| Programme | Matriculation to HND in Electrical and Electronic Engineering and Mechanical Engineering |
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| **Course Title** | **Electrical Machines** |
| **Guided Learning Hours** | **48** |

**Aims**

This unit provides learners with knowledge and an understanding of the features and applications of a range of electrical machines and the hazards, legislation and regulations related to working with electrical apparatus.

**Learning Outcomes**

On completing this course successfully learners will be able to:

1. Explain the operation and function of alternating current (AC) machines
2. Explain the operation and function of direct current (DC) machines
3. Describe the principle of operation of transformers
4. Describe how electrical machine control circuits and systems operate

**Indicative Content**

**1. Explain the operation and function of alternating current (AC) machines**

*Alternating current (AC) motors*: Explain the production of a rotating magnetic field; Differentiate between single and polyphase; Describe the principle of operation of various types of AC motors (induction motors, split-phase, capacitor start, capacitor start and run, shaded pole, universal, variable frequency drives), Describe the starting characteristics and torque of a three-phase cage- rotor induction motor and a split-phase, single phase induction motor; Explain methods of starting (Star-delta, autotransformer); Define and calculate synchronous speed, slip and slip speed; Describe typical applications of AC motor (pumps, machine shop equipment, fixed loads, variable loads); Solve problems relating to stator and rotor losses and efficiency.

*AC generator*: Describe the principle of operation of the following types of AC generators (single-phase, polyphase); Describe typical applications (stand-by generators, remote site generators, vehicle alternators with regulation and rectification).

**2. Explain the operation and function of direct current (DC) machines**

*Direct current (DC) motors*: Describe the principle of operation of various types of DC motors (series, shunt, compound (long and short shunt), brushless; construction); Derive the e.m.f, voltage, speed and torque equations and use these equations to obtain the speed/load torque characteristic for each type of DC motor; Describe methods of varying the speed of dc motors and explain their limitations; Describe typical applications of DC motors (motor vehicle starters and window operation, toys and models, industrial drives, crane hoists, fixed loads, variable loads).

*DC generator*: Describe the principle of operation and construction of the following types of DC generators (shunt, series, compound and separately excited); describe typical applications (motor vehicles, speed control/feedback systems such as tacho-generators).

**3. Describe the principle of operation of transformers**

*Transformers*: Describe with the aid of sketches the construction of a typical transformer and the types of winding (Construction: core, shell; Winding: disc, helical, layer and sandwich); Describe the principle of operation of various types of transformers (step up, step down, safety isolating); Describe the losses which occur for load and non-load conditions and explain the need for laminating the transformer core; Describe open-circuit and short-circuit tests and their use in determining losses and efficiency; Explain transformer winding 'tapping' to provide various voltage outputs; Describe the principle of operation of an autotransformer; Solve problems involving current, voltage, and efficiency for both open circuit and short circuit tests; Describe typical applications of transformers (incoming mains step down, portable transformer for hand tools, safety isolating transformer for electrical test-bench work, machine power supplies).

**4. Describe how electrical machine control circuits and systems operate**

*Control Relays*: Describe the use of control relays in the operation of electric machines (start/stop, overload, remote stop/start, safety).

*AC machine control*: Describe the various control systems used for AC machines (direct on line (DOL), star-delta, soft start and other solid state techniques such as triac, inverter drives, slip ring rotor resistance control, auto transformer, power factor correction)

*DC machine control*: Describe the various control systems used for DC machines (Starting methods and speed control: face plate, solid state systems, Emergency stop: closed contact devices to stop the machine/system from running or starting and turn power off under emergency conditions).

**Learning Outcomes**

Candidates will be able to:

**1. Explain the operation and function of alternating current (AC) machines**

1.1 Explain how a rotating magnetic field is produced.
1.2 Describe the principle of operation of various types of AC motors and generators.
1.3 Explain various methods of starting an AC machine.
1.4 Describe with the aid of diagrams, the starting characteristics and torque of an induction motor.
1.5 Describe typical applications of AC motors and generators.
1.1 Solve problems relating to stator and rotor losses and efficiency.

**2. Explain the operation and function of direct current (DC) machines**

2.1 Describe the principle of operation of various types of DC motors and generators.
2.2 Describe various methods of speed control for DC machines and explain their limitations.
2.3 Describe typical applications of DC motors and generators.
2.4 Solve problems relating to e.m.f, voltage, speed and torque.

**3. Describe the principle of operation of transformers**

3.1 Describe with the aid of sketches the construction of a typical transformer.
3.2 Describe the principle of operation of various types of transformers.
3.3 Explain transformer losses under load and non-load conditions.
3.4 Describe the principle of operation of an autotransformer.
3.5 Solve problems involving current, voltage and efficiency using data derived from both open and short-circuit tests.
3.6 Describe typical applications of transformers.

**4. Describe how electrical machine control circuits and systems operate**

4.1 Be able to describe the use of control relays in the operation of electric motors.
4.2 Be able to explain the operation of at least (2) types of control systems used for AC and DC machines.

**Outline Learning Plan:**

The outline learning plan has been included in this unit as guidance. It demonstrates one way of planning the delivery and assessment of this unit.

| Topic and suggested assignments/Activities | Hours |
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| Tutor led introduction to unit and programme of learning | 0.6 |
| Tutor Introduction To AC machines. Differentiate between motor and generator: Principle of operation | 1.8 |
| Understanding the production of a rotating magnetic field; Differentiate between single and polyphase; Describe the principle of operation of various types of AC motors (induction motors, split-phase, capacitor start, capacitor start and run, shaded pole, universal, variable frequency drives) | 2.4 |
| Introduction to starting methods: Understanding the starting characteristics and torque of a three-phase cage- rotor induction motor and a split-phase, single phase induction motor; Explain methods of starting (Star-delta, autotransformer, direct on line) | 2.4 |
| Tutor led Practical Activity: Learners are presented with a schematic diagram of a simple direct on line starter and are required to hardwire the circuit, identifying the main components that make up the circuit (switches, contactors, overload protection). Learners are required to produce a written assessment of lab explaining the operation of the circuit. | 2.4 |
| Introduction to calculation: Define and calculate synchronous speed, slip and slip speed; Describe typical applications of AC motor (pumps, machine shop equipment, fixed loads, variable loads); Solve problems relating to stator and rotor losses and efficiency. | 2.4 |
| Introduction to AC generators: Describe the principle of operation of the following types of AC generators (single-phase, polyphase); Describe typical applications (stand-by generators, remote site generators, vehicle alternators with regulation and rectification). | 2.4 |
| Tutor Introduction To DC machines. Differentiate between motor and generator: Principle of operation | 2.4 |
| Understand the principle of operation of various types of DC motors (series, shunt, compound (long and short shunt), brushless; construction); Derive the e.m.f, voltage, speed and torque equations and use these equations to obtain the speed/load torque characteristic for each type of DC motor; Describe methods of varying the speed of dc motors and explain their limitations; Describe typical applications of DC motors (motor vehicle starters and window operation, toys and models, industrial drives, crane hoists, fixed loads, variable loads). | 2.4 |
| Understand the principle of operation and construction of the following types of DC generators (shunt, series, compound and separately excited); describe typical applications (motor vehicles, speed control/feedback systems such as tacho-generators). | 2.4 |
| Tutor led Practical Activity: Learners are required to construct and examine the speed control of a DC motor using a variable resistor and plot a speed vs torque characteristic under varying conditions. Learners are required to produce a written assessment of lab explaining the operation of the circuit. | 2.4 |

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| Tutor Introduction to Transformers: Various types including their principle of operation | 2.4 |
| Understand the construction of a typical transformer and the types of winding (Construction: core, shell; Winding: disc, helical, layer and sandwich); Describe the principle of operation of various types of transformers (step up, step down, safety isolating); Describe the losses which occur for load and non-load conditions and explain the need for laminating the transformer core. | 2.4 |
| Understand open-circuit and short-circuit tests and their use in determining losses and efficiency; Explain transformer winding 'tapping' to provide various voltage outputs; Describe the principle of operation of an autotransformer; Describe typical applications of transformers (incoming mains step down, portable transformer for hand tools, safety isolating transformer for electrical test-bench work, machine power supplies). | 2.4 |
| Introduction to Calculation: Solve problems involving current, voltage, and efficiency for both open circuit and short circuit tests. | 2.4 |
| Tutor led Practical Activity: Learners conduct open circuit and short circuit tests on transformer and record values obtained from tests (Losses). Learners are required to produce a written assessment of lab using values obtained from tests to calculate the efficiency of the transformer. | 2.4 |
| Tutor Introduction to Relay control: Describe how electrical machine control circuits operate. | 2.4 |
| Understand the use of control relays in the operation of electric machines (start/stop, overload, remote stop/start, safety).<br>Understand the various control systems used for AC machines (direct on line (DOL), star-delta, soft start and other solid state techniques such as triac, inverter drives, slip ring rotor resistance control, auto transformer, power factor correction) | 2.4 |
| Understand the various control systems used for DC machines (Starting methods and speed control: face plate, solid state systems, Emergency stop: closed contact devices to stop the machine/system from running or starting and turn power off under emergency conditions). | 2.4 |
| Tutor led Practical Activity: Build a simple motor control circuit with the use of control relays in the operation of electric machines (start/stop, overload, remote stop/start, safety).<br>Learners are required to produce a written assessment of lab explaining the operation of the circuit. | 2.4 |
| Review of learning outcomes 1 to 4/ Feedback and guidance | 2.4 |
| **TOTAL LEARNING CONTACT HOURS** | **48** |

**Assessment Details**

| Methods of Assessment | Mid-term Examination | End of Term Examination |
|---|---|---|
| Grading Mode | Numeric | Numeric |
| Weighting % | 40 | 60 |
| Pass Mark% | 50 overall | |
| Outline Details | Three hour unseen closed book examination. (8) structured questions | Three hour unseen closed book examination. (10) structured questions |

**Essential Learning Resources:**

Learners will be given access to a wide range of publications relating to Electric machines from our library facility as well as access to the online EBSCO database. In addition Learners will access to our well-equipped electrical and electronics laboratory for practical training relating to this unit.

**Textbooks and Manuals**


1. Hughes A – Electric Motors and Drives: Fundamentals, Types and Applications (Newnes, 2005) ISBN 0750647183)
2. Schultz G – Transformers and Motors (Newnes, 1997) ISBN 0750699485