FUNDAMENTALS OF ELECTRONICS

Ordinary Level

(Syllabus NP01)

CONTENTS

INTRODUCTION

This syllabus develops in students an understanding of basic electronic principles and applications and provides the foundation for further studies in electronic engineering or related fields.

Students will be introduced to electronic circuit theories, device operating principles and applications of techniques of electronics in circuit design. They will gain an understanding of basic circuit laws and network theorems, as well as semiconductor physics, device characteristics, operating principles and common applications of diodes and transistors. Students will learn through a hands-on approach and through worked examples, tutorials, laboratory sessions, electronic project and e-learning materials.

This subject is suitable for upper secondary school students with no prior knowledge in electronics. Daily electronic application examples will be used to underpin student learning.

AIMS

The aims are to:

1. provide the fundamental knowledge in electronics to enable understanding of its applications;

2. provide hands-on opportunities for students to construct electronic circuits and build electronic projects of varying difficulty levels, ranging from simple to intermediate;

3. cultivate and sustain students' interest in learning through circuit simulations and self-assessment activities;

4. promote active learning through activities such as information search and presentations.

ASSESSMENT OBJECTIVES

A Knowledge with understanding (30%)

Students should be able to demonstrate knowledge and understanding related to:

- facts, laws, concepts, theories;
- engineering vocabulary, terminology, conventions;
- electrical/electronic measuring instruments and their use;
- electrical quantities and their determination.

B Handling information and solving problems (45%)

Students should be able to:

- carry out research, plan/design procedures to solve problems;
- handle information effectively. This would require them to locate, select, interpret, evaluate and manipulate data available to solve engineering problems;
- organise their data and then present their findings.

C Practical skills (25%)

Students should be able to:

- follow a sequence of instructions or test procedures;
- use systematic techniques and measuring instruments;
- make and record observations and measurements;
- suggest possible improvements to existing methods, setups or circuitries;
- perform computer simulations of a proposed design;
- construct a product based on findings and proposed design;
- evaluate the effectiveness of the product.

USE OF CALCULATORS

An approved calculator may be used in all papers.

SCHEME OF ASSESSMENT

Candidates are required to enter for Papers 1 and 2.

Paper	Type	Marks	Weighting	Duration
1	Section A (40 marks) Short answer questions	100	70%	2 h
	Section B (60 marks) Long questions			
2	An application-specific electronic project	100	30%	32 h

Paper 1

This written paper consists of two sections. Candidates must answer all the questions in the two sections:

- Section A: carries 40 marks and consists of 6 - 10 short answer questions.
- Section B: carries 60 marks and consists of three questions, each of 20 marks.

Paper 2

This project is carried out over a period of 32 hours in Year 2. It comprises three interrelated components.

a) The Portfolio Work Document (30 marks)
The portfolio work document shows evidence of the candidate's activities and project implementation. The portfolio reflects the candidate's understanding of the project specification, planning, design brief, analysis, investigation, ideas generation, design proposal, development, making, testing and evaluation.

The portfolio should articulate how information is obtained and used, and the basis on which decisions are made in the development of design proposal. The candidate is advised to use flow diagrams to exemplify the complex project stages and is encouraged to use pictures and graphical illustrations in the portfolio. Due recognition and acknowledgement should be accorded to information sources and person/s rendering help to the project.

b) The Project Hardware (60 marks)
The candidate is expected to demonstrate good quality work, appropriate use of electronic components and constructional methods. The candidate need not restrict the design of the project within the scope of the curriculum but should take the opportunity to make use of the latest technologies under the supervision of the supervisor.

c) The Evaluation Report (10 marks)
The report describes the strengths and weaknesses of the design and how problems, and issues surrounding the project were resolved. The candidate is encouraged to use pictures and graphical illustrations to support ideas and explanations in the report.

(Refer to Appendix A for *Assessment Rubric for Project*)

KEY AREAS COVERED

The specific areas are:

S/N	Scope
1.	Fundamentals of Electricity and Electronics
2.	Electronic Components and Circuit Theory
3.	Electronic Devices and Applications
4.	Electronic Test & Measurements
5.	Computer Aided Design & Simulation
6.	Electronic Project Design & Circuit Construction

SUBJECT CONTENT AND LEARNING OUTCOMES

Unit 1 Fundamentals of Physics/Electricity

Content

1.1 SI units (fundamental and derived)

1.2 Standard scientific notation and prefix form

1.3 Conventional current and electron flow

1.4 Charge, E.M.F and potential difference

1.5 Resistance and conductance

1.6 Ohm's law

1.7 DC current and voltage measurements

1.8 Electrical power and energy

Learning Outcomes:

Candidates should be able to:

(a) recall the following fundamental quantities and their SI units: mass (kg), length (m), time (s), electric current (A), temperature (K)

(b) recall derived quantities related to electricity such as electric charge, resistivity, frequency, etc. and their SI units

(c) express the magnitude of fundamental and derived quantities in exponential (scientific) notation

(d) use the following prefixes and their symbols to indicate decimal sub-multiples and multiples of the SI units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M)

(e) distinguish between conventional current and electron flow

(f) state that current is a rate of flow of charge and is measured in amperes (A)

(g) recall and apply the relationship *charge (Q) = current (I) x time (t)*

(h) distinguish between E.M.F. and potential difference

(i) recall and apply the relationship for resistance $R = 1/G$ and conductance $G = 1/R$

(j) state Ohm's law and apply Ohm's law to determine current, voltage, and resistance

(k) sketch and interpret the graphical linear relationship between current and voltage in a purely resistive circuit

(l) determine the total E.M.F. in a series/parallel practical resistive circuit with several sources

(m) determine the total current in a series/parallel practical resistive circuit

(n) use electronics test equipment to measure voltage, current and resistance

(o) distinguish between work and energy

(p) describe the use of the heating effect of electric current flowing through a conductor

(q) determine the efficiency of an electrical device

(r) recall the power equations $P = VI$, $P = I^2R$ and $P = V^2/R$ and apply the relationships $P = VI$ and $W = VIt$ to solve problems

Unit 2 Resistors

Content

2.1 Practical construction (fixed, variable and wire wound)

2.2 Working principle and resistor values

2.3 Building resistive ladder circuits

2.4 Temperature effect on resistance and its applications

Learning Outcomes:

Candidates should be able to:

(a) describe the construction of various types of resistors and select the appropriate resistor for a particular circuit design

(b) apply the resistor colour code to determine the ohmic value and tolerance of a resistor, and verify the value by measurement

(c) determine resistor power rating and explain the factors affecting it

(d) explain how changing the resistance in a circuit changes the current in the circuit

(e) show understanding of the use of variable resistors in electrical circuits

(f) sketch and interpret the graphical relationship between temperature and resistance

(g) recall and apply the effect of temperature on the resistance of a conductor to solve related problems

(h) recall and apply the characteristics and range of the common commercially available types of fixed and variable resistors to practical situations

Unit 3 Voltage and Current Sources

Content

3.1 Ideal and practical voltage and current sources

3.2 Conversion of sources

3.3 Voltage and current dividers

3.4 Open and short circuits

Learning Outcomes:

Candidates should be able to:

(a) distinguish between the two main types of voltage sources

(b) distinguish between a voltage source and a current source

(c) convert voltage sources to current sources, and vice versa

(d) identify a resistive voltage divider and apply the voltage division formula to solve related problems

(e) identify a resistive current divider and apply the current division formula to solve related problems

(f) define the terms 'circuit', 'load', 'source', 'short-circuit', 'open-circuit' and 'overload'

(g) show an understanding that current flows only in a closed circuit

Unit 4 Network Theorem/Analysis

Content

4.1 Kirchhoff's voltage law and current law

4.2 Branch current analysis

4.3 Thevenin's theorem

4.4 Maximum power transfer theorem

Learning Outcomes:

Candidates should be able to:

(a) apply Kirchhoff's current and voltage laws to a series-parallel resistive circuit

(b) apply branch current analysis to DC circuits

(c) apply Thevenin's theorem to simplify circuits for analysis

(d) calculate the Thevenin’s parameters at the input and output terminals of BJT transistor amplifiers

(e) determine the conditions for maximum power transfer to any circuit element

Unit 5 Capacitors

Content

5.1 Capacitors and capacitance

5.2 Construction and working principle

5.3 Series or/and parallel arrangements

5.4 Capacitor applications

Learning Outcomes:

Candidates should be able to:

(a) define capacitance and name its unit

(b) recall and apply the equation $C = Q/V$ to solve problems

(c) define relative permittivity and dielectric strength

(d) recall and use the relationship $\varepsilon = \varepsilon_o \varepsilon_r$

(e) recall and apply the equation $C = \varepsilon A/d$ to solve related problems

(f) describe the construction and working principle of basic capacitors using terms such as dielectric, non-polar, polar, variable and metal plates

(g) show understanding of the function of various types of capacitors in practical electronic circuits

(h) explain why a capacitor has a maximum working voltage

(i) apply the relevant relationships of capacitors connected in series and in parallel to solve related problems

(j) recall and apply the equation for the energy stored in a capacitor $W = ½ CV^2$ to solve problems

Unit 6 Inductors

Content

6.1 Inductors and inductance

6.2 Construction and working principle

6.3 Series or/and parallel arrangements

6.4 Inductor applications

Learning Outcomes:

Candidates should be able to:

(a) define inductance and name its unit

(b) recall and apply the equation $V = L I/t$ to solve problems

(c) describe and explain the principle of electromagnetic induction in terms of flux linkages

(d) distinguish between mutual inductance (M) and self-inductance (L)

(e) recall and apply the equation $L = \mu AN^2/\ell$ to solve related problems

(f) describe the basic construction and working principle of inductors

(g) recall and use the relationship $\mu = \mu_o \mu_r$

(h) apply the relevant relationships between inductors connected in series and in parallel

(i) recall and apply the equation for the energy stored in the inductor $W = ½ L I^2$ to solve problems

(j) show understanding of the functions of various types of inductors used in electrical and electronic circuits

Unit 7 Semiconductor PN Junction Diode

Content

7.1 Construction and working principle

7.2 Forward and reverse connections

7.3 PN Junction Diode applications

Learning Outcomes:

Candidates should be able to:

(a) describe the basic construction of the pn junction diode and explain how it is biased in the forward and reverse directions

(b) describe the I-V characteristics of a diode

(c) show understanding of the action of a diode as a rectifier

(d) describe and explain the use of diodes in half-wave and full-wave rectifiers

(e) interpret typical diode specification using its datasheet

Unit 8 Light Emitting Semiconductor, sensors and output devices

Content

8.1 Light emitting diode (LED)

8.2 7-segment display

8.3 Thermistor, light dependent resistor, microphone and infrared diodes

8.4 Loudspeaker, buzzer, electromechanical relay and transformer

8.5 Applications of sensors and output devices

Learning Outcomes:

Candidates should be able to:

(a) explain why a resistor should be connected in series with an LED in a circuit

(b) describe how different numbers (digit 0 to 9) can be displayed on a 7-segment display using a look-up table

(c) recall and apply the effect of changes in temperature on the resistance of a thermistor to practical situations

(d) recall and apply the effect of changes in light intensity on the resistance of a light-dependent resistor (LDR) to practical situations

(e) show understanding that, for reflection of infrared light, the angle of incidence is equal to the angle of reflection

(f) describe the use of an infrared light beam to control electrical and electronic appliances

(g) describe the use of infrared diodes as transmitting and receiving devices

(h) describe the principles of operation of loudspeakers, buzzers and microphones

(i) describe and explain the operation of an electromechanical relay

(j) show understanding of the use of electromechanical relay to:
   i. control a high-voltage circuit with a low-voltage signal
   ii. isolate the controlling circuit from the controlled circuit

(k) describe the basic construction and working principle of a transformer and use it in a DC power supply circuit

(l) sketch the schematic symbols for iron and air core transformers

(m) list and describe the use of various types of digital output devices, and analogue input and output devices

Unit 9 Zener Diode

Content

9.1 Construction and working principle

9.2 Zener diode applications

Learning Outcomes:

Candidates should be able to:

(a) describe the construction and working principle of a zener diode

(b) describe the I-V characteristics of a zener diode

(c) explain the use of zener diodes to regulate voltage

(d) describe basic zener voltage regulators

(e) interpret typical zener diode specification using its datasheet

Unit 10 BJT (Bipolar Junction) Transistor

Content

10.1 Construction and working principle

10.2 BJT applications

Learning Outcomes:

Candidates should be able to:

(a) describe the basic construction and working principle of BJT and explain how it is biased to operate as a switch and an amplifier

(b) apply the relationship between current, voltage and power of a transistor to solve related problems

(c) distinguish between the two main types of BJT transistors

(d) describe the different operating regions of BJT transistors and explain the switching action of transistors

(e) describe and explain the use of BJT in common-emitter, common-collector, and common-base transistor's amplifier circuits

(f) explain the function of coupling and bypass capacitors in transistor's amplifier circuits

Unit 11 AC theory – The Sinusoidal Wave

Content

11.1 Characteristics of sinusoidal alternating current/voltage

11.2 Resistors, capacitors and inductors in DC and AC circuits

Learning Outcomes:

Candidates should be able to:

(a) show understanding that alternating currents or voltages can be represented by sinusoidal waveforms

(b) recall and apply the equations $I(t) = I_o \sin \omega t$ and $V(t) = V_o \sin \omega t$ for sinusoidal current and voltage waveforms respectively

(c) convert radians to electrical degrees and vice versa

(d) calculate the phase angle between two given sinusoidal voltage waveforms and state which one is leading/lagging

(e) explain how alternating voltage is generated in a single turn coil rotated in a uniform magnetic field

(f) distinguish between direct and alternating currents/voltages

(g) determine the frequency, period, peak, peak-to-peak values and wavelength of a sinusoidal current/voltage from its waveform

(h) determine the average and RMS values of alternating voltage and current

(i) recall and apply the relationship between voltage and current in DC and AC circuits containing resistors, capacitors and/or inductors

Unit 12 Project Management

Content

12.1 Project planning and research

12.2 Circuit design and computer simulation

12.3 Project realisation

12.4 Test and measurement

12.5 Documentation

12.6 The portfolio work document

12.7 Project evaluation report

Learning Outcomes:

Candidates should be able to:

(a) recognise the characteristics of a successful project plan

(b) draw a GANTT Chart for a project with known tasks, precedence, and durations

(c) explore research methods including web search, textbooks, library resources, literature review, etc

(d) appraise the role of computer simulation in circuit design

(e) use computer simulations methods to carry out circuit design

(f) interpret the advantages and limits of computer simulation

(g) create new processes, products or projects through a synthesis of ideas from a wide range of sources

(h) use relevant test and measurement equipment and conduct experimental laboratory work

(i) create, organise, maintain and analyse portfolio work document

(j) write a project evaluation report using information collated from the project work

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The following list illustrates the common symbols and units that will be used in the question papers and is not meant to be exhaustive.

Quantity	Symbols	Unit
Base Quantities		
mass	m	kg
length	l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
Other Quantities		
distance	d	m
area	A	m^2
work	w, W	J
energy	E,U,W	J
power	P	W
angle	θ	°, rad
angular displacement	θ	°, rad
period	T	s
frequency	f	Hz
angular frequency	ω	rad s^{-1}
wavelength	λ	m
speed of electromagnetic waves	c	m s^{-1}
electric charge	Q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
resistance	R	Ω
conductance	G	Ω^{-1}
resistivity	ρ	Ω m
capacitance	C	F
inductance	L	H
electric field strength	E	N C^{-1}, V m^{-1}
permittivity of free space	ε_o	F m^{-1}

Quantity	Symbols	Unit
magnetic flux	Φ	Wb
magnetic flux density	B	T
permeability of free space	μ_o	H m^{-1}
Celsius temperature	θ	°C

APPENDIX A

ASSESSMENT RUBRIC FOR PROJECT

The Portfolio Work Document			
Project plan	The Project plan gives a good overview of the entire project development. It is well thought-out and contains detailed plan that makes the project implementation easy. It was completed with minimal or no guidance and assistance.	4 – 5	5
	The Project plan is well thought-out and serves as an effective guide for project implementation. It was completed with regular guidance and assistance.	2 – 3	
	The Project plan lacks clarity and is not an effective guide for project implementation. It was completed with little independent work and much help and guidance.	1	
Analysis of project specification	A step-by-step analysis of the project theme. It draws appropriate and inventive project specification supported with evidence. Able to pose thoughtful, creative questions resulting in challenging or provocative research. It was completed with minimal or no guidance and assistance.	4 – 5	5
	Good effort is made in analysing the project theme. It draws appropriate project specification supported with evidence. Able to pose some focused questions resulting in challenging research.	2 – 3	
	Simply restating project theme. It draws inadequate project specification not supported with evidence. Poses questions that lack relevance, quality and depth to facilitate research.	1	
Research	Extensive research carried out using web tools, textbooks and the library. The information is fully manifested in the portfolio. It was completed with minimal or no guidance and assistance.	4 – 5	5
	Research work is adequate but confined to only one method.	2 – 3	
	Poor research methodology and minimal research effort.	1	

Investigation and generation of ideas with computer simulations, mathematical analysis, etc.	Covers a wide range of ideas combined with logical interpretation, elaborate mathematical analysis and computer simulations, etc. It was completed with minimal or no guidance and assistance. Covers a fair range of ideas with sufficient logical interpretation, some mathematical analysis and computer simulations, etc. Few ideas which are not feasible or not likely to be feasible. Tendency to misdirect efforts.	4 – 5 2– 3 1	5
Detailed development of the proposed solution	Shows evidence of explicit, thorough and well-defined steps taken before arriving at the proposed solution. It was completed with minimal or no guidance and assistance. Shows evidence of steps taken before arriving at the proposed solution. The proposed solution lacks any meaningful preliminary thought.	4 – 5 2– 3 1	5
Organisation and Presentation	Clearly articulates all major points of research activities and findings. Display of information or data is precise, accurate and complete. Able to present a clear exposition of ideas and work done. It was completed with minimal or no guidance and assistance. Covers most of the major points of research activities and findings. Display of information or data is mostly precise, accurate and complete. Omits several important points of research activities and findings. Interpretations and explanations not clear.	4 – 5 2 – 3 1	5
The Project Hardware			
Creativity and Enhancement	Shows creativity in circuit design by using a minimum of (readily available) components consistent with good electronics design practice; a unique design approach that truly enhances the project. Shows creativity in circuit design and/or use of components. A few original touches added to enhance the project. Generally acceptable circuit design that contains some good features.	13 – 15 8 – 12 1 – 7	15

Quality of Project	High quality of finish and workmanship, sturdy and shows great details in design and construction. It was completed with minimal or no guidance and assistance.	4 – 5	5
	Good quality finishing, sufficient degree of workmanship and shows good details in design and construction.	2 – 3	
	Is of acceptable quality. Details in design and construction are adequate.	1	
Functionality of Project	Fully functional and reliable. Satisfies all the design specification. It was completed with minimal or no guidance and assistance.	13 – 15	15
	Functional but occasionally shows erratic behaviour. Satisfies all the design specification.	8 – 12	
	Semi-functional or not functional.	1 – 7	
A set of complete circuit diagrams	Provides a complete set of organised, well-structured circuit diagrams with all test points labelled.	4 – 5	5
	Provides a complete set of circuit diagrams and all test points labelled.	2 – 3	
	Most of the circuit diagrams are there and fairly organised.	1	
Testing activities	Test sequence is logical and thorough. Test results closely match the computer simulated results. Test outcomes show project's performance meets its specification in every detail. It was completed with minimal or no guidance and assistance.	8 – 10	10
	Test sequence is logical and adequate and test results match the computer-simulated results. Test outcomes show project's performance meets its specification.	5 – 7	
	Test sequence is adequate and test results are valid with slight deviation from the computer-simulated results. Test outcomes show project's performance barely meets its specification.	1 – 4	
Measurements results	Achieves all intended results and shows evidence of accurate readings, graphs and waveforms. It was completed with minimal or no guidance and assistance.	8 – 10	10
	Achieves all intended results with adequate evidence of accurate readings, graphs and waveforms.	5 – 7	

	Inaccurate, uncertain and incongruent measurements.	1 – 4	
The Evaluation Report			
Project evaluation	Gives clear and valid assessment of project worth. Report is organised, well-structured and layout is logical with sub headings.	8 – 10	10
	Highlights the key stages during project development and provides a comprehensive, honest and accurate account.	5 – 7	
	Is basic and fairly logical.	1 – 4	