Higher National Unit Specification

General information for centres

Unit title: Electrical Machine Principles

Unit code: DN4J 34

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

Credit points and level: 2 HN 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.*

Recommended prior knowledge and skills: Candidates should have a basic knowledge and understanding of electrical principles and machines. This may be evidence by possession of C025 11 Electronic and Electrical Fundamentals Intermediate 2 or the following NQ Electrical Principles and Machines Units: D132 11 Electrical Fundamentals, E9RX 12 Network Analysis, E9RY 12 Power Factor Improvement and Three-Phase Theory, E969 12 Electrical Machine Principles, E96A 12 Electrical Motor Applications and D987 12 Electrical Motor Starting and Speed Control. However, entry requirements are at the discretion of the centre.

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

General information for centres (cont)

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 a suggested order in which the six outcomes can be delivered and assessed. However, 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 question papers (details of which are provided in the following section), the first paper to be taken by candidates after the first three outcomes have been delivered and the second paper to be taken after the final three outcomes have been delivered.

Assessment: The written assessments for all six Outcomes in this Unit should consist of two assessment papers, each of two hours duration. The statement of standards sets out a suggested order in which the six Outcomes can be delivered. However, it is left to the discretion of the centre to decide the order in which the outcomes are delivered. Centres should take the first written assessment after the delivery of any three Outcomes and the second paper after delivery of the remaining three Outcomes. Assessments should be conducted under controlled, supervised conditions. It should be noted that, in order to pass the Unit, candidates must achieve all of the minimum evidence specified for each Outcome.

Higher National Unit specification: statement of standards

Unit title: Electrical Machine Principles

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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.

NOTE:

This statement of standards sets out a suggested order in which the six Outcomes can be delivered and assessed. However, it is left to the discretion of centres to decide the order in which the Outcomes are delivered. Centres must ensure that candidates are assessed by two question papers. The first paper to be taken by candidates after the delivery of any three outcomes and the second paper to be taken after the remaining three Outcomes have been delivered.

Outcome 1

Examine electromagnetic field concepts and circuits

Knowledge and/or skills

- Magnetic quantities (m.m.f., flux and reluctance)
- Simple magnetic circuit calculations
- Induced e.m.f. and current
- Leakage fluxes
- Magnetic losses
- Pulsating and rotating m.m.f.s
- Practical magnetic circuits

Outcome 2

Analyse the construction, operation and characteristics of d.c. motors.

Knowledge and/or skills

- Principle of operation of d.c. motors
- Main constructional features of d.c. motors
- Shunt, series and compound winding configurations
- Performance characteristics of shunt, series and compound motors
- Starting

- Typical applications of d.c. motors
- Calculations involving d.c. motors

Outcome 3

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

Knowledge and/or skills

- Creation of rotating magnetic field from single phase supply
- Constructional features and principles of operation 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

Outcome 4

Describe the construction and operation of a range of transformers.

Knowledge and/or skills

- Constructional features of single-phase power transformers
- Principle of operation of a single phase transformer
- Performance characteristics of ideal transformer
- Transformer ratio equations
- Calculations involving ideal transformer under load
- Winding resistance and reactance
- Calculations involving transformers under load with primary and secondary winding resistance and reactance
- Transformer core losses
- Construction features and principle of operation of autotransformers
- Constructional features and principle of operation of voltage and current transformers
- Typical transformer applications

Outcome 5

Analyse 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 toque-slip curve)
- Direct-on-line starting
- Awareness of other starting methods
- Typical applications of three-phase induction motors

Higher National Unit specification: statement of standards (cont)

Unit title: Electrical Machine Principles

Outcome 6

Analyse 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

Evidence Requirements

Evidence for the knowledge and/or skills in Outcomes 1 to 6 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 all six Outcomes.

In any assessment of the Outcomes the following should be sampled: **four out of seven** knowledge and/or skills items should be sampled from Outcome 1, **four out of seven** knowledge and skills items from Outcome 2, **three out of four** knowledge and skills items for Outcome 3, **six out of eleven** knowledge and/or skills items should be sampled from Outcome 4, **four out of seven** knowledge and skills items from Outcome 5 and **four out of six** knowledge and skills items for Outcome 6.

In order to ensure that candidates will not be able to foresee what items they will be questioned on, a different sample of four out of seven knowledge and/or skills items from Outcome 1, four out of seven knowledge and/or skills items from Outcome 2, three out of four knowledge and skills items from Outcome 3, six out of eleven knowledge and/or skills items from Outcome 4, four out of seven knowledge and/or skills items from Outcome 5 and four out of six knowledge and skills items from Outcome 6 are required each time the Unit is assessed. Candidates must provide a satisfactory response to all items.

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

- explain magnetic field quantities: m.m.f., flux and reluctance
- perform calculations on a simple magnetic circuit with a single air-gap
- explain how e.m.f. and currents are induced in typical magnetic circuits
- explain what is meant by leakage flux
- explain hysteresis and eddy current losses
- explain, with the aid of diagrams, what is meant by a pulsating and rotating m.m.f.
- identify two examples of practical magnetic circuits (core of a power transformer, stator/rotor of an a.c. motor or armature/field of a d.c. motor)

Higher National Unit specification: statement of standards (cont)

Unit title: Electrical Machine Principles

Outcome 2

- explain the principle of operation of a d.c. motor
- identify the main constructional features of a d.c. 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 d.c motors
- explain the principle of starting a d.c. motor
- explain one application of a series, shunt and compound motor
- perform two calculations involving d.c. motors

Outcome 3

- explain how a rotating magnetic field can be produced from a single-phase supply
- explain, with aid of diagrams, the main construction features and principles of operation of at least two of the main types of single phase motors (split phase, capacitor start, capacitor start - capacitor run, shaded pole)
- differentiate the performance characteristic of principal motor types
- explain one applications of principal motor types

Outcome 4

- identify the main constructional features of single-phase power transformers
- explain the principle of operation of a single phase power transformer
- describe the main characteristics of an ideal transformer
- use the transformer ratio equations in transformer calculations
- perform calculations on ideal transformers under load
- explain winding resistance and reactance
- perform calculations on transformers with significant winding resistance and reactance (but negligible core losses) under load
- explain hysteresis and eddy current losses in the core of power transformers
- explain the constructional features and principle of operation of an autotransformer
- explain the constructional features and principle of operation of voltage and current transformers
- explain one application of a power transformer, autotransformer and voltage and current transformer

Outcome 5

- identify the main construction features of three-phase induction motors
- explain the principle of operation of three-phase induction motor
- explain the terms synchronous speed and slip and perform calculations involving these two quantities
- explain, 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
- state other induction motor starting methods as Star-Delta, Auto-Transformer, Rotor Resistance and Soft Starting

- explain two applications of three-phase induction motors

Outcome 6

- identify the main constructional features of a synchronous machine
- explain 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
- explain the principle of operation of a synchronous motor
- explain two applications of synchronous motors
- explain the advantages and disadvantages of a synchronous motor over other motor types

Assessment guidelines

The statement of standards sets out a suggested order in which the six Outcomes can be delivered and assessed. However it is left to the discretion of centres to decide the order in which the Outcomes are delivered and assessed. Centres must ensure that candidates are assessed by two question papers. The first paper to be taken by candidates after the delivery of any three Outcomes and the second paper to be taken after the remaining three Outcomes have been delivered. The assessment paper may be composed of an appropriate balance of short answer, restricted response and structured questions. Assessments should be conducted under closed book conditions and as such candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators.

Administrative Information

Unit code: DN4J 34

Unit title: Electrical Machine Principles

Superclass category: XJ

Date of publication: May 2005

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Source: SQA

SQA acknowledges the valuable contribution that Scotland's colleges have made to the development of Higher National qualifications.

Additional copies of this Unit specification can be purchased from the Scottish Qualifications Authority. Please contact the Customer Contact Centre for further details, telephone 0845 279 1000.

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, operation and characteristics of d.c. motors.
3. The construction, operation and characteristics of single-phase motors.
4. The construction and operation of a range of transformers.
5. The construction, operation and characteristics of three-phase induction 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 (9 hours)

Examine electromagnetic field concepts and circuits

- Concept of mmf, flux and reluctance
- Comparison to emf, current and resistance
- Series magnetic circuit calculations (up to two air-gaps)
- Parallel magnetic circuit calculations
- Concept of a distributed mmf and flux
- Diagrams of typical magnetic fields in motors and transformers

Higher National Unit specification: support notes (cont)

Unit title: Electrical Machine Principles

Outcome 2 (19 hours)

Analyse the construction, operation and characteristics of d.c. motors.

- Principle of operation of dc motors
- Main constructional features of dc motor
- Explanation of information on the face plate of a d.c. 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 d.c. motors
- Development of speed/load and torque/load graphs for basic motor types using dc motor equations (e.g. $E = V - I_aR$, $E = k_1N\Phi$ and $M = k_2\Phi I_a$)
- Starting (including the precautions required when starting a dc motor)
- Typical applications involving the three basic configurations
- Calculations involving changes in speed and torque

Outcome 3 (10 hours)

Analyse 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 4 (16 hours)

Describe the construction and operation of a range of transformers.

- Explanation of the principle of operation of an idea transformer
- Constructional features of single phase transformer types (both core and windings)
- Explanation of the information on the face plate of a transformer
- 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 5 (12 hours)

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

- Constructional features of wound rotor and squirrel cage machines (e.g. 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 6 (10 hours)

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

- Constructional features of synchronous machines (types of rotor an 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 – 2 written assessment papers each of 2 hours duration

Guidance on the delivery and assessment 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.

Higher National Unit specification: support notes (cont)

Unit title: Electrical Machine Principles

The Higher National Unit specification: statement of standards sets out a suggested order in which the six Outcomes can be delivered and assessed. However, 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 question papers, the first paper to be taken by candidates after any three Outcomes have been delivered and the second paper to be taken after the remaining three Outcomes have been delivered.

Information on Evidence requirements and Assessment guidelines is given after in the Higher National Unit specification: statement of standards section. The first written assessment should take place after the delivery of any three Outcomes have been completed and the second written assessment should take place after the delivery of the remaining three Outcomes have been completed.

Open 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 assessment, whether done at a single or multiple events, was conducted under controlled, supervised conditions.

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.

For information on normal open learning arrangements, please refer to the SQA guide *Assessment and Quality Assurance of Open and Distance Learning* (SQA 2000).

Candidates with additional support needs

This Unit specification is intended to ensure that there are no artificial barriers to learning or assessment. The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments or considering alternative Outcomes for Units. For information on these, please refer to the SQA document *Guidance Assessment Arrangements for Candidates with Disabilities and/or Additional Support Needs,* which is available on the SQA website www.sqa.org.uk.

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 double credit 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.

Practical work is not formally assessed in this Unit. However, you are likely to get plenty of exposure to electrical motors and transformers: for example, being allowed to study the various components of motors and transformers at close quarters and undertaking various tests to determine the performance characteristics of motors and transformers.

Assessment for the Unit will comprise of two, two hour tests. The first to be sat approximately half way through the Unit and the second at the end of the Unit. Ask your lecturer for more details about what form and when these two assessments will take place.