Higher National Unit specification: general information

Unit title: Electrical Machine Principles

Unit code: H01T 34

Superclass: XJ

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Unit purpose

This Unit has been designed to give candidates a fundamental knowledge and understanding of a range of electrical motors and transformers. In particular, candidates will study the constructional features, principle of operation, performance characteristics and applications of DC motors, single phase motors, three phase motors, synchronous generators and motors, and different types of transformers. The Unit acts as a good foundation Unit for more in depth studies in specialist areas of electrical motors and transformers.

On completion of the Unit the candidate should be able to:

1 Demonstrate knowledge of electromagnetic field concepts and circuits.
2 Analyse the construction and operation of a range of transformers.
3 Analyse the construction, operation and characteristics of DC motors.
4 Describe the construction, operation and characteristics of three-phase induction motors.
5 Describe the construction, operation and characteristics of single-phase motors
6 Describe the construction, operation and characteristics of synchronous generators and motors.

Recommended prior knowledge and skills

Candidates should have a basic knowledge and understanding of electrical principles and machines. However, entry requirements are at the discretion of the centre.

General information (cont)

Credit points and level

2 Higher National Unit credits at SCQF level 7: (16 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the Support Notes of this Unit specification.

There is no automatic certification of Core Skills or Core Skill components in this Unit.

Context for delivery

This Unit has been developed for the HNC and HND Electrical Engineering awards. If the Unit is delivered as part of another Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

The Higher National Unit specification: statement of standards sets out the six Outcomes. It is left to the discretion of centres to decide the order in which these Outcomes are to be delivered.

Higher National Unit specification: statement of standards

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The sections of the Unit stating the Outcomes, Knowledge and/or Skills, and Evidence Requirements are mandatory.

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. Candidates 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

Demonstrate knowledge of electromagnetic field concepts and circuits.

Knowledge and/or Skills

- Simple magnetic circuit calculations
- Magnetic quantities (mmf, flux and reluctance)
- Induced emf. and current
- Leakage fluxes
- Magnetic losses
- Pulsating and rotating mmfs

Outcome 2

Analyse the construction and operation of a range of transformers.

Knowledge and/or Skills

- Calculations involving transformers under load with primary and secondary winding resistance and reactance
- Constructional features and principles of operation of single-phase power transformers
- Performance characteristics of ideal transformer
- Construction features and principle of operation of autotransformers
- Constructional features and principle of operation of voltage and current transformers
- Typical transformer applications

Higher National Unit specification: statement of standards (cont)

Unit title: Electrical Machine Principles

Outcome 3

Analyse the construction, operation and characteristics of DC motors.

Knowledge and/or Skills

- Calculations involving DC motors
- Principle of operation of DC motors
- Main constructional features of DC motors
- Shunt, series and compound winding configurations
- Performance characteristics of shunt, series and compound motors
- DC motors starting methods
- Typical applications of DC motors

Outcome 4

Describe the construction, operation and characteristics of three-phase induction motors.

Knowledge and/or Skills

- Constructional features of squirrel cage and wound rotor machines
- Principle of operation of three phase induction motor
- Synchronous speed and slip
- Performance characteristics of three-phase induction motors (relate to torque-slip curve)
- Direct-on-line starting
- Awareness of other starting methods
- Typical applications of three-phase induction motors

Evidence Requirements for Outcomes 1, 2, 3 and 4

Evidence for the Knowledge and/or Skills in Outcomes 1 to 4 will be provided on a sample basis. The evidence may be presented in responses to specific questions. Each candidate will need to demonstrate that she/he can answer correctly questions based on a sample of the items shown under the knowledge and skills items in each of the four Outcomes.

In any assessment of Outcome 1, Knowledge and/or Skills **item 1 must always be assessed plus any three out of the remaining five**. In any assessment of Outcome 2, Knowledge and/or Skills **item 1 must always be assessed plus any three out of the remaining five.** In any assessment of Outcome 3, Knowledge and/or Skills **item 1 must always be assessed plus any three out of the remaining six.** In any assessment of Outcome 4, **four out of seven** Knowledge and/or Skills items should be sampled.

Higher National Unit specification: statement of standards (cont)

Unit title: Electrical Machine Principles

Note, Knowledge and/or Skills item 1 must always be assessed each time Outcomes 1, 2 and 3 are assessed In order to ensure that candidates will not be able to foresee what items they will be questioned on, a different sample of **three out of the remaining five** Knowledge and/or Skills items from Outcome 1, **three out of the remaining five** Knowledge and/or Skills items from Outcome 2, **three out of the remaining six** knowledge and skills items from Outcome 3, and **four out of seven** Knowledge and/or Skills items from Outcome 4 are required each time the Unit is assessed.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

Outcome 1

- perform calculations on a simple magnetic circuit with a single air-gap.
- define magnetic field quantities: mmf, flux and reluctance.
- describe how emfs and currents are induced in typical magnetic circuits.
- explain what is meant by leakage flux.
- explain hysteresis and eddy current losses.
- state two types of mmf (static, pulsating, rotating).

Outcome 2

- perform calculations on transformers with significant winding resistance and reactance (but negligible core losses) under load.
- describe the main constructional features and principle of operation of single-phase power transformers.
- describe the main characteristics of an ideal transformer.
- describe the constructional features and principle of operation of an autotransformer.
- describe the constructional features and principle of operation of voltage and current transformers.
- state one application each of a power transformer, autotransformer, voltage, and current transformer.

Outcome 3

- perform calculations involving a shunt or series connected DC motor.
- describe the principle of operation of a DC motor.
- identify the main constructional features of a DC motor.
- identify the differences between shunt, series and compound winding configurations.
- differentiate, with the aid of graphs, the main performance characteristics of series, shunt and compound DC motors.
- explain the principle of starting a DC motor.
- state one application each of a series, shunt and compound motor.

Outcome 4

- identify the main construction features of squirrel cage and wound rotor three-phase induction motors.
- describe the principle of operation of a three-phase induction motor.
- perform calculations involving synchronous speed and slip.
- describe, with the aid of torque — slip curves, the performance characteristics of a three-phase induction motor.
- explain, with the aid of a circuit diagram, Direct-on-Line starting (diagram may be provided).
- state three other induction motor starting methods (such as Star-Delta, Auto-Transformer, Rotor Resistance, Soft Starting).
- state two applications of three-phase induction motors.

Outcome 5

Describe the construction, operation and characteristics of single-phase motors.

Knowledge and/or Skills

- Constructional features and principles of operation of main type of single-phase motors (split-phase, capacitor start, capacitor start — capacitor run, shaded pole)
- Performance characteristics of principal motor types
- Typical applications of single phase motors

Outcome 6

Describe the construction, operation and characteristics of synchronous generator and motors.

Knowledge and/or Skills

- Constructional features of synchronous machines (types of rotors and stator windings, and excitation systems)
- Principle of operation of synchronous generators
- Voltage regulation in synchronous generators
- Principle of operation of a synchronous motor
- Typical applications of synchronous motors
- Advantage and disadvantage of synchronous motors over other motor types

Higher National Unit specification: statement of standards (cont)

Unit title: Electrical Machine Principles

Evidence Requirements for Outcomes 5 and 6

Evidence for the Knowledge and/or Skills in Outcomes 5 and 6 will be provided by the candidate undertaking an assignment task in which he/she demonstrates that they can answer correctly questions based on **all** of the Knowledge and/or Skills items in both Outcomes. The evidence may be presented in response to specific questions.

A candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

Outcome 5

- describe, with aid of diagrams, the main construction features and principles of operation of the main types of single phase motors (split phase, capacitor start, capacitor start — capacitor run, shaded pole).
- differentiate the performance characteristic of the principal motor types.
- state one application each of the principal motor types.

Outcome 6

- identify the main constructional features of a synchronous machine.
- describe the principle of operation of a synchronous generator.
- explain, with the aid of a terminal voltage-load current graph, what is meant by the term voltage regulation as applied to synchronous generators.
- describe the principle of operation of a synchronous motor.
- state two applications of synchronous motors.
- state the advantages and disadvantages of a synchronous motor over other motor types.

Higher National Unit specification: support notes

Unit title: Electrical Machine Principles

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 80 hours.

Guidance on the content and context for this Unit

This Unit has been written in order to allow candidates to develop their knowledge, understanding and skills in the following areas:

1 Electromagnetic field concepts and circuits.
2 The construction and operation of a range of transformers.
3 The construction, operation and characteristics of DC motors.
4 The construction, operation and characteristics of three-phase induction motors.
5 The construction, operation and characteristics of single-phase motors.
6 The construction, operation and characteristics of synchronous generator and motors.

This Unit has been developed to provide all HNC and HND electrical engineering candidates with a fundamental level of knowledge, understanding and skills in electrical motors and transformers. It is a 2-credit Unit at SCQF level 7 (16 SCQF credit points at SCQF level 7). The Unit can be offered on a free standing basis, but also provides a foundation level Unit for more specialist Units in the HNC and HND Electrical Engineering awards such as Electrical Motor Drive Systems, Applications of Power Electronics in Electrical Motor Drive Systems, Three Phase Induction Motors, Synchronous Machines and Transformers.

In designing this Unit, the Unit writer has identified the range of topics expected to be covered by lecturers. The writer has also given recommendations as to how much time should be spent on each Outcome. This has been done to help lecturers decide what depth of treatment should be given to the topics attached to each of the Outcomes. Whilst it is not mandatory for centres to use this list of topics it is strongly recommended that they do so to ensure continuity of teaching and learning, and because the assessment exemplar pack for this Unit is based on the Knowledge and/or Skills and list of topics in each of the Outcomes.

A list of topics is given below. Lecturers are advised to study this list of topics in conjunction with the assessment exemplar pack so that they can get a clear indication of the standard of achievement expected of candidates in this Unit.

Outcome 1 (12 hours)

Demonstrate knowledge of electromagnetic field concepts and circuits

- Concept of mmf, flux and reluctance
- Comparison to emf, current and resistance
- Series magnetic circuit calculations (with an air gap)
- Concept of leakage flux
- Hysteresis and eddy current losses
- Concepts of static, pulsating and rotating emfs

Higher National Unit specification: support notes (cont)

Unit title: Electrical Machine Principles

Outcome 2 (14 hours)

Analyse the construction and operation of a range of transformers

- Explanation of the principle of operation of an ideal transformer
- Constructional features of single phase transformer types (both core and windings)
- Performance characteristics of ideal transformer
- Transformer ratio equations
- Calculations involving ideal transformers under load
- Phasor diagram for ideal transformer
- Winding resistance and leakage reactance
- Methods of minimising leakage flux
- Calculations involving transformers on load with significant winding resistance and leakage reactance
- Phasor diagram for transformer on load with winding resistance and leakage reactance
- Discussion of transformer core losses
- Constructional features and principle of operation of autotransformers
- Constructional features and principle of operation of voltage and current transformers
- Typical applications of different transformer types

Outcome 3 (16 hours)

Analyse the construction, operation and characteristics of DC motors

- Principle of operation of DC motors
- Main constructional features of DC motor
- Explanation of information on the face plate of a DC motor
- Brief discussion of wave and lap windings
- Armature reaction
- Commutation
- Methods of reducing sparking at brushes
- Basic winding configurations (shunt, series and compound)
- Losses in DC motors
- Development of speed/load and torque/load graphs for basic motor types using DC motor equations (eg $E = V - IaR$, $E = k1N\Phi$ and $M = k2\Phi Ia$)
- Starting (including the precautions required when starting a DC motor)
- Typical applications involving the three basic configurations
- Calculations involving changes in speed and torque

Higher National Unit specification: support notes (cont)

Unit title: Electrical Machine Principles

Outcome 4 (12 hours)

Describe the construction, operation and characteristics of three-phase induction motors.

- Constructional features of wound rotor and squirrel cage machines (eg. double-layer stator windings and different types of cage construction)
- Explanation of information on the face plate of an induction motor
- Development of a rotating magnetic field in a three-phase system
- Principle of operation of three-phase induction motor
- Synchronous speed and slip
- Simple calculations involving synchronous speed and slip
- Key features of Torque-slip curve
- Imposition of different types of load on Torque-slip curve
- Direct-on-Line starting only
- Mention of other starting methods
- Typical applications of three phase induction motor (comparison to DC shunt motor)

Outcome 5 (12 hours)

Describe the construction, operation and characteristics of single-phase motors

- Explanation with diagrams of the creation of a rotating magnetic field from a single phase supply
- Main construction features and principle of operation of main types of single phase motor (split phase, capacitor start, capacitor start — capacitor run, shaded pole)
- Torque speed characteristics of motor types
- Typical applications of main motor types

Outcome 6 (10 hours)

Describe the construction, operation and characteristics of synchronous generators and motors

- Constructional features of synchronous machines (types of rotor and stator windings, and excitation systems)
- Principle of operation of synchronous generators
- The importance of voltage regulation and frequency control in synchronous generators
- Principle of operation of synchronous motor
- Different motor types in relation to power range
- Typical applications of synchronous motors
- Advantages and disadvantages of synchronous motors over other motor types

Assessment — two written examination papers each of 1.5 hours duration and a written assignment which may be completed outwith the classroom.

Higher National Unit specification: support notes (cont)

Unit title: Electrical Machine Principles

Guidance on the delivery of this Unit

This Unit has been designed to incorporate sufficient time to allow lecturers to teach all of the electrical motor and transformer subjects contained in the Unit. There is also sufficient time for candidates to practice what they have learnt through appropriate formative assessment exercises and practical laboratory work. In regard to practical work, it is recommended that candidates are allowed to see different types of motors and transformers disassembled so that they can study the various component parts of motors and transformers at close hand. Good charts showing the disassembled parts of motors and transformers will also assist candidate learning. Centres are strongly recommended to allow candidates to perform a range of practical test on different motors and transformers to determine essential performance characteristics. This will help candidates to relate theory to practice.

Guidance on the assessment of this Unit

It is left to the discretion of centres to decide the order in which the Outcomes are to be delivered. Regardless of the order chosen centres must ensure that candidates are assessed by two examination papers and one assignment exercise. Outcomes 1 to 4 should be assessed by means of the examinations, and Outcomes 5 and 6 should be assessed by the assignment task.

The assessment for this 2-credit Unit should consist of two closed-book written examinations, and a written assignment.

Outcomes 1 to 4 should be assessed by the examinations. Both of these written examinations should have durations of 1.5 hours and should be separate assessment events. Each examination should assess two of the Outcomes. Both examinations should be composed of a mixture of structured and short answer questions. These assessments should be conducted under closed-book, controlled and supervised conditions.

Outcomes 5 and 6 should be assessed by means of an assignment in which the candidate is required to provide responses to specific questions. This assignment may be completed outwith the classroom, and candidates will require access to relevant notes, text books, on-line resources etc.

Assessment Guidelines

Outcomes 1, 2, 3 and 4

The assessment or Outcomes 1 to 4 should be carried out by two written assessment papers. Both of these papers should take the form of a examinations. Each should have a duration of 1.5 hours and should be a separate assessment event. Each examination should assess two of the Outcomes. It is left to the discretion of the centre to decide which two Outcomes to combine in each paper. Both examinations should be composed of a mixture of structured and short answer questions. These assessments should be conducted under closed-book, controlled and supervised conditions, and candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators.

Outcomes 5 and 6

Outcomes 5 and 6 should be assessed by means of an assignment in which the candidate is required to provide satisfactory responses to specific questions. This assignment may be completed outwith the classroom, and candidates will require access to relevant notes, text books, on-line resources etc.

Online and Distance Learning

This Unit could be delivered by distance learning, which may incorporate some degree of on-line support. However, with regards to assessment, planning would be required by the centre concerned to ensure the sufficiency and authenticity of candidate evidence. Arrangements would be required to be put in place to ensure that examinations were conducted under controlled, supervised conditions. With regards to the assessment task for Outcomes 5 and 6, centres would be required to take steps to check that the assignment was the candidate's own work.

To keep administrative arrangements to a minimum, it is recommended that for distance learning candidates two assessment papers are taken at two separate assessment events following the guidance given in the Higher National Unit specification: statement of standards section.

Opportunities for developing Core Skills

There may be opportunities to gather evidence towards the following listed Core Skills or Core Skills components in this Unit, although there is no automatic certification of Core Skills or Core Skills components:

- Using Number at Higher
- Using Graphical Information at Higher
- Critical Thinking at Higher
- Working with Others at Intermediate 1

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**

History of changes to Unit

Version	Description of change	Date

General information for candidates

Unit title: Electrical Machine Principles

Electrical motors and transformers are very important items of electrical equipment being found in many different types of appliances and plant from the washing machine in the home to large items of plant in industry. In this Unit you will have an opportunity to develop a fundamental knowledge and understanding of a range of electrical motors and transformers. In particular you will study the constructional features, principle of operation, performance characteristics and applications of the following: DC motors, single phase motors, three phase motors, synchronous generators and motors and different types of transformers. This Unit will act as a very useful foundation for more in depth studies in electrical motors and transformers in other parts of the HNC and HND Electrical Engineering awards.

This is a double credit Unit. Assessment will comprise two written examination papers which must be done under closed-book conditions, and one written assignment which you may be allowed to complete outwith the classroom. The examinations may take place at two separate events and will involve calculations and descriptive type questions. The assignment will require you to write about different types of motors and generators.