ZIMSEC

For Performance Measurement

ZIMBABWE SCHOOL EXAMINATIONS COUNCIL (ZIMSEC)

ADVANCED LEVEL SYLLABUS

PHYSICS 9188

EXAMINATION SYLLABUS FOR 2013 - 2016

AIMS

These are not listed in order of priority.

The aims of a course based on this syllabus should be to:

1. provide, through well-designed studies of experimental and practical science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge to:

    1.1 become confident citizens in a technological world and be able to take or develop an informed interest in matters of scientific import;

    1.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life,

    1.3 be suitably prepared for studies beyond A-Level in Physics, in Engineering or in Physics dependent vocational courses.

2. develop abilities and skills that

    2.1 are relevant to the study and practice of science;

    2.2 are useful in everyday life;

    2.3 encourage efficient and safe practice;

    2.4 encourage effective communication.

3. develop attitudes relevant to science such as

    3.1 concern for accuracy and precision;

    3.2 objectivity;

    3.3 integrity;

    3.4 the skills of enquiry;

    3.5 initiative;

    3.6 inventiveness.

4 stimulate interest in, and care for, the environment in relation to the environmental impact of Physics and its applications.

5. promote an awareness

   5.1 that the study and practice of Physics are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations;

   5.2 that the implications of Physics may be both beneficial and detrimental to the individual, the community and the environment;

6. stimulate students and create a sustained interest in Physics so that the study of the subject is enjoyable and satisfying.

ASSESSMENT OBJECTIVES

The assessment objectives listed below reflect those parts of the Aims which will be assessed in the examination.

A *Knowledge with understanding*

Candidates should be able to demonstrate knowledge and understanding in relation to:

1. scientific phenomena, facts, laws, definitions, concepts, theories;
2. scientific vocabulary, terminology, conventions (including symbols, quantities and units);
3. scientific instruments and apparatus, including techniques of operation and aspects of safety;
4. scientific and technological applications with their social, economic and environmental implications.

   The syllabus content defines the factual knowledge that candidates may be required to recall and explain.

B *Handling, applying and evaluating information*

Candidates should be able - in words or by using written, symbolic, graphical and numerical forms of presentation - to:

1. locate, select, organise and present information from a variety of sources;
2. translate information from one form to another;
3. manipulate numerical and other data;
4. use information to identify patterns, report trends, draw inferences and report conclusions;
5. present reasoned explanations for phenomena, patterns and relationships;
6. make predictions and put forward hypotheses;
7. apply knowledge, including principles, to novel situations;
8. evaluate information and hypotheses;
9. demonstrate an awareness of the limitations of physical theories and models.

C ***Experimental skills and investigations***

Candidates should be able to:

1. follow a detailed set or sequence of instructions and use techniques, apparatus and materials safely and effectively;

2. make observations and measurements with due regard for precision and accuracy;

3. interpret and evaluate observations and experimental data;

4. identify a problem, design and plan investigations, evaluate methods and techniques, and suggest possible improvement;

5. record observations, measurement, methods and techniques with due regard for precision accuracy and units.

SCHEME OF ASSESSMENT

Candidates will be required to enter for Papers 1, 2, 3, 4 and 5.

Paper	Type Of Paper	Duration	Marks
1	Multiple Choice	1 hr	40
2	Structured Questions	1 hr 15 min	60
3	Free Response Questions	50 min	40
4	Practical	2 hrs 30 min	50
5	Free Response Questions	1 hr 15 min	60

Paper 1 (40 marks)

The paper will consist of 40 questions, all of the direct choice type.

Paper 2 (40 marks)

This paper will consist of a variable number of short structured questions with at least one question from each of the six sections of the syllabus. **Candidates will answer all questions.** Candidates will answer on the question paper.

Paper 3 (40 marks)

This paper will consist of four free response questions from **section I-II** of the syllabus.
Question 1 is compulsory.
Candidates will answer any other TWO questions from the remaining THREE.
Question 1 carries 20 marks. Questions 2, 3 and 4 carry 10 marks each. Candidates will answer on separate answer paper.

Paper 4 (50 marks)

Practical Test
This paper will consist of two compulsory one-hour practical experiments (18 marks each) and oen compulsory half-hour design exercise (14 marks).

Paper 5 (60 marks)

This paper will consist of five free response questions from **sections IV-VI** of the syllabus.
Question number 1 is compulsory.
Candidates will answers any other THREE questions from the remaining FOUR.
Question 1 carries 24 marks. Questions 2, 3, 4 and 5 carry 12 marks each. Candidates will answer on separate answer paper.

<u>Skills weighting and distribution</u>

Skill	**Paper 1**		**Paper 2**		**Paper 3**		**Paper 4**		**Paper 5**		**Subject Weighting %**
	M	W%	M	W%	M	W%	M	W%	M	W%	
1 Factual recall and Comprehension	20	50	20	33	12	30	5	10	18	30	**30**
2 Handling and Application	15	37.5	30	50	16	40	25	50	24	40	**44**
3 Deductive Reasoning and Synthesis	5	13.5	10	17	12	30	20	40	18	30	**26**
TOTAL	**40**	**100**	**60**	**100**	**40**	**100**	**50**	**100**	**60**	**100**	**100**

M – marks allocated
W – skill weighting per paper

Notes: Paper 4 (C1 to C5 skills) – Refer to page 6.

Skill 1: skill C1
Skill 2: skills C2 & C3
Skill 3: skills C4 & C5

SUBJECT CONTENT

SECTION I: GENERAL PHYSICS

1.0 Physical Quantities and Units

Content

1.1 Physical quantities
1.2 SI Units
1.3 Avagadro constant
1.4 Scalars and vectors

Assessment Objectives

Candidates should be able to:

(a) show an understanding that all physical quantities consist of a numerical magnitude and a unit.

(b) recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol).

(c) express derived units as products or quotients of the base units and use the named units listed on pages 45 and 46 as appropriate.

(d) use base units to check the homogeneity of physical equations.

(e) show an understanding and use the conventions for labelling graph axes and table columns as set out in the "ASE publication SI Units, Signs, Symbols and Abbreviations", except where these have been superseded by Signs, Symbols and Systematics (The ASE Companion to 5-16 Science, 1995).

(f) use the following prefixes and their symbols to indicate decimal sub-multiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T).

(g) make reasonable estimates of physical quantities included within the syllabus.

(h) show an understanding of the significance of the Avogadro constant as the number of atoms in 0.012 kg of Carbon-12.

(i) use molar quantities where one mole of any substances is the amount containing a number of particles equal to the Avogadro constant.

(j) distinguish between scalar and vector quantities and give examples of each.

(k) add and subtract coplanar vectors.
(l) represent a vector as two perpendicular components.

2.0 Measurement Techniques

Content

2.1 Measurements
2.2 Errors and uncertainties

Assessment Objectives

Candidates should be able to:

(a) use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus.

In particular, candidates should be able to:

(1) measure length using a ruler, vernier scale and micrometer;

(2) measure weight and hence mass using spring and level balances;

(3) measure an angle using a protractor;

(4) measure time intervals using clocks, stopwatches and the calibrated time-base of a cathode-ray oscilloscope (c.r.o);

(5) measure temperature using a thermometer as a sensor;

(6) use ammeters and voltmeters with appropriate scales;

(7) use a galvanometer in null methods;

(8) use a calibrated Hall probe;

(b) use both analogue scales and digital displays.

(c) use calibration curves.

(d) show an understanding of the distinction between systematic error (including zero errors) and random errors.

(e) show an understanding of the distinction between precision and accuracy.

(f) assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties (a rigorous statistical treatment is not required).

SECTION II: NEWTONIAN MECHANICS

3.0 Kinematics

Content

3.1 Rectilinear motion
3.2 Non-linear motion

Assessment Objectives

Candidates should be able to:

(a) define displacement, speed, velocity and acceleration.

(b) use graphical methods to represent displacement, speed, velocity, and acceleration.

(c) find displacement from the area under a velocity-time graph.

(d) use the slope of a displacement-time graph to find the velocity.

(e) use the slope of a velocity-time graph to find the acceleration.

(f) derive, from the definitions of velocity and acceleration, equations which represent uniformly accelerated motion in a straight line.

(g) solve problems using equations which represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitional field without air resistance.

(h) recall that the weight of a body is equal to the product of its mass and the acceleration of free fall.

(i) describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction (Projectiles).

(j) solve problems using standard equations for projectile motion.

(k) state and explain some everyday examples of rectilinear and non-linear motion.

4.0 Dynamics

Content

4.1 Newton's laws of motion
4.2 Linear momentum and its conservation
4.3 Impulse

Assessment Objectives

Candidates should be able to:

(a) state each of Newton's laws of motion.

(b) show an understanding that mass is the property of a body which resists change in motion.

(c) describe and use the concept of weight as the effect of a gravitational field on a mass.

(d) define linear momentum as the product of mass and velocity.

(e) define force as rate of change of momentum.

(f) recall and solve problems using the relationship $F = ma$, appreciating that acceleration and force are always in the same direction.

(g) state the principle of conservation of momentum.

(h) use the principle of conservation of momentum on simple applications including elastic and inelastic collisions between two bodies in one dimension (calculations involving the use of coefficient of restitution are not required).

(i) recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation.

(j) show an understanding that, whilst momentum of a system is always conserved in collisions between bodies, some change in kinetic energy usually takes place.

(k) define impulse as 'change in momentum'.

(l) explain the significance of area under a force - time graph.

(m) state and describe applications of Newton's laws of motion and conservation of linear momentum.

5.0 Forces

Content

5.1 Types of force
5.2 Equilibrium of forces
5.3 Centre of gravity
5.4 Turning effects of forces

Assessment Objectives

Candidates should be able to:

(a) describe the forces on mass and change in uniform gravitational and electric fields, as appropriate.

(b) state the origin of the upthrust acting on a body in a fluid.

(c) calculate the upthrust in terms of the weight of the displaced fluid (Archimedes Principle).

(d) describe friction as a force which opposes motion (knowledge of coefficient of friction and viscosity is required).

(e) use Stoke's law to explain quantitatively how a body falling through a viscous fluid under laminar conditions attains a terminal velocity.

(f) describe an experiment, based on the measurement of terminal velocity, to determine the viscosity of a liquid.

(g) use a vector triangle to represent forces in equilibrium.

(h) show an understanding that the weight of a body may be taken as a force acting at a single point known as its centre of gravity.

(i) describe a couple as a pair of forces tending to produce rotation only.

(j) define and use the moment of a force and the torque of a couple.

(k) show an understanding that, when there is no resultant force and no resultant torque, a system is in equilibrium.

(l) apply the principle of moments.

(m) describe everyday application of forces in equilibrium.

6.0 Work, Energy, Power

Content

6.1 Energy conversion and conservation
6.2 Work
6.3 Potential energy, kinetic energy and internal energy
6.4 Power

Assessment Objectives

Candidates should be able to:

(a) give examples of energy in different forms, its conversion and conservation, and apply the principles of energy conservation to simple examples.

(b) define work in terms of the product of a force and displacement in the direction of the force.

(c) calculate the work done in a number of situations including the work done by a gas which is expanding against a constant external pressure: $W = p\Delta V$.

(d) derive, from the equations of motion, the formula $E_k = ½mv^2$.

(e) recall and apply the formula $E_k = ½ mv^2$.

(f) distinguish between gravitational potential energy, electric potential energy and elastic potential energy.

(g) show an understanding of the relationship between force and potential energy in a uniform field.

(h) derive, from the defining equation $W = Fs$, the formula $E_p = mgh$ for potential energy changes near the Earth's surface.

(i) recall and use the formula $E_p = mgh$ for potential energy changes near the Earth's surface.

(j) show an understanding of the concept of internal energy.

(k) explain that there are energy losses in practical devices and use the concept of efficiency.

(l) show an understanding and use the kilowatt-hour as a unit of energy.

(m) calculate energy costs based on cost per kilowatt-hour.

(n) relate power to work done and time taken using appropriate examples.

(o) derive and use power as the product of force and velocity.

(p) describe and explain everyday examples of energy conversion (e.g. hydroelectric power and environmental concerns).

7.0 Motion in a Circle

Content

7.1 Kinematics of uniform circular motion
7.2 Centripetal acceleration
7.3 Centripetal force

Assessment Objectives

Candidates should be able to:

(a) express angular displacement in radians.

(b) show an understanding of the use of the concept of angular velocity.

(c) derive and use $v = r\omega$.

(d) describe qualitatively the motion in curved path due to a perpendicular force.

(e) show an understanding of the centripetal acceleration in the case of uniform motion in a circle.

(f) use centripetal acceleration $a = v^2/r$, $a = r\omega^2$.

(g) recall and use centripetal force $F = mv^2/r$, $F = mr\omega^2$.

(h) describe and explain everyday examples of motion in a circle (to include banked roads, geostationary orbits and their applications)

8.0 Gravitational Field

Content

8.1 Gravitational field
8.2 Force between point masses
8.3 Field of a point mass
8.4 Field near to the surface of the Earth
8.5 Gravitational potential

Assessment Objectives

Candidates should be able to:

(a) show an understanding of a gravitational field as a field of force.

(b) define gravitational field strength as force per unit mass.

(c) state and use Newton's law of gravitation in the form $F = G(m_1m_2)/r^2$.

(d) analyse circular orbits in inverse square law fields by relating the gravitational force to the centripetal acceleration it causes.

(e) derive from Newton's law of gravitation and the definition of gravitational field strength, the equation $g = Gm/r^2$ for the gravitational field strength of a point mass.

(f) recall and use the equation $g = Gm/r^2$ for the gravitational field strength of a point mass.

(g) explain that on the surface of the Earth g is approximately constant and is called the acceleration of free fall.

(h) describe an experiment to determine the acceleration of free fall using a falling body.

(i) define potential at a point as the work done in bringing unit mass from infinity to the point.

(j) use the equation $\varphi = - Gm/r$ for the potential in the field of a point mass.

(k) recognise the analogy between certain qualitative and quantitative aspects of gravitational and electric fields.

(l) describe and explain everyday applications of the gravitational force of attraction (include satellite and period of rotation).

SECTION III: OSCILLATONS AND WAVES

9.0 Oscillations

Content

9.1 Simple Harmonic Motion
9.2 Damped and Forced Oscillations

Assessment Objectives

Candidates should be able to:

(a) describe simple examples of free oscillations such as the simple pendulum, mass spring and torsional pendulum.

(b) explain the terms amplitude, period, frequency, angular frequency and phase difference.

(c) express period in terms of frequency and angular frequency, $f = 1/T$ and $T = 2\pi/\omega$

(d) express graphically the changes in displacement, velocity and acceleration for a simple oscillator.

(e) recognise and use

$V = V_o \cos \omega t$

$V = \pm\omega\sqrt{(x_0^2 - x^2)}$

(f) prove that for simple oscillations $a = -\omega^2 x$.

(g) recall and use $x = x_0 \sin\omega t$ as a solution to the equation $a = -\omega^2 x$.

(h) describe analytically and graphically the inter-change between kinetic and potential (gravitational/elastic) energy in a simple oscillator.

(i) describe examples of damped oscillations such as car suspension systems and moving coil meters.

(j) describe graphically the degrees of damping.

(k) describe practical examples of forced vibrations and resonance.

(l) depict graphically how the amplitude changes with frequency near to the natural frequency of an oscillation system.

(m) state examples where resonance is useful and where it is a nuisance.

10.0 Waves

Content

10.1 Reflection and refraction of light
10.2 Progressive waves
10.3 Transverse and longitudinal waves
10.4 Polarisation
10.5 Electromagnetic waves

Assessment Objectives

Candidates should be able to:

(a) recall laws of reflection and refraction of light.

(b) state properties of images formed by a plane mirror.

(c) describe what is meant by critical angle and total internal reflection.

(d) use the equation $n = \frac{1}{\sin c}$.

(e) describe examples of application of total internal reflection.

(f) appreciate the advantages of fibre optics transmission.

(g) understand and use the terms speed of a wave, wave length, frequency, period, amplitude and phase difference.

(h) distinguish between a transverse and a longitudinal wave.

(i) represent graphically transverse and longitudinal waves.

(j) deduce from definition of speed, frequency and wavelength the equation $v = f\lambda$.

(k) understand polarisation as a phenomenon associated with transverse waves only.

(l) describe the main features of the electromagnetic spectrum and characteristics of electromagnetic waves.

(m) give a simple description of the production of X-rays by electron bombardment on a metal target.

(n) understand the use of X-rays in imaging internal structures and treatment of malignancy.

(o) describe examples of the use of lasers in clinical therapy, e.g. as a scalpel or as a coagulator.

11.0 Superposition

Content

11.1 Stationary waves
11.2 Diffraction
11.3 Interference
11.4 Two-source interference patterns

Assessment Objectives

Candidates should be able to:

(a) explain and use the principle of superposition in simple application.

(b) show an understanding of experiments which demonstrate stationary waves.

(c) explain and identify nodes and antinodes.

(d) distinguish between stationary and progressive waves.

(e) determine the wavelength of sound using stationary waves.

(f) show an understanding of experiments which demonstrate two-source interference (Young's two-slit experiment).

(g) explain the term coherence.

(h) explain the conditions required if two-source interference fringes are to be observed.

(i) use the equation, for fringe spacing $x = \frac{\lambda D}{a}$.

(j) explain the term diffraction.

(k) show an understanding of experiments which demonstrate diffraction such as ripple tank and diffraction grating.

(l) use the formula $n\lambda = d\sin\theta$ to determine the wavelength of light.

SECTION IV: ELECTRICITY & MAGNETISM

12.0 Electrostatics

Content

2.1 Simple electrostatic phenomena

Assessment Objectives

Candidates should be able to:

(a) state that there are two types of charge.

(b) describe and explain charging by friction and by induction, appreciating that charge is always conserved .

(c) describe experiments which demonstrate that like charges repel and unlike charges attract.

(d) distinguish between electrical conductors and insulators and give typical examples.

(e) use a simple electron model to distinguish between conductors and insulators.

(f) describe simple practical applications of electrostatic phenomena including paint spraying and dust extraction.

(g) appreciate the potential hazards associated with charging by friction and give examples.

(h) show an understanding of the construction of a simple lightning conductor and its function.

13.0 Current Electricity

Content

13.1 Electric current
13.2 Potential difference
13.3 Resistance and resistivity
13.4 Sources of electromotive force

Assessment Objectives

Candidates should be able to:

(a) state that electric current is the flow of charged particles.

(b) define charge and the coulomb.

(c) recall and solve problems using the equation $Q = It$.

(d) define potential difference and the volt.

(e) recall and solve problems using $V = W/Q$.

(f) recall and solve problems using $P = VI$, $P = I^2R$.

(g) define resistance and the ohm.

(h) recall and solve problems using $V = IR$.

(i) sketch and explain the *I-V* characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp.

(j) sketch the temperature characteristic of a thermistor.

(k) state Ohm's Law.

(l) recall and solve problems using $R = \dfrac{\rho \ell}{A}$

(m) define e.m.f. in terms of the energy transferred by a source in driving unit charge round a complete circuit.

(n) distinguish between e.m.f. and p.d in terms of energy considerations.

(o) show an understanding of the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power.

(p) calculate the internal resistance of a source of e.m.f.

(q) recall and use the equation $V = E - Ir$.

14.0 D.C. Circuits

Content

14.1 Practical circuits
14.2 Conservation of charge and energy
14.3 Balanced potentials

Assessment Objectives

Candidates should be able to:

(a) recall and use appropriate circuit symbols as set out in *SI units, Signs, Symbols and Abbreviations* (ASE, 1981) and *Signs, Symbols and Systematics* (ASE, 1995).

(b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters and any type of component referred to in the syllabus.

(c) recall Kirchhoff's first law and appreciate the link to conservation of charge.

(d) recall Kirchhoff's second law and appreciate the link to conservation of energy.

(e) derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series.

(f) solve problems using the formula for the combined resistance of two or more resistors in series.

(g) derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel.

(h) solve problems using the formula for the combined resistance of two or more resistors in parallel.

(i) apply Kirchhoff's laws to solve simple circuit problems.

(j) use potential divider as a source of variable p.d.

(k) describe and explain the use of the thermistor, LDR, and strain gauge in potential divider circuits to provide voltage representatives of physical quantities.

(l) use the principle of the potentiometer as a means of comparing potential differences.

15.0 Electric Fields

Content

15.1 Concept of an electric field
15.2 Uniform electric fields
15.3 Force between point charges
15.4 Electric field of a point charge
15.5 Electric potential

Assessment Objectives

Candidates should be able to:

(a) describe an electric field as an example of a field of force and define electric field strength as force per unit positive charge.

(b) represent an electric field by means of field lines.

(c) recall and use $E = V/d$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation.

(d) calculate the forces on charges in uniform electric fields.

(e) describe the effect of a uniform electric field on the motion of charged particles.

(f) recall and use Coulomb's law in the form $F = Q_1Q_2/4\pi\varepsilon_o r^2$ for the force between two point charges in free space or air.

(g) recall and use $E = Q/4\pi\varepsilon_o r^2$ for the field strength of a point charge in free space or air.

(h) define potential at a point in terms of the work done in bringing a unit positive charge from infinity to the point.

(i) state that the field strength of the field at a point is numerically equal to the potential gradient at that point.

(j) use the equation $V = Q/4\pi\varepsilon_o r$ for the potential in the field of a point charge.

(k) compare qualitative and quantitative aspects of electric and gravitational fields.

16.0 Capacitance

Content

16.1 Capacitors and capacitance
16.2 Energy stored in a capacitor

Assessment Objectives

Candidate should be able to:

(a) describe the function of capacitors in simple circuits.

(b) define capacitance and the farad.

(c) recall and solve problems using $C = Q/V$.

(d) derive, using the formulae $C = Q/V$, conservation of charge and the addition of p.d's, the formulae for capacitors in series and parallel.

(e) solve problems using formulae for capacitors in series and in parallel.

(f) deduce from the area under a potential-charge graph, the equation $W = ½QV$ and hence $W = ½CV^2$.

(g) describe charging and discharging of capacitors in RC circuits.

17.0 Magnetic Field

Content

17.1 Concept of magnetic field

Assessment Objectives

Candidates should be able to:

(a) describe a magnetic field as an example of a field of force produced either by current-carrying conductors or by permanent magnets.

(b) represent a magnetic field by field lines.

18.0 Electromagnetism

18.1 Force on current-carrying conductor
18.2 Force on a moving charge
18.3 Magnetic fields due to currents
18.4 Force between current-carrying conductors

Assessment Objectives

Candidates should be able to:

(a) state that a force might act on a current-carrying conductor placed in a magnetic field.

(b) recall and solve problems using the equation $F = BIl\sin\theta$ with directions as interpreted by Fleming's left-hand rule.

(c) define magnetic flux density and the tesla.

(d) show an understanding of how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance.

(e) predict the direction of the force on a charge moving in a magnetic field.

(f) recall and solve problems using $F = BQv\sin\theta$.

(g) sketch flux patterns due to a long straight wire, a flat circular coil and a long solenoid.

(h) show an understanding that the field due to a solenoid may be influenced by the presence of a ferrous core.

(i) describe the principle of the electromagnet and state its uses.

(j) explain the force between current-carrying conductors and predict the direction of the force.

(k) describe and compare the forces on mass, charge and current in gravitational, electric and magnetic fields, as appropriate.

(l) describe how a calibrated Hall probe can be used to measure flux density.

19.0 Electromagnetic Induction

Content

19.1 Laws of electromagnetic induction

Assessment Objectives

Candidates should be able to:

(a) define magnetic flux and the Weber

(b) recall and solve problems using $\varphi = BA$.

(c) define magnetic flux linkage

(d) infer from appropriate experiments on electromagnetic induction

(i) that a changing magnetic flux can induce an e.m.f. in a circuit,
(ii) that the direction of the induced e.m.f. opposes the change producing it
(iii) the factors affecting the magnitude of the induced e.m.f.

20.0 Alternating Currents

Content

20.1 Characteristics of alternating currents
20.2 The transformer
20.3 Transmission of electrical energy
20.4 Rectification

Assessment Objectives

(a) define and use the terms period, frequency, peak value and root-mean-square value as applied to an alternating current or voltage.

(b) deduce that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current.

(c) represent an alternating current or an alternating voltage by an equation of the form $x = x_o \sin\omega t$.

(d) distinguish between r.m.s and peak values and recall and solve problems using the relationship $I_{rms} = I_o/\sqrt{2}$ for the sinusoidal case.

(e) show an understanding of the principle of operation of a simple iron-cored transformer and solve the problems using $N_s/N_P = V_s/V_p = I_p/I_s$ for an ideal transformer.

(f) show an appreciation of the scientific and economic advantages of alternating current and of high voltages for the transmission of electric energy.

(g) state the scientific and economic advantages of alternating current and of high voltage.

(h) distinguish graphically between half-wave and full-wave rectification.

(i) explain the use of a single diode for the half-wave rectification of an alternating current.

(j) explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current.

(k) analyse the effect of a single capacitor in smoothing, including the effect of the value of capacitance in relation to the load resistance.

21.0 Analogue Electronics

Content

21.1 Transducers
21.2 The ideal operational amplifier
21.3 Operational amplifier circuits

Assessment Objectives

Candidates should be able to:

(a) describe the use of the light-emitting diode (LED), the buzzer and the relay as output devices.

(b) describe the properties of the ideal amplifier as a comparator.

(c) understand the use of an operational amplifier as a comparator.

(d) understand the principles of negative and of positive feedback in an amplifier.

(e) describe the circuit diagrams for both the inverting and the non-inverting amplifier for single signal input.

(f) use the virtual earth approximation to derive an expression for the gain of inverting amplifiers.

(g) recall and use expression for the voltage gain of inverting and non-inverting amplifiers.

(h) describe the effect of negative feedback on the gain and on the bandwidth of an operational amplifier.

(i) describe the use of an operational amplifier as a summing amplifier in the inverting mode.

(j) describe the use of an operational amplifier as a voltage follower.

(k) describe the use of an operational amplifier as a non-inverting Schmitt-trigger, with positive feedback provided by a potential divider.

22.0 Digital Electronics

Content

22.1 Logic gates
22.2 Logic gates combinations
22.3 The impact of electronics in society and industry

Assessment Objectives

Candidates should be able to:

(a) describe the function of each of the following gates: NOT, AND,NAND, OR, NOR and represent these functions by means of truth tables (limited to a maximum of two inputs, where appropriate).

(b) describe how to combine AND, NOT and OR gates, or NAND gates only, to form EX-OR and EX-NOR gates.

(c) analyse circuits using combinations of logic gates to perform control functions.

(d) explain how to construct and interpret truth tables for combinations of logic gates.

(e) describe the function of simple electronic devices and systems which are found in the home, in industry and in communications.

(f) appreciate the impact of electronic devices and systems on domestic and industrial activities.

(g) appreciate the impact of electronic devices and systems on modern communications

SECTION V: MATTER

23.0 Phase of Matter

23.1 Density
23.2 States of matter
23.3 Change of phase
23.4 Pressure in fluids

(a) define density.

(b) relate the difference in the structures and densities of solids, liquids and gases to simple ideas of the spacing, ordering and motion of molecules.

(c) describe a simple kinetic model for solids, liquids and gases.

(d) describe an experiment which demonstrates Brownian Motion and appreciate the evidence for the movement of molecules provided by such an experiment.

(e) distinguish between the process of melting, boiling and evaporation.

(f) define the term pressure and using the kinetic model explain the pressure exerted by gases.

(g) derive, from the definitions of pressure and density the equation $p = \rho gh$.

(h) use the equation $p = \rho gh$.

24.0 Deformation of Solids

Content

24.1. Stress, strain
24.2 Elastic and plastic behaviour
24.3 Grain structure and metals
24.4 Deterioration and failure

Assessment Objectives

Candidates should be able to:

(a) show an appreciation that deformation is caused by a force and that, in one dimension, the deformation can be tensile or compressive.

(b) describe the behaviour of springs in terms of load, extension, elastic limit, Hooke's law and the spring constant (i.e. force per unit extension).

(c) define and use the terms stress, strain and the Young modulus.

(d) describe an experiment to determine the Young Modulus of a metal in the form of a wire.

(e) distinguish between elastic and plastic deformation of a material.

(f) deduce the strain energy in a deformed material from the area under the force-extension graph.

(g) demonstrate knowledge of the force-extension graphs for the typical ductile, brittle and polymeric materials, including an understanding of ultimate tensile stress.

(h) recognise fatigue as a consequence of cyclic stress insufficient to cause immediate failure.

(i) describe situations which lead to fatigue failure.

(j) recall that creep is failure due to sustained stress, below that required for immediate failure, combined with elevated temperature.

(k) apply knowledge of properties of materials to the solving of simple engineering problems.

25.0 Temperature

Content

25.1 Temperature scales
25.2 Practical thermometers

Assessment Objectives

Candidates should be able to:

(a) show an appreciation that a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties.

(b) use the equation $\frac{\theta}{100} = \frac{X_\theta - X_0}{X_{100} - X_0}$ to calibrate a thermometer where X is a proportionally varying physical property.

(c) explain the principal features and operation of a liquid-in-glass, resistance and thermocouple thermometers and state the advantages and disadvantages of each.

(d) demonstrate knowledge that there is an absolute scale of temperature which does not depend on the property of any particular substance (i.e. the thermodynamic scale and the concept of absolute zero).

(e) show familiarity with temperatures measured in Kelvin, degree Celsius and on empirical centigrade scales.

26.0 Thermal Properties of Materials

Content

26.1 Specific heat capacity
26.2 Specific latent heat
26.3 Internal energy
26.4 First law of thermodynamics

Assessment Objectives

Candidates should be able to:

(a) relate a rise in temperature of a body to an increase in internal energy.

(b) define and use specific heat capacity, and show an awareness of the principles of its determination by electrical methods.

(c) describe melting and boiling in terms of energy input without a change in temperature.

(d) define and use specific latent heat, and show an awareness of the principles of its determination by electrical methods.

(e) describe and explain the cooling which accompanies evaporation both in terms of specific latent heat and in terms of the escape of high energy molecules.

(f) show an awareness that internal energy is determined by the state of the system and can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system.

(g) recall the first law of thermodynamics expressed in terms of the changes in internal energy, the heating of the system and the work done on the system.

27.0 Ideal Gases

Content

27.1 Equation of state
27.2 Kinetic theory of gases
27.3 Pressure of a gas
27.4 Kinetic energy of a molecule
27.5 Work done by an ideal gas

Assessment Objectives

Candidates should be able to:

(a) recall the assumptions of the kinetic theory of gases.

(b) recall and use the equation of state for an ideal gas expressed as $pV = nRT$ (n = number of moles).

(c) explain how molecular movement causes the pressure exerted by a gas and provide a simple derivation of $p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$ (N = number of molecules).

(d) compare $pV = \frac{1}{3}Nm\langle c^2\rangle$ with $pV = NkT$ and hence deduce that the average translational kinetic energy of a molecule is proportional to T.

(e) calculate work done by an ideal gas from p - V graphs.

28.0 Non-Viscous Fluid Flow

Content

28.1 Ideal fluids in motion
28.2 Streamlines and the equation of continuity
28.3 The Bernoulli effect

Assessment Objectives

Candidates should be able to:

(a) show an understanding of the terms steady (laminar, streamline) flow, incompressible flow, non-viscous flow, as applied to the motion of an ideal fluid.

(b) show an understanding of how the velocity vector of a particle in an ideal fluid in motion is related to the streamline associated with that particle.

(c) show an understanding of how streamlines can be used to define a tube of flow.

(d) derive and use the equation $Av = constant$ (the equation of continuity) for the flow of an ideal, incompressible fluid.

(e) show an appreciation that the equation of continuity is a form of the principle for conservation of mass.

(f) show an appreciation that pressure differences can arise from different rates of flow of a fluid (the Bernoulli effect).

(g) derive the Bernoulli equation in the form $p_1 + ½\rho v_1^2 = p_2 + ½\rho v_2^2$ for the case of a horizontal tube to flow.

(h) show an appreciation that the Bernoulli equation is a form of the principle of conservation of mass.

(i) explain how the Bernoulli effect is applied in the filter pump, in the Venturi meter, in atomizers and in the flow of air over an aerofoil.

29.0 Transfer of Thermal Energy

Content

29.1 Thermal equilibrium
29.2 Thermal conduction
29.3 Convection
29.4 Radiation

Assessment Objectives

Candidates should be able to:

(a) show an appreciation that thermal energy is transferred from a region of higher temperature to a region of low temperature.

(b) show an appreciation that regions of equal temperature will be in thermal equilibrium.

(c) describe and explain the process of convection as a consequence of change of density.

(d) demonstrate a qualitative understanding that bodies emit electromagnetic radiation at a rate which increases with increasing temperature.

(e) describe and explain simple applications involving the transfer of thermal energy by conduction, conversion and radiation.

SECTION VI: MODERN PHYSICS

31.0 CHARGED PARTICLES

Content

30.1 Electrons
30.2 Beams of charged particles

Assessment Objectives

Candidates should be able to:

(a) summarise and interpret the experimental evidence for quantisation of change.

(b) understand the principles of determination of e by Millikan's experiment.

(c) describe and analyse quantitatively the deflection of beams of charged particles by uniform electric and uniform magnetic fields.

(d) explain how electric and magnetic fields can be used in velocity selection.

(e) explain the principles of one method for the determination of v and e/m_e for electrons.

31.0 Quantum Physics

Content

31.1 Energy of a photon
31.2 Photoelectric emission of electrons
31.3 Wave particle duality
31.4 Energy levels in atoms
31.5 Line spectra

Assessment Objectives

Candidates should be able to:

(a) show an appreciation of the particulate nature of electromagnetic radiation.

(b) recall and use $E = hf$.

(c) describe the phenomena of the photoelectric effect.

(d) recall the significance of threshold frequency.

(e) explain why the maximum photoelectric energy is independent of intensity, and why the photoelectric current is proportional to intensity.

(f) explain photoelectric phenomena in terms of photon energy and work function energy.

(g) recall, use and explain the significance of $hf = \phi + ½mv^2_{max.}$

(h) show an appreciation that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provides evidence for a wave nature.

(i) describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles.

(j) recall and use the relation for the de Braglie wavelength $\lambda = h/p$.

(k) show an understanding of the existence of discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) and explain how this leads to spectral lines.

(l) distinguish between emission and absorption line spectra.

(m) recall and use the relation $hf = E_1 - E_2$.

32.0 Atomic Structure

Content

32.1 The nuclear atom
32.2 The nucleus
32.3 Isotopes
32.4 Mass excess and nuclear binding energy
32.5 Nuclear processes

Assessment Objectives

Candidates should be able to:

(a) demonstrate a qualitative understanding of the α - particle scattering experiment and the evidence it provides for the existence and small size of the nucleus.

(b) describe a simple model for the nuclear atom to include protons, neutrons and orbital electrons.

(c) distinguish between nucleon number (mass number) and proton number (atomic number).

(d) show an understanding that an element can exist in various isotopic forms each with a different number of neutrons.

(e) use the usual notation of the presentation of nuclides.

(f) show an appreciation of the association between energy and mass as represented

by
$E = mc^2$.

(g) illustrate graphically the variation of binding energy per nucleon with nucleon number.

(h) describe the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission.

(i) show an appreciation that nucleon number, proton number, energy and mass are all conserved in nuclear processes.

(j) represent simple nuclear reactions by nuclear equations of the form
$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$.

33.0 Radioactivity

Content

33.1 Types of ionising radiation
33.2 Hazards and safety precautions
33.3 Radioactive decay
33.4 Radioisotopes

Assessment Objectives

Candidates should be able to:

(a) show an appreciation of the spontaneous and random nature of nuclear decay.

(b) show an awareness of the existence, origins and scientific and environmental importance of background radiation.

(c) describe the nature of α - particles, β - particles and γ - rays with reference to charge, mass, speed, effect of electric and magnetic fields, and penetrating properties.

(d) illustrate the random nature of radioactive decay by observation of the fluctuations in count rate.

(e) show an awareness of the environmental hazards of ionisations and the safety precautions which should be taken in the handling and disposal of radioactive material.

(f) define the terms activity and decay constant and recall and use $A = \lambda N$.

(g) recognise, use and represent graphically solutions of the decay law based on
$x = x_0 \exp(-\lambda t)$.

(h) define half-life ($t_{½}$).

(i) use the relation $\lambda = \frac{0.693}{t_{1/2}}$.

(j) describe briefly the use of radioisotopes, providing one example of each of the following: the use of tracers, the use of penetrating properties of radiation, the use of ionising radiation in radiotherapy.