SMART ELECTRICAL TECHNOLOGY

NORMAL (TECHNICAL) EXAMINATION SYLLABUS

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I INTRODUCTION

Home automation technology and systems, with their ability to make everything that is used daily in homes, offices and buildings (e.g., electrical lighting, appliances, air-conditioning systems, security locks, curtains and blinds, even smartphones and tablets) work together, provide users with improved convenience, comfort, energy savings, security and increase quality of life.

It is no wonder why home automation systems have seen rapidly increasing adoption and use worldwide, with many manufacturers getting into the market and a wide range of offerings.

This is a Normal (Technical) examination syllabus for a 2-year course in Smart Electrical Technology undertaken at upper secondary. The syllabus aims to provide students with training in the core, foundational concepts and principles of operation of all home automation systems, i.e., hardware and devices, software, combination and integration of the technologies involved, programming techniques, communication protocols and testing.

The inclusion of training in the use of smartphones to manage and control a home automation system by means of apps also serves to introduce the much talked about ‘Internet of Things’ today to students.

As the devices, loads and equipment controlled by home automation solutions are invariably electrical in nature, students will also be provided with foundational training in electrical circuits and technology in the applied subject. For home automation, students will learn, through a combination of theory lessons and hands-on practical training, the most commonly used basic and advanced control functions.

The training in electrical circuits and home automation systems will help prepare and enable students to take up further studies in electrical, control and computer engineering or related fields at post-secondary level.

II AIMS OF SYLLABUS

The syllabus aims to:

1. equip students with foundational knowledge of electrical circuits and systems and home automation systems in preparation for further engineering studies at post-secondary level;

2. enable students to acquire skills and knowledge related to electrical technology and home automation that are of immediate interest, relevance and use in daily life;

3. enable students to understand the applications of electrical and home automation technology in homes and built environments;

4. inculcate students with safety consciousness and safe working habits;

5. enable students to develop their analytical abilities and problem-solving skills; and

6. develop in students an interest in a post-secondary engineering-based education.

III ASSESSMENT OBJECTIVES

The assessment objectives are classified into**:**

1. Practical Skills

Candidates should be able to:

1.1 Follow a sequence of instructions or test procedures;

1.2 Draw and read instructions and circuit diagrams;

1.3 Use correct tools and systematic techniques;

1.4 Connect electrical and home automation system components and circuits with reference to instructions, diagrams and drawings;

1.5 Evaluate, set up, program and test operation of electrical and home automation components, devices, circuits and panel;

1.6 Obtain, record and/or interpret observations and test results; and

1.7 Adopt safe working habits and practices in the handling of equipment and tools and when working with electricity.

2. Analytical and Problem-Solving Skills

Candidates should be able to:

2.1 Apply knowledge acquired in the subject to analyse the requirements of a home automation solution or application; and

2.2 Design, implement and test home automation solutions for a given requirement or application.

3. Knowledge with Understanding

Candidates should be able to demonstrate knowledge and understanding of electrical and home automation systems, including:

3.1 Facts, natural laws and concepts, theories and principles of operation;

3.2 Terminology, conventions (including symbols, quantities, units of measurement); and

3.3 Programming principles and techniques, test instruments and tools (including their operation, safety aspects, and care).

IV SCHEME OF ASSESSMENT

Number of Examination Papers

1. Candidates will be required to attempt all three compulsory papers:
   - Written Examination Paper 1
   - Practical Examination
     - Paper 2: Electrical Principles & Conventional Lighting
     - Paper 3: Home Automation

Assessment Weighting

2. The assessment weighting for each paper is as shown in Table 1.

Table 1: Assessment Modes and Weightings

Paper	Mode	Duration	Marks	Weighting
1	Written Examination	1 hr	30	30%
2	Practical Examination (Electrical Principles & Conventional Lighting)	1 hr 20 mins	132	30%
3	Practical Examination (Home Automation)	1 hr 30 mins	84	40%

Assessment Timeline

3. The timeline showing the recommended schedule for the conduct of the assessment is shown in Table 2.

Table 2: Assessment Timeline

Paper	Date
Paper 2 Practical Examination (Electrical Principles & Conventional Lighting)	September[1] of Year 2
Paper 3 Practical Examination (Home Automation)	September[1] of Year 2
Paper 1 Written Examination	October of Year 2

Written Examination Details

4. The assessment grid for Paper 1 is shown in Table 3. The assessment objectives are weighted to give an indication of their relative importance. They are not intended to provide a precise statement of the marks allocated to each assessment objective.

Table 3: Assessment Grid

Paper 1	Assessment Objectives			Marks
	Knowledge	Comprehension	Application	
	30% – 40%	30% – 40%	20% – 30%	30

[1] Paper 2 and Paper 3 will be on different dates in September, during the N-Level practical examinations period.

Practical Examination Details

5. Candidates will be tested on their ability to perform a series of tasks by applying the appropriate skills and knowledge.

Practical Paper 2 **Duration:** 1 hour and 20 minutes **Electrical Principles & Conventional Lighting**
This paper requires students to connect circuits and/or perform measurements using a multimeter, design and connect a conventional lighting circuit and/or a 13 A radial power circuit using a pre-built training kit.

Practical Paper 3 **Duration:** 1 hour and 30 minutes **Home Automation**
This paper requires students to develop an application for a home automation system for mobile access, and then execute the application on the Home Automation Training Kit using a laptop.

6. The two practical papers shall be conducted under examination conditions. The weighting of Paper 2 and Paper 3 is 30% and 40% respectively. Students are not allowed to communicate with their classmates or to seek guidance and advice from their teachers, except for the control circuit design assessment. Marking will take the assistance provided into consideration.

7. The main criteria for assessment can be summarised as follows:

    7.1 Electrical and home system components, devices, wiring drawn must be labelled correctly and in accordance with instructions;

    7.2 Cables and circuit connections must comply with approved standards;

    7.3 All connections must be correct as well as electrically and mechanically sound;

    7.4 The ability to link, integrate and program home automation system including function tests;

    7.5 The ability to apply knowledge to devise solutions for home automation applications; and

    7.6 Observation and/or adherence to safety rules and precautions.

8. Task specific assessment rubrics will be used for awarding raw marks of practical examinations. A criticality value (1, 2, 3) will be factored on the raw score based on the relative importance of the element being assessed in terms of safety and risk of damage or loss of life, equipment or property in the event of a mishap caused as result of failure to meet requirement or standard of performance. Elements which would have a serious impact in all these aspects are pegged at 3; those with little or no impact would be pegged at 1. Criticality factor 2 is assigned to elements that are rated between 1 and 3. A difficulty value (1, 2, 3) will be factored on the raw score based on how difficult the task or requirement is.

V USE OF CALCULATOR

An approved calculator may be used for all written and practical examinations.

VI SYLLABUS CONTENT

1. ELECTRICAL PRINCIPLES AND CIRCUITS

This section covers the basic principles of electricity, connection of simple electrical lighting circuits for residential premises and the use of multimeters to measure and monitor electrical quantities and test for electrical continuity.

1.1 Electrical Safety

Students should be able to:

1.1.1 Explain the two types of electric shock:
- Direct contact
- Indirect contact

1.1.2 Explain the potential dangers in electrical work

1.1.3 Understand the danger of hazardous work practices

1.1.4 Explain the precautions and procedures for safe electrical work

1.1.5 Explain the benefits of good housekeeping in electrical work

1.1.6 Recommend measures to protect against electrical hazards

1.2 Electric Circuits

Students should be able to:

1.2.1 Explain how an electric circuit works

1.2.2 State the three basic electrical quantities: voltage, current and resistance

1.2.3 State the units of measurement for voltage, current and resistance

1.2.4 Describe the use of a voltmeter for measuring voltage

1.2.5 Describe the use of an ammeter for measuring current

1.2.6 Describe the use of an ohmmeter for measuring resistance

1.2.7 State the different uses of a multimeter

1.2.8 Use the multimeter to measure voltage, current and resistance, and to check for continuity of an electrical installation

1.2.9 Exercise safety precautions when handling and using measuring instruments

1.3 Electric Circuit Laws

Students should be able to:

1.3.1 Understand the relationship between voltage, current and resistance (Ohm's law): $V = I \times R$

1.3.2 Apply Ohm's law to determine voltage, current or resistance in an electric circuit

1.3.3 Connect a simple electric circuit comprising a voltmeter, an ammeter, a load and a power supply to verify Ohm's law

1.4 Electric Circuit Connections

Students should be able to:

1.4.1 Identify the three methods of connecting electrical loads:
- Series
- Parallel
- Series-parallel

1.4.2 State the characteristics of a series circuit:
- One path for current flow
- Supply voltage is equal to the sum of all individual voltages
- Total resistance is higher than the highest individual resistance

1.4.3 State the characteristics of a parallel circuit:
- Supply voltage is the same as all branch voltages
- Supply or total current is equal to the sum of all individual branch currents
- Total resistance is lower than the lowest individual resistance

1.4.4 Determine the total resistance of a series circuit comprising two resistors using the formula: $R_T = R_1 + R_2$

1.4.5 Determine the total resistance of a parallel circuit comprising two resistors using the formula: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

1.4.6 Connect a series circuit comprising two resistors, a voltmeter and an ammeter for the purpose of verifying the characteristics of a series circuit

1.4.7 Connect a parallel circuit comprising two resistors, a voltmeter and an ammeter for the purpose of verifying the characteristics of a parallel circuit

1.4.8 Recognise that a series-parallel circuit has the characteristics of both series and parallel circuits

1.5 Power and Energy in an Electric Circuit

Students should be able to:

1.5.1 Define the terms “power” and “energy” in electric circuits

1.5.2 State the units of measurement for power (watt) and energy (joule)

1.5.3 State and apply the formula to determine the power in an electric circuit comprising one electrical load: $P = V \times I$

1.5.4 State and apply the formula to determine the energy in an electric circuit comprising one electrical load: $E = P \times t$

1.5.5 State the practical unit of energy consumption in a household (kilowatt-hour or kWh)

1.5.6 Calculate the energy consumption of an electrical load in kilowatt-hours

1.6 Electric Power Sources

Students should be able to:

1.6.1 State that supply sources can be direct current (DC) or alternating current (AC)

1.6.2 Distinguish the differences between DC and AC

1.6.3 Identify the common sources of DC and AC

1.6.4 Define the function of a cell

1.6.5 Draw the symbol of a cell

1.6.6 Explain the difference between a cell and a battery

1.7 Electrical Hazards and Protection

Students should be able to:

1.7.1 Explain the electrical hazards caused by overcurrent and earth fault

1.7.2 Understand the need to protect people and properties against electrical hazards

1.7.3 Explain the importance of earthing to avoid the risk of electric shock

1.7.4 Describe the application and selection of different electrical protective devices for residential use (fuses, circuit breakers, residual current circuit breakers)

1.7.5 Explain how protective devices can protect against electrical hazards

1.8 Electrical Cables

Students should be able to:

1.8.1 State the function of a cable

1.8.2 State the three main parts of a cable

1.8.3 Describe the specific roles of the three main parts of a cable

1.8.4 State the common materials used to make conductors and insulators

1.8.5 Identify the common sizes of cable used in residential premises

1.9 Electrical Test Instruments

Students should be able to:

1.9.1 Explain the purpose of test instruments in electrical work (continuity tester, multimeter, insulation resistance tester)

1.9.2 Explain the functions of a socket outlet polarity tester

1.9.3 Explain the method to test for the correct polarity of a socket outlet

1.10 Conventional Lighting Circuits

Students should be able to:

1.10.1 Define the term “final circuit”

1.10.2 Analyse the design and characteristics of common final circuits:
- Lighting final circuit
- Power final circuit

1.10.3 Understand the two methods of wiring a socket outlet final circuit:
- Radial final circuit
- Ring final circuit

1.10.4 State the cable sizes commonly used for lighting and power circuits

1.10.5 State the standard cable colour codes for a single-phase circuit

1.10.6 State the protective device sizes commonly used for lighting final circuits

1.10.7 State the application of the following electrical accessories:
- One-way switch
- Two-way switch
- Dimmer switch

1.10.8 Wire up and test a conventional lighting final circuit with:
- One-way control
- Two-way control
- Dimmer control

1.10.9 Wire up and test a 13 A radial power circuit

1.10.10 Explain the method for testing wiring circuits for safe use

1.10.11 Analyse test results to identify the type of faults

1.11 Electrical Supply Systems

Students should be able to:

1.11.1 Explain how electricity is transmitted from a power station to consumers

1.11.2 Explain how electricity is distributed in residential, commercial and industrial premises

1.11.3 Explain the function of transformers in the transmission and distribution of electricity

1.11.4 State the voltages for the generation, transmission and distribution of electricity in Singapore

2. HOME AUTOMATION SYSTEMS

This section covers the common technology used in home automation and installing and programming for smart control of lighting circuits in homes.

2.1 Home Automation Basics

Students should be able to:

2.1.1 List common functions of building automation systems (e.g., lifts, fire alarms and ventilation)

2.1.2 List common functions of home automation systems (e.g., lighting, appliances, blinds and security)

2.1.3 Explain the benefits of using a home automation system over a conventional system

2.1.4 List examples of common home automation standards and products, such as:

- KNX (used by Jung, ABB, Schneider, etc.)
- LonWorks
- C-Bus
- Modbus
- Z-Wave (used by MK Astral)
- ZigBee

2.2 Basic Home Automation Devices

Students should be able to:

2.2.1 Describe the key features of home automation systems and their relevant devices:

- Switching (e.g., switch)
- Dimming (e.g., dimmer)
- Timing (e.g., timer)
- Sensing (e.g., motion sensor)
- Scene control (e.g., scene master)
- Central control (e.g., control panel)
- Visualisation (e.g., tablet)

2.3 Network Topology and Z-Wave Command Class

Students should be able to:

2.3.1 Describe the two methods by which devices can be linked:
- Twisted pair (TP) cables
- Radio frequency (RF) signals

2.3.2 State the benefits of RF control over TP cables

2.3.3 Describe a topology as the way in which devices are connected to one another

2.3.4 Identify the following common topologies for home automation:
- Bus
- Ring
- Mesh
- Star

2.3.5 State the advantages and disadvantages of common topologies for home automation

2.3.6 Describe a protocol as the rules used for communication between devices to send digital signals

2.3.7 Understand that signals are classified into command classes

2.4 Z-Wave Network Setup

Students should be able to:

2.4.1 Install up to five common control devices such that they communicate through radio frequency correctly

2.4.2 Describe that every automation system device has a unique identity

2.5 Switching and Dimming

Students should be able to:

2.5.1 Describe the function of intelligent switches

2.5.2 Describe the differences between intelligent switches and conventional switches (e.g., one-way and two-way switches or dimmers)

2.5.3 Describe and program intelligent switches to control lighting and electrical devices

2.6 Timing and Sensing

Students should be able to:

2.6.1 Describe the functions of timers

2.6.2 Describe the functions of sensors, and use motion and light sensors as examples of sensors commonly used in home automation systems

2.6.3 State how timers and sensors can be used to switch devices on and off automatically to conserve energy

2.6.4 Describe and program timers and sensors to control lighting and electrical devices

2.7 Scene Control

Students should be able to:

2.7.1 Describe the function of the scene master of a home automation system

2.7.2 Describe and program the scene master for complex lighting scenes (e.g., switching, dimming)

2.7.3 Describe and program a button as a master-off scene

2.7.4 Describe the use of remote control to access complex scenes

2.8 Central Control and Visualisation

Students should be able to:

2.8.1 Describe and program a central control device for switching, dimming and scene control

2.8.2 Convert a conventional lighting circuit to be controlled by a home automation system

2.9 Home Automation Controllers

Students should be able to:

2.9.1 State how a controller communicates with the home automation system

2.9.2 State the purpose and benefits of using a home automation controller

2.9.3 List common hardware modules for a home automation controller, such as:

- Universal communication module (UCM)
- Input/output expansion board
- Keypad
- Direct digital controller (DDC)

2.9.4 Install and configure a home automation controller to communicate with devices and control electrical loads correctly

2.9.5 Use a home automation controller to automate the activation of devices and electrical loads correctly, based on a given scenario

2.9.6 Send commands to devices and electrical loads (e.g., switches, dimmers, blinds, buzzers)

2.9.7 Monitor energy usage of electrical devices

2.10 Basic Networking and Installing Mobile App

Students should be able to:

2.10.1 State the function of a router

2.10.2 Determine the IP address of a router

2.10.3 Write basic programs (with guided steps) to create an application that controls electrical loads via mobile devices

2.11 Controlling Electrical Loads and Security Features via Mobile Phone

Students should be able to:

2.11.1 Test the control of electrical loads via a computer

2.11.2 State the security features that are possible using a mobile app and home automation controller

VII GLOSSARY OF TERMS USED

This glossary is to provide candidates with a clear understanding of the meaning, intent and expectations relating to the requirements of learning outcomes and/or questions in test papers.

1 **Analyse** refers to the ability to consider, in detail, results, data and/or information available to deduce or discover essential features, the possible causes or the correct answer or solutions to a problem at hand.

2 **Apply** refers to the ability to put one's knowledge of natural laws, principles or formulae to some practical or specific use.

3 **Calculate** refers to the use of mathematical methods to determine a result.

4 **Compare** would require students to give the similarities and differences between items, concepts, ideas etc.

5 **Connect** refers to the joining or fastening together, physically or by wires, two or more circuit components and devices.

6 **Construct** means to draw and form, on a display screen, a circuit diagram comprising parts or elements in a systematic manner so as to meet specified requirements.

7 **Define** would require a formal statement or declaration of the meaning of a given term or phrase.

8 **Describe** would require students to state in words (with diagrams or drawings as appropriate) the component, condition, type of operation etc.

9 **Determine** means to establish or ascertain the value, answer or result by means of calculation, investigation, experiment, survey or study.

10 **Distinguish** refers to the ability to perceive or identify the differences between given systems and/or equipment.

11 **Download** refers to copy (data) from one computer system to another, typically over the Internet.

12 **Explain** would require an answer that could include the definition of the term(s), some relevant comments and/or reference to theory.

13 **Identify** as applied to a component, device, drawing symbol etc refers to the recognition and giving the correct term, phrase and/or cause or reason.

14 **Interpret** refers to the ability to conceive the significance of a problem or event, offer an explanation and/or explain the meaning of the problem or event.

15 **Investigate** means to observe or inquire into in detail on the operation or operational performance of an equipment or system.

16 **List** means a series of words, items etc.

17 **Measure** refers to the use of a measuring or test instrument to determine the value of an electrical quantity in a circuit or equipment.

18 **Outline** refers to a listing or summary of the main points and/or differences between two or more devices or equipment items.

19 **Read** as applied to the use of measuring instruments refers to the ability to derive the true value of the electrical quantity being measured.

20 **Recognise** means to know, accept or remember something that is true of a concept, idea or fact.

21 **Recommend** refers to the ability to come up with a correct solution or solutions to solve a given problem or restore a circuit or equipment to its normal condition based on an understanding of the underlying causes of the problem.

22 **State** would require a straightforward and direct answer with little or no supporting comments or reference to theory or concepts.

23 **Test** refers to the process of verifying whether a component, circuit, appliance, equipment and/or system works or performs as per requirements and specifications

24 **Troubleshoot** calls for the ability to determine, by means of testing and observation, the causes and solutions to a problem. It also means the ability to restore an equipment or system to normal operation by means of replacement of a part(s) or removing the cause of the abnormal operation.

25 **Understand** means the ability to perceive and comprehend the meaning, nature and significance of a concept, equipment or system.

26 **Wire** is the act of connecting wires between circuit components and devices.