann equation to solve heat transfer rates from plane walls and pipelines.

Outcome 2 will introduce the concept of the use of dimensionless groups to simplify natural convection. Learners will learn to apply this and acquired knowledge from Outcome 1 to solve a more complex problem involving simultaneous conduction, natural convection and radiation. Numerical data can be provided to allow the learner to determine, both graphically and by iterative calculations, the surface temperature of a pipe or wall. This will enable the learners to temperature value and will now permit calculation of both heat loss rate to the surroundings and interface temperatures in composite walls.

Outcome 3 involves the practical aspect of the Unit. Practical work could include two different heat exchangers, for example a 'concentric tube exchanger' and a 'plate heat exchanger' or a spiral heat exchanger'. The learner could apply much of the theory learned in the previous Outcomes to practical situations. Examples of suitable experiments include (but are not limited to) determining heat transfer rates and overall heat transfer coefficients with variation of either flowrates, heat transfer area or process fluids.

Guidance on approaches to assessment of this Unit

Evidence can be generated using different types of assessment. The following are suggestions only. There may be other methods that would be more suitable to learners.

It is envisaged that Outcomes 1 and 2 could be assessed once teaching of these two Outcomes has been completed. Outcome 3 could be assessed at any suitable point during the delivery of the Unit.

Outcomes 1 and 2 could be assessed by a single holistic closed-book assessment with an appropriate cut-off score. The assessment should contain both theory and calculation questions. Assessment should be carried out in supervised conditions and it is recommended to last for 90 minutes. Learners should have access to non-programmable calculators when sitting the assessment.

Centres are reminded that prior verification of centre-devised assessments would help to ensure that the national standard is being met. Where learners experience a range of assessment methods, this helps them to develop different skills that should be transferable to work or further and higher education.

Opportunities for e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all learner evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. The most up-to-date guidance on the use of e-assessment to support SQA's qualifications is available at **www.sqa.org.uk/e-assessment**.

Opportunities for developing Core and other essential skills

There are opportunities to develop the Core Skill of *Numeracy* and *Working with Others*, and the component Critical Thinking of the Core Skill of *Problem Solving* at SCQF level 6 in this Unit, although there is no automatic certification of Core Skills or Core Skills components.

Throughout this Unit, learners are required to perform calculations, manage formulae and equations that provide the opportunity to develop the Core Skill of *Numeracy* at SCQF level 6. In Outcome 2 learners will also be required to interpret and plot graphs and perform iterative calculations which again provide the opportunity to develop Numeracy skills.

The presentation of problems in assessments which learners require to interpret and work through will also develop the Critical Thinking component of *Problem Solving* at SCQF level 6.

The production of a laboratory report and pro forma based report on practical activities provides opportunities to develop the component Written Communications of the Core Skill of *Communication*.

Learners working in labs may develop the Core Skill of *Working with Others*, if working with lab partners.

This Unit has the Critical Thinking components of Problem Solving and Using Number components of Numeracy embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show they have achieved Critical Thinking at SCQF level 6 and Using Number at SCQF level 6.

History of changes to Unit

Version	Description of change	Date

FURTHER INFORMATION: Call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

General information for learners

Unit title: Heat Transfer Theory and Practical Skills (SCQF level 7)

This section will help you decide whether this is the Unit for you by explaining what the Unit is about, what you should know or be able to do before you start, what you will need to do during the Unit and opportunities for further learning and employment.

This is a 1 credit Unit at SCQF level 7, which is suitable for learners studying at SQA Advanced level. It is designed to provide you with the knowledge of some of the main concepts and some practical skills in Heat Transfer. Whilst access to this Unit is at the discretion of the centre, it would be beneficial if you had studied Mathematics at SCQF level 6 or equivalent.

On completion of this Unit you should be able to:

- describe the terms conduction, convection, radiation, thermal conductivity, emissivity and black body radiation.
- apply the Fourier equation for conduction to walls, pipes and spheres.
- use heat transfer coefficients and log mean temperature differences to determine heat transfer surface requirements.
- apply the Stefan-Boltzmann equation for radiation heat transfer between surfaces.
- apply the combined mechanisms of conduction, convection and radiation to heat transfer applications.
- perform experiments on heat exchangers to determine heat transfer data.

Outcomes 1 and 2 may be assessed together as a single supervised closed-book assessment. Outcome 3 will be assessed by means of a laboratory report and pro forma based report on practical activities related to the topics in Outcomes 1 and 2.

Throughout the Unit you will also have the opportunity to develop Core Skills in *Numeracy* and *Problem Solving* at SCQF level 6. You will perform calculations, manage formulae and equations that may develop the Core Skill of *Numeracy* at SCQF level 6. You will also be required to interpret and plot graphs and perform iterative calculations, which again provides the opportunity to develop *Numeracy* skills.

The practical focus of the Unit will require you to interpret and work through set problems which will develop critical thinking skills. The Laboratory component in Outcome 3 may also provide the opportunity to develop critical thinking skills, developing the Critical Thinking component of *Problem Solving* at SCQF level 6. Learners working in labs may develop the Core Skill of *Working with Others*, if working with lab partners.

The production of a laboratory report and pro forma based report on practical activities provides opportunities to develop the component Written Communications of the Core Skill of *Communication*. However, there is no automatic certification of Core Skills or Core Skills components.