CARIBBEAN
EXAMINATIONS
COUNCIL

Caribbean Advanced Proficiency Examination®

SYLLABUS
PHYSICS

CXC A16/U2/17

Effective for examinations from May–June 2019

CAPE®

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Contents

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Please check the website, www.cxc.org for updates on CXC's syllabuses.

Introduction

The Caribbean Advanced Proficiency Examination® (**CAPE®**) is designed to provide certification of the academic, vocational and technical achievement of students in the Caribbean who, having completed a minimum of five years of secondary education, wish to further their studies. The examinations address the skills and knowledge acquired by students under a flexible and articulated system where subjects are organised in 1-Unit or 2-Unit courses with each Unit containing three Modules. Subjects examined under **CAPE®** may be studied concurrently or singly.

The Caribbean Examinations Council offers three types of certification at the **CAPE®** level. The first is the award of a certificate showing each **CAPE®** Unit completed. The second is the **CAPE®** Diploma, awarded to candidates who have satisfactorily completed at least six Units, including Caribbean Studies. The third is the **CXC®** Associate Degree, awarded for the satisfactory completion of a prescribed cluster of eight **CAPE®** Units including Caribbean Studies, Communication Studies and Integrated Mathematics. Integrated Mathematics is not a requirement for the **CXC®** Associate Degree in Mathematics. The complete list of Associate Degrees may be found in the **CXC®** Associate Degree Handbook.

For the **CAPE®** Diploma and the **CXC®** Associate Degree, candidates must complete the cluster of required Units within a maximum period of five years. To be eligible for a **CXC®** Associate Degree, the educational institution presenting the candidates for the award, must select the Associate Degree of choice at the time of registration at the sitting (year) the candidates are expected to qualify for the award. Candidates will not be awarded an Associate Degree for which they were not registered.

Physics Syllabus

♦ RATIONALE

Science plays a major role in the evolution of knowledge. It empowers us to use creative and independent approaches to problem-solving. It arouses our natural curiosity and enables us to meet diverse and ever expanding challenges. It enhances our ability to inquire, seek answers, research, and interpret data. These skills which lead to the construction of hypotheses, theories and laws that help us to explain natural phenomena and exercise control over our environment. Science is, thus, an integral component of a balanced education.

Physics is generally regarded as the most fundamental scientific discipline and forms the basis of many other sciences including Chemistry and Seismology, and can be applied to Biology and Medicine. The study of Physics is necessary to explain our physical environment. In fact, this is the role of the laws and theories of Physics that influence every aspect of our physical existence. In particular, whatever conveniences and luxuries we enjoy as citizens of Caribbean nations can either directly or indirectly be traced to these fundamental physical laws, theories, and new technologies. Physics plays a role in providing the tools for the sustainable development of the Caribbean, in particular, the development of environmentally friendly forms of power generation, monitoring, and modelling of our environment.

The most important natural resource in the Caribbean is its people. If the Caribbean is to play an important role in the new global village and survive economically, a sustained development of the scientific and technological resources of its people is essential. The **CAPE®** Physics Syllabus is redesigned with a greater emphasis on the application of scientific concepts and principles. Such an approach is adopted in order to develop those long-term transferrable skills of ethical conduct, team work, problem-solving, critical thinking, innovation, and communication. In addition, it encourages the use of various student-centred teaching-learning strategies and assessment to inculcate these skills, while, at the same time, catering to multiple intelligences and different learning styles and needs. The syllabus will assist students to develop positive values and attitudes towards the physical components of the environment, and will also provide a sound foundation for those who wish to pursue further studies in science.

This syllabus contributes to the development of the Ideal Caribbean Person as articulated by the CARICOM Heads of Government in the following areas: respect for human life; awareness of the importance of living in harmony with the environment; demonstration of multiple literacies; independent and critical thinking and the innovative application of science and technology to problem-solving. Such a person should demonstrate a positive work ethic and value and display creative imagination and entrepreneurship. In keeping with the UNESCO Pillars of Learning, on completion of the study of this course, students will learn to do, learn to be and learn to transform themselves and society.

♦ AIMS

The syllabus aims to:

1. enable students to develop an understanding and knowledge of technological and scientific applications of Physics, especially in the Caribbean context;

2. enable students to demonstrate an understanding of natural phenomena which affect this region and their sensitivity to concerns about the preservation of our environment;

3. encourage the development of rational and ethical attitudes and behaviours in the application of Physics;

4. assist in the development of critical thinking, analytical, and practical skills;

5. provide appropriate scientific training for the purposes of employment, further studies, and personal enhancement;

6. assist in the development of good laboratory skills and in the practice of safety measures when using equipment;

7. enhance an interest in and love for the study of Physics;

8. facilitate the development of the ability to communicate scientific information in a logical and structured manner;

9. develop the ability to work independently and collaboratively with others when necessary;

10. promote an appreciation of the significance and limitations of science in relation to social and economic development; and,

11. promote the integration of Information and Communication Technology (ICT) tools and skills.

♦ SKILLS AND ABILITIES TO BE ASSESSED

The skills students are expected to have developed on completion of this syllabus, have been grouped under three main headings, namely:

1. Knowledge and Comprehension;

2. Use of Knowledge; and,

3. Experimental Skills.

1. Knowledge and Comprehension (KC)

(a) Knowledge - the ability to identify, remember and grasp the meaning of basic facts, concepts and principles.

(b) Comprehension - the ability to select appropriate ideas, match, compare and cite examples and principles in familiar situations.

2. **Use of Knowledge (UK)**

(a) Application

The ability to:

(i) use facts and apply concepts, principles and procedures in familiar and in novel situations;

(ii) transform data accurately and appropriately; and,

(iii) use formulae accurately for computational purposes.

(b) Analysis and Interpretation

The ability to:

(i) identify and recognise the component parts of a whole and interpret the relationship among those parts;

(ii) identify causal factors and show how they interact with each other;

(iii) infer, predict and draw conclusions; and,

(iv) make necessary and accurate calculations and recognise the limitations and assumptions involved.

(c) Synthesis

The ability to:

(i) combine component parts to form a new and meaningful whole; and,

(ii) make predictions and solve problems.

(d) Evaluation

The ability to:

(i) make reasoned judgements and recommendations based on the value of ideas and information and their implications;

(ii) analyse and evaluate information from a range of sources to give concise and coherent explanations of scientific phenomena; and,

(iii) assess the validity of scientific statements, experiments, results, conclusions and inferences.

3. **Experimental Skills (XS)**

(a) Observation, Recording and Reporting

The ability to:

(i) make accurate observations and minimise experimental errors;

(ii) report and recheck unexpected results;

(iii) select and use appropriate modes of recording data or observations, for example, graphs, tables, diagrams;

(iv) record observations, measurements, methods and techniques with due regard for precision, accuracy, and units;

(v) present data in an appropriate manner, using the accepted convention of recording errors and uncertainties;

(vi) organise and present information, ideas, descriptions and arguments clearly and logically in a complete report, using spelling, punctuation and grammar with an acceptable degree of accuracy; and,

(vii) report accurately and concisely using scientific terminology and conventions as necessary.

(b) Manipulation and Measurement

The ability to:

(i) follow a detailed set or sequence of instructions;

(ii) use techniques, apparatus and materials safely and effectively; and,

(iii) make observations and measurements with due regard for precision and accuracy.

(c) Planning and Designing

The ability to:

(i) make predictions, develop hypotheses and devise means of carrying out investigations to test them;

(ii) plan experimental procedures and operations in a logical sequence within time allocated;

(iii) use experimental controls where appropriate;

(iv) modify an original plan or sequence of operations as a result of difficulties encountered in carrying out experiments or obtaining unexpected results;

(v) take into account possible sources of errors and danger in the design of an experiment; and,

(vi) select and use appropriate equipment and techniques.

♦ PREREQUISITES OF THE SYLLABUS

Any person with a good grasp of the Caribbean Secondary Education Certificate (**CSEC®**) Physics syllabus, or its equivalent, should be able to pursue the course of study defined by this syllabus. However, successful participation in the course of study will also depend on the possession of good verbal and written communication and mathematical skills (see page 103 for mathematical requirements).

♦ STRUCTURE OF THE SYLLABUS

The subject is organised in two (2) Units. A Unit comprises three (3) Modules each requiring fifty (50) hours. The total time for each Unit, is therefore, expected to be one hundred and fifty (150) hours. Each Unit can independently offer students a comprehensive programme of study with appropriate balance between depth and coverage to provide a basis for further study in this field.

Unit 1: Mechanics, Waves, Properties of Matter

Module 1 Mechanics
Module 2 Oscillations and Waves
Module 3 Thermal and Mechanical Properties of Matter

Unit 2: Electricity and Magnetism, A.C. Theory and Electronics and Atomic and Nuclear Physics

Module 1 Electricity and Magnetism
Module 2 A C Theory and Electronics
Module 3 Atomic and Nuclear Physics

It is recommended that of the approximately 50 hours suggested for each Module, a minimum of about 20 hours be spent on laboratory-related activities, such as conducting experiments, making field trips and viewing audio-visual materials.

♦ SUGGESTIONS FOR TEACHING THE SYLLABUS

The organisation of each module in the syllabus is designed to facilitate inquiry-based learning and to ensure that connections among physical concepts are established. Teachers should ensure that their lessons stimulate the use of the senses in learning as this will help students view science as a dynamic and exciting investigative process.

The general and specific objectives indicate the scope of the content including practical work that should be covered. However, unfamiliar situations may be presented as stimulus material in examination questions. Explanatory notes are provided to the right of some specific objectives. These notes provide further guidance to teachers as to the level of detail required. Suggested practical activities indicate those areas of the syllabus that are suitable for practical work. However, practical work should not necessarily be limited to these activities.

This syllabus caters to varying teaching and learning styles, with specific attention being drawn to the interrelatedness of concepts. Whenever possible, a practical approach should be employed, with special attention given to the identification of variables, the use of information gathering technological tools and social networking media to aid investigations and teamwork. The need for good observational, mathematical, data analysis and reporting skills must be emphasised.

While classical Physics is several hundred years old, it is the fundamental discipline responsible for the modern technological era in which we live and a strong appreciation of this must be inculcated by linking the work of the classical scientists to present technological development.

Greater emphasis should be placed on the application of scientific concepts and principles, and less on the factual materials, which encourage memorisation and short-term recall. Opportunities should be provided for relating the study of physical principles to relevant, regional and global examples. The relationship between the theory and practical is to be continually highlighted.

The role of the teacher is to facilitate students' learning of accurate and unbiased information that will contribute to a more scientifically literate society, capable of making educated decisions regarding the world in which we live.

♦ THE PRACTICAL APPROACH

The syllabus is designed to foster the use of inquiry-based learning through the application of the practical approach. Students will be guided to answer scientific questions by a process of making observations, asking questions, doing experiments, and analysing and interpreting data. The **CAPE®** Physics Syllabus focuses on the following skills.

1. Planning and Designing (PD)

   Student's ability to:

   (a) Ask questions: how, what, which, why or where. (Students must be guided by their teachers to ask scientific questions).

   Example: How does the length of the simple pendulum affect its period of swing?

   (b) Construct a hypothesis: The hypothesis must be clear, concise and testable.

   Example: There is direct correlation between the length of the pendulum and period of the swing.

   (c) Design an experiment to test the hypothesis. Experimental report must include the following:

   (i) problem statement;

   (ii) aim;

   (iii) list of materials and apparatus to be used;

   (iv) identification of variables;

(v) clear and concise step by step procedure;

(vi) display of expected results;

(vii) use of results;

(viii) possible sources of error/precaution; and,

(ix) possible limitations.

2. Measurement and Manipulation (MM)

(a) Student's ability to handle scientific equipment competently.

The list of equipment is:

(i) Bunsen burner;

(ii) Vernier callipers;

(iii) measuring cylinder;

(iv) beakers;

(v) thermometer;

(vi) ruler;

(vii) stop watch/clock;

(viii) balance;

(ix) micrometer screw gauge;

(x) voltmeter;

(xi) multimeter; and,

(xii) ammeter.

(b) Student's ability to take accurate measurements.

(c) Student's ability to use appropriate units.

3. <u>Observation, Reporting and Recording (ORR)</u>

(a) Recording

Student's ability to record observations and to collect and organise data; observations and data may be recorded in:

(i) Prose
Written description of observations in the correct tense.

(ii) Table
Numerical: physical quantities with symbols and units stated in heading, significant figures.

(iii) Graph
Title axes labelled, correct scales, accurate plotting fine points, smooth curves/best fit lines.

(iv) Calculations
Calculations must be shown with attention paid to units.

(b) Reporting

Student's ability to prepare a comprehensive written report on their assignments using the following format.

(i) **Date** (date of experiment).

(ii) **Aim** (what is to be accomplished by doing the experiment).

(iii) **Apparatus and Materials** (all equipment and materials used in the experiment must be listed).

(iv) **Method/Experimental Procedure** (step by step procedure written in the past tense).

(v) **Results and Observations** (see (a) above: Recording).

(vi) **Discussion**.

(vii) **Conclusion** (*should be related to the Aim*).

4. <u>Analysis and Interpretation</u>

Student's ability to:

(a) make accurate calculations;

(b) identify patterns and trends, cause and effect, and stability and change;

(c) compare actual results with expected results if they are different;

(d) identify limitations and sources of error and error ranges if appropriate;

(e) suggest alternative methods or modification to existing methods; and,

(f) draw a conclusion justified by data.

♦ UNIT 1: MECHANICS, WAVES, PROPERTIES OF MATTER

MODULE 1: MECHANICS

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand physical quantities;

2. apply the SI system of units and standard conventions;

3. solve problems of bodies at rest, in uniform motion, or uniformly accelerated motion under the influence of forces in one and two dimensions;

4. appreciate the effects of forces acting on a body;

5. understand the principle of conservation of energy;

6. design and carry out experiments to test relationships between physical quantities; and,

7. appreciate that the measurement of a physical quantity is subject to uncertainty.

Please note that Module 1, Specific Objectives 1.1-2.6 which cover Physical Quantities and SI Units are relevant to both Unit 1 and Unit 2.

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
1.	**<u>Physical Quantities</u>**		
Students should be able to:			
1.1.	express physical quantities as a numerical magnitude and unit;	Some quantities are dimensionless, for example, refractive index, relative density.	
1.2.	distinguish between scalar and vector quantities, and state examples;		
1.3.	*resolve vectors;*	Both graphically and by calculation. Add and subtract vectors using components. *For example, air and sea travel; flying a kite.*	The resolution of vectors using strings and masses.

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Physical Quantities (cont'd)</u>			
Students should be able to:			
1.4.	measure physical quantities using appropriate instruments;	A practical approach should be used, for example, using a Vernier caliper, screw gauge, multi-meter.	
1.5.	construct calibration curves;	A practical approach can be used. Non-linear curves may be included. Calibration is an operation that, under specific conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties.	*Calibrate a spring to measure mass or a bottle to measure volume. Use a dropper pipette to get the exact volume. Estimate the volume of an instrument given a portion of a linear scale.*
1.6.	*use calibration curves;*	*Use calibration curves to establish a relation for obtaining a measurement result from a reading given by a meter or a gauge. For example, determine the temperature indicated by a thermistor from a calibration curve of temperature versus resistance.*	*Use calibration curves to determine the volume of water in a container of different orientations.*
1.7.	rearrange relationships between physical quantities so that linear graphs may be plotted;	Include logarithmic plots to test exponential and power law variations.	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Physical Quantities (cont'd)			
Students should be able to:			
1.8.	distinguish between precision and accuracy; and,		*A dart board could be used as a practical demonstration of the difference between the two. Or a makeshift dartboard - a circular piece of cardboard and small pieces of modelling clay as the darts.* Practical activity on the distribution of errors in physical measurements. (See Appendix II.)
1.9.	estimate the uncertainty in a derived quantity from actual, fractional or percentage uncertainties.	Uncertainties can be combined according to the relationship of the various quantities, for example, addition, subtraction, multiplication and raising to powers.	
2.	**SI Units**		
Students should be able to:			
2.1.	state the base quantities including their symbols and SI units;	Mass, length, time, temperature, current, luminous intensity and amount of substance.	
2.2.	use base quantities or units to obtain expressions for derived quantities or units;	Summary of key quantities, symbols and units on pages 107–109.	
2.3.	use prefixes and their symbols to express multiples (up to 10^9) and sub-multiples (down to 10^{-12}) of units of base and derived quantities; and,	Solve problems where the indices have to be substituted before calculation. For example, C= $^{6km}/20\ \mu s$	

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
SI Units (cont'd)		
Students should be able to:		
2.4. use base units to check the homogeneity of physical equations.		
3. Motions		
Students should be able to:		
3.1. explain displacement, speed, velocity, and acceleration;		
3.2. use graphs to represent displacement, speed, velocity, and acceleration in a single dimension;		Perform experiments using an object rolled down an inclined plane, for example, a marble rolled down an inclined PVC gutting.
3.3. use the gradient of and area under motion graphs to solve problems;		
3.4. derive equations representing uniformly accelerated motion in a single dimension;	A non-calculus approach may be used: $v = u + at$ $v^2 = u^2 + 2as$ $s = \frac{(u+v)t}{2}$ $s = ut + \frac{1}{2}at^2$ $s = vt - \frac{1}{2}at^2$	
3.5. use the equations of motion to solve problems, on uniformly accelerated motion;		

UNIT 1
MODULE 1: MECHANICS (cont'd)

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Motions (cont'd)</u>			
Students should be able to:			
3.6.	solve problems involving bodies undergoing projectile motion;	Requires only a non-calculus *approach*. Consider *bodies launched from level ground or from elevation.*	*Investigate projectile motion using a device or machine such as a cricket bowling machine, trebuchet (catapult) or ballistic pendulum. Additionally, virtual experiments of projectile motion can be explored.*
3.7.	show that projectile motion is parabolic;	Include both vertical and horizontal projection.	
3.8.	state Newton's laws of motion;	An UNBALANCED external force is required to change the velocity.	
3.9.	explain 'linear momentum';		
3.10.	state the principle of conservation of linear momentum;		
3.11.	apply the principle of conservation of linear momentum;	For example, collisions in one or two dimensions, such as in billiards, "explosions" as in the recoil of a gun.	Use Newton's cradle.
3.12.	distinguish between inelastic and perfectly elastic collisions;	Collisions should be limited to two objects only.	
3.13.	explain the concept of the impulse of a force;		
3.14.	use the concept of the impulse of a force;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Motions (cont'd)</u>			
Students should be able to:			
3.15.	draw F-t graphs;	For example, car crash.	
3.16.	interpret F-t graphs;		
3.17.	solve problems related to Newton's laws of motion;	Problems should include uniform acceleration only.	Demonstrate: First Law using the *coin drop experiment*; Second Law using inclined plane varying mass and recording acceleration or experiment using Atwood's machine; and Third Law using a Balloon Propeller (blow up a balloon).
3.18.	express angular displacement in radians;	*For example, the ratio between: arc length of bat lift and bat length with shoulder as centre; arc length of windmill dunk and length of arm with shoulder as centre;*	
3.19.	apply the concept of angular velocity to problems involving circular motion;	*An observation of road damage in bends or curves due to the provision of centripetal force to provide the circular motion.*	
3.20.	use equations for centripetal acceleration and centripetal force;	$a = r\omega^2$ $v = r\omega$ $a = \frac{v^2}{r}$ $F = mr\omega^2$ $F = m\frac{v^2}{r}$	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Motions (cont'd)			
Students should be able to:			
3.21.	use the equations of circular motion to solve problems;	Include working for horizontal circles, vertical circles, conical pendulum and banked circles	
3.22.	use Newton's Law of Universal Gravitation in problems involving attraction between masses;	$F = \frac{GM_1M_2}{r^2}$	
3.23.	explain the term gravitational field strengths (at the Earth's surface or above);	$g = \frac{F}{m}$, units for g: Nkg^{-1}	
3.24.	use the term gravitational field strengths (at the Earth's surface or above);	*(Include relationship with height).*	
3.25.	solve problems involving circular orbits; and,	Include apparent weightlessness.	
3.26.	discuss the motion of geostationary satellites and their applications.	Compare with other orbits, for example, those of Global Positioning System (GPS) satellites.	
4.	**Effects of Forces**		
Students should be able to:			
4.1.	explain the origin of the upthrust acting on a body wholly or partially immersed in a fluid;	Upthrust due to pressure difference.	See Appendix II for suggested practical activity.
4.2.	explain the nature, cause and effects of resistive forces;	Include drag forces in fluids and frictional forces, *and the effects of air*	Use a one mass (weight) on the desk attached to a mass hanging off the edge of the desk.

resistance on rain drops.

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Effects of Forces (cont'd)</u>			
Students should be able to:			
4.3.	use the concept of terminal velocity to solve problems involving motion through a fluid;	*Include Stoke's Law for viscous drag = 6πηrv*	Use a steel ball bearing in a clear glass tube of clear viscous liquid, for example, glycerine.
4.4.	apply the principle of moments to solve problems; and,		See Appendix II for suggested practical activity.
4.5.	use the concepts of static and dynamic equilibria to solve problems.	Sum of forces equals zero. Sum of torques equals zero.	
5.	**<u>Conservation of Energy</u>**		
Students should be able to:			
5.1.	use the concept of work as the product of force and displacement in the direction of the force;	$W = Fx$	
5.2.	use the formula for kinetic energy $E_k = \frac{1}{2}mv^2$;	A non-calculus approach may be used.	
5.3.	distinguish between different types of potential energy;	Such as gravitational, electrical, elastic and strain energy.	
5.4.	use the formula $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface;		
5.5.	apply the concept of power as the rate of doing work;	$P = \frac{W}{t}$, *also* $P = Fv$	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Conservation of Energy (cont'd)			
Students should be able to:			
5.6.	describe examples of energy conversion;	*Examples of different forms of energy and the efficiency of conversion among them. Include examples occurring in industry and in everyday life.*	
5.7.	apply the concept of energy conversion to Caribbean situations; and,	Special reference is to be made to non-traditional and renewable sources such as biofuel and ethanol, geothermal, solar, wind and hydro which are applicable to the Caribbean.	Demonstrate using existing system to show energy conversion, for example, solar panel, bio-digester and wind turbine.
5.8.	discuss the mechanisms for the efficient use of energy in the Caribbean.	Emphasis should be on measures which are suited to tropical climates like the Caribbean.	

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives of this Module, teachers are advised to engage students in teaching and learning activities listed below.

1. Allow students to investigate the Physics of the motion of a cricket ball after delivery by bowler, for example, reverse swing.

2. Ask students to investigate factors influencing deviation of a struck cricket ball, or any ball, from an ideal parabolic path. For example, factors such as atmospheric conditions or defects in the ball.

3. Have students investigate the effect of the "follow through" on the motion of struck balls in different ball sports, for example, cricket and tennis.

4. Allow students to design and construct a model for a geostationary satellite.

5. Ask students to design and construct energy conversion models, for example, solar → electricity.

6. Allow students to investigate efficiency of different energy conversion models.

7. Have students investigate useful energy conservation mechanisms applicable to the design and construction of buildings in the Caribbean.

8. *Students could visit an airport or dock to observe landing, positions of wings, approach angles, forward speed and drop speed.*

9. *Observe game of lawn tennis, different actions and positions, and associate movement of ball with projectile motion. Consider the final movement of racquet as a combination of vectors to produce spin.*

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UNIT 1
MODULE 2: OSCILLATIONS AND WAVES

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand the different types of oscillatory motion;
2. appreciate the properties common to all waves;
3. recognise the unique properties of different types of waves; and,
4. apply their knowledge of waves to the functioning of the eye and the ear.

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
1. Harmonic Motion		
Students should be able to:		
1.1. use the equations of simple harmonic motion to solve problems;	$A = -\omega^2 x$ $x = A sin(\omega t)$ or $x = A cos(\omega t)$ $v = v_0 \, cos(\omega t)$ or $v = v_0 \, sin(\omega t)$ $v^2 = \omega^2(A^2 - x^2)$ and $v_0 = \omega A$ $T = \frac{2\pi}{\omega}$ *Refer to Hooke's Law. Consider using the projection of uniform circular motion to describe simple harmonic motion.*	
1.2. recall the conditions necessary for simple harmonic motion;		
1.3. describe graphically the changes in displacement, velocity and acceleration during simple harmonic motion;	*The graphs need to be done with respect to time and displacement.*	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Harmonic Motion (cont'd)			
Students should be able to:			
1.4.	use the period of the simple pendulum as $T = 2\pi\sqrt{\frac{l}{g}}$ and of the mass on a spring as $T = 2\pi\sqrt{\frac{m}{k}}$;	Include springs joined in series or in parallel.	*Determine the period of oscillating systems, for example, the use* of vertical and horizontal springs and weights. Use the graphical techniques covered in Specific Objective 1.3 to record results.
1.5.	describe the interchange of kinetic and potential energies of an oscillating system during simple harmonic motion;	Relate displacement-time graphs to the interchange of kinetic energy and potential energy.	Use a water or broom pendulum with sand to demonstrate a displacement-time graph.
1.6.	calculate the energy of a body undergoing simple harmonic motion;		
1.7.	describe examples of forced oscillations and resonance;	Use graphs to illustrate the effect on the amplitude of oscillations as the frequency approaches the system's natural frequency. Discussion on how swaying high-rise buildings or skyscrapers are affected by resonance frequencies and the impact on their structural integrity during an earthquake.	
1.8.	discuss cases in which resonance is desirable and cases in which it is not;		
1.9.	describe damped oscillations and represent such motion graphically; and,	Pay particular attention to the levels of damping and the importance of critical damping.	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Harmonic Motion (cont'd)			
Students should be able to:			
1.10.	explain how damping is achieved in some real-life examples.	Use examples such as motor vehicle suspension, rally car driving, *analogue electrical meters and door closures.*	
2.	**Properties of Waves**		
Students should be able to:			
2.1.	use the following terms: displacement, amplitude, period, frequency, velocity in relation to the behaviour of waves;	Explanation through the use of graphs and sketches.	
2.2.	differentiate between transverse and longitudinal mechanical waves;	Explanation of the movement of particles in the medium of transmission and the energy of the waves.	Use virtual labs (PhET Suite).
2.3.	represent transverse and longitudinal waves graphically;		
2.4.	explain "polarisation";	*Give examples of polarised waves.*	
2.5.	use the equation $v = f\lambda$ to solve problems involving wave motion;		
2.6.	use the relationship intensity is proportional to $(\text{amplitude})^2$ for a wave;	$I \propto A^2$	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Properties of Waves (cont'd)			
Students should be able to:			
2.7.	use the terms phase, and phase difference with reference to behaviour of waves;		
2.8.	distinguish between stationary and progressive waves;	Explanation of nodes and anti-nodes.	
2.9.	explain the properties of stationary waves and perform related calculations;	For example, microwaves, waves on strings, closed and open pipes (include resonance tube).	See Appendix II for suggested practical activity.
2.10.	describe practical applications of sound waves in industry;	Use of sonar waves in determining the depth of the sea, and in medicine, such as in foetal imaging.	
2.11.	discuss application of sound waves to musical instruments;	Include percussion instruments such as the steel pan; stringed instruments such as the guitar; and wind instruments such as the flute.	
2.12.	apply the laws of reflection and refraction to the behaviour of waves;		
2.13.	describe experiments to demonstrate diffraction of waves in both narrow and wide gaps;		Use a ripple tank together with both narrow and wide gaps, microwaves, lasers. Use virtual labs to demonstrate diffraction.
2.14.	explain the meaning of coherence as applied to waves;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Properties of Waves (cont'd)			
Students should be able to:			
2.15.	explain the terms superposition and interference of waves;		
2.16.	state the conditions necessary for two-source interference fringes of waves to be observed;		Use a simple Young's slit interference experiment for light or microwaves and two speakers for sound.
2.17.	discuss the principles of interference and diffraction as applied to waves;	Constructive and destructive interference.	
2.18.	use the approximation $y = \frac{\lambda D}{a}$ to solve problems;		
2.19.	use the expression $n\lambda = a\,sin(\theta)$ for interference and diffraction (a=slit spacing);	For two-source interference and for diffraction grating (a=slit spacing).	
2.20.	use the diffraction grating to determine the wavelength and frequency of light waves;		Use the same activity for Specific Objective 2.16.
2.21.	discuss the nature of light as electromagnetic radiation with reference to its diffractive properties;		
2.22.	list the orders of magnitude of the wavelengths of the e-m spectrum;	Include range of wavelengths of visible light.	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Properties of Waves (cont'd)			
Students should be able to:			
2.23.	define refractive index in terms of velocity of waves;		See Appendix II for suggested practical activity.
2.24.	use Snell's Law;	$n_1\sin(\theta_1)=n_2\sin(\theta_2)$	
2.25.	explain total internal reflection;	Use two media with indices n_1 and n_2.	Use same suggested practical activity for Specific Objective 2.23.
2.26.	determine the value of critical angle; and,		
2.27.	discuss practical applications of total internal reflection.	For example, fibre optic cables.	
3.	**Physics of the Ear and Eye**		
Students should be able to:			
3.1.	discuss the response of the ear to incoming sound waves;	Consider sensitivity, frequency response and intensity. Precise numerical values related to the response of the ear are not required.	Download and use an audiometer to demonstrate the difference in hearing thresholds for individuals. Focus on the change in thresholds with age. Play high frequency tones above 10 kHz to check whether all individuals can hear.
3.2.	state the orders of magnitude of the threshold of hearing and the intensity at which discomfort is experienced;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Physics of the Ear and Eye (cont'd)</u>			
Students should be able to:			
3.3.	use the equation intensity level in dB $=10log_{10}(I/I_0)$;	I = intensity I_0 = threshold intensity dBA scale	
3.4.	discuss the subjective qualities of the terms 'noise' and 'loudness';		
3.5.	solve problems using lens formulae;	$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ Power in dioptres $=\frac{1}{f}$ with f in metres.	*Determine the focal length of a lens.*
3.6.	discuss how the eye forms focused images of objects at different distances;		
3.7.	explain the terms: (a) depth of focus; (b) accommodation; (c) long sight; (d) short sight; (e) astigmatism; and, (f) cataracts;	Calculations on power of correcting lens required.	*Investigate depth of focus by applying the lens formulae by keeping one constant and varying the other.*
3.8.	discuss how defects of the eye can be corrected; and,		
3.9.	discuss the formation of focused images in the simple camera and magnifying glass.		

UNIT 1
MODULE 2: OSCILLATIONS AND WAVES (cont'd)

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives of this Module, teachers are advised to engage students in teaching and learning activities listed below.

1. Ask students to conduct research on how light is transmitted along an optical fibre. Students could investigate the effect of fibre thickness on reduction of light intensity of a specific frequency or the effect of the light frequency on loss in intensity for the identical fibre.

2. Have students construct a model of an electricity generator that can be powered by the energy of sea waves.

3. Ask students to construct a model of an "invisible" aircraft similar to the stealth aircraft which is constructed to be invisible to radar waves. In the stealth aircraft flat panels are angled so as to reflect incident radar signals up or down rather than back to the radar station.

4. Ask students to construct a model of the eye that demonstrates its operation and common defects. A simple laser pointer could be used as the light source.

5. Allow students to investigate the factors influencing the quality of notes produced through the vibration of waves in strings and pipes.

6. Have students investigate the use of ultrasonic waves in cleaning jewellery and teeth.

7. Allow students to investigate the use of ultrasonic waves in medicine.

8. Ask students to conduct research on the use of sonar waves.

9. Ask students to investigate the use of ultrasonics in systems, such as alarms.

10. Have students measure the frequency response of the ear with respect to gender and age.

11. Allow students to measure the "noise" in different locations, for example, factories, airports, classrooms.

12. Ask students to gather information and present data on seismographs.

13. Allow students to investigate the design of speaker boxes and musical instruments.

14. Ask students to measure the 'reverberation time' in a place, such as an auditorium, church or classroom.

15. Have students investigate damping in shock absorbers, car mufflers, acoustic tiles.

16. Invite guest lecturers to discuss the importance of damping.

UNIT 1
MODULE 2: OSCILLATIONS AND WAVES (cont'd)

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UNIT 1
MODULE 3: THERMAL AND MECHANICAL PROPERTIES OF MATTER

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand the principles involved in the design and use of thermometers;
2. be aware of the thermal properties of materials and their practical importance in everyday life;
3. understand the various modes of heat transfer;
4. be familiar with the kinetic theory of gases and the equation of state of an ideal gas;
5. display a working knowledge of the first law of thermodynamics; and,
6. be aware of the mechanical properties of materials and their practical importance in everyday life.

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
1. Design and Use of Thermometers		
Students should be able to:		
1.1. discuss how a physical property may be used to measure temperature;	Include both linear and non-linear variation with temperature. *Use equation* $\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100$ *for temperature values on the Empirical scale.* *Explanation of the reason why different thermometers when using the Empirical centigrade scale do not agree.*	*Calibrate a thermometer using a ruler using the following points: steam point, ice point and water at room temperature.* *Plot a calibration graph (resistance vs temperature for a thermistor with a negative temperature coefficient.*
1.2. describe the physical features of specific thermometers;	Liquid-in-glass, resistance (including thermistor), thermocouple and constant volume gas thermometer.	Show students different types of thermometers.

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Design and Use of Thermometers (cont'd)		
Students should be able to:		
1.3. discuss the advantages and disadvantages of these thermometers; and,	*Give typical situations where the different types of thermometers will be best suited, based on their particular advantages.*	
1.4. recall that the absolute thermodynamic scale of temperature does not depend on the property of any particular substance.	*Discussion on absolute zero and the triple point of water (0.01°C).* *Discussion on the conversion of °C to K* *ϑ/°C = T/K – 273.15* *Use the equation* $T = \frac{P_T}{P_{tr}} \times 273.16$	
2. Thermal Properties		
Students should be able to:		
2.1. express the internal energy of a system as the sum of the kinetic and potential energies associated with the molecules of the system;		
2.2. relate a rise in temperature to an increase in internal energy;		
2.3. explain the terms 'heat capacity' and 'specific heat capacity';		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Thermal Properties (cont'd)			
Students should be able to:			
2.4.	perform experiments to determine the specific heat capacity of liquids and metals by electrical methods and by the method of mixtures;	Both electrical methods and the method of mixtures are to be covered. *The Callender and Barnes continuous flow calorimeter for finding specific heat capacity of a liquid can be discussed. Mention that the main advantage is that the heat capacity of the apparatus itself need not be known. Calculations involving this method should be done.*	
2.5.	explain the concepts of 'melting' and 'boiling' in terms of energy input with no change in temperature;		Find freezing or melting points and boiling points using graphs of temperature against time.
2.6.	relate the concepts of melting and boiling to changes in internal potential energy;		
2.7.	discuss how specific latent heat of a fluid affects heat transfer during mixing;	Explanation of the term 'specific latent heat'. Both electrical methods and the method of mixtures are to be covered.	Perform experiments to determine the specific latent heats. *Use a calorimeter (for example, a styrofoam cup) to demonstrate latent heats.* *See Appendix 11* for suggested practical activity.
2.8.	explain the cooling which accompanies evaporation; and,	This should be done in terms of latent heat and in terms of the escape of molecules with high kinetic energy.	

UNIT 1

MODULE 3: THERMAL AND MECHANICAL PROPERTIES OF MATTER (cont'd)

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Thermal Properties (cont'd)		
Students should be able to:		
2.9. solve numerical problems using the equations $E_H = mc\Delta\theta$ and $E_H = mL$.		
3. Heat Transfer		
Students should be able to:		
3.1. describe the mechanism of thermal conduction;	*Discussion on why solids are generally better conductors of heat than liquids and gases.*	
3.2. use the equation $(\frac{Q}{t} = -kA\frac{\Delta\theta}{\Delta x})$ to solve problems in one-dimensional heat flow;	Restrict use to cases of one-dimensional heat flow. *Temperature gradient* = $-\frac{\Delta\theta}{\Delta x}$	*Use a thermocouple to measure the temperature difference across a lagged bar.*
3.3. solve numerical problems involving composite conductors;	Use of concept of equivalent conductor.	
3.4. discuss the principles involved in the determination of thermal conductivity of good and bad conductors;	*Discussion on both Searle's bar and Lee's disc.*	Use Searle's apparatus.
3.5. explain the process of convection as a consequence of a change of density;	Use this concept to explain ocean currents and winds.	
3.6. discuss thermal radiation;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Heat Transfer (cont'd)			
Students should be able to:			
3.7.	solve problems using Stefan's equation;	*For a black body $P = \sigma AT^4$ Include net rate of radiation.* $P = \sigma A(T_1^4 - T_2^4)$	
3.8.	*relate Stefan's equation to the greenhouse effect and to climate change;*	*The greenhouse effect caused by re-radiation of energy from the earth.*	
3.9.	discuss applications of the transfer of energy by conduction, convection and radiation; and,	Include vacuum flasks and solar water heaters *and other examples*.	
3.10.	discuss the development of heating and cooling systems to reduce the Caribbean dependency on fossil fuels.	Discussion on improving the design of a building to take advantage of natural resources and reduce dependence on fossil fuels.	
4.	**The Kinetic Theory of Gases**		
Students should be able to:			
4.1.	use the Avogadro constant (the number of atoms in 0.012 kg of the C-12 isotope) as a numerical entity;		
4.2.	use the concept of the mole as the quantity of substance containing a number of particles equal to the Avogadro constant;		
4.3.	use the equation of state for an ideal gas expressed as $pV = nRT$ and $pV = N\kappa T$;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
The Kinetic Theory of Gases (cont'd)			
Students should be able to:			
4.4.	discuss the basic assumptions of the kinetic theory of gases;		
4.5.	explain how molecular movement is responsible for the pressure exerted by a gas;		
4.6.	*solve problems using the equation* $pV = \frac{1}{3}Nm\overline{c^2}$;	*Use the equation* $p = \frac{1}{3}\rho <c^2>$.	
4.7.	use $pV = \frac{1}{3}Nm\overline{c^2}$ to deduce the equation for the average translational kinetic energy of monatomic molecules; and,	Include calculations of r.m.s. speed, $\sqrt{\overline{c^2}}$ or $\sqrt{<c^2>}$ Ek = 3/2 kT	
4.8.	deduce total kinetic energy of a monatomic gas.	Total kinetic energy: $E_k = \frac{3}{2}nRT$	
5.	**First Law of Thermodynamics**		
Students should be able to:			
5.1.	use the term 'molar heat capacity';	$E_h = nC_v\Delta\theta$ *or* $E_h = nC_p\Delta\theta$	
5.2.	discuss why the molar heat capacity of a gas at constant volume is different from that of a gas at constant pressure;	$C_p = C_v + R$ *Discuss why* $C_p > C_v$	
5.3.	calculate the work done on a gas using the equation $W = p\Delta V$;	*Distinguish between work done on gas during a compression and work done by gas in expanding.*	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
First Law of Thermodynamics (cont'd)			
Students should be able to:			
5.4.	deduce work done from a p-V graph;	*Draw graphs and find work done with the different types of systems, that is, isothermal, isobaric, isochoric, adiabatic.*	
5.5.	express the first law of thermodynamics; and,	Change in internal energy, the heat supplied to the system, and the work done on the system. $\Delta U = \Delta Q + \Delta W$	
5.6.	solve problems involving the first law of thermodynamics.		
6.	**Mechanical Properties of Materials**		
Students should be able to:			
6.1.	explain the terms: (a) density; and (b) pressure;		
6.2.	*use the equations* $p = \frac{F}{A}$ *and* $\rho = \frac{m}{V}$ *to solve problems;*		
6.3.	derive the equation $\Delta p = \rho g \Delta h$ $p = \frac{F}{A}$ and $\rho = \frac{m}{V}$ for the pressure difference in a liquid;	Playing football at high altitude.	
6.4.	use the equation $\Delta p = \rho g \Delta h$ to solve problems;		

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Mechanical Properties of Materials (cont'd)</u>		
Students should be able to:		
6.5. relate the difference in the structures and densities of solids, liquids and gases to simple ideas of the spacing, ordering, and motion of their molecules;		
6.6. describe a simple kinetic model for the behaviour of solids, liquids and gases;		
6.7. distinguish between the structure of crystalline and non-crystalline solids;	Make particular reference to metals, polymers and glasses.	
6.8. discuss the stretching of springs and wire in terms of load extension;	Hooke's law. Spring constant.	
6.9. use the relationship among 'stress', 'strain' and 'the Young modulus' to solve problems;	*Definitions of stress and strain and Young modulus* $E = \frac{stress}{strain}$ *and* $E = \frac{Fl}{Ae}$.	
6.10. perform experiments to determine the Young modulus of a metal in the form of a wire;		
6.11. perform experiments based on knowledge of the force-extension graphs for typical ductile, brittle and polymeric materials;	For example, copper, glass, rubber.	
6.12. deduce the strain energy in a deformed material from a force-extension graph;		See Appendix II for suggested practical activity.

UNIT 1
MODULE 3: THERMAL AND MECHANICAL PROPERTIES OF MATTER (cont'd)

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Mechanical Properties of Materials (cont'd)			
Students should be able to:			
6.13.	distinguish between elastic and inelastic deformations of a material; and,	Only qualitative knowledge is required.	Use the same activity as above.
6.14.	discuss the importance of elasticity in structures.	Consider what happens to tall buildings, bridges, and bones when large forces are applied.	

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives of this Module, teachers are advised to engage students in teaching and learning activities listed below.

1. Have students investigate how three different physical properties vary with temperature.

2. Allow students to investigate the suitability of using iron, copper or aluminum as the metal for making an engine block.

3. Allow students to investigate the heat flow through different materials of the same thickness and recommend the use of one in the construction industry, for example, brick, concrete, glass and wood.

4. Ask students to investigate this statement: heat flow in textiles can occur by all three methods of heat transfer, but for metals only conduction is possible.

5. Allow students to investigate the effect of greenhouse gases on global warming.

6. Allow students to investigate heat transfer processes in the solar water heater.

7. Ask students to construct a model of a solar crop dryer.

8. Ask students to construct a model of a solar air conditioner.

9. Allow students to construct a model of a solar still.

10. Have students construct a model of a solar refrigerator.

11. Ask students to investigate the role of thermodynamics in the operation of the four-stroke petrol engine.

12. Ask students to investigate the uses of crystalline and non-crystalline solids in the semiconductor industry.

13. Allow students to investigate the uses of polymers and glasses.

14. Allow students to investigate force-extension graphs for metal wires, glass fibres and rubber.

15. Ask students to design a model structure or building to take advantage of natural resources and reduce dependence on fossil fuels.

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♦ UNIT 2: ELECTRICITY AND MAGNETISM, AC THEORY AND ELECTRONICS AND ATOMIC AND NUCLEAR PHYSICS

MODULE 1: ELECTRICITY AND MAGNETISM

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand electrostatic phenomena;
2. understand electrical quantities and the relationships among them;
3. analyse circuits with various electrical components;
4. understand the concept of electric fields;
5. be aware of the design and use of capacitors;
6. demonstrate a conceptual understanding of magnetic fields;
7. understand how magnetic forces arise; and,
8. demonstrate a working knowledge of electromagnetic phenomena.

Please note that Unit 1, Module 1, Specific Objectives 1.1-2.6 which cover Physical Quantities and SI Units are relevant to Unit 2.

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
1. <u>Electrical Quantities</u>		
Students should be able to:		
1.1. use the equations $Q = It$ and $Q = \pm Ne$ *(N refers to number of charges)* to solve problems;		
1.2. define the 'Coulomb';		
1.3. define *potential difference and* the 'Volt';		
1.4. use the equation **V = W/Q** to solve problems;		
1.5. use the equation **V = IR** to solve problems;		

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Electrical Quantities (cont'd)		
Students should be able to:		
1.6. use the equations **$P = IV$, $P = I^2R$, $P = V^2/R$** to solve problems;		
1.7. use the formula $R = \frac{\rho L}{A}$ to determine resistivity;	Definition of resistivity.	Determine the resistance of wire at varying points and plot a graph of resistance versus length.
1.8. use energy considerations to distinguish between e.m.f. and p.d.;	Include the observation that e.m.f. is associated with sources or active devices whereas p.d. is used in reference to an electric field or passive device.	
1.9. explain drift velocity (**v**) in terms of the charge carriers;		
1.10. derive the equation ***I = nqvA*** for *charges* moving in a metal (n = charge density); and		
1.11. use the equation ***I = nqvA*** for *charges* moving in a metal (n = charge density).	Since a similar equation describes the flow of particles in uniform channels, candidates should be able to apply such equations to semiconductors and electrolytes.	

UNIT 2
MODULE 1: ELECTRICITY AND MAGNETISM (cont'd)

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
2.	**<u>Electrical Circuits</u>**		
Students should be able to:			
2.1.	compare Ohmic and non-Ohmic devices using an IV graph;	Explanation of these characteristics in terms of the variation in resistance of the device.	Sketch the I - V characteristic for a metallic conductor at constant temperature, a semiconductor diode, and a filament lamp.
2.2.	sketch the variation of resistance with temperature for a thermistor with negative temperature co-efficient;	Also include different types of thermistors and discuss the differences between the R – T characteristics.	
2.3.	solve problems involving terminal p.d. and external load, given that sources of e.m.f. possess internal resistance;	Use examples of different types of source, for example, primary and secondary chemical cells, solar cells, generators.	Determine resistance of small battery or small solar cell.
2.4.	draw circuit diagrams;		
2.5.	interpret circuit diagrams;	*Consider d.c. circuits involving sources of e.m.f. and resistive circuit elements.*	
2.6.	apply Kirchhoffs laws to given circuits;	Consider d.c. circuits involving sources of e.m.f. and resistive circuit elements. Kirchhoff's First Law is a consequence of conservation of charge and Kirchhoff's Second Law, a consequence of conservation of energy.	
2.7.	derive the formula for the effective resistance of two or more resistors in series or parallel;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Electrical Circuits (cont'd)			
Students should be able to:			
2.8.	use the formula for two or more resistors in series or parallel;		
2.9.	use the potential divider as a source of variable and fixed p.d.; and,	*Introduce students to a metre-bridge, for example, potentiometer.*	Construct potential divider to provide both variable and fixed p.d.
2.10.	use the Wheatstone bridge as a means of comparing resistances.	Treat as a double potential divider.	Use the Wheatstone bridge to determine unknown resistance.
3.	**Electric Fields**		
Students should be able to:			
3.1.	explain the difference between electrical conductors and insulators;	An electron model should be used in the explanation.	
3.2.	use Coulomb's Law: $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ to calculate the force between charges in free space or air to solve problems;	Consider combinations of charges in very simple arrangements. Use a vector approach to determine the resultant force on a single point charge due to other point charges.	
3.3.	use $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ for the field strength due to a point charge;	E is a vector.	
3.4.	calculate the field strength of the uniform field between charged parallel plates;	Consider potential difference and separation of the plates. $E = \frac{V}{d}$	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Electric Fields (cont'd)			
Students should be able to:			
3.5.	calculate the force on a charged particle in a uniform electric field;	F = EQ	
3.6.	describe the effect of a uniform electric field on the motion of charged particles;	Consider motions perpendicular and parallel to the electric field.	
3.7.	solve numerical problems involving the motion of charged particles in a uniform electric field;		
3.8.	compare the motion of charged particles in a uniform electric field to that of a projectile in a gravitational field;		
3.9.	use the fact that the field strength at a point is numerically equal to the potential gradient at that point;	Consider the uniform electric field and by determining the work done per unit charge, verify this relationship. Refer to Specific Objective 3.7.	
3.10.	use the equation $V = \frac{Q}{4\pi\varepsilon_0 r}$ for the potential due to a point charge; and,	Compare the potential due to a point charge with that due to a charged sphere of radius r. V is a scalar.	
3.11.	find the potential at a point due to several charges.	Compare with vector addition in Specific Objectives 3.5 and 3.6.	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
4.	**Capacitors**		
Students should be able to:			
4.1.	define capacitance;		
4.2.	use the equation $C = \frac{Q}{V}$ to solve problems;		
4.3.	use the formula $C = \frac{\varepsilon A}{d}$;	$C = \frac{\varepsilon_r \varepsilon_o A}{d}$ *ε_r – relative permittivity or dielectric constant* *ε_0 – permittivity of free space.* Refer to the use of dielectrics to produce capacitors of larger values with the same dimensions. Mention the types of dielectrics and the range of their dielectric constants or relative permitivity.	
4.4.	derive formulae for capacitors in parallel and series to solve problems;		
4.5.	use formulae for capacitors in parallel and series to solve problems;	Include problems on equivalent capacitance for simple series parallel combinations.	
4.6.	use the formulae for energy stored in a capacitor as $W = \frac{CV^2}{2}, W = \frac{QV}{2}$ $and\ W = \frac{Q^2}{2C}$ to solve problems;	*Discussion on* the mechanism of energy storage in a capacitor.	

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Capacitors (cont'd)		
Students should be able to:		
4.7. recall the equations for capacitor charge and discharge;	$Q = Q_0 \exp\left(\frac{-t}{RC}\right)$ $Q = Q_0\left(1 - exp\left(\frac{-t}{RC}\right)\right)$ $I = I_0 \exp\left(\frac{-t}{RC}\right)$ $I = I_0\left(1 - exp\left(\frac{-t}{RC}\right)\right)$ $V = V_0 \exp\left(\frac{-t}{RC}\right)$ $V = V_0\left(1 - exp\left(\frac{-t}{RC}\right)\right)$ (RC is the "time constant" and measured in seconds.)	
4.8. use the equations for capacitor *charge and* discharge; and,		
4.9. sketch graphs illustrating the charge and discharge of a capacitor.	Q, V or I against t.	
5. Magnetic Fields		
Students should be able to:		
5.1. explain 'magnetic flux density' and the 'tesla';		
5.2. sketch magnetic flux patterns due to a long straight wire, a flat circular coil and a long solenoid; and,		

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Magnetic Fields (cont'd)		
Students should be able to:		
5.3. use the expressions for the magnetic flux density:		See Appendix II for suggested practical activity.
(a) of a *perpendicular* distance r from a long straight wire;	$B = \mu_0 I/2\pi r$	
(b) the centre of a flat circular coil; and,	$B = \mu_0 NI/2r$ *[N = number of turns]*	
(c) near the centre of *an infinitely* long solenoid.	$B = \mu_0 nI$ *[n = number of turns per unit length = N/L]*	
6. Magnetic Forces		
Students should be able to:		
6.1. use Fleming's Left-Hand Rule to predict the direction of the force on a current-carrying conductor in a magnetic field;		
6.2. use the equation $F = BIL\sin\theta$ to solve problems;		
6.3. explain how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field by means of a current balance;		See Appendix II for suggested practical activity.

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Magnetic Forces (cont'd)		
Students should be able to:		
6.4. predict the direction of the force on a charge moving in a magnetic field;	Use Fleming's Left-Hand Rule and treat the moving charge as an electric current. Qualitative discussion of the trapping of charged particles by magnetic fields with specific mention of earth's magnetic field and the Van Allen radiation belt.	
6.5. use the expression $F = BQv\sin\theta$ to solve problems;		
6.6. solve problems involving charged particles moving in mutually perpendicular electric and magnetic fields;		
6.7. describe the effect of a soft iron core on the magnetic field due to a solenoid;	Compare this effect with that of the dielectric in a capacitor.	Make a small electro magnet with varying cores and see how many paper clips can be picked up. *See Appendix II for suggested practical activity.*
6.8. explain the principle of the electromagnet;	Uses in door locks, switches and other applications.	
6.9. explain the origin of the forces between current-carrying conductors;		
6.10. predict the direction of the forces;		

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Magnetic Forces (cont'd)		
Students should be able to:		
6.11. explain the Hall effect; and,	In developing the explanation, refer to Specific Objective 6.5.	
6.12. use the Hall probe to show variations of flux density.		
7. Electromagnetic Induction		
Students should be able to:		
7.1. explain magnetic flux;		
7.2. use the equation $\Phi = BA$ to solve problems;		
7.3. interpret experiments which demonstrate the relationship between the magnitude and direction of an induced e.m.f. and the change of flux linkage producing the e.m.f.;		Conduct investigations on effects obtained when: (a) bar magnet moves inside a solenoid; (b) two flat coils move with respect to each other; (c) bar magnet moves with respect to flat coil; (d) one solenoid moves inside another; and, (e) solenoid moves inside a flat coil. In your explanation, refer to Specific Objective 7.5.

UNIT 2
MODULE 1: ELECTRICITY AND MAGNETISM (cont'd)

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Electromagnetic Induction (cont'd)		
Students should be able to:		
7.4. use Faraday's Law of electromagnetic induction to determine the magnitude of an induced e.m.f.;	Include $E = BLv$ for a straight conductor.	See Appendix II for suggested practical activity.
7.5. use Lenz's Law to determine the direction of an induced e.m.f.; and,		
7.6. discuss Lenz's Law as an example of conservation of energy.		

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives of this Module, teachers are advised to engage students in Practical Activities outlined below.

1. Allow students to conduct research on the origins of the different laws outlined in the Module, for example, Ohm's law, Faraday's laws and Lenz's law.

2. Encourage students to incorporate the use of online resources, such as videos, to visualise concepts.

UNIT 2
MODULE 1: ELECTRICITY AND MAGNETISM (cont'd)

RESOURCES

Adams, S. and Allay, J.	Advanced Physics. Oxford: Oxford University Press, 2000.
Breithaupt, J.	Understanding Physics for Advanced Level, 4th Edition. Cheltenham: Nelson Thornes Publishers, 2000.
Crundell, M. and Goodwin, G.	Cambridge International AS and A Level Physics. London: Hodder Education, 2014.
David, T.	*Physics for Cape Unit 2, A* ***CXC®*** *Study Guide. Oxford University Press, 2013.*
Dobson, K., Grace, D. and Lovett, D.	Physics, 3rd Edition. London: Harper Collins Publishers, 2008.
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Websites

https://www.penflip.com/shikamikonotz/shika-na-mikono/blob/master/chapter28.txt

UNIT 2
MODULE 2: AC THEORY AND ELECTRONICS

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand the principles and operation of the p-n junction diode;
2. understand the characteristics of alternating currents and their applications;
3. understand the use of transducers as input and output devices;
4. understand the use of operational amplifiers in analogue circuits; and,
5. demonstrate proficiency in the use of logic gates in digital circuits.

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
1. <u>Alternating Currents</u>		
Students should be able to:		
1.1. use the following terms in relation to an alternating current or voltage: (a) frequency; (b) peak value; and, (c) root-mean-square value;	Recognition that ac voltages and currents are commonly quoted in terms of the RMS values.	
1.2. use an equation of the form $x = x_0 \sin \omega t$ to represent an alternating current or voltage;		
1.3. use the relationship that the peak value is √2 times the r.m.s. value for the sinusoidal case; and,	*Recognition that the r.m.s. value of an ac current (or voltage) is equivalent to that value of dc current (or voltage) which would dissipate power at the same rate in a given resistor.*	*Perform an experiment to verify the relationship between the peak value of an ac current and the equivalent dc current.*

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Alternating Currents (cont'd)</u>			
Students should be able to:			
1.4.	discuss the advantages of using alternating current and high voltages for the transmission of electrical energy.	*The role of step up and step down transformers in the transmission of electrical power should be mentioned.* *The magnitudes of transmission voltages and associated safety concerns should be included.*	*Record the highest voltages observed on electrical transformers in their neighbourhood.*
2.	**<u>The p-n Junction Diode</u>**		
Students should be able to:			
2.1.	describe the electrical properties of semiconductors;	The population density of holes and electron in intrinsic and doped semiconductors should be mentioned and compared with that for conductors. Resistivity of semiconductors should be compared to that of conductors in order to place the values in meaningful contexts.	
2.2.	distinguish between p- type and n-type material;		
2.3.	explain the formation of a depletion layer at a p-n junction;	The fact that a depletion layer forms in the unbiased p-n junction should be emphasised.	
2.4.	discuss the flow of current when the p-n junction diode is forward-biased or reverse-biased;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
The p-n Junction Diode (cont'd)			
Students should be able to:			
2.5.	discuss the IV characteristic of the p-n junction diode;	Mention some applications of diodes and show how these simple characteristics lead to these applications.	Use the diode in a circuit with multimeters and a suitable power source to investigate the IV characteristics.
2.6.	*recall that junction transistors consisting of two back-to-back diodes are manufactured as either n-p-n or p-n-p;*	*Draw diagrams showing the arrangement of the semiconductor types and the labelled circuit symbol for each type of transistor.*	*Perform experiments to demonstrate qualitatively the operation of the transistor as a switch or amplifier, that is, at cutoff/ saturation and the active regions.*
2.7.	use the diode for half-wave rectification;		
2.8.	*recall the arrangement of the ac supply, transformer and bridge rectifier diodes in a power supply circuit;*	*Description of the flow of current through the individual diodes in a bridge rectifier circuit.*	
2.9.	represent half-wave and full-wave rectification graphically; and,		
2.10.	discuss the use of a capacitor for smoothing a rectified ac wave.	Include significance of the time-constant RC.	*Set up a simple bridge rectifier circuit with capacitor smoothing, measure and record the shape and magnitude of voltages at important points in the circuit.*

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
3. Transducers		
Students should be able to:		
3.1. explain the use of the light-dependent resistor (LDR), the thermistor and the microphone as input devices for electronic circuits; and,	Used if necessary in a potential divider or in a Wheatstone bridge circuit.	Demonstrate using the named devices to show their characteristics.
3.2. describe the operation of the light-emitting diode (LED), the buzzer and the relay as output devices.	Include use of protective resistor for the LED.	
4. Operational Amplifiers		
Students should be able to:		
4.1. describe the properties of the ideal operational amplifier;	Infinite input impedance, infinite open loop gain, zero output impedance.	
4.2. compare the properties of a real operational amplifier with the ideal operational amplifier;		
4.3. use the operational amplifier as a comparator;	For example, converting sine wave to square wave, turning on an alarm when the temperature exceeds a fixed value.	*Perform experiment to demonstrate the operation of an op-amp comparator.*
4.4. use the fact that magnitude of the output voltage cannot exceed that of the power supply;	Introduce "clipping" and "saturation".	*Demonstrate clipping and saturation using an oscilloscope.*
4.5. explain the meaning of gain and bandwidth of an amplifier;	Typical as well as ideal values for these quantities should be discussed.	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Operational Amplifiers (cont'd)			
Students should be able to:			
4.6.	explain the gain-frequency curve for a typical operational amplifier;	Include the fact that gain and frequency are usually plotted on logarithmic axes and explain the reason for this.	
4.7.	determine bandwidth from a gain-frequency curve;		
4.8.	draw the circuit diagram for both the inverting and non-inverting amplifier with a single input;	Students should be familiar with several representations of the same circuit.	
4.9.	use the concept of virtual earth in the inverting amplifier;	Explanation of why the virtual earth cannot be connected directly to earth although it is "virtually" at earth potential.	
4.10.	use expressions for the gain of both the inverting amplifier and the non-inverting amplifier;	Use the properties of the ideal op-amp.	
4.11.	discuss the effect of negative feedback on the gain and bandwidth of an inverting operational amplifier and non-inverting amplifier;	Mention the effect of negative feedback on other op-amp characteristics.	Use the inverting amplifier to investigate the gain as frequency of the input signal is varied. See Appendix II for suggested practical activity.
4.12.	perform calculations related to single-input amplifier circuits;	Include "cascaded" amplifiers.	
4.13.	use the fact that a non-inverting amplifier has a very high input impedance;		

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
<u>Operational Amplifiers (cont'd)</u>			
Students should be able to:			
4.14.	describe the use of the inverting amplifier as a summing amplifier;	Mention of practical uses of summing amplifier, for example, mixing boards.	Use two separate power supplies along with multimeters to investigate the output voltage compared to the input voltages.
4.15.	solve problems related to summing amplifier circuits;	Relate to the use of summing amplifier as a digital to analogue convert.	
4.16.	describe the use of the operational amplifier as a voltage follower; and,	Mention the important practical use of the voltage follower as a buffer or matching amplifier, for example, effect pedals for guitarists.	
4.17.	analyse simple operational amplifier circuits.	Analysis of the response of amplifier circuits to input signals, using timing diagrams.	
5.	**<u>Logic Gates</u>**		
Students should be able to:			
5.1.	describe the function of the following logic gates: NOT, AND, NAND, OR, NOR, EXOR, EXNOR;	*For logic gate circuit symbols, use the ANSI system.* Include the equivalence relationship between different gates, for example, AND from NOR^{S}, OR from NAND^{S}, NOR from OR+NOT, NOT from NOR.	

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Logic Gates (cont'd)			
Students should be able to:			
5.2.	use truth tables to represent the function of logic gates with no more than two inputs;		Use of logic tutors (combinations of logic gate chips on one board) to investigate the truth tables of these gates.
5.3.	re-design a logic circuit to contain only NOR gates or only NAND gates;	Circuit should be reduced to minimum chip count.	
5.4.	analyse circuits using combinations of logic gates to perform control functions;		
5.5.	construct truth tables for a combination of logic gates;	Students should familiarise themselves at the earliest possible opportunity with the application of logic gates to solve simple real-world problems and a familiar practical example should be described.	Logic tutor can be used to investigate these combinations.
5.6.	interpret truth tables for a combination of logic gates;		
5.7.	use timing diagrams to represent the response of digital circuits to different input signals;		
5.8.	draw a circuit to show the construction of a half-adder;	From two NORs and an AND or from EXOR and an AND.	Set up circuits to investigate both the half adder and full adder.
5.9.	explain the operations of a half-adder;		
5.10.	use two half-adders and an OR to construct a full-adder;		

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Logic Gates (cont'd)		
Students should be able to:		
5.11. explain the operation of a flip-flop consisting of two NAND gates or two NOR gates;	Use of the S-R flip-flop as a latch or memory.	
5.12. describe the operation of the triggered bistable;		
5.13. combine triggered bistables (T flip-flops) to make a 3-bitbinary counter; and,		
5.14. discuss the application of digital systems in the home and in industry.	Automobile applications can also be used as examples.	

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives of this Module, teachers are advised to engage students in teaching and learning activities listed below.

1. Allow students to measure the IV characteristics of different p-n junction diodes.
2. Ask students to construct and test half-wave and full-wave rectification circuits.
3. Have students investigate the smoothing effect of a capacitor on a rectified ac wave.
4. Ask students to measure the response of LDRs, thermistors and microphones to different inputs.
5. Ask students to conduct an investigation on the response of LEDs, buzzers and relays to input signals.
6. Allow students to construct and test comparator circuits using operational amplifiers.

Suggested Teaching and Learning Activities (cont'd)

7. Ask students to measure the bandwidth of an operational amplifier circuit and determine the effect of negative feedback on bandwidth using an oscilloscope.

8. Encourage students to construct simple amplifier circuits and investigate their response to different signals.

9. Allow students to investigate operational amplifier circuits, which use various input and output transducers.

10. Ask students to design and construct digital circuits using logic gates to perform functions such as alarms and door locks.

11. Engage students in the construction and testing of flip-flop circuits using logic gates to switch devices on and off in a controlled fashion.

RESOURCES

Adams, S. and Allay, J.	*Advanced Physics*. Oxford: Oxford University Press, 2000.
Breithaupt, J.	*Understanding Physics for Advanced Level, 4th Edition*. Cheltenham: Nelson Thornes Publishers, 2000.
Crundell, M. and Goodwin, G.	*Cambridge International AS and A Level Physics.* London: Hodder Education, 2014.
David, T.	*Physics for Cape Unit 2, A **CXC®** Study Guide. Oxford University Press, 2013.*
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Muncaster, R.	*Advanced Level Physics, 4th Edition*. London: Nelson Thornes Publishers, 1993.

UNIT 2
MODULE 3: ATOMIC AND NUCLEAR PHYSICS

GENERAL OBJECTIVES

On completion of this Module, students should:

1. appreciate the photon model for electromagnetic radiation;
2. understand the development of the nuclear model of the atom;
3. appreciate the wave-particle nature of matter and energy;
4. understand the relationship between mass and energy;
5. demonstrate a knowledge of radioactivity and its applications; and,
6. *apply the laws of Physics to solve appropriate problems.*

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
1. Particulate Nature of Electromagnetic Radiation		
Students should be able to:		
1.1. describe the phenomenon of photoelectric emission;	*A description of what happens when uv radiation falls on a zinc plate, or light on materials such as cadmium sulfide and photovoltaic cells.*	*Measuring current and or change in resistance in devices exposed to light such as photocells.*
1.2. use the relationship **E = h f** to solve problems;		
1.3. discuss the shortcomings of classical physics to explain aspects of the photoelectric effect;	*Mention effect of high and low intensity below and above the cutoff frequency.*	
1.4. explain how the photon theory better suits the emission of a photon;	Explanation of the photoelectric effect as evidence for the particulate nature of electromagnetic radiation.	

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Particulate Nature of Electromagnetic Radiation (cont'd)		
Students should be able to:		
1.5. define: (a) work function (Φ); (b) threshold frequency (f_o); (c) cut-off wavelength (λo); and, (d) stopping potential (Vs);	$\Phi = hf_0$	
1.6. use the relationship $hf = \Phi + \frac{1}{2}mv^2$ to solve problems;	Or $hf = \Phi + eV_s$ Explanation of why the maximum photoelectric energy is independent of intensity, whereas the photoelectric current is proportional to Intensity.	
1.7. use the electron-volt as a unit of energy;	Students should be familiar with calculations for converting the KE of particles to eV.	
1.8. explain the principles of the production of X-rays by electron bombardment of a metal target;	Include the fact that the emission spectrum has a continuous background component and several line spectra series. Description of the main features of a modern X-ray tube, including control of the intensity.	
1.9. explain the origins of line and continuous X-ray spectra;	*Include the absorption or release of energy due to movement of electrons between energy levels. Include $hf = E_2 - E_1$.*	

UNIT 2
MODULE 3: ATOMIC AND NUCLEAR PHYSICS (cont'd)

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Particulate Nature of Electromagnetic Radiation (cont'd)		
Students should be able to:		
1.10. solve problems by using the equation $I = I_0 \exp(-\mu x)$ for the attenuation of X-rays in matter;	μ = linear absorption co-efficient.	*Measuring attenuation of light through of layers of light filters unto the photocell using a multimeter.*
1.11. discuss the use of X-rays in radiotherapy and imaging in medicine;	Qualitative description of the operation of a CAT scanner should be included here.	
1.12. discuss how line spectra provide evidence for discrete energy levels in isolated atoms;		
1.13. use the relationship $hf = E_2 - E_1$ to solve problems;	An understanding of the existence of discrete electron energy levels in isolated atoms (for example, atomic hydrogen) and deduction of how this leads to spectral lines.	
1.14. distinguish between absorption and emission line spectra;	*Include absence/presence of emission of band of frequencies.*	
1.15. explain the wave-particle nature of matter;	Mention Quantum Physics.	
1.16. describe the evidence provided by electron diffraction for the wave nature of particles;		

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Particulate Nature of Electromagnetic Radiation (cont'd)		
Students should be able to:		
1.17. discuss interference and diffraction as evidence of the wave nature of electromagnetic radiation; and,		
1.18. use the relation for the de Broglie wavelength $\lambda = h/p$ to solve problems.		
2. Atomic Structure		
Students should be able to:		
2.1. describe the (Geiger-Marsden) α-particle scattering experiment;	Brief account of early theories of atomic structure, including those of Thomson, Bohr and Rutherford, should introduce this section. Interpretation of the results of Geiger Marsden experiment.	
2.2. discuss the evidence the (Geiger-Marsden) α-particle scattering experiment provides for the nuclear model of the atom;	*Large relative atomic volume compared to nucleus, positive charge on nucleus, mass of nucleus is approximately mass of atom.*	
2.3. describe Millikan's oil drop experiment; and,	Include details of Millikan's experimental design. Mention Stoke's law.	
2.4. discuss the evidence in Millikan's oil drop experiment for the quantisation of charge.	Include interpretation of graphical representation of results.	The experiment includes results for terminal velocity calculations, size of a drop.

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
3.	**Atomic Mass**		
Students should be able to:			
3.1.	define 'mass defect' and 'binding energy';	Nuclear Stability should be mentioned. Refer to Specific Objective 4.1.	
3.2.	calculate mass defect and binding energy in eV or joules;	Explanation of the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission.	
3.3.	use the relationship between energy and mass in nuclear reactions **$\Delta E = \Delta m c^2$** to solve problems;	Include calculation of energy release in fission, fusion or nuclear decay. Sketch a labelled diagram to illustrate a chain reaction.	
3.4.	use the atomic mass unit (u) as a unit of energy;	Brief account of early theories of atomic structure, including those of Thomson, Bohr and Rutherford, should introduce this section.	
3.5.	represent graphically the relationship between binding energy per nucleon and nucleon number;	Mention "Island of stability".	
3.6.	compare the values of binding energy per nucleon when undergoing nuclear fission or fusion;	Nuclear fusion is the process by which stars release energy and elements are made, for example, H -> He.	

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Atomic Mass (cont'd)		
Students should be able to:		
3.7. *illustrate by examples the conservation of nucleon number, proton number, energy and charge in nuclear reactions; and,*	*Naturally occurring processes such as spontaneous decay of radioactive elements, as well as nuclear fission and nuclear fusion should be referenced.*	
3.8. interpret nuclear reactions in the form: $^{1}_{1}\mathrm{H} + ^{2}_{1}\mathrm{H} = ^{3}_{2}\mathrm{He}$ $^{14}_{7}\mathrm{N} + ^{4}_{2}\mathrm{He} = ^{17}_{8}\mathrm{O} + ^{1}_{1}\mathrm{H}$	Briefly review isotopes.	
4. Radioactivity		
Students should be able to:		
4.1. relate radioactivity to nuclear instability;	Refer to Specific Objective 3.1.	
4.2. discuss the spontaneous and random nature of nuclear decay;	Refer to the random nature of radioactive decay from the fluctuations in count rate. Sketch the exponential nature of radioactive decay.	See Appendix II for suggested practical activity.
4.3. identify the origins and environmental hazards of background radiation;	The deleterious effects of high energy radiation on living tissue should be highlighted.	
4.4. describe experiments to distinguish between the three types of emissions from radioactive substances;		

SPECIFIC OBJECTIVES	EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Radioactivity (cont'd)		
Students should be able to:		
4.5. write equations for radioactive decay;		
4.6. interpret equations for radioactive decay;		
4.7. discuss the environmental hazards of radioactive emissions;	Special attention should be paid to potential nuclear biohazards in the Caribbean environment.	
4.8. discuss the necessary safety precautions for handling and disposal of radioactive material;	*Including the use of personal protective equipment (PPE), double hull ships and thick concrete as part of handling and disposal.*	
4.9. *explain*: (a) activity; (b) decay constant; and, (c) half- life;	$A = \lambda N$	See Appendix II for suggested practical activity.
4.10. use the law of decay $\frac{dN}{dt} = -\lambda N$ and $N = N_0 \exp(-\lambda t)$ to solve problems;		See Appendix II for suggested practical activity.
4.11. use the relation $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ to solve problems;	*Apply this equation to any similar process such as half thickness.*	
4.12. describe an experiment to determine the half-life of a radioactive isotope with a short half-life;	*Half life of Radon-220.*	*Simulations of the half life/half thickness using absorption of light through filters of varying thickness.*

SPECIFIC OBJECTIVES		EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Radioactivity (cont'd)			
Students should be able to:			
4.13.	discuss uses of radioisotopes as tracers for carbon dating and in radiotherapy; and,	The characteristics of an isotope which make it suitable for use in radiotherapy should be highlighted.	
4.14.	describe the operation of simple detectors.	(For example, G-M tube, spark counter, cloud chamber, ratemeter and scaler). *Include explanation of jet trail in upper atmosphere.*	

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives of this Module, teachers are advised to engage students in teaching and learning activities listed below.

1. Allow students to examine the line spectra of different substances to deduce information about energy levels.

2. Ask students to measure the absorption effect of different materials of different thickness (on the three types of radioactive emissions).

3. Allow students to test whether the water loss from a burette or a leaky soft drink bottle is exponential.

4. Have students perform a radioactive decay simulation using dice or coins.

5. *Have students simulate radioactive decay and absorption using photocell and filters.*

RESOURCES

Adams, S. and Allay, J.	Advanced Physics. Oxford: Oxford University Press, 2000.
Breithaupt, J.	Understanding Physics for Advanced Level, 4th Edition. Cheltenham: Nelson Thornes Publishers, 2000.
Crundell, M. and Goodwin, G.	Cambridge International AS and A Level Physics. London: Hodder Education, 2014.
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https://www.youtube.com/watch?v=uHu9aa0QDiE

https://www.youtube.com/watch?v=wiINTUZoAiw

https://www.youtube.com/watch?v=1uPyq63aRvg

https://www.youtube.com/watch?v=zDQH5x7svfg

https://www.youtube.com/watch?v=IXs61QYyU5o

https://www.youtube.com/watch?v=dNp-vP17asI

♦ OUTLINE OF ASSESSMENT

EXTERNAL ASSESSMENT ***(80%)***

Paper 01 (1 hour 30 minutes)	Forty-five multiple-choice items, 15 from each Module.	*40%*
Paper 02 (2 hours 30 minutes)	Three compulsory structured essay questions, one from each Module. Each question is worth 30 marks.	*40%*
Paper 032 ***For private candidates only (2 hours)***	*Three questions, one from each Module, as follows:* *(a) a practical-based question to be executed by the candidate;* *(b) a question based on data analysis; and* *(c) a data analysis/a planning and design exercise.*	*20%*

SCHOOL-BASED ASSESSMENT ***(20%)***

The School-Based Assessment will consist of selected practical laboratory exercises and one research project aligned to any Unit of the ***CAPE®*** *Sciences (Biology, Chemistry or Physics).*

MODERATION OF SCHOOL-BASED ASSESSMENT

The reliability (consistency) of the marks awarded by teachers on the School-Based Assessment is an important characteristic of high quality assessment. To assist in this process, the Council undertakes on-site moderation of the School-Based Assessment during Term 2/3. This is conducted by visiting External Moderators who will visit the centre.

Teachers are required to present to the Moderator ***ALL*** *Assessment Sheets (Record of Marks),* ***ALL*** *lab books, Mark Schemes and the project or evidence of the project. This is also required when marks are being transferred from one Unit/subject to another. Candidates marks are to be recorded on the School-Based Assessment Record Sheets which are available online via the* ***CXC®****'s website www.cxc.org.* ***All candidates' marks are to be submitted electronically*** *using the SBA data capture module of the Online Registration System (ORS).* ***Teachers are NOT required to submit to CXC® samples of candidates' work, unless specifically requested to do so by the Council.***

The Moderator will re-mark the skills and projects for a sample of five candidates using the guidelines below. This is ***only*** *applicable if the candidates selected in the sample are not using transferred marks for the projects.*

1. Candidates' total marks on the SBA are arranged in descending order (highest to lowest).

2. The sample comprises the work of the candidates scoring the:

   (a) highest Total Mark;

   (b) middle Total Mark;

   (c) lowest Total Mark;

   (d) mark midway between the highest and middle Total Mark; and,

   (e) mark midway between the middle and lowest Total Mark.

3. *The Moderator will also re-mark the laboratory practical activities for the other skills (ORR, AI and PD) that are recorded in the lab books for the five candidates in the sample.*

4. *The Moderator will re-mark the skills for **ALL** the candidates where the total number of candidates is five or less than five.*

5. *The Moderator will provide teachers with feedback. Please note that Candidates' marks may be adjusted as a result of the moderation exercise.*

*The Moderators are required to submit the moderated marks (Moderation of SBA Sample Form), the Moderation Feedback Report and the External Moderator Report to the Local Registrar by **30 June** of the year of the examination.*

*A copy of the Assessment Sheets and all candidates' work must be retained by the school for t**hree months** after the examination results are published by **CXC®**.*

ASSESSMENT DETAILS

Each Unit of the syllabus is assessed as outlined below.

<u>External Assessment by Written Papers (*80*% of Total Assessment)</u>

1. Paper 01 consists of 45 multiple-choice items. There will be a combined question paper and answer booklet for Paper 02.

2. S.I. Units will be used on all examination papers.

3. The use of silent, non-programmable calculators will be allowed in the examination. Candidates are responsible for providing their own calculators.

4. Data not specifically required to be recalled, defined or stated will be made available for this examination.

Paper 01 (1 hour 30 minutes – *40%* of Total Assessment)

1. **Composition of the Paper**

   This paper will consist of *45* multiple-choice items, *15* from each Module. All questions are compulsory and knowledge of the entire Unit is expected. The paper will assess the candidate's knowledge across the breadth of the Unit.

2. **Mark Allocation**

   The paper will be worth 45 marks, which will be weighted to 90 marks.

3. **Question Type**

   Questions may be presented using diagrams, data, graphs, prose or other stimulus material.

Paper 02 (2 hours 30 minutes – *40%* of Total Assessment)

1. **Composition of Paper**

   This paper will consist of three questions, one from each module. *All questions are compulsory.*

   Questions on this paper test all three skills KC, UK and XS.

   Knowledge of the entire Unit is expected.

2. **Mark Allocation**

   The paper will be worth 90 marks, 30 marks per question *and distributed across the question sub-parts.*

3. **Question Type**

   Questions will be presented in *structured essay format. The questions will test the skills of KC, UK and XS.* Answers are to be written in the question booklet.

School-Based Assessment (*20%*)

School-Based Assessment is an integral part of student assessment in the course covered by this syllabus. It is intended to assist students in acquiring certain knowledge, skills and attitudes that are associated with the subject. *Students are encouraged to work in groups.*

During the course of study for the subject, students obtain marks for the competence they develop and demonstrate in undertaking their School-Based Assessment assignments. These marks contribute to the final marks and grades that are awarded to students for their performance in the examination.

School-Based Assessment provides an opportunity to individualise a part of the curriculum to meet the needs of students. It facilitates feedback to the student at various stages of the experience. This helps to build the self- confidence of students as they proceed with their studies. School-Based Assessment also facilitates the development of the critical skills and abilities emphasised by this **CAPE®** subject and enhances the validity of the examination on which candidate performance is reported.

School-Based Assessment, therefore, makes a significant and unique contribution to both the development of relevant skills and the testing and rewarding of students for the development of those skills.

The Caribbean Examinations Council seeks to ensure that the School-Based Assessment scores that contribute to the overall scores of candidates are valid and reliable estimates of accomplishment. The guidelines provided in this syllabus are intended to assist in doing so.

Award of Marks

The following skills will be assessed through the laboratory practical activities:

1. Analysis and Interpretation;
2. Manipulation and Measurement;
3. Observation, Recording and Reporting; and,
4. Planning and Designing.

The candidates are also required to do an investigative project in any one Unit of the ***CAPE®*** *Sciences. The table below shows how the marks are allocated for each Unit.*

Table 1
School-Based Assessment Skills

Skill	**Unit 1**	**Unit 2**
Observation, Recording and Reporting	*12*	*12*
Manipulation and Measurement	*12*	*12*
Analysis and Interpretation*	*12*	*12*
Planning and Designing*	*12*	*12*
TOTAL	*48 marks*	*48 marks*

***Includes *an* investigative project**

Teachers are required to provide criteria which clearly indicate how they award marks.

Please note that candidates will be required to do one investigative project in any Unit of any of the **CAPE®** Sciences (Biology, Chemistry or Physics) *in the first sitting, and can* use that mark for the other Units of the Sciences. So for example, a candidate may do the investigative project in Unit 2 Physics *in the first sitting*, and then (transfer) use the AI and PD marks for Unit 1 Physics, Units 1 and 2 Chemistry and Units 1 and 2 Biology.

Each Module will carry a maximum of *16* marks.

Each candidate's total School-Based Assessment mark for any Unit should be divided in three and allocated to each Module equally.

Fractional marks should not be awarded. Wherever the Unit mark is not divisible by three, then

(a) when the remainder mark is 1, it should be allocated to Module 1; and,

(b) when the remainder is 2, one of the marks should be allocated to Module 2 and the other mark to Module 3.

Appropriate practical exercises for assessing any skill may be selected from any Module in the relevant Unit.

♦ INVESTIGATIVE PROJECT

Objectives of the Investigative Project

The Investigative Project must focus on a challenge to be addressed within the environment or society. *On completion of the Investigative Project students should:*

1. *Appreciate the use of the scientific method for discovery of new knowledge and to the solution of problems;*
2. *Communicate accurately and effectively the purpose and results of research;*
3. *Apply experimental skills and theory to the solution of problems; and,*
4. *Synthesise information based on data collected.*

Students are encouraged to work collaboratively. Where collaborative work is done, group sizes must not exceed six (6) persons per group. The teacher is expected to use the group mark for the project and add it to the marks for the other skills for each individual candidate within the group.

CRITERIA FOR ASSESSING INVESTIGATIVE SKILLS

A.	**PLANNING AND DESIGN**			
	• **HYPOTHESIS**		**1**	
	• **AIM**		**1**	
	• **MATERIALS AND APPARATUS**		**1**	
	• **VARIABLES STATED** - Controlled - Manipulated - Responding	 1 1 1	**3**	

	• **METHOD**		2	
	- Clearly outlining how manipulated variable will be changed and measured.	1		
	- Clearly outlining how the responding variable will be measured.	1		
	• **RESULTS**		**2**	
	- Expected Results	1		
	- Treatment of Results	1		
	• **PRECAUTIONS AND LIMITATIONS/ASSUMPTIONS**		**2**	
	- Two or more stated	2		
	- Anyone stated	1		
	TOTAL			**(12)**

B.	**ANALYSIS AND INTERPRETATION**			
	• **RESULTS**		**2**	
	- Complete set of results from quantities mentioned in method.	2		
	• **DISCUSSION**		**4**	
	- Complete set of calculations or statement of observations or trends.	2		
	- Interpretations of calculated values, observations or trends linked to data in results.	2		
	• **LIMITATIONS AND SOURCES OF ERROR**		**2**	
	- Limitation stated	1		
	- Source of error stated	1		
	• **REFLECTIONS**		**3**	
	- Relevance of experiment to real life.	1		
	- Impact of knowledge gained from experiment.	1		
	- How can experiment be changed and improved.	1		
	• **CONCLUSION**			
	- Clearly stated and related to Aim in PD.	1	**1**	
	TOTAL			**(12)**

SCHOOL-BASED ASSESSMENT – GENERAL GUIDELINES FOR TEACHERS

1. Each candidate is required to keep a laboratory workbook which is to be marked by the teacher. Teachers are also expected to assess candidates as they perform practical exercises in which Manipulation and Measurement skills are required.

2. A maximum of two skills may be assessed by any one experiment.

3. The mark *awarded* for each skill assessed by practical exercises should be the average of at LEAST TWO separate assessments. *The average mark for AI and PD* ***must*** *include the mark from the investigative project.* In each Unit, total marks awarded at the end of each Module will be 0 to *16.*

4. The maximum mark for any skill will be *12.* The mark *awarded* for each skill assessed by practical exercises should be the average of at LEAST TWO separate assessments. In each Unit, total marks awarded at the end of each Module will be 0 to *16.*

5. Candidates who do not fulfil the requirements for the School-Based Assessment will be considered absent from the whole examination.

Candidates' laboratory books should contain all practical work undertaken during the course of study. Those exercises which are selected for use for the School-Based Assessment should be clearly identified. The skill(s) tested in these selected practical exercises, the marks assigned and the scale used must be placed next to the relevant exercises.

♦ REGULATIONS FOR PRIVATE CANDIDATES

1. Candidates who are registered privately will be required to sit Papers 01, 02 and 032. Detailed information on Papers 01, *02 and 032* is given on page 70 of this syllabus.

2. Paper 032 will constitute *20 per cent* of the overall assessment of the candidates' performance on the Unit.

♦ REGULATIONS FOR RESIT CANDIDATES

1. *Candidates may reuse any moderated SBA score within a two-year period. In order to assist candidates in making decisions about whether or not to reuse a moderated SBA score, the Council will continue to indicate on the preliminary results if a candidate's moderated SBA score is less than 50 per cent in a particular Unit.*

2. *Candidates reusing SBA scores should register as "Re-sit candidates" and must provide the previous candidate number when registering.*

3. *Resit candidates must complete Papers 01 and 02 of the examination for the year in which they register.*

♦ ASSESSMENT GRID

The Assessment Grid for each Unit contains marks assigned to papers and to Modules and percentage contribution of each paper to total scores.

Paper	***Module 1***	***Module 2***	***Module 3***	***Paper Total (Weighted Total)***	***% Weighting of Papers***
Paper 01	*15* (30)	15 (30)	15 (30)	45 (90)	40
Paper 02	*30*	*30*	*30*	*90*	40
Paper 031	*16 (15)*	*16 (15)*	*16 (15)*	*48 (45)*	*20*
Paper 032	*15*	*15*	*15*	*45*	*20*
Module Totals	60	60	60	180 (225)	*100*
Weighted Module	75	75	75	225	*100*

♦ GLOSSARY OF EXAMINATION TERMS

KEY TO ABBREVIATIONS

KC – Knowledge and Comprehension
UK – Use of Knowledge
XS – Experimental Skills

WORD	DEFINITION	NOTES
Analyse	examine in details.	(UK)
Annotate	requires a brief note to be added to a label.	(KC)
Apply	requires the use of knowledge or principles to solve problems and to explain or predict behaviours in other situations.	(UK)
Assess	requires the inclusion of reasons for the importance of particular structures, relationships or processes.	(UK)
Calculate	requires a numerical answer for which working must be shown.	(UK)
Cite	requires a quotation or a reference to the subject.	(KC)
Classify	requires a division into groups according to observable and stated characteristics.	(UK)
Comment	requires the statement of an opinion or a view, with supporting reasons.	(UK)
Compare	requires a statement about similarities and differences.	(UK)

WORD	DEFINITION	NOTES
Construct	requires either the use of a specific format for the representations, such as graphs, using data or material provided or drawn from practical investigations, or the building of models or the drawing of scale diagrams.	(UK)
Deduce	implies the making of logical connections between pieces of information.	(UK)
Define	requires a formal statement or an equivalent paraphrase, such as the defining equation with symbols identified.	(KC)
Demonstrate	show; requires an algebraic deduction to prove a given equation.	(KC/UK)
Derive	implies a deduction, determination, or extraction of some relationship, formula or result from data by a logical set of steps.	(UK)
Describe	requires a statement in words (using diagrams where appropriate) of the main points of the topic. This can also imply the inclusion of reference to (visual) observations associated with particular phenomena or experiments. The amount of description intended should be interpreted from the context.	(KC)
Design	includes planning and presentation with appropriate practical detail.	(UK/XS)
Determine	implies that the quantity concerned should not be measured directly but should be obtained by calculation or derivation.	(UK)

WORD	DEFINITION	NOTES
Develop	implies an expansion or elaboration of an idea or argument, with supporting evidence.	(UK)
Differentiate or Distinguish	requires a statement and brief explanation of the differences between or among items which can be used to define the items or place them into separate categories.	(KC/UK)
Discuss	requires a critical account of the points involved in the topic.	(UK)
Draw	requires a line representation of the item, showing accurate relationships between the parts.	(KC/UK)
Estimate	implies a reasoned order of magnitude, statement or calculation of the quantity concerned, using such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included.	(UK)
Evaluate	requires the weighing of evidence and judgements based on stated criteria.	(UK)
Explain	implies that a definition or a description should be given, together with some relevant comment on the significance or context of the term or situation concerned. The amount of supplementary comment intended should be interpreted from the context.	(KC/UK)
Find	requires the location of a feature or the determination as from a graph.	(KC/UK)

WORD	DEFINITION	NOTES
Formulate	implies the articulation of a hypothesis.	(UK)
Identify	requires the naming of specific components or features.	(KC)
Illustrate	implies a clear demonstration, using appropriate examples or diagrams.	(KC)
Interpret	explain the meaning of.	(UK)
Investigate	requires the careful and accurate gathering and analysis of data concerning a given topic (numerical or otherwise).	(UK/XS)
Label	implies the inclusion of names to identify structures or parts as indicated by pointers.	(KC)
List	requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.	(KC)
Measure	implies that the quantity concerned can be directly obtained from a suitable measuring instrument.	(UK/XS)
Name	requires only the identification of the item.	(KC)
Note	implies recording observations.	(KC/XS)
Observe	implies the direction of attention to details which characterise reaction or change taking place and examination and scientific notations.	(UK/XS)

WORD	DEFINITION	NOTES
Plan	implies preparation to conduct an exercise or operation.	(XS)
Predict	implies the use of information to arrive at a likely conclusion or the suggestion of possible outcomes.	(UK)
Record	implies an accurate account or description of the full range of observations made during given procedure.	(XS)
Relate	implies the demonstration of connections between sets of facts or data.	(UK)
Show	See Demonstrate.	
Sketch	in relation to graphs, implies that the shape or position of the curve need only be qualitatively correct and depending on the context, some quantitative aspects may need to be included. In relation to diagrams, implies that a simple, freehand drawing is acceptable, provided proportions and important details are made clear.	(KC/UK/XS)
State	implies a concise statement with little or no supporting argument.	(KC)
Suggest	could imply either that there is no unique response or the need to apply general knowledge to a novel situation.	(UK)
Test	implies the determination of a result by following set procedures.	(UK/XS)
Use	implies the need to recall and apply knowledge or principles in order to solve problems and to explain or predict behaviours.	(UK)

♦ PRACTICAL ACTIVITIES

The teacher is urged to reinforce the relevant approved codes and safety practices during the delivery of all practical activities in the Module.

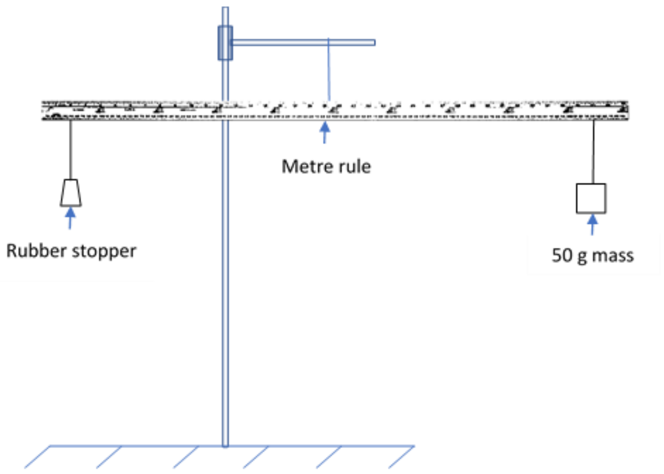
ARCHIMEDES' PRINCIPLE

Refer to Unit 1, Module 1, Specific Objective 4.1 and 4.4

Aim: To determine the upthrust on an object totally immersed in water.

The balance you will use, illustrated in Fig. 1, consists of a metre rule suspended by a thread from a retort stand and clamp.

Method: First, adjust the position of the thread on the rule so that it balances horizontally on its own with no other masses suspended. Record the position of the thread.



Take the RUBBER stopper provided and suspend it by a thread close to one end of the metre rule. Now balance the rule by suspending a 100g mass by a thread on the other side of the rule. The rule should be horizontal when balanced. Record the point of suspension of the 100g mass.

When the rule is balanced, the principle of moments states that the sum of the moments of forces about the point of suspension in the clockwise direction is equal to the sum of the moments in the anticlockwise direction.

Draw a diagram indicating forces acting on the rule. Write an equation for the balance of the moments of the forces. Hence, determine the mass of the stopper.

Q.1 Why balance the metre rule with nothing suspended at the start?

Leaving the stopper suspended from the same point, place a beaker of water below the stopper and arrange it so that the stopper is completely immersed in water. Now find a new position for suspension of the 100 g mass so that the rule is again balanced. Be careful to see that the stopper does not touch the edge or bottom of the beaker. All the results should be carefully tabulated.

PRACTICAL ACTIVITIES (cont'd)

From the above readings calculate the "apparent weight" of the stopper while it was immersed in water. The loss of weight is due to the upthrust of the water or "buoyancy force". Archimedes Principle shows that: upthrust = weight in air – apparent weight in water (assuming air gives negligible upthrust). Thus, find the upthrust on the stopper.

Q.2 Does it matter how far below the surface of the water you immerse the stopper, providing you do not touch the bottom? Why?

A. Determination of upthrust on an object floating in water

Place the CORK stopper provided in a beaker of water. Note that since the cork is floating it is only partially immersed.

Q.3 What must the relation be between the upthrust on the stopper and its weight? What is this upthrust in your case? You may use the commercial balance to determine the mass of the cork.

B. Determination of the weight of water displaced by the rubber and cork stoppers

For these measurements a displacement measuring vessel (d.m.v.) is used. Place the d.m.v. on the shelf over the sink. Fill it with water until water runs out of the spout into the sink. Wait a minute or so until the water has stopped draining from the spout then place an empty beaker under the spout and carefully lower the rubber stopper into the displacement measuring vessel (d.m.v). Find the weight of the displaced water collected in the beaker. Again, wait until the water has completely stopped draining from the spout. Repeat the above procedure with the cork and find the weight of water displaced by the floating cork in the beaker.

Compare the weights of displaced water with the upthrust found in the corresponding cases in A and B above.

PRACTICAL ACTIVITIES (cont'd)

THE DISTRIBUTION OF ERRORS IN PHYSICAL MEASURMENTS

Refer to Unit 1, Module 1, Specific Objective 1.8

Aim: To examine how errors are distributed in measurements of a physical quantity.

Method: The experiment is divided into three sections.

A. The Normal Distribution

Attach a plain sheet of paper to the soft board mounted on the wall. Make a suitable mark or marks on the paper at the level of the middle of the paper. Stand at a distance from the board and throw darts at the level on the paper where your estimate your eye level to be. According to your throwing ability several trial throws may be necessary before the most suitable throwing distance is found.

Make a total of 100 throws. More than one sheet of paper may be used (if necessary) as long as the same reference marks are used to position each. Be careful, however, otherwise your graph will be poor.

Divide the vertical range of the points on the paper(s) into 10 equal sections of the suitable width, say, for example, 2 cm. (See Figure 1). Count the number of points in each section and tabulate the results. A few points may be below section 1 or above section 10 but they should NOT be discarded. Label these sections 0, 1,….. (Note: Use a big enough sheet of paper so that your throws land on paper).

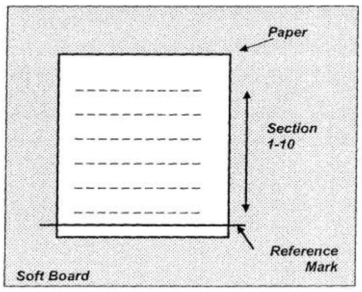


Fig. 1

Draw a histogram illustrating the number of times, n_i, that points occur in a certain section, x_i (Figure 2). Note the following about the histogram:

- Each number 0, 1……….10, on the x_i axis, is at the centre of a section, for example, 9 is at the centre of section 9.
- The histogram must show a section with n_i at both the start and end.
- Connect the mid-points by a smooth curve as shown. This need not go through all the midpoints.

PRACTICAL ACTIVITIES (cont'd)

Random errors should cause the histogram to approximately follow a bell-shaped curve called the **Normal Distribution**.

Now calculate the mean value of the measurements, $\bar{x}$, using the formula:

$\bar{x} = \frac{1}{N} \sum n_i x_i$ where N=total number of points and x_i can have 1 – 10. Mark the mean value $\bar{x}$ on the histogram.

Finally, note on your paper where the mean value x_i is located and reposition your paper on the soft board. Use the meter rule provided to obtain the height of the mean value x_i above the floor. Example: Suppose $\bar{x}$ = 5.2 locate the height of section 5.2 above the ground level. (It would be about 150 – 22 cm). Note that 5.0 refers to the midpoints of section 5 and 0.2 is 0.2 x the distance between the midpoints of sections 5 and 6.

Also measure directly the height of your eyes above the floor.

Comment on your results.

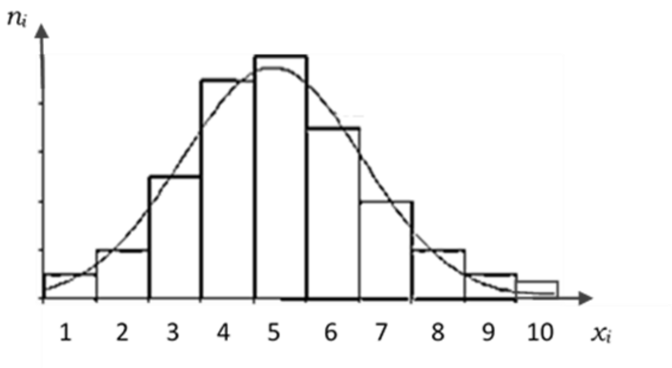


Fig. 2

B. Standard Deviation

The degree to which numerical data are scattered about an average value is called the dispersion of the data. Common measures of the dispersion are the mean deviation and the standard deviation may be used.

If data are grouped such that x_1, x_2, ….. occur with frequencies n_i x_i the following form of standard deviation may be use.

$$\sqrt{\frac{\sum n_1 (x_1 - \bar{x})^2}{N}}$$

Small values of standard deviation indicate that there is not much dispersion or scatter of the data.

(i) For the data obtained in part (A) of the experiment calculate the standard deviation.

PRACTICAL ACTIVITIES (cont'd)

(ii) Your experimental value for your eye level is, therefore, $\bar{x} \pm s$. Express this in term of heights. (Remember you have already found $\bar{x}$ from (A). Example: Suppose s = 1.4. If each section in your experimental sheet was 1.5 cm wide, then s = 1.4 implies 1.4 x 1.5=2.1 cm.

Your experimental value for your eye level is $\bar{x}$ in cm $\pm$ s in cm.

C. Repeat the experiment by standing at a longer distance (½ to 2 times your previous throwing distance) away from the board. You may have to use more sheets firmly fastened together so that all your throws land on the sheets. You may also have to divide your sheets into more sections of approximately 2 cm to cover all your points.

Plot a histogram of the new results and calculate $\bar{x} \pm$ s in cm again.

Comment on your results.

STATIONARY WAVES

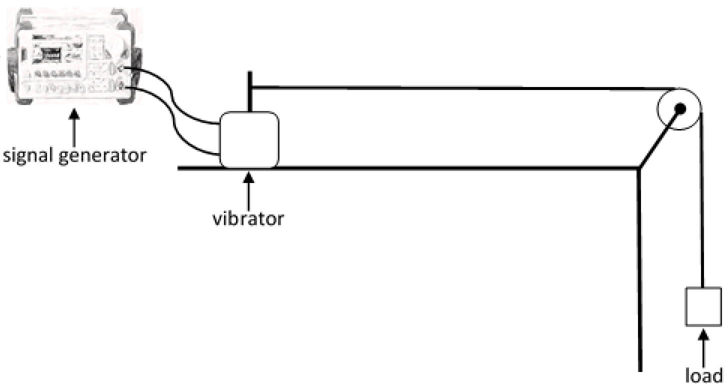
Refer to Unit 1, Module 2, Specific Objective 2.9

Aims: (a) To investigate the properties of stationary waves.
(b) To measure the wavelength and frequency of microwaves.
(c) To estimate the velocity of sound in free air.

Method:

A. Stationary waves on a string

To signal generator

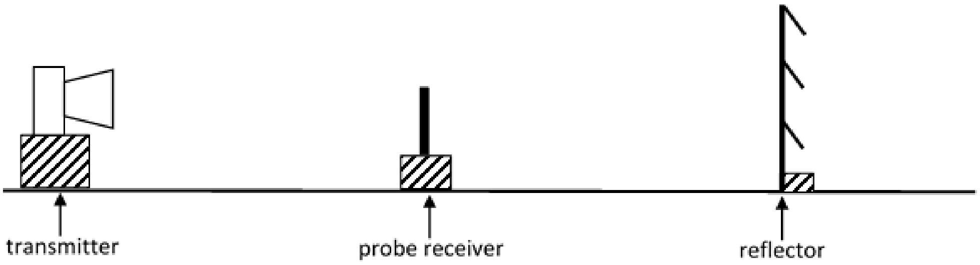


Turn on the signal generator and find the frequency required to produce a one-loop standing wave. Then find other frequencies which give 2 loops, 3 loops ………….

By means of a linear graph use your results to find the velocity of the waves on the string.

PRACTICAL ACTIVITIES (cont'd)

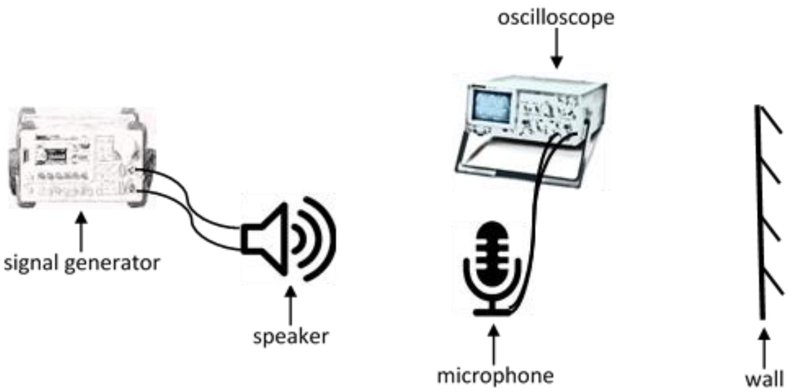
B. Stationary Microwaves



By moving the probe receiver find a number of consecutive nodes and hence measure the wave length. Explain why this is better than trying to find the distance between two nodes. Use c=f**λ** to find the frequency of the microwaves
($c = 3.00 \times 10^8$ ms^{-1})

C. Stationary Sound Waves

(Note that this set-up will only yield an approximate value for the wavelength)



Find the distance between two consecutive nodes and, hence, find the wavelength of the sound. Find v from v=f**λ** . Repeat the experiment for a different frequency.

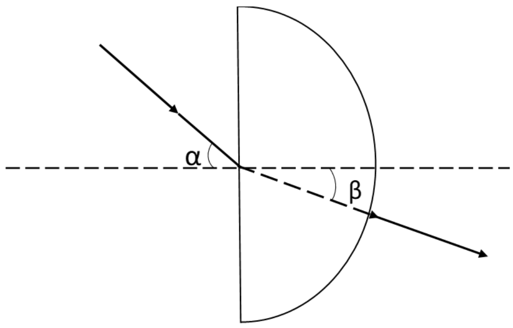
REFRACTION AND THE CRITICAL ANGLE

Refer to Unit 1, Module 2, Specific Objective 2.23 and 2.25

Aim: To investigate the refraction of light at an air/Perspex boundary and use the data obtained to find the critical angle for light traveling from Perspex to air.

Method: Use pins to trace the passage of light through a semi-circular block of perspex for various angles of incidence. Note that the light is incident on the flat face and you must look at the alignment of the pins through the curved surface. [If available a light box could be used to trace the rays instead of pins]

PRACTICAL ACTIVITIES (cont'd)



It is important that you take care in setting up the apparatus: if the incident ray does not go through the centre of the circle then the refracted ray will bend again at the curved surface.

Plot a graph of β against α and extend the graph to find the value of β when α is 90°.

Also plot a linear graph with the same data and obtain a second value for the critical angle.

In your summary comment on the relative merits of the two alternative ways of handling the data.

LATENT HEAT

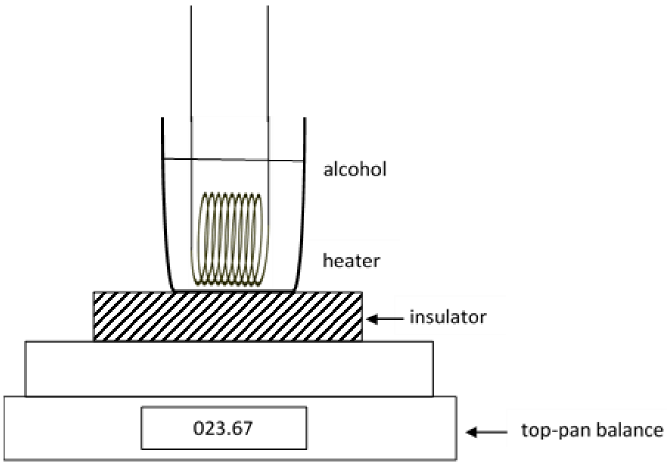
Refer to Unit 1, Module 3, Specific Objective 2.7

Aim: To determine:

(i) the specific latent heat of vaporisation of a liquid by an electrical method: and

(ii) the specific latent heat of fusion of ice by the method of mixtures.

Method: (a) The more sophisticated apparatus in the text may not be available, in which case the apparatus shown below can be used. The principle is the same. The energy supplied after the liquid has started to boil is equal to the heat required to boil off a mass n of liquid plus the heat to the surroundings, H, that is, $VIt = mL+H$.



If the procedure is repeated with different values of V and I but with the same time, t, then the last term may be eliminated by subtraction. (Explain why the heat loss is the same in both cases, provided the time is the same).

(b) A Styrofoam cup, which has a negligible heat capacity, is to be used as the calorimeter.

Carefully consider the possible errors in this method before starting. A good way of reducing the effect of the surroundings is to start the experiment with the water in the cup above room temperature and add small pieces of dried ice until the temperature is same amount below room temperature.

STRETCHING GLASS AND RUBBER

Refer to Unit 1, Module 3, Specific Object 6.12

Aims: (a) To compare the breaking stress of glass with that of rubber.
(b) To investigate the behaviour of rubber when it is loaded and unloaded.

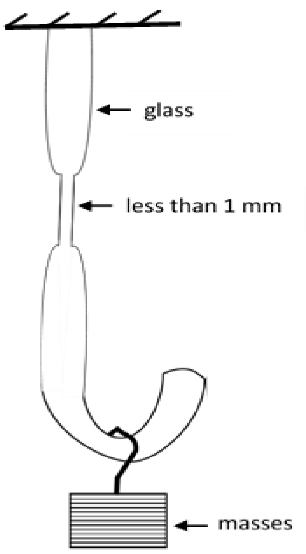
Method: **Stretching glass could be dangerous so this part of the experiment will be performed by the laboratory assistant. Warning: BE VERY CAREFUL with the glass. Do not have your eyes near it at any time.**

You will be provided with a piece of rubber band. Add loads to it until it breaks and make other necessary measurements so that you can work out the breaking stress.

Using a similar piece of rubber to that in (a) add masses in 100 g increments until the load is 300 g less than the maximum. For each load measure the extension of the rubber. Continue measuring the extension as the load is removed. Plot a graph to illustrate your results.

Note: It is best not to measure the length of the rubber between the support and the knot because the rubber might slip. Instead use two fine ink marks drawn on the band.

(Preparation: Glass rod is heated and a hook made. Then it is heated in the centre and stretched to produce a thin section.)



THE MAGNETIC FIELD OF A SOLENOID

Refer to Unit 2, Module 1, Specific Objective 5.3

Aim: To investigate the factors affecting the magnetic flux density of a solenoid.

This experiment uses a Hall probe and a direct current flowing in the solenoid. The reading on the voltmeter connected to the probe is directly proportional to B. Sometimes, the meter is already calibrated in mT but usually a conversation factor is used.

Method:

(a) Two of the solenoids provided have the same area and length but a different number of turns (which is marked on them). Ensuring that the currents are the same in each by connecting them in series, investigate how B at the centre of the solenoid depends on n, the turn concentration, for at least three different current values.

Also move the probe from side to see how the field varies across the solenoid.

(b) Choose a pair of solenoids with the same number of turns per unit length, n, but different areas and investigate how B depends on the area of cross-section when the other factors are kept constant. Repeat with different currents.

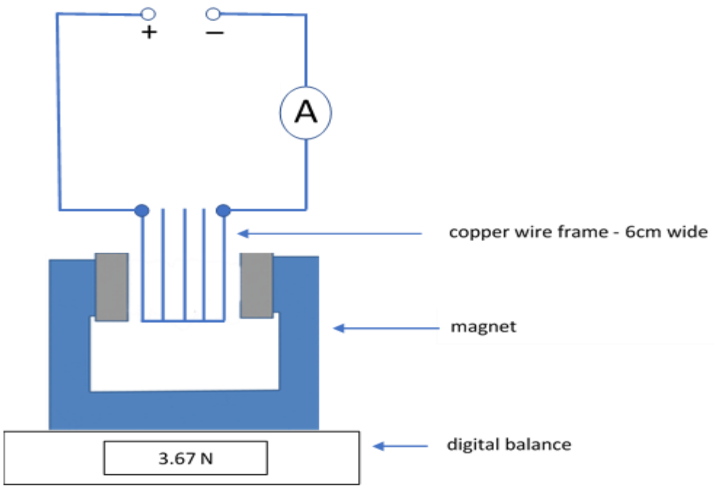
(c) Investigate how the field at the centre of a solenoid depends on the current flowing in it.

Find B at various positions along the solenoid axis and plot a graph to display your results.

FORCE ON CURRENT-CARRYING CONDUCTOR

Refer to Unit 2, Module 1, Specific Objective 6.3

Aim: To test the relationship F=BIL for the force on a current-carrying conductor.



Method: Set up the apparatus shown above so that an upward force will be exerted on the wire when the current is flowing. Before switching on, press the tare bar on the balance to set the reading at zero.

Since the conductor is forced upward, an equal and opposite force will push the magnet down (Newton III) so the force on the wire may be calculated from the balance reading.

According to the texts, the force on a current-carrying wire AT RIGHT ANGLES to a uniform field is:

(a) proportional to the current, I, flowing in the conductor; and,

(b) proportional to the length, L, of the conductor.

Use this apparatus to test these two statements.

Also use both sets of data to find the proportionally constant B (known as the flux density of the uniform field) in the relationship, F=BIL.

THE LAWS OF ELECTROMAGNETIC INDUCTION

Refer to Unit 2, Module 1, Specific Objective 7.4

Aim: To test the Faraday relationship: induced e.m.f. equals the rate of change of magnetic flux linkage.

$$E = N A\frac{dB}{dt}$$

Theory

Flux linkage = NAB where N is the number of turns in the secondary coil, A is the area of the coil and B is the magnetic flux density produced by the primary coil.

To investigate the relationship above, two of the quantities must remain constant while the third is varied. (Note that the rate of change of B depends on the rate of change of I which is proportional to the frequency).

Apparatus: Pair of solenoids of square cross-section; one has twice the area of the other.

Signal generator: use the low impedance output and set the frequency on the 100 to 1000 Hz range.

Cathode ray oscilloscope for measuring the peak induced voltage.

A.C. ammeter to ensure that the current is constant (so that B is constant).

Long length of insulated copper wire to wind various numbers of turns on the solenoids.

PRACTICAL ACTIVITIES (cont'd)

THE GAIN OF AN INVERTING AMPLIFIER

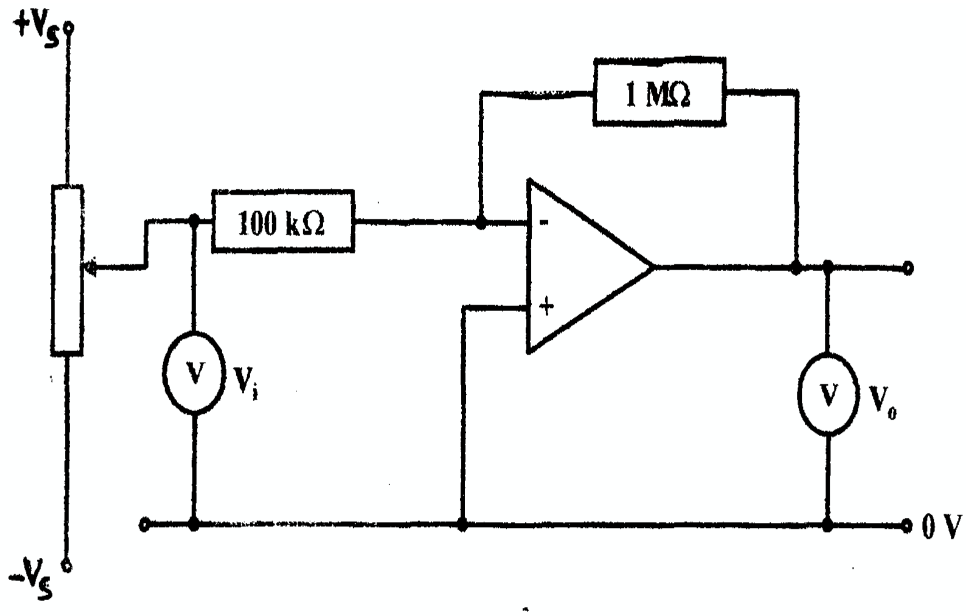
Refer to Unit 2, Module 2, Specific Objective 4.11

Aim: To plot the transfer characteristic of an op. amp. connected as an inverting amplifier and measure its gain.

Method: Set up the circuit shown. Use one of the potential dividers provided on the op. amp. Board to control the input and digital voltmeters to monitor the input and the output p.d.'s.

Use the data collected to plot the transfer characteristic (V_o against V_i).

Find the gain of the amplifier from a second graph of the linear region only and compare the value with the theoretical value.



THE FREQUENCY RESPONSE OF A NON-INVERTING AMPLIFIER

Refer to Unit 2, Module 2, Specific Objective 4.11

Aim: To investigate how the gain of an amplifier changes when the frequency is increased.

Method: Using one of the blue op. amp. circuit boards, set up a non-inverting amplifier with a feedback resistance of 1000 **kΩ** and input resistance of **10kΩ**. Theoretically the gain should be 101 but, given the tolerance of the resistors, it can be taken as 100 for the purposes of this investigation.

Use an audio-frequency signal generator to provide a sinusoidal input and monitor both the input signal and the output using a double beam oscilloscope.

Note:

1. Make sure that both the gain controls of the c.r.o. are set on calibrate before taking measurements.

2. A quick way to check that the gain of the non-inverting amplifier is 100 is to set the gain (volts per division) for the output trace on a value 100 times bigger than that for the input trace. If the gain is 100 the two traces will then be the same size.

3. If the output is saturated the input signal may be reduced using the volume control and/or the attenuator control.

Repeat the investigation using a gain of about 1000 and plot log graphs to display the results of your investigation.

RADIOACTIVITY

Refer to Unit 2, Module 3, Specific Objective 4.2

Aims:
(a) To show that radioactive decay is a random process.
(b) To investigate the decay of thoron (radon-220) gas.

Method:
(a) Radium-226 has a half-life of 1620 years and so its activity cannot change appreciably during the course of an experiment.

Set the scaler-timer on "rate" and "continuous". Bring the radium source close to the G-M tube and leave it fixed in this position. Obtain a series of readings for the count-rate and plot them on a histogram to show their distribution about the mean value.

(b) Thoron gas is an isotope of radon $^{220}_{86}Rn$ produced in the radioactive series that starts with a long half-life isotope of thorium $^{232}_{90}Th$. All the other nuclides in the series have half-lives either much longer or much shorter than thoron gas so they do not contribute to the activity of the sample of the gas. The thorium is in powdered form in a sealed plastic bottle and the thoron gas is produced in the air space above the powder.

Set the scaler timer to "count". Find the background count-rate by switching on the counter for 100s. This value is used to correct the count-rates in the thoron decay.

Using two-tubes with one-way valves, the radon gas can be transferred into a bottle containing the end of a Geiger- Muller tube by squeezing the thorium bottle a few times. The whole system is sealed and should be quite safe but to make sure, keep all the windows open and **if any leak occurs, evacuate the room, and report to your teacher or the laboratory technician immediately.**

When the gas is transferred, switch on the counter and start timing. Record the count every 20 seconds for about 5 minutes. From these readings the number of decays in each 20s interval can be found and hence the count-rate at
10s, 30s, 50s.

Plot a graph to show how the activity varies with time and use the graph to obtain a value for the half-life of the radon.

The activity of the thoron (radon-220) will decay exponentially so you should be able to derive an equation suitable for plotting a linear graph from which the half-life may also be found. By selecting the part of the graph before the decay gets too random a more precise value than the first one may be obtained.

RADIOACTIVE DECAY SIMULATION

Refer to Unit 2, Module 3, Specific Objective 4.9

Aim: To verify some of the principles of radioactivity using dice as simulated atoms.

Method: Throw the entire set of 500 cubes into the large tray provided and remove every cube with a six facing up. It may be necessary to carefully move some of the cubes so that they are not stacked on top each other. Place the remaining cubes into the original container and repeat the entire process until less than 10 cubes are left. Plot the total number left for each trial against the throw number. You should remember that the curve should be smooth. It does not need to go through every point.

Also, use the data to plot a linear graph. From each graph determine the half-life of your cubes in terms of throws and, from this, find the decay constant.

How does the decay constant compare with the probability of an individual cube "decaying"?

HALF-LIFE OF A CAPACITOR DISCHARGE

Refer to Unit 2, Module 3, Specific Objective 4.10

Aim: To use the concept of half-life to accurately measure a large capacitance.

Theory:

During discharge, the p.d. across a capacitor varies exponentially:

$$\mathbf{V = V_o \exp(-t / RC)}$$

Use this equation to derive the relationship between RC and the half-life of the discharge (that is, the time it takes for the p.d. to fall $^1/_2$ $\mathbf{V_0}$.

Method: You will be provided with a set of 1% tolerance resistors and a high impedance (digital) voltmeter. Design a suitable circuit and have the supervisor check it before switching on.

Use the circuit to find the average time it takes for the p.d. to reduce to half its initial value. Vary the value of R to obtain sufficient data to plot a suitable linear graph. Use the graph to determine the given capacitance.

THE MAGNETIC FIELD LINES AROUND CURRENT CARRYING SOLENOID.

Refer to Unit 2 Module 1 Specific Objective 6.7

Objective:
To observe the magnetic field lines around current carrying solenoid.

Theory:

1. A coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called a solenoid.

2. The pattern of the magnetic field lines around a current-carrying solenoid is illustrated in Fig.1.

3. The pattern of the field is similar to magnetic field around a bar magnet. One end of the solenoid behaves as a magnetic north pole, while the other behaves as the south pole.

4. The field lines inside the solenoid are in the form of parallel straight lines. This indicates that the magnetic field is the same at all points inside the solenoid. That is, the field is uniform inside the solenoid.

Apparatus:
A cardboard, a circular coil, a battery, a switch and iron filings.

Procedure:

1. Take a cardboard with two holes in it.

2. Pass a circular coil having large number of turns through these holes such that half the coil is above it and the remaining part is below the cardboard.

3. Connect the free ends of the coil to a battery, and a switch in series.

4. Sprinkle iron filings on the cardboard and on the switch.

5. Tap the cardboard few times and observe the pattern of iron filings that is formed on cardboard.

Observations:

1. You will observe that the field lines inside the solenoid are in the form of parallel straight lines.

2. When the current is reduced to 0, magnetic field intensity around the solenoid reduces to 0.

3. When we increase the amplitude of 'current' or the 'coil turn density', the magnetic field intensity around the solenoid increases.

4. When we reverse the direction of current the polarity of the solenoid is also reversed.

cdac.olabs.edu.in,. (2012). The magnetic field lines around current carrying solenoid.. Retrieved 30 May 2017, from cdac.olabs.edu.in/?sub=74&brch=9&sim=91&cnt=6

♦ LIST OF MINIMUM LABORATORY REQUIREMENTS

(Recommended quantity per 15 candidates)

QTY	ITEM
Mechanics	
7	Balances - Spring balance (0 – 10N)
7	Balances - Top-pan
15	Stop watches
7	Micrometers
15	Meter rules
7	Vernier calipers
7	Trolleys
7	Springs
7	Strings
7	Pulleys
7	Pendulums
7	Masses
Oscillation and Waves	
7	Diffraction grating
7	Waves sources
7	Turning forks
7	Resonance tubes
15	Ray boxes
7	Slinkies
1	Ripple tanks
15	Pendulum bobs
7	Lenses
7	Glass blocks
15	Prisms

QTY	ITEM
A C Theory and Electronics	
7	Logic gates (NAND, NOR, NOT, AND and OR)
7	Breadboards
24	Connecting wires
7	Logic tutors
7	Semiconductor diodes
7	Operational amplifiers
7	Resistors
7	Rheostats
7	Thermistors
7	Multimeters
7	Centre-zero galvanometers
7	Voltmeters
7	Ammeters
9	AC-DC power supplies
2	Soldering irons
7	Microphones
15	Speakers
7	Battery holders
20	Flashlight bulbs
7	Dual power supplies
Atomic and Nuclear Physics	
7	∝, β and γ (lab) sources
7	GM tubes
7	Geiger counters
7	Ratemeters
	Scalers
7	Lead (Pb)
7	Aluminium (Al) foil
7	LDRs
15	LEDs
7	Buzzers
7	Relays

LIST OF MINIMUM LABORATORY REQUIREMENTS (cont'd)

Thermal and Mechanical Properties of Matter

15	Heating coils
7	Bunsen burners
7	Immersion heaters
3	Heating plates
	Thermometers
7	Calorimeters
3	Serle's apparatus
3	Lee's discs

Electricity and Magnetism

7	Copper rods
7	Copper wires
7	Nylon wires
7	Constantan wires
7	Other resistance wires
10	Plastic wrap or cling film
7	Glass rods
7	Polythene rods
7	Material strips - fur or cotton
7	Magnets
7	Plotting compasses
7	Hall probes
7	Signal generators
3	CRO
10	Capacitors

APPENDIX IV

♦ LIST OF PHYSICAL CONSTANTS

Universal gravitational constant	G	=	6.67 x 10−11 N m2 kg-2
Acceleration due to gravity	g	=	9.80 m s –2
Radius of the Earth	R_E	=	6380 km
Mass of the Earth	M_E	=	5.98 x 10 24 kg
Mass of the Moon	M_m	=	7.35 x 10 22 kg Atmosphere
Atmosphere	Atm	=	1.00 x 10^{5} N m^{-2}
Boltzmann's constant	k	=	1.38 x 10^{-23} J K^{-1}
Coulomb constant		=	9.00 x 10^{9} N m^{2} C^{-2}
Mass of the electron	m^{e}	=	9.11 x 10^{-31} kg
Electron charge	e	=	1.60 x 10^{-19} C
Density of water		=	1.00 x 10^{3} kg m^{-3}
Resistivity of steel		=	1.98 x 10^{-7} Ωm
Resistivity of copper		=	1.80 x 10^{-8} Ωm
Thermal conductivity of copper		=	400 W m^{-1} K^{-1}
Specific heat capacity of aluminium		=	910 J kg^{-1} K^{-1}
Specific heat capacity of copper		=	387 J kg^{-1} K^{-1}
Specific heat capacity of water		=	4200 J kg^{-1} K^{-1}
Specific latent heat of fusion of ice		=	3.34 x 10^{5} J kg^{-1}
Specific latent heat of vaporisation of water		=	2.26 x 10^{6} J kg^{-1}
Avogadro number	N_A	=	6.02 x 10^{23} per mole
Speed of light in free space	c	=	3.00 x 10^{8} m s^{-1}
Permeability of free space	μ_0	=	4π x 10^{-7} H m^{-1}

LIST OF PHYSICAL CONSTANTS (cont'd)

Permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
The Planck constant	h	=	6.63×10^{-34} J s
Unified atomic mass constant	u	=	1.66×10^{-27} kg
Rest mass of proton	m_p	=	1.67×10^{-27} kg
Molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
Stefan- Boltzmann constant	σ	=	5.67×10^{-8} W m^{-2} K^{-4}
Mass of neutron	m_n	=	1.67×10^{-27} kg

♦ MATHEMATICAL REQUIREMENTS

Arithmetic

Students should be able to:

1. recognise and use expressions in decimal and standard form (scientific notation);

2. recognise and use binary notations;

3. use appropriate calculating aids (electronic calculator or tables) for addition, subtraction, multiplication and division. Find arithmetic means, powers (including reciprocals and square roots), sines, cosines, tangents (and the inverse functions), natural and base-10 (In and Ig);

4. take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified; and,

5. make approximations to check the magnitude of machine calculations.

Algebra

Students should be able to:

1. change the subject of an equation. Most relevant equations involve only the simpler operations but may include positive and negative indices and square roots;

2. solve simple algebraic equations. Most relevant equations are linear but some may involve inverse and inverse square relationships. Linear simultaneous equations and the use of the formula to obtain the solution of quadratic equations are included;

3. substitute physical quantities into physical equations, using consistent units and check the dimensional consistency of such equations;

4. formulate simple algebraic equations as mathematical models of physical situations, and identify inadequacies of such models;

5. recognise and use the logarithmic forms of expressions like ab, a/b, xn, ekx, and understand the use of logarithms in relation to quantities with values that range over several orders of magnitude;

6. express small changes or errors as percentage and vice versa; and,

7. comprehend and use the symbols <, >, ≈, ⁄, ∝, <x> or = $\bar{x}$, Σ, Δx, δx, √.

MATHEMATICAL REQUIREMENTS (cont'd)

Geometry and Trigonometry

Students should be able to:

1. calculate areas of right-angled and isosceles triangles, circumferences and areas of circles and areas and volumes of rectangular blocks, cylinders and spheres;

2. use Pythagoras' theorem, similarity of triangles, and the sum of the angles of a triangle;

3. use sines, cosines and tangents (especially for 0°, 30°, 45°, 60°, 90°). Use the trigonometric relationship for triangles:
$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$; $\mathbf{a^2 = b^2 + c^2 - 2bc \cos A}$**;**

4. use $\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small θ and $\sin^2\theta + \cos^2\theta = 1$; and,

5. understand the relationship between degrees and radians (defined as arc/radius), translate from one to the other and use the appropriate system in context.

Vectors

Students should be able to:

1. find the resultant of two coplanar vectors, recognising situations where vector addition is appropriate; and,

2. obtain expressions for components of a vector in perpendicular directions and using this to add or subtract vectors.

Graphs

Students should be able to:

1. translate information between graphical, numerical, algebraic and verbal forms;

2. select appropriate variables and scales for graph plotting;

3. determine the slope, intercept and intersection for linear graphs;

4. choose by inspection, a line which will serve as the best line through a set of data points presented graphically;

5. recall standard linear form $\mathbf{y = mx + c}$ and rearrange relationships into linear form where appropriate;

6. sketch and recognise the forms of plots of common simple expressions like $1/x$, x^2, a/x^2, $\sin x$, $\cos x$, e^{-x}, $\sin^2 x$, $\cos^2 x$;

MATHEMATICAL REQUIREMENTS (cont'd)

7. use logarithmic plots to test exponential and power law variations;

8. understand, draw and use the slope of a tangent to a curve as a means to obtain the gradient, and use notation in the form dy/dx for a rate of change; and,

9. understand and use the area below a curve, where the area has physical significance.

♦ SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The following list illustrates the symbols and units which will be used in question papers.

Quantity	Usual Symbols	Usual Unit
<u>Base Quantities</u>		
mass	M	kg
length	L	M
time	T	S
electric current	I	A
Luminous intensity	Iv	Cd
thermodynamic temperature	n	K
amount of substance	N	mol
<u>Other Quantities</u>		
distance	D	M
displacement	s, x	M
area	A	m^2
volume	V, v	m^3
density	ρ	kg m^{-3}
speed	u, v, w, c	m s^{-1}
velocity	u, v, w, c	m s^{-1}
acceleration	a	m s^{-2}
acceleration of free fall	g	m s^{-2}
force	F	N
weight	W	N
momentum	p	N s

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS (cont'd)

Quantity	Usual Symbols	Usual Unit
<u>Other Quantities (cont'd)</u>		
work	w, W	J
energy	E, U, W	J
potential energy	E_p	J
kinetic energy	E_k	J
heat energy	Q	J
change of internal energy	ΔU	J
power	P	W
pressure	p	Pa
torque	τ	N m
gravitational constant	G	N kg^{-2} m^2
gravitational field strength	g	N kg^{-1}
gravitational potential	ϕ	J kg^{-1}
angle	θ	°, rad
angular displacement	θ	°, rad
angular speed	ω	rad s^{-1}
angular velocity	ω	rad s^{-1}
period	T	s
frequency	f	Hz
angular frequency	ω	rad s^{-1}
wavelength	λ	m
speed of electromagnetic waves	c	m s^{-1}

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS (cont'd)

Quantity	Usual Symbols	Usual Unit
<u>Other Quantities (cont'd)</u>		
electric charge	Q	C
elementary charge	e	C
electric potential	V	V
electric potential difference	V	V
electromotive force	E	V
resistance	R	Ω
resistivity	ρ	Ω m
electric field strength	E	$N\ C^{-1}$, $V\ m^{-1}$
permittivity of free space	ε_0	$F\ m^{-1}$
capacitance	C	F
time constant	τ	s
magnetic flux	Φ	Wb
magnetic flux density	B	T
permeability of free space	μ_0	$H\ m^{-1}$
stress	σ	Pa
strain	ε	
force constant	k	$N\ m^{-1}$
Young modulus	E	Pa
Celsius temperature	θ	°C
molar gas constant	R	$J\ K^{-1}\ mol^{-1}$
Boltzmann constant	k	$J\ K^{-1}$

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS (cont'd)

Quantity	Usual Symbols	Usual Unit
Other Quantities (cont'd)		
Avogadro constant	N_A	mol^{-1}
number density (number per unit volume)	N	m^{-3}
Planck constant	h	J s
work function energy	Φ	J
activity of radioactive source	A	Bq
decay constant	λ	s^{-1}
half-life	t½	s
relative atomic mass	A_r	
relative molecular mass	M_r	
atomic mass	m_a	kg, u
electron mass	m_e	kg, u
neutron mass	m_n	kg, u
proton mass	m_p	kg, u
molar mass	M	kg
proton number	Z	
nucleon number	A	
neutron number	N	
Stefan-Boltzmann constant	σ	$W\ m^{-2}\ K^{-4}$

♦ RESOURCES

Supplementary Texts

Christman, R. J. — A *Student's Companion: Halliday, Resnick and Walker. Fundamentals of Physics (including extended chapter)*. New York: John Wiley and Sons, Inc., 1997.

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<u>Western Zone Office</u>
9 August 2018

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PHYSICS

Specimen Papers and Mark Schemes/Keys

Specimen Papers:

Unit 1 Paper 01
Unit 1 Paper 02
Unit 2 Paper 01
Unit 2 Paper 02
Unit 2 Paper 32

Mark Schemes and Key:

Unit 1 Paper 01
Unit 1 Paper 02
Unit 2 Paper 01
Unit 2 Paper 02
Unit 2 Paper 32

C A R I B B E A N   E X A M I N A T I O N S   C O U N C I L

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION

PHYSICS

SPECIMEN 2017

TABLE OF SPECIFICATIONS

Unit 1 – Paper 02

Module	Question	Specific Objective	Content	Cognitive Level Marks			Total
				KC	UK	XS	
1	1	3.17,3.19, 3.20, 4.3, 4.5,	Effects of Forces Motions -Newton's Laws, Circular motion	10	15	5	30
2	2	1.4, 1.7, 2.23, 2.26,	Harmonic Motion Properties of Waves	10	15	5	30
3	3	4.1, 4.2, 4.3, 4.5, 5.5, 5.6,	Kinetic Theory of Gases First Law of Thermodynamics	10	15	5	30
Total				**30**	**45**	**15**	**90**

Unit 1 – Paper 032 (Alternative to SBA)

Module	Question	Specific Objective	Content	Cognitive Level Marks			Total
				KC	UK	XS	
1	1	Practical	Module 2	0	5	10	15
2	2	Data Analysis	Module 3	0	5	10	15
3	3	Planning & Design	Module 2	0	5	10	15
Total				**0**	**15**	**30**	**45**

Unit 2 – Paper 02

Module	Question	Specific Objective	Content	Cognitive Level Marks			Total
				KC	UK	XS	
1	1	1.9, 1.10, 1.11, 4.6, 4.7, 4.8, 4.9,	Electrical Quantities Capacitors	10	15	5	30
2	2	4.10, 4.11, 4.14, 5.1, 5.2, 5.4, 5.6, 5.9, 5.10	Operational Amplifiers Logic gates	10	15	5	15
3	3	1.15, 1.18, 3.2, 3.3, 4.5, 4.9, 4.10, 4.11, 4.12	Atomic and Nuclear Physics Atomic Mass Radioactivity	10	15	5	30
Total				**30**	**45**	**15**	**90**

Unit 2 – Paper 032 Alternative to SBA

Module	Question	Specific Objective	Content	Cognitive Level Marks			Total
				KC	UK	XS	
1	1	Practical	Module 2	0	5	10	15
2	2	Data Analysis	Module 1	0	5	10	15
3	3	Planning & Design	Module 3	0	5	10	15
Total				**0**	**15**	**30**	**45**

CANDIDATE – PLEASE NOTE!

PRINT your name on the line below and return this booklet with the answer sheet. Failure to do so may result in disqualification.

____

TEST CODE **02138010**

SPEC 2017/02138010

C A R I B B E A N   E X A M I N A T I O N S   C O U N C I L

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

PHYSICS

Unit 1 - Paper 01

1 hour 30 minutes

SPECIMEN PAPER

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This test consists of 45 items. You will have 1 hour and 30 minutes to answer them.
2. In addition to this test booklet, you should have an answer sheet.
3. Do not be concerned that the answer sheet provides spaces for more answers than there are items in this test.
4. Each item in this test has four suggested answers lettered (A), (B), (C), (D). Read each item you are about to answer and decide which choice is best.
5. On your answer sheet, find the number which corresponds to your item and shade the space having the same letter as the answer you have chosen. Look at the sample item below.

   Sample Item

   Which of the following lists has one scalar quantity and one vector quantity?

   (A) Mass:temperature
   (B) Momentum:pressure
   (C) Force:velocity
   (D) Potential energy:volt

   Sample Answer

   (A) ● (C) (D)

   The correct answer to this item is "Momentum:pressure", so (B) has been shaded.
6. If you want to change your answer, erase it completely before you fill in your new choice.
7. When you are told to begin, turn the page and work as quickly and as carefully as you can. If you cannot answer an item, go on to the next one. You may return to that item later.
8. You may do any rough work in this booklet.
9. Figures are not necessarily drawn to scale.
10. You may use a silent, non-programmable calculator to answer items.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

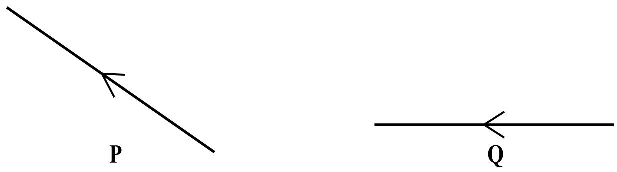
LIST OF PHYSICAL CONSTANTS

Universal gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
Acceleration due to gravity	g	=	9.81 m s^{-2}
1 Atmosphere	atm	=	1.00×10^{5} N m^{-2}
Boltzmann's constant	k	=	1.38×10^{-23} J K^{-1}
Density of water	ρ_w	=	1.00×10^{3} kg m^{-3}
Specific heat capacity of water	C_{water}	=	4200 J kg^{-1} K^{-1}
Specific latent heat of vaporization of water	L_Y	=	2.26×10^{6} J kg^{-1}
Avogadro's number	N_A	=	6.02×10^{23} per mole
Molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
Stefan–Boltzmann's constant	σ	=	5.67×10^{-8} W m^{-2} K^{-4}
Speed of light in free space (vacuum)	c	=	3.0×10^{8} m s^{-1}
Triple point temperature	T_{tr}	=	273.16 K
1 tonne	t	=	1000 kg

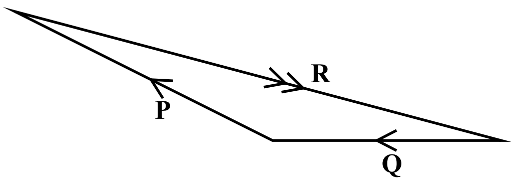
1. Which of the following pairs of units are SI base units?

(A) ampere, newton
(B) kelvin, ampere
(C) watt, coulomb
(D) coulomb, kelvin

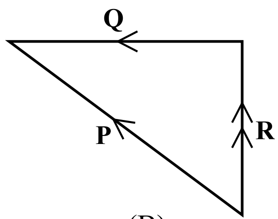
Item **2** refers to the following two vectors, P and Q.



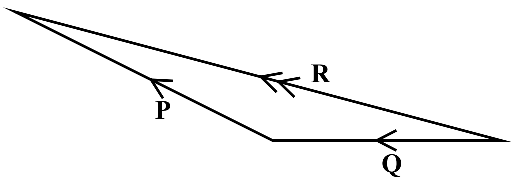
2. Which of the vector triangles shows the correct resultant R = Q + P?



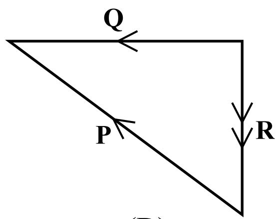
(A)



(B)

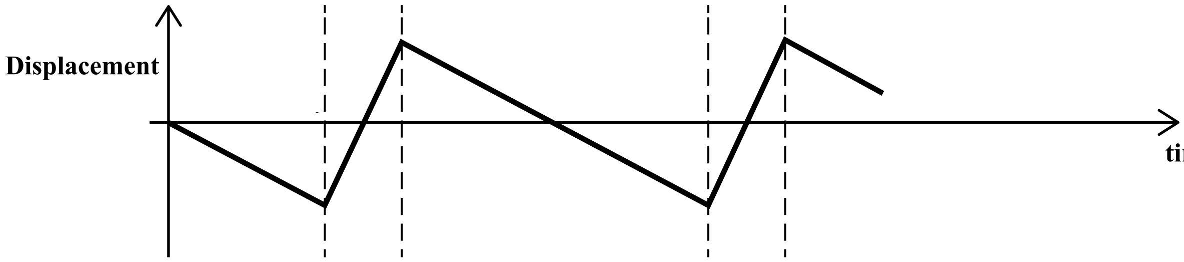


(C)

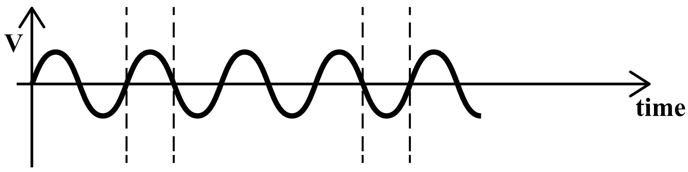


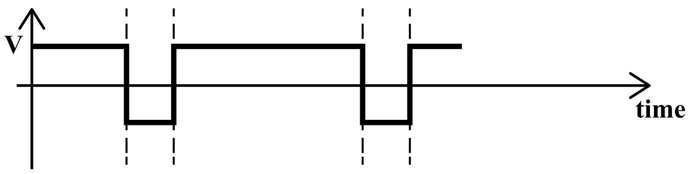
(D)

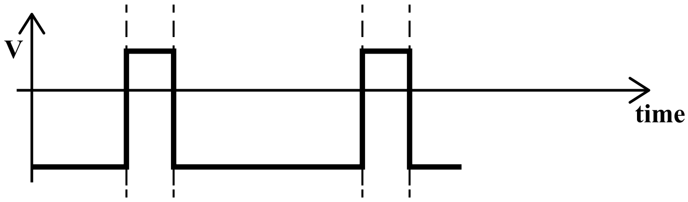
<u>Item **3**</u> refers to the following figure showing how the displacement of a particle varies with time.

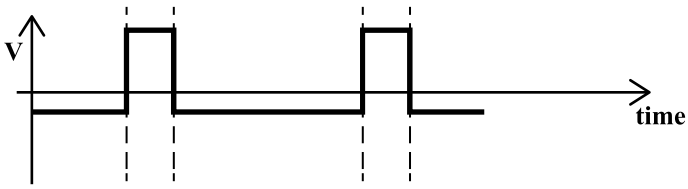


3. Which of the following graphs correctly represents the dependance of velocity with time for this motion?

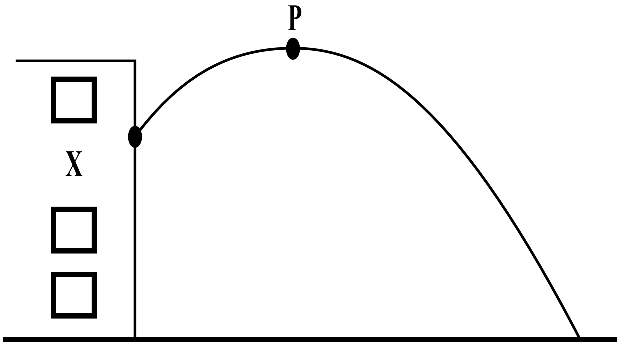








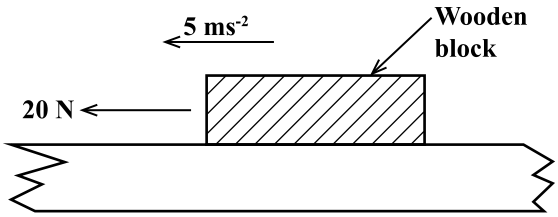
Item **4** refers to the following diagram.



4. A stone is thrown from a building at X, and follows a parabolic path as shown in the diagram. The maximum height reached by the stone is P. The vertical component of acceleration of the stone is

(A) maximum at P
(B) maximum at X
(C) the same at both X and P
(D) zero at P

Item **5** refers to the following diagram.



5. A wooden block of mass 0.80 kg is being pulled along a rough horizontal surface with a force of 20 N as shown above. The block experiences an acceleration of 5 ms^{-2}. What is the magnitude of the frictional force?

(A) 24 N
(B) 20 N
(C) 16 N
(D) 4 N

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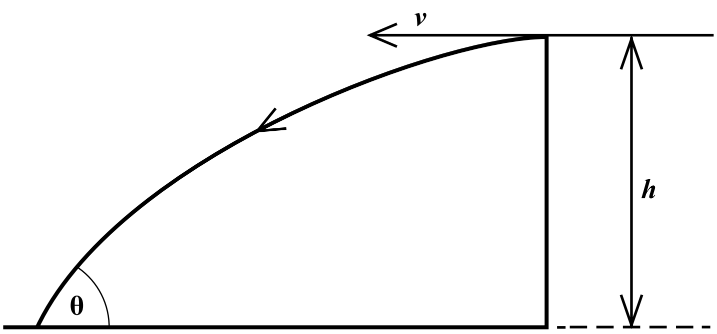
<u>Item 6</u> refers to the following diagram, which shows a projectile fired with a horizontal velocity, *v*, from the edge of a cliff. The height of the cliff is 6 metres.



6. Which of the following pairs of values of *v* and *h* give the maximum value of Θ?

	v/m s^{-1}	h/m
(A)	50	10
(B)	30	50
(C)	30	30
(D)	10	50

7. A monkey of mass 20 kg rides on a 40 kg trolley moving with a steady speed of 8 ms^{-1} along a flat surface. The monkey jumps vertically to grab the overhanging branch of a tree. At what speed will the trolley move off?

(A) 12 ms^{-1}
(B) 8 ms^{-1}
(C) 5 ms^{-1}
(D) 0.33 ms^{-1}

8. The velocity of a body with kinetic energy E_k and mass *m*, is

(A) $\frac{2E_k}{m}$

(B) $\sqrt{\frac{2E_k}{m}}$

(C) $\frac{E_k}{2m^2}$

(D) $\sqrt{\frac{2E_k^2}{m}}$

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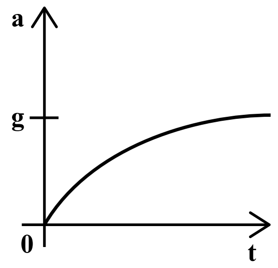
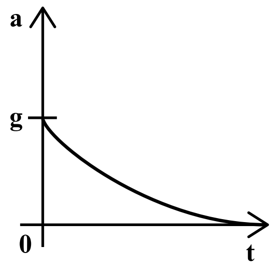
9. A parachutist is falling through air of uniform density from a great height. (g is the acceleration of free fall.)

Which of the following graphs show how his acceleration varies with time?

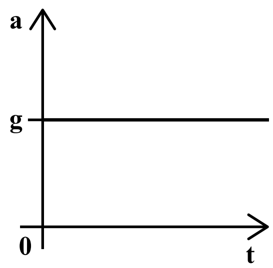
(A)



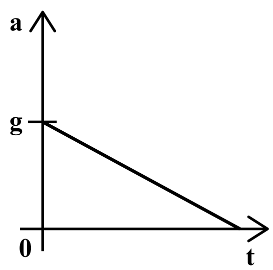
(B)



(C)



(D)



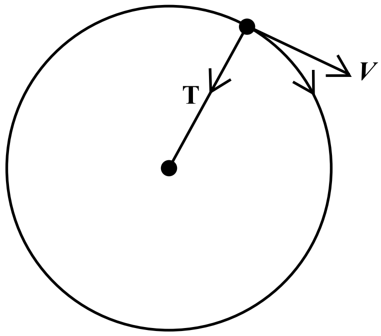
10. Two rocks are spun around in circular paths at the ends of strings of equal length. What quantity MUST be the same for both rocks if the tension in the strings are equal?

(A) Mass
(B) Speed
(C) Acceleration
(D) Kinetic energy

11. Aeroplane A is travelling at twice the speed of Aeroplane B. Plane A is half the mass of Aeroplane B. Which of the following statements is correct?

(A) The two aeroplanes have the same kinetic energy
(B) Aeroplane A has twice the kinetic energy of Aeroplane B
(C) Aeroplane A has half the kinetic energy of Aeroplane B
(D) Aeroplane A has one quarter of the kinetic energy of Aeroplane B

12. An object is rotated in a vertical circle with a constant angular velocity as shown in the diagram below.



Which of the following quantities remain constant as the object moves round its circular path?

I. The tension in the string
II. The acceleration of the object
III. The kinetic energy of the object

(A) I and II only
(B) I and III only
(C) II and III only
(D) I, II and III

13. In a 100 m race, the winner finished in a time of 9.90 s and the fourth place sprinter finished 12 ms later. In what time did he finish the race?

(A) 9.912 s
(B) 9.780 s
(C) 10.002 s
(D) 10.200 s

14. A geostationary satellite traces an orbit with angular velocity ω_s a distance r above the earth's surface. Which of the following quantities will be the same for both the satellite and the fixed point of the earth's surface?

I. Speed
II. Angular velocity
III. Angular displacement

(A) I and II only
(B) I and III only
(C) II and III only
(D) I, II and III

15. Marcia needs to find the mass of her dog but he will not stay on the bathroom scale. So first she weighs herself, getting 47 ±1 kg. Then she stands on the balance holding her dog and the reading becomes 64 ±1 kg. From these readings the percentage error (or uncertainty) in the mass of the dog is

(A) 1%
(B) 2%
(C) 6%
(D) 12%

16. Which of the following CANNOT be demonstrated in sound waves?

(A) Reflection
(B) Diffraction
(C) Polarisation
(D) Interference

17. Which of the following gives the correct relationship between the intensity and amplitude of sound waves?

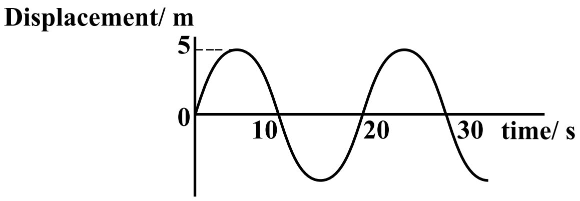
(A) Intensity $\alpha \dfrac{1}{amplitude}$

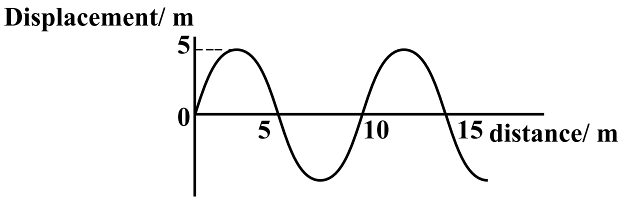
(B) Intensity α $(amplitude)^2$

(C) Intensity $\alpha \dfrac{1}{amplitude^2}$

(D) Intensity α amplitude

18. The displacement-time and displacement-distance graphs for a transverse wave are shown below.





What is the wave speed?

(A) 0.25 m s^{-1}
(B) 0.5 m s^{-1}
(C) 1.0 m s^{-1}
(D) 2.0 m s^{-1}

19. For light passing from air to Material X, the refractive index is 1.3 and for light passing from air to Material Y, the refraction index is 1.5. Which of the following shows the speed of light in air, X and Y in **descending** order of magnitude? (fastest to slowest)

(A) air, X, Y
(B) air, Y, X
(C) Y, air, X
(D) X, Y, air

20. Light from a source is incident normally on a diffraction grating which has 2000 lines per mm. What is the wavelength of the light if the first order maximum makes an angle of 30^0 with the zero order?

(A) 125 nm
(B) 250 nm
(C) 433 nm
(D) 866 nm

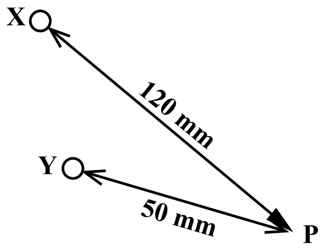
21. A converging lens has a focal length of 12 cm. If an object is placed 20 cm from the lens, the image would be

(A) 8 cm from the lens
(B) 12 cm from the lens
(C) 20 cm from the lens
(D) 30 cm from the lens

22. The value of a possible wavelength for radiation in the visible region in the electromagnetic spectrum is

(A) 5 x 10^{-8} m
(B) 5 x 10^{-7} m
(C) 5 x 10^{-6} m
(D) 5 x 10^{-5} m

Item 23 refers to the following diagram.



23. Two wave sources X and Y are positioned as shown 50 mm and 120 mm from a point P. The two sources produce waves which are in phase and which both have wavelengths of 20 mm. The phase difference between the waves arriving at P is

(A) 45^{o}
(B) 90^{o}
(C) 180^{o}
(D) 360^{o}

24. The magnitude of the threshold of hearing at 1 kHz is

(A) 10^{-8} Wm^{-2}
(B) 10^{-10} Wm^{-2}
(C) 10^{-11} Wm^{-2}
(D) 10^{-12} Wm^{-2}

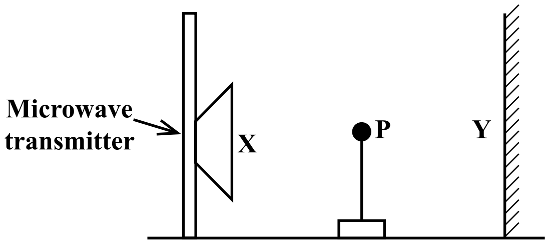
25. Which of the following is NOT a condition necessary for the formation of stationary waves from two progressive waves?

(A) Progressive waves must be superimposed.
(B) Progressive waves must be travelling in opposite directions.
(C) Progressive waves must be of the same amplitude and frequency.
(D) The distance between the sources of progressive waves must be a whole number of wavelengths.

26. A glass tube of effective length 0.60 m is closed at one end. Given that the speed of sound in air is 300 ms^{-1}, the two LOWEST resonant frequencies are

(A) 125 Hz, 250 Hz
(B) 125 Hz, 375 Hz
(C) 250 Hz, 375 Hz
(D) 500 Hz, 750 Hz

Item **27** refers to the following diagram.



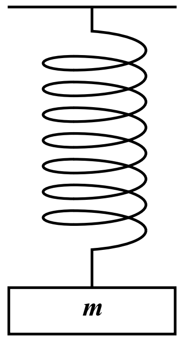
27. A microwave transmitter X sends radio waves to a metal sheet Y. A probe, P, between X and Y is moved from one node through 20 antinodes to a node 0.3 m away. What is the frequency of the microwaves emitted from X?

(A) 3×10^{-2} Hz
(B) 3×10^{-8} Hz
(C) 2×10^{10} Hz
(D) 1×10^{10} Hz

28. Which of the following quantites does NOT remain constant when a particle moves in simple harmonic motion?

(A) Force
(B) Amplitude
(C) Total energy
(D) Angular frequency

Item **29** refers to the following diagram.

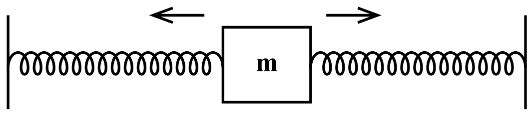


29. A mass, m, is attached to a vertical helical spring and displaced a distance "A" from equilibrium as shown in the diagram. The mass is released so that it oscillates with simple harmonic motion with angular frequency ω.

Which of the following expressions gives the variation of velocity, v, with time, t?

(A) $v = A \sin \omega t$
(B) $v = A \cos \omega t$
(C) $v = A \omega \sin \omega t$
(D) $v = -A \omega^2 \sin \omega t$

Item **30** refers to the following diagram.



30. A mass m, undergoes horizontal simple harmonic motion under the action of two springs as shown. Its equation of motion is $\frac{-2k}{m}x$ and its amplitude is A.

What is its MAXIMUM kinetic energy?

(A) $\frac{1}{2} kA^2/m$
(B) $2 m^2 A^2/K$
(C) $2 k^2A^2/m$
(D) kA^2

GO ON TO THE NEXT PAGE

31. One fixed point on the thermodynamic temperature scale is identified by the

(A) ice point of water
(B) steam point of water
(C) triple point of water
(D) boiling point of water

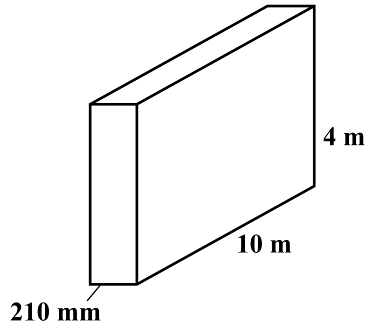
32. Two bodies when in thermal equilibrium will have the same

A pressure
B temperature
C kinetic energy
D potential energy

33. The temperature of 50 g of liquid was raised by 60 K when it was used to cool a steel ball of mass 100 g from 150^0 C to 70^0 C. If the specific heat capacity of steel is 450 J/kg K, what is the specific heat capacity of the liquid?

(A) 1200 J/kg K
(B) 675 J/kg K
(C) 300 J/kg K
(D) 120 J/kg K

Item **34** refers to the following diagram.



A brick wall 10 m long by 4 m high is insulated with a material of thermal conductivity 0.70 Wm^{-1} K^{-1}. If the insulating material is 210 mm thick, the interface between the wall and material is at 95°C and the rate of heat flow into the interface is 4 kW, what is the temperature of the other end of the insulation?

(A) 125^oC
(B) 98^oC
(C) 94.7^oC
(D) 65^oC

35. What is the SI base unit for specific heat capacity?

A $kg^2\ m^2\ K^{-1}$
B $m^2\ s^{-1}\ K$
C $m\ kg^{-1}\ K^1$
D $m^2\ s^{-2}\ K^{-1}$

36. What is the average kinetic energy of helium atoms at 27^0 C?

(A) 2.8×10^{-21} J
(B) 2.5×10^{-22} J
(C) 6.2×10^{-21} J
(D) 5.6×10^{-21} J

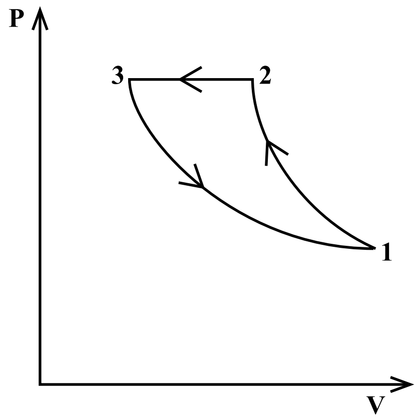
37. Which of the following is NOT an assumption of the kinetic theory of gases?

(A) A gas consists of a large number of molecules.
(B) The gas molecules are in constant, random motion.
(C) The gas molecules collide in elastically with each other.
(D) The duration of a collision is negligible when compared to the time interval between collisions.

38. A monatomic gas at 18 °C and 1.2×10^5 Pa is contained in a vessel of capacity one cubic metre. What is the approximate number of atoms present?

(A) 4×10^{26}
(B) 3×10^{25}
(C) 6×10^{23}
(D) 1×10^{24}

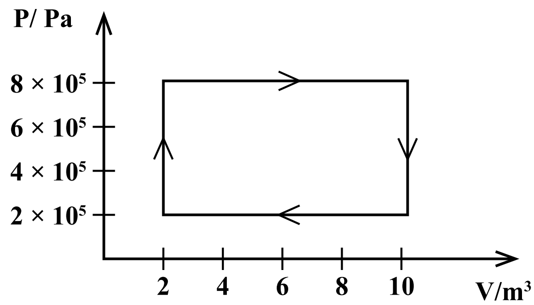
Item **39** refers to the following P-V diagram, which represents a gas being taken through three processes, 1 to 2, 2 to 3 and 3 to 1 to complete the cycle.



39. In which process(es) is work being done on the gas?

(A) 1 to 2 and 2 to 3
(B) 2 to 3 and 3 to 1
(C) 3 to 1 only
(D) 2 to 3 only

Item **40** refers to the following diagram.



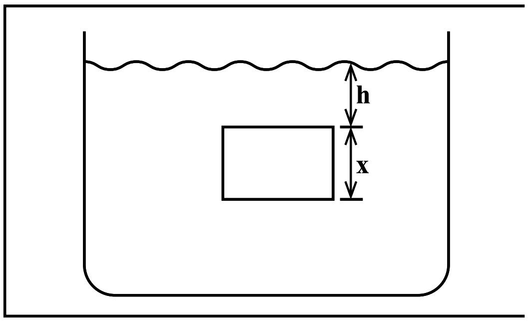
40. An ideal gas initially at 2 m^3 and a pressure of 2.0×10^5 Pa is taken through a cycle as shown in the diagram above.

The work done on the gas in the complete cycle is

(A) +6.4 MJ
(B) +4.8 MJ
(C) -4.8 MJ
(D) -6.4 MJ

A cube of side x cm is submerged in a fluid of density ρ, at a depth h below the surface of the fluid as shown in the following diagram.

41. A cube of side *x* cm is submerged in a fluid of density ρ , at a depth h below the surface of the fluid as shown in the following diagram.



What is the pressure experienced by the bottom surface of the cube?

(A) hρg
(B) xρg
(C) (x - h) ρg
(D) (x + h) ρg

42. A steel wire of length 3 m and uniform cross-sectional area $0.1 mm^2$ is used in an experiment to determine the Young's modulus of steel. The gradient of the force-extension graph obtained is 6.7×10^3 Nm^{-1}.

What is Young's modulus of steel?

(A) 2.0×10^{11} Pa
(B) 2.0×10^{8} Pa
(C) 4.5×10^{11} Pa
(D) 2.2×10^{10} Pa

43. Which of the following equations is correct?

(A) $Stress = \frac{length}{extension}$

(B) $Strain = \frac{extension}{length}$

(C) $Strain = \frac{force}{area}$

(D) $Stress = \frac{area}{force}$

44. The equation for the net rate of heat radiation between two bodies is given as

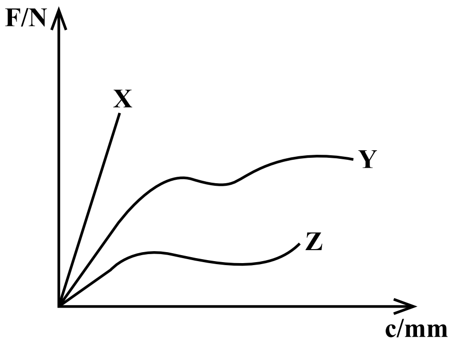
(A) P = σAT4

(B) $P = \sigma A(T_1 - T_2)$

(C) $P = \sigma A(T_1 - T_2)^4$

(D) $P = \sigma A\ (T_1^4 - T_2^4)$

Item **45** refers to the following force-extension graph for three different materials, X, Y and Z.



45. Which of the following options correctly labels the graphs?

	X	Y	Z
(A)	brittle	polymeric	ductile
(B)	ductile	polymeric	brittle
(C)	brittle	ductile	polymeric
(D)	ductile	brittle	polymeric

END OF TEST

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Question	Module/Syllabus Reference	Profile	Key
1	1.2.1	KC	B
2	1.1.3	KC	C
3	1.3.2	UK	D
4	1.3.6	KC	C
5	1.4.2	UK	C
6	1.3.6	KC	D
7	1.3.11	UK	A
8	1.1.7	UK	B
9	1.3.2	KC	B
10	1.3.20	UK	D
11	1.5.2	UK	B
12	1.3.21	KC	C
13	1.2.3	KC	A
14	1.3.26	KC	C
15	1.1.9	UK	D
16	2.1.1	KC	C
17	2.1.5	KC	B
18	2.1.4	UK	B
19	2.3.3	KC	A
20	2.3.8	UK	B
21	2.3.11	UK	D
22	2.3.2	KC	B
23	2.4.2	UK	C
24	2.4.9	KC	D
25	2.4.12	KC	D
26	2.5.1	UK	B
27	2.4.12	UK	D
28	2.5.4	KC	A
29	2.5.2	KC	C
30	2.5.8	UK	D
31	3.1.4	KC	C
32	3.2.1	KC	B
33	3.2.4	UK	A
34	3.3.2	UK	D
35	3.2.3	KC	D
36	3.4.8	UK	C
37	3.4.4	KC	C
38	3.4.3	UK	B
39	3.5.4	KC	A
40	3.5.4	UK	C
41	3.6.3	KC	D
42	3.6.9	UK	A
43	3.6.9	KC	B
44	3.3.7	UK	D
45	3.6.7, 6.11	KC	C

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1. Fill in all the information requested clearly in capital letters.

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SUBJECT: PHYSICS – UNIT 1 – Paper 01

PROFICIENCY: ADVANCED

REGISTRATION NUMBER: | | | | | | | | | | |

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SUBJECT PHYSICS – UNIT 1 – Paper 02

PROFICIENCY ADVANCED

REGISTRATION NUMBER

SCHOOL/CENTRE NUMBER					

NAME OF SCHOOL/CENTRE

CANDIDATE'S FULL NAME (FIRST, MIDDLE, LAST)

DATE OF BIRTH

D	D	M	M	Y	Y	Y	Y

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PHYSICS

UNIT 1 – Paper 02

2 hours 30 minutes

SPECIMEN PAPER

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of THREE questions. Answer ALL questions.
2. Write your answers in the spaces provided in this booklet.
3. Do NOT write in the margins.
4. ALL WORKING MUST BE SHOWN in this booklet.
5. You may use a silent, non-programmable calculator to answer questions, but you should note that the use of an inappropriate number of figures in answers will be penalized.
6. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
7. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

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LIST OF PHYSICAL CONSTANTS

Universal gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
Acceleration due to gravity	g	=	9.81 m s^{-2}
1 Atmosphere	atm	=	1.00×10^5 N m^{-2}
Boltzmann's constant	k	=	1.38×10^{-23} J K^{-1}
Density of water	ρ_w	=	1.00×10^3 kg m^{-3}
Specific heat capacity of water	C_w	=	4200 J kg^{-1} K^{-1}
Specific latent heat of fusion of ice	L_f	=	3.34×10^5 J kg^{-1}
Specific latent heat of vaporization of water	L_v	=	2.26×10^6 J kg^{-1}
Avogadro's constant	N_A	=	6.02×10^{23} per mole
Molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
Stefan–Boltzmann's constant	σ	=	5.67×10^{-8} W m^{-2} K^{-4}
Speed of light in free space (vacuum)	c	=	3.00×10^8 m s^{-1}
Speed of sound in air	c	=	340 m s^{-1}
Planck's constant	h	=	6.626×10^{-34} J s
Triple point temperature	T_{tr}	=	273.16 K
1 tonne	t	=	1000 kg

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

1. The data in Table 1 were collected in a terminal velocity experiment. Small metal spheres were timed over a distance of 80.0 cm as they fell at constant velocity in thick engine oil.

TABLE 1. DATA FROM TERMINAL VELOCITY EXPERIMENT

Radius r/mm	Time/s	Velocity v/cm s^{-1}	lg (v/cm s^{-1})	lg (r/mm)
1.00	44.8			
1.49	20.1			
2.02	11.3			
2.51	7.2			
2.99	5.0			

(a) Explain the term ‘terminal velocity’.

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[1 mark]

(b) Draw a force diagram to explain why the velocity is constant.

[**2 marks**]

(c) Complete Table 1 by inserting the missing values in Columns 3, 4 and 5.

[**3 marks**]

GO ON TO THE NEXT PAGE

(d) Using the grid provided on page 7, plot a suitable graph to find the value of n. **(Note that it is NOT necessary to convert the units to metres.)**

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[**4 marks**]

(e) Write the equation of the graph you have drawn in Part (d).

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[**1 mark**]

(f) What are the MOST likely values of the constants n and k?

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[**4 marks**]

(g) Using Newton's laws, explain how the propeller of a light aeroplane similar to the one shown in Figure 1 is able to provide forward thrust.

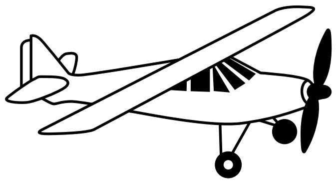

Figure 1. Light aeroplane

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[**3 marks**]

(h) In order to turn, an aeroplane must "bank" as shown in Figure 2, so that the lift force is no longer vertical. (Assume that the aeroplane remains in level flight and travels at constant speed.)

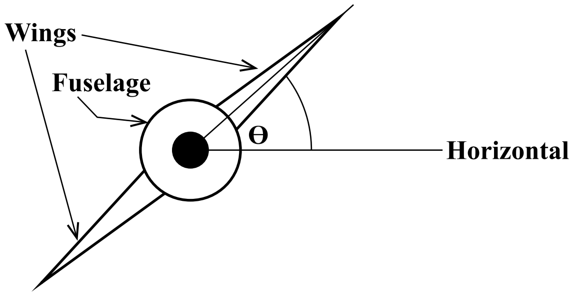

Figure 2. Banking aeroplane

(i) Draw a diagram similar to that in Figure 2, with arrows to show the direction of the external forces acting on the aeroplane as it turns. On a second similar diagram, show the direction of the RESULTANT force acting on the plane.

[**4 marks**]

(ii) Calculate the radius of the circular path for a plane of mass 3 000 kg with a horizontal speed of 120 km per hour, if the resultant force acting is 16 000 N.

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[4 marks]

(iii) Find the size of the lift force on the plane and the banking angle θ.

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[4 marks]

Total 30 marks

2. (a) An oscillating system has a period, T, which is related to the length, l, of the suspension by the equation $T = al^n$, where a and n are constants. Table 2 shows the time periods obtained as the length was changed.

(i) Complete Table 2 by inserting the values for *lg l* and *lg T*.

Table 2

l/mm	2.31	292	411	515	859
T/s	0.94	1.06	1.27	1.42	1.86
lg l					
lg T					

[**3 marks**]

(ii) Express the above equation in the form of a straight line.

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[**2 marks**]

(iii) Using the grid provided on page 13, plot a suitable graph to determine the values of *a* and *n*. **[4 marks]**

(b) Use the graph to find the value of n.

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[2 marks]

(c) Use your value of n to find a.

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[2 marks]

(d) Suggest an accurate means of determining the time period, T.

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[2 marks]

(e) (i) Define the 'refractive index' of a medium.

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[2 marks]

GO ON TO THE NEXT PAGE

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(ii) Define the 'critical angle'.

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[2 marks]

(iii) State what is meant by 'total internal reflection', explaining the significance of the word 'total'.

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[3 marks]

(f) Figure 3 shows a prism of index of refraction of 1.45 in air.

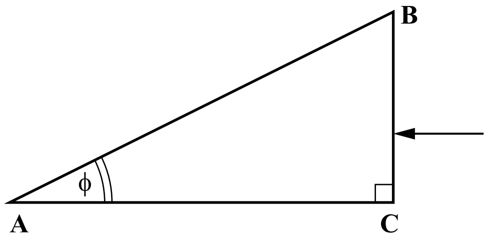

Figure 3

(i) Determine the critical angle for light travelling from the prism into air.

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[**2 marks**]

(ii) A ray of light is incident perpendicular to the surface BC, as shown in Figure 3. If total internal reflection occurs, determine the maximum angle ϕ of the prism.

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[**3 marks**]

(g) The prism in part (f) is immersed in a liquid. Find the ratio of the speed of light in the prism to the speed of light in the liquid, if the critical angle for light travelling from the prism into the liquid is 32.0°.

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[**3 marks**]

Total 30 marks

3. (a) A cylinder with a leak proof movable piston is filled with 0.1 moles of Helium gas. The piston moves gradually outwards at a constant temperature and the pressures at particular volumes are noted in Table 3.

Pressure /kPa	**Volume /cm^3**
800	300
600	400
480	500
400	600
340	700
300	800
270	900
240	1000
220	1100
200	1200

Using the results in Table 3, plot a graph of pressure against volume on the grid on page 17. Start both axes at the origin. [**5 marks**]

(b) (i) Prove that the process is isothermal.

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[3 marks]

(ii) Calculate the temperature.

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[3 marks]

(c) State the first law of thermodynamics and explain each of the terms.

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[4 marks]

(d) Calculate the values for EACH of the terms stated in part (c), for the helium going through the expansion process from 300 cm^3 to 1200 cm^3.

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[5 marks]

(e) Explain why heat was supplied to the gas.

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[**2 marks**]

(f) Using the kinetic theory of gases, briefly explain

(i) what accounts for the pressure on the wall of the container when the helium gas fills it.

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[**2 marks**]

GO ON TO THE NEXT PAGE

(ii) why does the pressure decrease with increasing volume?

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[2 marks]

(g) Given that the relative molar mass of Helium is 4.0 $gmol^{-1}$, calculate the r.m.s. speed of the Helium molecules at the end point. ($p = 200$ kPa; $V = 1200$ cm^3).

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[4 marks]

Total 30 marks

END OF TEST

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

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EXTRA SPACE

If you use this extra page, you MUST write the question number clearly in the box provided.

Question No.

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SUBJECT: PHYSICS – UNIT 1 – Paper 02

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Date: ________________________________

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ADVANCED PROFICIENCY EXAMINATION

PHYSICS

UNIT 1 - PAPER 02

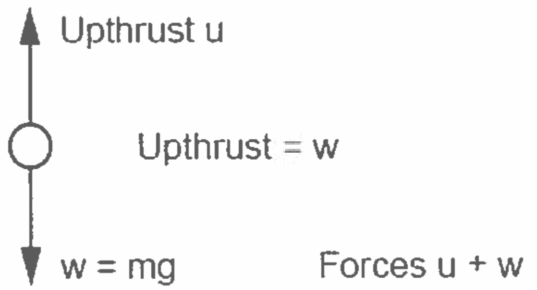
MARK SCHEME

2017

<u>**Question 1**</u>

(a) When a body is released in a viscous liquid it accelerates first, then its velocity soon reaches a steady value called the terminal velocity.

(b)



1 KC mark for each correct label

(c) Completing Table 1

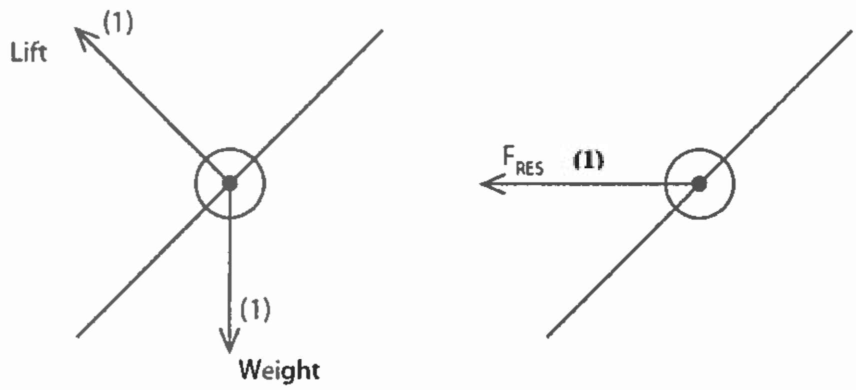
Radius r/mm	**Time t/s**	**Velocity v/cms^{-1}**	**lg (v/cms^{-1})**	**lg (r/mm)**
1.00	44.8	1.79	0.252	0.000
1.49	20.1	3.98	0.600	0.173
2.02	11.3	7.08	0.850	0.305
2.51	7.2	11.1	1.045	0.400
2.99	5.0	16.1	1.204	0.476

- 1 UK mark for each error

(d) For plotting graph

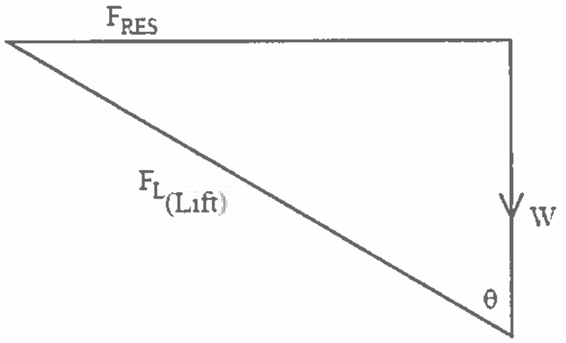
Labelled axes (quantity and unit) **(1)**
5 correct points **(3)**
4 correct points **(Award 2 marks only)**
2-3 correct points **(Award 1 mark only)**
< 2 correct points **(0)**

	KC	**UK**	**XS**
(a)	1		
(b)	2		
(c)		3	
(d)			4

Question 1 continued	KC	UK	XS
(e) lgv = nlgr + lgk		1	
(f) Gradient calculation **(1)** n = 2 **(1)** Intercept measurement **(1)**, calculating k **(1)**		3	1
(g) Newton's 2nd law: force on the air equals its rate of change of momentum **(1)** Newton's 3rd : plane pushes back air, therefore pushes the plane forward **(1)** Using both laws to explain **(1)**	3		
(h) (i)  Showing two forces at correct angle **(1)** **[-1 mark for each extra arrow added to a diagram]**	4		
(ii) $F = \frac{mv^2}{R} \Rightarrow R = \frac{mv^2}{F}$ **(1)** $= \frac{3000\ v^2}{16000}$ **(1)** $[v = \frac{120\ 000m}{3600s} = 33.3\ ms^{-1}]$ **(1)** So $R = \frac{3\ 000}{16\ 000} \times (33.3)^2 = 208$ m **(1)**		4	

Question 1 continued

(iii)



Vector Diagram (1)

$$\text{Tan } \theta = \frac{F_{RES}}{W} = \frac{16\ 000}{3000 \times 9.81} = 0.544$$

$\theta = \tan^{-1}(0.544) \gg \theta = 28.5^0$ **(1)**

$F_{RES} = F_L \sin \theta$ **(1)**

$F_L = \dfrac{16\ 000}{\text{Sin } 28.5} = 33.5 \times 10^3$ N **(1)**

	KC	UK	XS
		4	
Total 30 marks	10	15	5

Question 2	KC	UK	XS
(a) (i) Correctly completing data (3)		3	
(ii) $\text{Log } T = \text{Log } A + n\text{Log } l$ (2)	2		
(iii) Graph of log T/Log *l* Suitable scales **(1)** 5 correct points **(2)** 3 - 4 correct points **(1)** < 3 correct points **(0)** Line of best fit **(1)**			4
(b) Gradient = n = 0.52 Read off **(1)** Calculation **(1)**		1	1
(c) $T = al^{0.52}$ $\text{Log } T = \log a + 0.52 \log l$ $0.302 = \log a + 0.52 \times 3.0$ **(1)** $\text{Log } a = -1.26$; $a = 0.055$ **(1)**		2	
(d) Many (N) oscillations observed, T total, and Time, T, = $\frac{T \text{ total}}{N}$ **(1)** Repeat timing to check **(1)**		2	
(e) (i) The refractive index of a medium is the ratio of the sine of the angle of incidence to the sine of the angle of refraction (in the medium) **(1)** of the ray when traveling from air to the medium **(1)**.	2		
(ii) The critical angle is the angle of incidence for a ray traveling from a dense to a less dense medium **(1)**, for an angle of refraction of 90^0 **(1)**.	2		
(iii) Total internal reflection occurs when the critical angle has been exceeded **(1)**. The ray is reflected internally **(1)** from the medium boundary. Only when moving from a dense to a less dense medium **(1)**.	3		

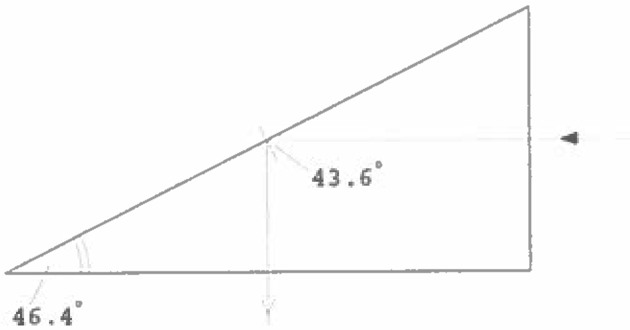
Question 2

(f) (i) $n = 1.45$ **(1)**

$$\text{Sin } c = \frac{1}{1.45} = 0.689$$

$C = 43.6^{0}$ **(1)**

(ii)



For Total Internal Reflection

Angle of incidence must be at least 43.6^{0} **(1)**
i.e. angle of prism = 90 − 43.6 = 46.4^{0}
(1) **(1)**

If critical angle= 32^{0}
then $n = \dfrac{1}{\sin C}$
$= 1.89$ **(1)**

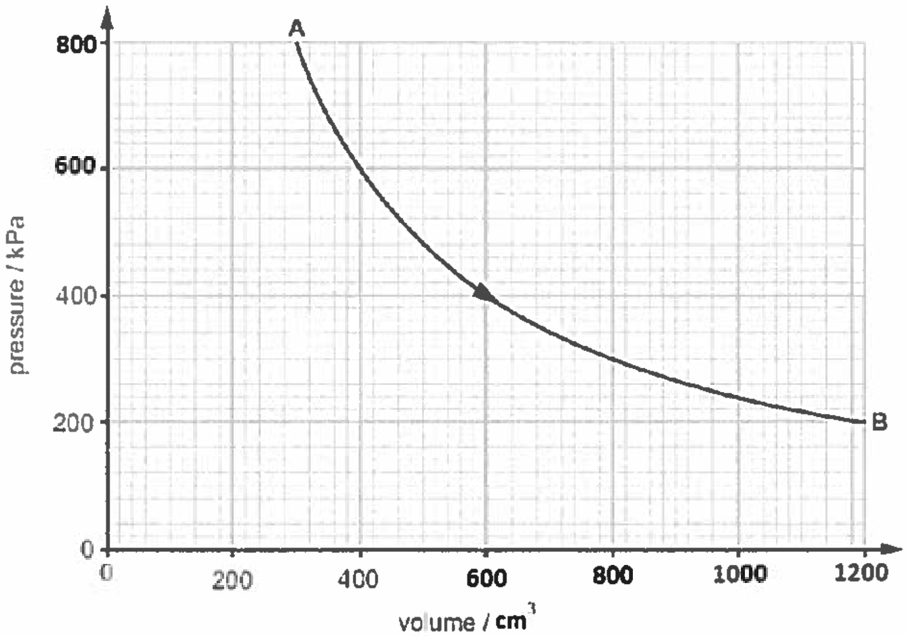
(g) $C_1/C_2 = n_2/n_2$ **(1)**

$= 1.89/1.45 = 1.30$ **(1)**

Part	KC	UK	XS
(f)(i)	1		
(ii)		3	
(g)		3	
Total 30 marks	10	15	5

Question 3

(a)



	KC	UK	XS
Labeled axes (quantity and unit) (1) Appropriate scale (1) 8-10 points correctly plotted (2) 5-7 points correctly plotted (1) <5 points correctly plotted (0) Best fit curve (1)			5

Question 3

		KC	UK	XS
(b) (i)	Showing at least 3 calculations of pV, indicating that the values are equal (2) Stating that in an isothermal process the product pV = constant (1)		3	
(ii)	$pV = nRT$ (1) $T = \frac{pV}{nR}$ $T = \frac{800 \times 10^3 \times 300 \times 10^{-6}}{0.1 \times 8.31}$ (1) T = 289 K (1)	1	2	
(c)	$\Delta U = \Delta Q + \Delta W$ (1) ΔU – change in internal energy ΔQ – heat supplied to the gas ΔW – work done on the gas (3)	4		
(d)	ΔU = 0 J (1) ΔW = area under graph (1) # blocks = 820 Area of 1 block = 0.4 J Total area = 328 J (1) ΔW = – 328 J (1) ΔQ = 328 J (1)		5	
(e)	In expanding, the gas is doing work and therefore losing energy. This means that the gas cools as it expands (1) In order for the temperature to remain the same, heat energy must be added to the gas to replace what is lost during the expansion process (1).		2	
(f) (i)	Gas particles are in constant random motion. They collide with each other and the walls of the container, exerting a force (1). The pressure is because of the continuous bombardment (force) by the particles on the walls (1).	2		

Question 3

		KC	UK	XS
(ii)	As the volume of the container increases, there is more space for the particles to move in, therefore, there are less frequent collisions with the walls of the container (1). This means that there will be a smaller resultant force exerted on the walls and therefore a smaller pressure (1).	2		
(g)	$m = 0.1 \times 4 \times 10^{-3}$ $m = 4 \times 10^{-4}$ kg (1) $pV = Nm\langle c^2 \rangle$ (1) $\langle c^2 \rangle = \frac{200 \times 10^3 \times 1200 \times 10^{-6} \times 3}{4 \times 10^{-4}}$ $\langle c^2 \rangle = 1.8 \times 10^6 \ m^2 s^{-2}$ (1) r.m.s. $= \sqrt{1.8 \times 10^6}$ $= 1341$ m/s (1)	1	3	
	Total 30 marks	10	15	5

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SUBJECT PHYSICS – UNIT 1 – Paper 032

PROFICIENCY ADVANCED

REGISTRATION NUMBER

SCHOOL/CENTRE NUMBER					

NAME OF SCHOOL/CENTRE

CANDIDATE'S FULL NAME (FIRST, MIDDLE, LAST)

DATE OF BIRTH

D	D	M	M	Y	Y	Y	Y

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CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

PHYSICS

UNIT 1 – Paper 032

ALTERNATIVE TO SCHOOL-BASED ASSESSMENT

2 hours

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of THREE questions. Answer ALL questions.
2. Write your answers in the spaces provided in this booklet.
3. Do NOT write in the margins.
4. Where appropriate, ALL WORKING MUST BE SHOWN in this booklet.
5. You may use a silent, non-programmable calculator to answer questions, but you should note that the use of an inappropriate number of figures in answers will be penalized.
6. You are advised to take some time to read through the paper and plan your answers.
7. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
8. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

1. (a) In this experiment, you will investigate the relationship between the period of oscillation of a cantilever and the mass attached at its end; and use this relationship to determine the Young modulus of wood.

You are provided with the following pieces of apparatus:

- G clamp
- A metre ruler
- Six 100-g slotted masses
- Stopwatch
- Pencil or biro
- Thick rubber band
- Vernier caliper

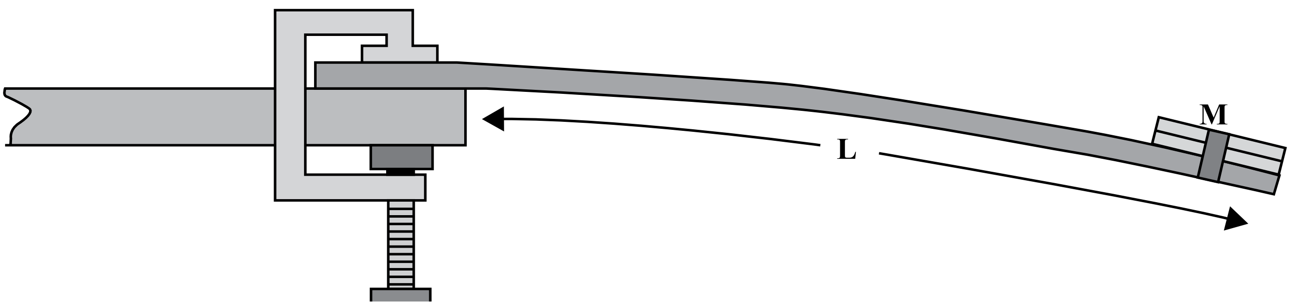

Figure 1. Diagram of set-up of apparatus

Procedure:

1. Using your Vernier caliper, measure and record the values for the width, W, and thickness, t, of the metre ruler.
2. Set up the apparatus as shown in Figure 1 with one end securely clamped to the bench. Ensure that the length, L, of the metre ruler is set to 90 cm.
3. Using your rubber band, secure a 100-g mass to the end of the ruler. Ensure that the masses line up exactly with the end of the ruler.
4. Displace the ruler slightly and record the time for 15 oscillations. Repeat this step to find an average value.
5. Add another 100-g mass to the end of the ruler. Secure with a rubber band and record the time for 15 oscillations.
6. Repeat steps 4 and 5 until you have completed the oscillations with 600 g on the end of the ruler.
7. Record your measurements in Table 1.
8. Determine the values of the period, T, lg m and lg T and record these values in Table 1.

Results:

Width (W) of ruler ……………………………………………………………...……

Thickness (t) of ruler………………………………………………………...………..

TABLE 1: RESULTS OF EXPERIMENT

Mass on end of ruler (m)/ kg	Time for 15 oscillations /s			Period (T)/s	lg m	lg T
	Trial #1	Trail #2	Average			
0.1						
0.2						
0.3						
0.4						
0.5						
0.6						

[2 marks]

(b) The period of a cantilever is given by an equation of form T = **a**m^{b} where **'a'** is a constant that depends on the other physical properties of the set up i.e. the dimensions of the ruler.

Plot a graph of lg T vs lg m, on the grid provided on page 6.

[7 marks]

GO ON TO THE NEXT PAGE

(c) From your graph, determine the values of

(i) **b**

....

....

....

....

[3 marks]

(ii) **a**

....

....

....

....

[2 marks]

(d) Rewrite the equation in (b) with the calculated values of **a** and **b**.

....

....

[1 mark]

Total 15 marks

2. Table 2 represents the data obtained from a Young's Modulus experiment.

TABLE 2: VALUES OF FORCE AND EXTENSION

Force (F) /N	1.9	6.08	9.12	9.88	11.59	14.06
Extension(e)/m	0.01	0.032	0.048	0.052	0.061	0.074

The original length of the wire used in the experiment was 1.85 m and the diameter of the wire was 2.5 mm.

The Young's Modulus, *E*, of the wire is given by the equation

$$E = \frac{F/A}{e/L}$$

where *F* is the force on the wire, *A* is the cross sectional area of the wire, *e* is the extension and *L* is the original length of the wire.

(a) On the grid provided on page 9, plot a graph of force versus extension.

[7 marks]

GO ON TO THE NEXT PAGE

(b) Use your graph to determine the Young's Modulus of the wire.

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[8 marks]

Total 15 marks

3. A student is asked to investigate the variation of light intensity with the thickness of glass, given the following apparatus. Each glass slide is covered with automotive tint.

List of apparatus:

- Glass slides 5 inches x 5 inches
- Light intensity meter
- Light source
- Meter rule
- Matt black card
- Micrometer screw gauge

Design an experiment to investigate the variation of light intensity with the thickness of glass. Write your answers under the following headings.

(a) Identification of variables

....

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....

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....

....

[3 marks]

(b) Set up of apparatus

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[3 marks]

(c) Procedure

....

....

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....

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....

[4 marks]

(d) Results

....

....

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....

[3 marks]

(e) Conclusion

....

....

....

[2 marks]

Total 15 marks

EXTRA SPACE

If you use this extra page, you MUST write the question number clearly in the box provided.

Question No.

EXTRA SPACE

If you use this extra page, you MUST write the question number clearly in the box provided.

Question No.

DO NOT
WRITE ON
THIS PAGE

CANDIDATE'S RECEIPT

INSTRUCTIONS TO CANDIDATE:

1. **Fill in all the information requested clearly in capital letters.**

TEST CODE: | 0 | 2 | 1 | 3 | 8 | 0 | 3 | 2 |

SUBJECT: PHYSICS – UNIT 1 – Paper 032

PROFICIENCY: ADVANCED

REGISTRATION NUMBER: | | | | | | | | | | |

FULL NAME: ____
(BLOCK LETTERS)

Signature: ____

Date: ____

2. **Ensure that this slip is detached by the Supervisor or Invigilator and given to you when you hand in this booklet.**

3. **Keep it in a safe place until you have received your results.**

INSTRUCTION TO SUPERVISOR/INVIGILATOR:

Sign the declaration below, detach this slip and hand it to the candidate as his/her receipt for this booklet collected by you.

I hereby acknowledge receipt of the candidate's booklet for the examination stated above.

Signature: ______________________________
Supervisor/Invigilator

Date: ______________________________

C A R I B B E A N   E X A M I N A T I O N S   C O U N C I L

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

SPECIMEN

PHYSICS

UNIT 1 – PAPER 032

KEY AND MARK SCHEME

MAY/JUNE 2017

PHYSICS
UNIT 1 — PAPER 032
MARK SCHEME

Question 1

	KC	UK	XS
(a) Results of Experiment:			
Measured values to a consistent number of decimal places **(1)**			1
Calculated values to a consistent number of significant figures **(1)** **[2 marks]**		1	
(b) Graph of lg T vs lg m: Suitable scales **(2)** Labelled axes (quantity and unit)**(1)** 5-6 correct points **(3)** 3-4 correct points **(Award 2 marks only)** 1-2 correct points **(Award 1 mark only)** Best-fit straight line**(1)** **[7 marks]**			7
(c) Analysis (i) b = gradient of line large gradient triangle **(1)** correct read off of points **(1)** correct calculated value (approx. 0.5) **(1)** **[3 marks]**		1	2
(ii) lg a = y-intercept **(1)** correct calculation of a **(1)** **[2 marks]**		2	
(d) Correct statement of equation with values of a and b **(1)**		1	
Total 15 marks		**5**	**10**

PHYSICS
UNIT 1 — PAPER 032
MARK SCHEME

Question 2

	KC	UK	XS
(a) Plotting of graph:			
Suitable scales **(2)**			
Labelled axes (quantity and unit)**(1)**			
5-6 correct points **(3)**			
3-4 correct points **(Award 2 marks only)**			7
1-2 correct points **(Award 1 mark only)**			
Best-fit line **(2)**			
[7 marks]			
(b) Calculation of gradient:			3
large gradient triangle **(1)**			
correct read off of points **(2)**			
correct calculated value (approx. 0.5) **(1)**		1	
Calculation of cross-sectional area			
Correct formula **(1)**			
Calculation with units **(1)**			
Calculation of E			
Correct formula**(1)**		4	
Calculation with units**(1)**			
[8 marks]			
Total 15 marks		**5**	**10**

PHYSICS
UNIT 1 — PAPER 032
MARK SCHEME

Question **3**

		KC	UK	XS
(a)	Identification of variables Identifies light intensity of source **(1)**, distance from source to sample **(1)** and distance from sample to detector **(1)** as variables. **[3 marks]**			**3**
(b)	Setup of apparatus Accurate labels **(1)** Correct placement of essential apparatus **(2)** **Award 1 mark only if one piece of apparatus incorrectly placed.** **[3 marks]**			**3**
(c)	Procedure • Excludes other light sources **(1)** • Keeps distance from source to sample constant **(1)** • Keeps intensity from source constant by monitoring with a light meter **(1)** • Measures intensity of source with light intensity meter **(1)** **[4 marks]**			**4**
(d)	Results Plot results **(1)** should show a decrease in light intensity with thickness **(1)**. No direct proportional variation between light intensity and thickness **(1)**. **[3 marks]**			**3**
(e)	Conclusion Valid conclusion drawn from results **(1)**. Results following the inverse square law **(1)**. **[2 marks]**			**2**
	Total 15 marks			**15**

CANDIDATE – PLEASE NOTE!

PRINT your name on the line below and return this booklet with your answer sheet. Failure to do so may result in disqualification.

TEST CODE **02238010**

SPEC 2017/02238010

C A R I B B E A N   E X A M I N A T I O N S   C O U N C I L

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

PHYSICS

Unit 2 – Paper 01

1 hour 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This test consists of 45 items. You will have 1 hour and 30 minutes to answer them.
2. In addition to this test booklet, you should have an answer sheet.
3. Do not be concerned that the answer sheet provides spaces for more answers than there are items in this test.
4. Each item in this test has four suggested answers lettered (A), (B), (C), (D). Read each item you are about to answer and decide which choice is best.
5. On your answer sheet, find the number which corresponds to your item and shade the space having the same letter as the answer you have chosen. Look at the sample item below.

   Sample Item

   Kirchoff's first law for electric currents can be derived by using the conservation of

   (A) energy
   (B) current
   (C) charge
   (D) power

   Sample Answer

   (A) (B) ● (D)

   The correct answer to this item is "charge", so (C) has been shaded.
6. If you want to change your answer, erase it completely before you fill in your new choice.
7. When you are told to begin, turn the page and work as quickly and as carefully as you can. If you cannot answer an item, go on to the next one. You may return to that item later.
8. You may do any rough work in this booklet.
9. Figures are not necessarily drawn to scale.
10. You may use a silent, non-programmable calculator to answer items.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

LIST OF PHYSICAL CONSTANTS

Speed of light in free space	c	=	3.00×10^{8} m s^{-1}
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
Permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
	$\frac{1}{4\pi\varepsilon_0}$	=	9.0×10^{9} m F^{-1}
Elementary charge	e	=	1.60×10^{-19} C
Planck's constant	h	=	6.63×10^{-34} J s
Unified atomic mass constant	u	=	1.66×10^{-27} kg (931 MeV)
Rest mass of electron	m_e	=	9.11×10^{-31} kg
Rest mass of proton	m_p	=	1.67×10^{-27} kg
Acceleration due to gravity	g	=	9.81 m s^{-2}
1 Atmosphere	atm	=	1.00×10^{5} N m^{-2}
Avogadro's number	N_A	=	6.02×10^{23} per mole

1. A 3V battery causes a current of 0.5 A to flow along a wire for 4 seconds. What is the quantity of charge that passes in this time?

(A) 0.125 C
(B) 1.5 C
(C) 2 C
(D) 6 C

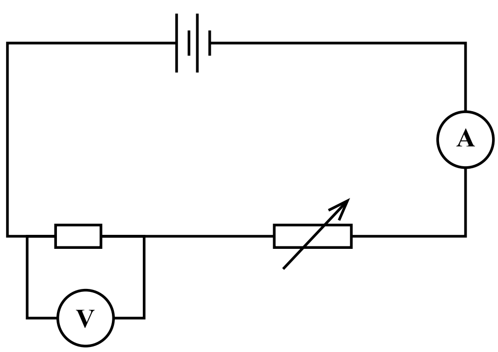
2. Energy per unit of charge is a measure of

(A) power
(B) capacitance
(C) electric field strength
(D) potential difference

3. A current of 0.25 A flows in a uniform wire of length 2 metres and cross-sectional area 2 x 10^{-9} m^2, when the potential difference across the wire is 4.25 V. What is the resistivity of the material from which the wire is made?

(A) 5.9 x 10^{-11} Ωm
(B) 4.25 x 10^{-9} Ωm
(C) 1.7 x 10^{-8} Ωm
(D) 3.4 x 10^{-8} Ωm

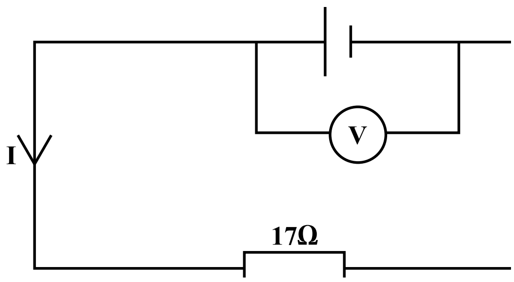
<u>Item 4</u> refers to the following diagram which shows an arrangement of electrical components in a circuit.



4. The variable resistor is adjusted to provide a smaller resistance. Which changes BEST describe the changes in the ammeter and voltmeter readings?

	Ammeter Reading	**Voltmeter Reading**
(A)	decrease	increase
(B)	decrease	decrease
(C)	increase	increase
(D)	increase	decrease

5. The cell in the following diagram has an e.m.f of 9.0V. The reading on the high resistance voltmeter is 5.0V.



What is the current I?

(A) $\frac{14}{17}$ A

(B) $\frac{9}{17}$ A

(C) $\frac{5}{17}$ A

(D) $\frac{4}{17}$ A

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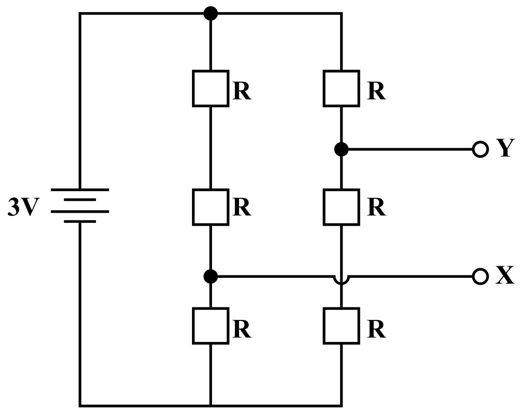
6. A 3V battery of negligible internal resistance is connected to six identical resistors as shown in the diagram below.



What is the potential difference between X and Y?

(A) 1.0V
(B) 1.5V
(C) 2.0V
(D) 3.0V

7. In a closed circuit or loop, the algebraic sum of the e.m.f. is equal to the algebraic sum of the products of current and resistance.

Which of the following statements is correct?

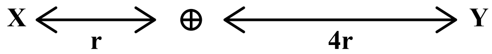
(A) This is Kirchhoff's first law which is a consequence of conservation of energy.

(B) This is Kirchhoff's first law which is a consequence of conservation of charge.

(C) This is Kirchhoff's second law which is a consequence of conservation of energy.

(D) This is Kirchhoff's second law which is a consequence of conservation of charge.

Item 8 refers to the following diagram which shows a positive point charge in free space. The distances from the charge to points X and Y are shown.



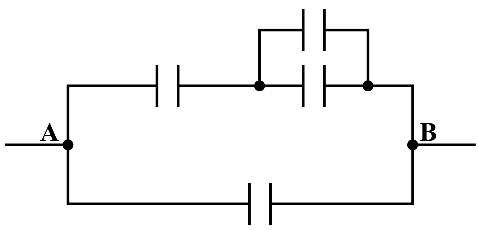
8. What is the ratio of the electric field strength at X, to the field strength at Y?

(A) 1:4
(B) 4:1
(C) 16:1
(D) 1:16

9. The force per unit charge on a positive test charge placed at a point in a field is called

(A) electric energy
(B) electric potential
(C) dielectric constant
(D) electric field strength

Item 10 refers to the following diagram



10. Each capacitor in the diagram above has capacitance C. What is the effective capacitance between A and B?

(A) $\frac{3C}{5}$

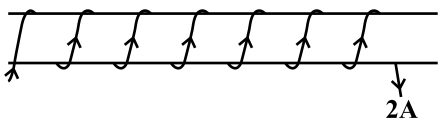
(B) $\frac{C}{4}$

(C) $\frac{5C}{3}$

(D) $4C$

GO ON TO THE NEXT PAGE

Item 11 refers to the following diagram.



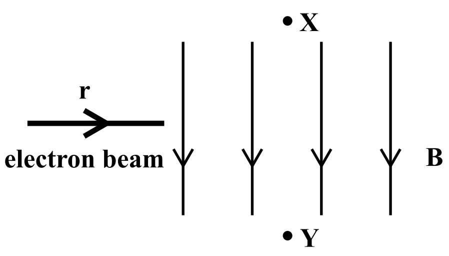
11. A hollow solenoid has 100 turns in a length of 0.5 m. If a steady current of 2A flows in the solenoid as shown in the diagram, what is the magnitude and direction of the flux density in the middle?

(A) 1.3×10^{-4} T to the left
(B) 5.0×10^{-4} T to the left
(C) 1.3×10^{-4} T to the right
(D) 5.0×10^{-4} T to the right

12. A wire of length 0.5 m and resistance 5Ω moves vertically with a velocity of 10 m s^{-1} perpendicular to a uniform magnetic field of flux density 4.0×10^{-5} T. What is the magnitude of the e.m.f. generated between the ends of the wire?

(A) 1.0×10^{-4} V
(B) 2.0×10^{-4} V
(C) 4.0×10^{-4} V
(D) 8.0×10^{-4} V

13. An electron beam moving with speed v enters a uniform magnetic field B, acting down the page as shown.



The beam of electrons will bend

(A) out of the paper
(B) into the paper
(C) towards X
(D) towards Y

14. Which diagram correctly shows the direction of the forces acting on adjacent current carrying conductors?

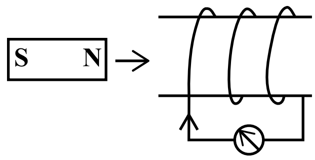
(A) ⊗ →← ⊙

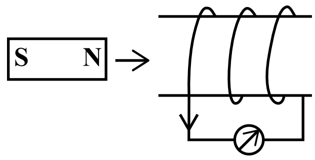
(B) ⊗ → ⊙ →

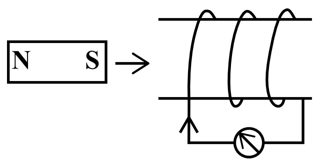
(C) ← ⊗ ← ⊙

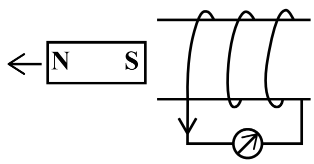
(D) ⊗ ⊙ →

15. The following diagrams illustrate a demonstration of Lenz's law of electromagnetic induction. In which diagram is the current in the correct direction?

(A) 

(B) 

(C) 

(D) 

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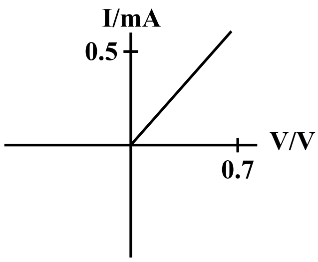
16. A sinusoidal alternating current of a peak value 20A dissipates power of 50W in a resistor R. The value of the resistor is

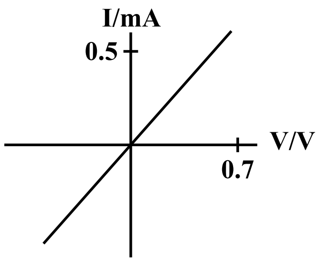
(A) 0.03 Ω
(B) 0.06 Ω
(C) 0.13 Ω
(D) 0.25 Ω

17. Which of the following graphs BEST represent the I -V characteristics of a silicon p - n unction diode?

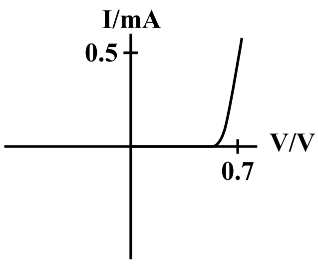
(A)



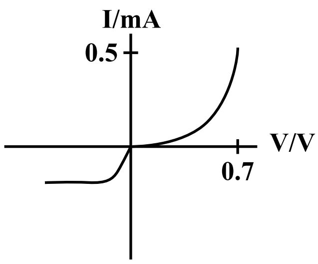
(B)



(C)



(D)



18. A direct current of 5A dissipates heat in a given resistor at the same rate as a sinusoidal alternating current slowing through the same resistor. What is the root mean square value of the alternating current?

(A) $\sqrt{2A}$

(B) 5A

(C) $\sqrt[5]{2A}$

(D) $\frac{5}{\sqrt{2}}A$

19. The ratio of the secondary turns to the primary turns in an ideal transformer is 1:30. A 120V a.c. supply is connected to the primary coil and a load of 20 Ω connected to the secondary coil. What is the secondary current?

(A) 180 A
(B) 6 A
(C) 1.5 A
(D) 0.2 A

Item 20 refers to the following diagrams.

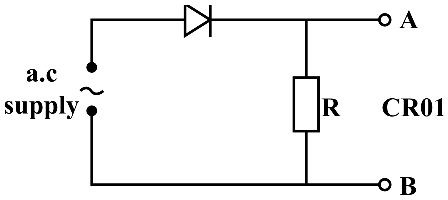


Figure 1

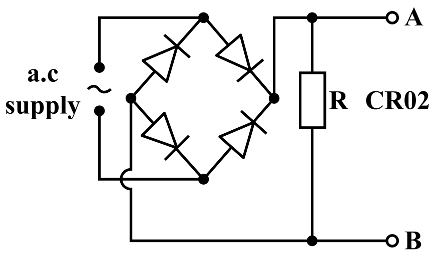
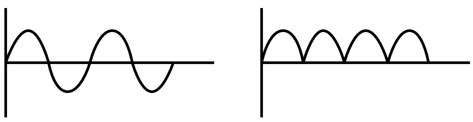
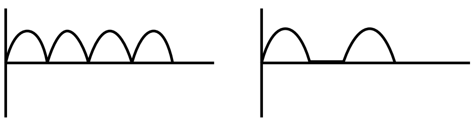
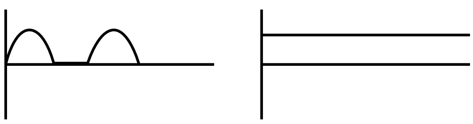


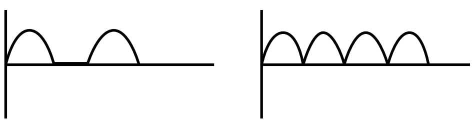
Figure 2

20. Which of the following traces will be seen on the cathode ray oscilloscopes in Figure 1 and Figure 2?

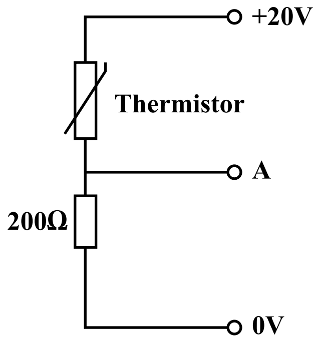
(A) 

(B) 

(C) 

(D) 

Item 21 refers to the following diagram.



21. The potential divider above is formed from a thermistor and a 200 Ω resistor.

The thermistor has a resistance of 2 kΩ at room temperature and 200 Ω at 100 ^{0}C.

What is the change in the potential at A when the thermistor is moved from water at room temperature to boiling water?

(A) Rise of about 8V
(B) Fall of about 8V
(C) Rise of about 18V
(D) Fall of about 18V

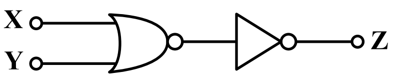
22. Which pair of values gives the open-loop gain of an ideal op. amp. and that of a typical op. amp?

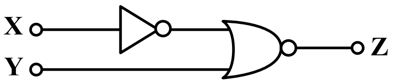
	Ideal	**Typical**
(A)	0	100
(B)	∞	100000
(C)	100000	∞
(D)	0	100000

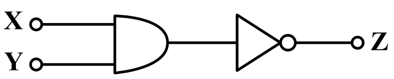
Item 23 refers to the following table.

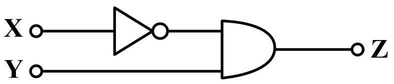
X	Y	Z
0	0	1
0	1	1
1	0	0
1	1	1

23. Which of the following combinations gives the truth table shown above?

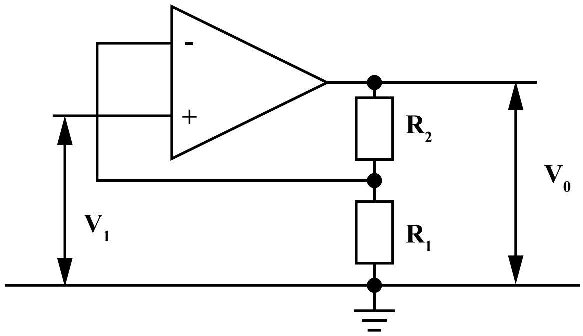
(A)


(B)


(C)


(D)


Item 24 refers to the following diagram which shows a non-inverting amplifier with negative feedback.



24. Which of the following represents the gain of the amplifier?

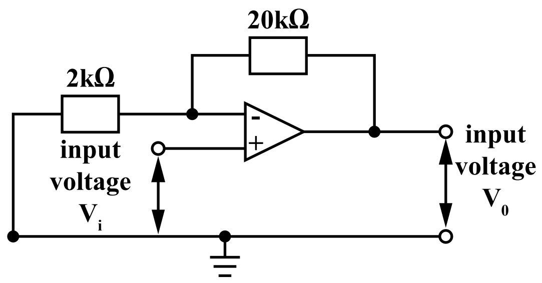
(A) $1+\frac{R_2}{R_1}$

(B) $-\frac{R_2}{R_1}$

(C) $\frac{R_1}{R_1+R_2}$

(D) $1+\frac{R_1}{R_2}$

Item 25 refers to the following diagram



25. The gain of the op-amp in the diagram above is

(A) -10
(B) -9
(C) 10
(D) 11

Item 26 refers to the following diagrams.

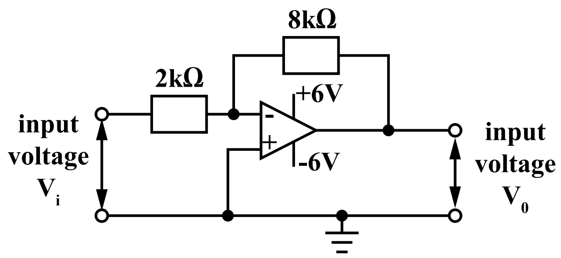


Figure 1

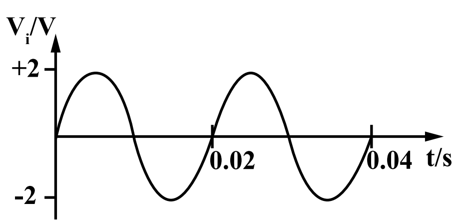
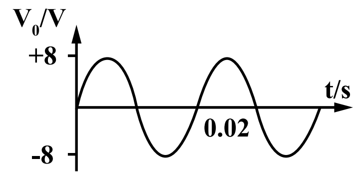


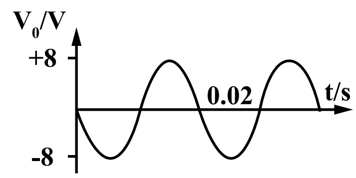
Figure 2

26. The sinusoidal alternating voltage shown in Figure 2 is applied to the input of the op-amp shown in Figure 1. The voltage of the power supply is + 6V. Which one of the following graphs correctly shows the output voltage with time?

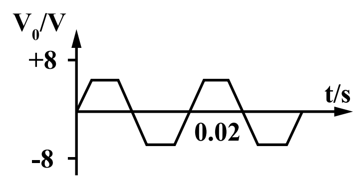
(A)



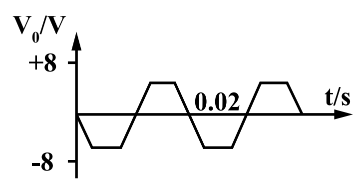
(B)



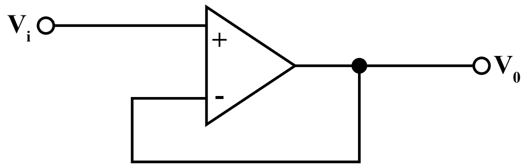
(C)



(D)



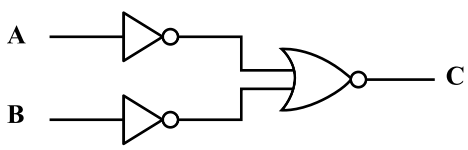
Item 27 refers to the following diagram.



27. Which of the following statements does NOT apply to the op-amp in the diagram above?
The op-amp circuit

(A) is called a voltage follower
(B) is used as an inverter
(C) is used as a buffer
(D) has a gain of one

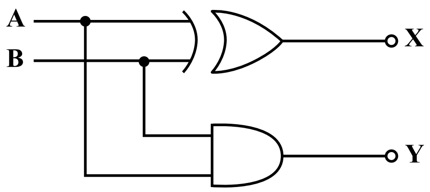
Item 28 refers to the following diagram.



28. Which of the following gates is equivalent to the combination above?

(A) OR
(B) EXOR
(C) AND
(D) NAND

Item 29 refers to the following diagram of a half-adder.



29. If A = 1 and B = 0, what are the values of the outputs X and Y?

(A) X = 0, Y = 0
(B) X = 1, Y = 1
(C) X = 1, Y = 0
(D) X = 0, Y = 1

30. Which of the following statements about R-S flip-flops are correct?

I. It contains 2 cross-linked NAND or NOR gates
II. The output is unpredictable for one combination of inputs.
III. It has 2 input and one stable output state

(A) I and II only
(B) I and III only
(C) II and III only
(D) I, II and III

31. Which of the following phenomena BOTH demonstrate the wave nature of matter?

(A) Reflection and Refraction
(B) Interference and Diffraction
(C) Line spectra and Interference
(D) Polarisation and Photoelectric effect

32. In which of the following radiations do the photons have the LEAST energy?

(A) x-rays
(B) ultra violet
(C) γ -rays
(D) infrared

33. Photoelectrons are emitted from the surface of zinc metal when light of intensity, I, and wavelength, λ, is incident on it. What is the effect on the work function of the zinc metal if the intensity is doubled and the wavelength is reduced to $\frac{1}{4}$ of its previous value?

The work function is

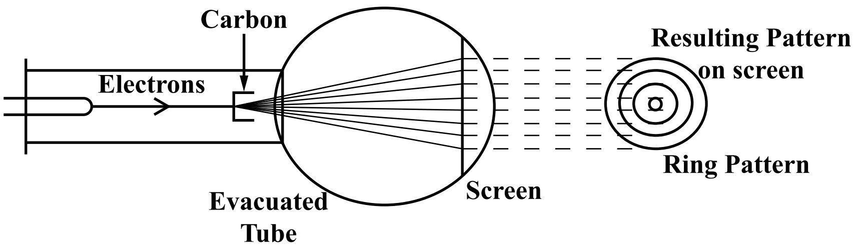
(A) doubled
(B) halved
(C) quartered
(D) unchanged

34. E.M. radiation is produced when very high speed elections strike a hard target. This type of electromagnetic radiation is known as

(A) U.V
(B) x-rays
(C) γ -rays
(D) microwaves

35. Which of the following graphs correctly show the relationship between the energy, E, of photons of light and their wavelength?

<u>Item 36</u> refers to the following diagram



36. A beam of electrons is made to strike a thin layer of carbon in an evacuated tube as shown in the diagram above.

This experiment provides evidence for

(A) interference
(B) polarisation
(C) the particle nature of light
(D) the wave nature of particle

37. An object of mass *m* has kinetic energy, E_k. Which of the following is a correct expression for its de Broglie wavelength?

(A) $\lambda = E_k / h$

(B) $\lambda = h(2mE_k)^{\frac{1}{2}}$

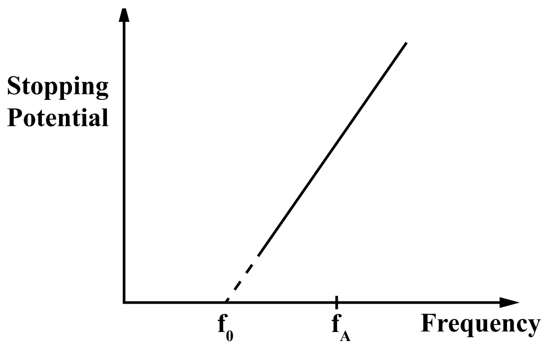
(C) $\lambda = \dfrac{h}{(2mE_k)^{\frac{1}{2}}}$

(D) $\lambda = \dfrac{2h}{(mE_k)^{\frac{1}{2}}}$

38. An isotope of nickel is represented by $^{60}_{28}\text{Ni}$. Which line in the following table correctly describes a neutral atom of this isotope?

	Number of Neutrons	Number of Protrons	Number of Electrons
(A)	32	28	32
(B)	32	28	28
(C)	60	32	28
(D)	28	32	28

<u>Item 39</u> refers to the following diagram.



39. In an experiment to investigate photoelectricity, a graph of stopping potential of photoelectrons is plotted against frequency of incident radiation. What is the MAXIMUM kinetic energy of photoelectrons emitted by photons with frequency f_A?

(A) hf_o

(B) hf_A

(C) $hf_o - hf_A$

(D) $hf_A - hf_o$

40. The mass of a nucleus is found to be 8.0032 u and that of its individual constituent nucleus is 8.0045 u. What is the binding energy of this nucleus?

(A) 6.5×10^{22} J
(B) 1.9×10^{-13} J
(C) 6.9×10^{-16} J
(D) 2.4×10^{-47} J

41. The decay constant of a radioactive sample of radon gas 1×10^{-2} s^{-1}. If there were 1.6×10^5 atoms of radon gas present at a certain time, T, how much time must elapse before there is only 1.2×10^5 atoms of radon left?

(A) 25s
(B) 29s
(C) 45s
(D) 400s

42. A nucleus of element A decays to mendelevium $^{255}_{101}Md$ by a sequence of three α particle emissions. How many neutrons are there in a nucleus of A?

(A) 267
(B) 207
(C) 160
(D) 154

43. A radioactive substance emits a type of ionising radiation, P, with the following properties:
mass: zero
speed: 3×10^8 m s^{-1}

Which of the following statement(s) about P is/are true?

I. P is not deflected by an electric field
II. P has a charge of equal to that of an electron
III. P maybe stopped by a piece of cardboard

(A) I only
(B) II only
(C) I and II only
(D) II and III only

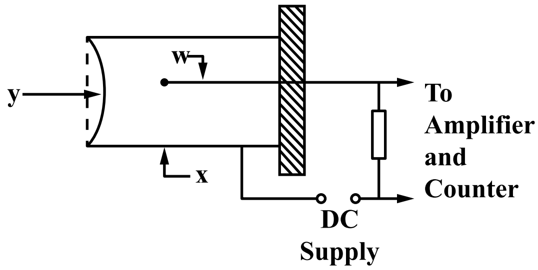
44. An archaeologist finds an ancient wooden relic and obtains its count rate as 20 counts per minute per gram of sample. The count rate obtained from the bark of a living tree is 104 counts per minute per gram and the background count rate is 8 counts per minute. What is the approximate age of the relic?

[Radioactive carbon $^{14}_{6}C$ has a half-life of 5600 years]

(A) 3000 years
(B) 11 000 years
(C) 17 000 years
(D) 22 000 years

GO ON TO THE NEXT PAGE

Item 45 refers to the following diagram which shows a Geiger-muller tube.



45. What are the parts labelled w, x and y?

	w	x	y
(A)	Cathode	Anode	Glass window
(B)	Anode	Cathode	Glass window
(C)	Cathode	Anode	Mica window
(D)	Anode	Cathode	Mica window

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Master Data Sheet: Unit 2

Question	Module/Specific Objective	Profile	Key
1	1.1.1	UK	C
2	1.1.3	KC	D
3	1.1.5,1.1.7	UK	C
4	1.2.5	UK	C
5	1.1.5, 1.1.9,1.2.5	UK	C
6	1.2.5, 1.2.8	UK	A
7	1.2.6	KC	C
8	1.3.3	UK	C
9	1.3.6	KC	D
10	1.4.5	UK	C
11	1.5.3	UK	B
12	1.7.4	UK	B
13	1.6.4	UK	A
14	1.6.10	KC	D
15	1.7.5	UK	A
16	2.2.1	UK	D
17	2.1.4	KC	C
18	2.2.3	KC	B
19	2.2.5	UK	D
20	2.2.9	KC	D
21	2.3.1	UK	A
22	2.4.2	KC	B
23	2.5.4	UK	B
24	2.4.11	KC	A
25	2.4.14	UK	D
26	2.4.19	UK	D
27	2.4.19	KC	B
28	2.5.1	KC	C
29	2.5.6	KC	C
30	2.5.2	UK	A
31	3.1.20	KC	B
32	3.1.2	UK	D
33	3.1.6	KC	D
34	3.1.10	KC	B
35	3.1.2	KC	B
36	3.1.19	KC	D
37	3.1.21	UK	C
38	3.2.4	KC	B
39	3.1.7	UK	D
40	3.3.2	UK	B
41	3.4.8	UK	B
42	3.3.7	UK	A
43	3.4.4	KC	A
44	3.4.10	UK	C
45	3.4.11	KC	D

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PHYSICS

UNIT 2 – Paper 02

2 hours 30 minutes

SPECIMEN PAPER

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of THREE questions. Answer ALL questions.
2. Write your answers in the spaces provided in this booklet.
3. Do NOT write in the margins.
4. Where appropriate, ALL WORKING MUST BE SHOWN in this booklet.
5. You may use a silent, non-programmable calculator to answer questions, but you should note that the use of an inappropriate number of figures in answers will be penalized.
6. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
7. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

NOTHING HAS BEEN OMITTED.

LIST OF PHYSICAL CONSTANTS

Speed of light in free space	c	=	3.00×10^{8} m s^{-1}
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
Permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
	$\frac{1}{4\pi\,\varepsilon_0}$	=	9.0×10^{9} m F^{-1}
Elementary charge	e	=	1.60×10^{-19} C
Planck's constant	h	=	6.63×10^{-34} J s
Unified atomic mass constant	u	=	1.66×10^{-27} kg (931 MeV)
Energy equivalence	l u	=	931 MeV/c^2
Rest mass of electron	m_e	=	9.11×10^{-31} kg
Rest mass of proton	m_p	=	1.67×10^{-27} kg
Acceleration due to gravity	g	=	9.81 m s^{-2}
1 Atmosphere	atm	=	1.00×10^{5} N m^{-2}
Avogadro's constant	N_A	=	6.02×10^{23} per mole

GO ON TO THE NEXT PAGE

SECTION A

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

1. The circuit shown in Figure 1 is used to study the discharge of a capacitor. When the moveable contact is connected to P, the capacitor, C, charges.

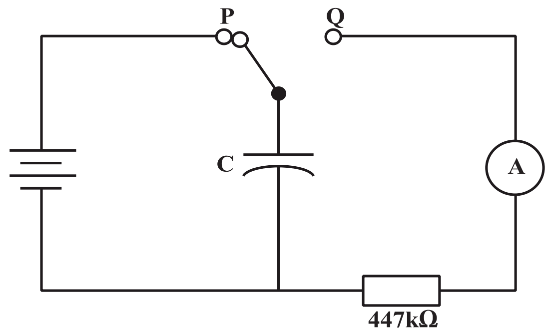

Figure 1. Circuit diagram

(a) Explain how energy is stored in the capacitor when the switch is connected to **P**.

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[**2 marks**]

(b) When the switch is in position **P**, calculate the energy stored in the capacitor if the voltage, V, is 1.5 V and the value of the capacitor is 1 000 μF.

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[**3 marks**]

GO ON TO THE NEXT PAGE

(c) In the space below, sketch the graph of the voltage across the capacitor versus time, from the time the switch reaches **P** until the capacitor fully charges.

[**3 marks**]

(d) The switch is now moved to position **Q** and the capacitor discharges.

(i) In the space below, sketch the graph of the voltage across the capacitor, Vc, versus time, from the time the switch reaches Q until the capacitor discharges.

[**3 marks**]

(ii) Write the equation for the current during capacitor discharge.

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[**1 mark**]

(iii) The initial current Io was 100 mA. R is 47 KΩ and C is 1 000 μF. Determine the time constant of the discharge in seconds.

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[**3 marks**]

GO ON TO THE NEXT PAGE

(e) Describe the motion of the free electrons in a metallic conductor

(i) before the current is switched on
(ii) after the current is turned on.

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[**2 marks**]

(f) Using your answers to (e) (i) and (e) (ii), explain the meaning of the term 'drift velocity'.

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[**1 mark**]

(g) Show that the drift velocity in a metallic conductor is given by $v = \frac{I}{neA}$ where n is the electron charge density, *e* is the electron charge, *I* is the current and *A* is the cross-sectional area of the conductor.

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[**3 marks**]

(h) A length of Nichrome wire with cross-sectional area 2.60 x 10^{-6} m^2 has a potential difference of 100 V across it. Nichrome has a resistivity of 5.0 x 10^{-7} Ωm. The element dissipates thermal energy at a rate of 500 W.

Calculate

(i) the current flowing through the wire

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[2 marks]

(ii) the resistance of the wire

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[2 marks]

(iii) the length of the wire

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[3 marks]

(i) Calculate the drift velocity of the electrons, given that each cubic metre of Nichrome contains 9.0 x 10^{28} conduction electrons.

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[2 marks]

Total 30 marks

2. The variation in the gain of an inverting amplifier at different frequencies may be investigated with the circuit shown in Figure 2. The input and output signals are displayed on the screen of a double beam cathode ray oscilloscope. A signal generator provides the input signal.

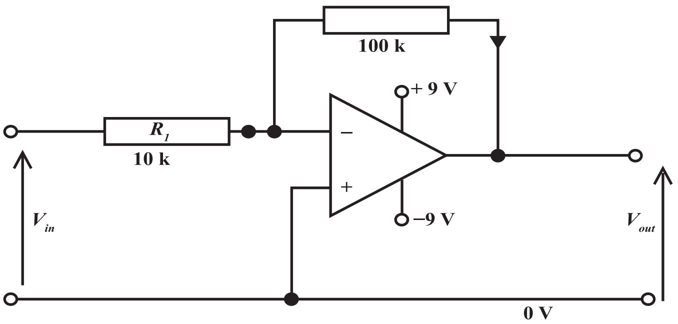

Figure 2. Circuit diagram

(a) What is the output of the amplifier when V_{in} is 0.5V?

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[2 marks]

(b) The graph on page 12 shows the data collected in such an experiment.

(i) Use the graph to obtain a value of the gain A curves pointing to the following frequencies:

100 Hz, 1 000 Hz, 10 000 Hz, 32 000 Hz, 100 000 Hz.

Present your results in an appropriate table.

[4 marks]

GO ON TO THE NEXT PAGE

(ii) State what is meant by the bandwidth of an amplifier.

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[**1 mark**]

(iii) Explain the use of logarithmic scales on the vertical and horizontal axes.

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2 marks]

(c) Draw tangents to the graph at the points ($\log_{10} f = 2.0$, $\log_{10} A = 2.0$) and ($\log_{10} f = 4.8$, $\log_{10} A = 1.54$) and produce them to find the point at which they intersect.

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[**3 marks**]

(d) The point of intersection of the tangents gives the bandwidth of the amplifier.

(i) Determine the bandwidth of this amplifier.

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[**1 mark**]

(ii) Calculate the resulting bandwidth of the amplifier if the input resistor was changed to 1 kΩ.

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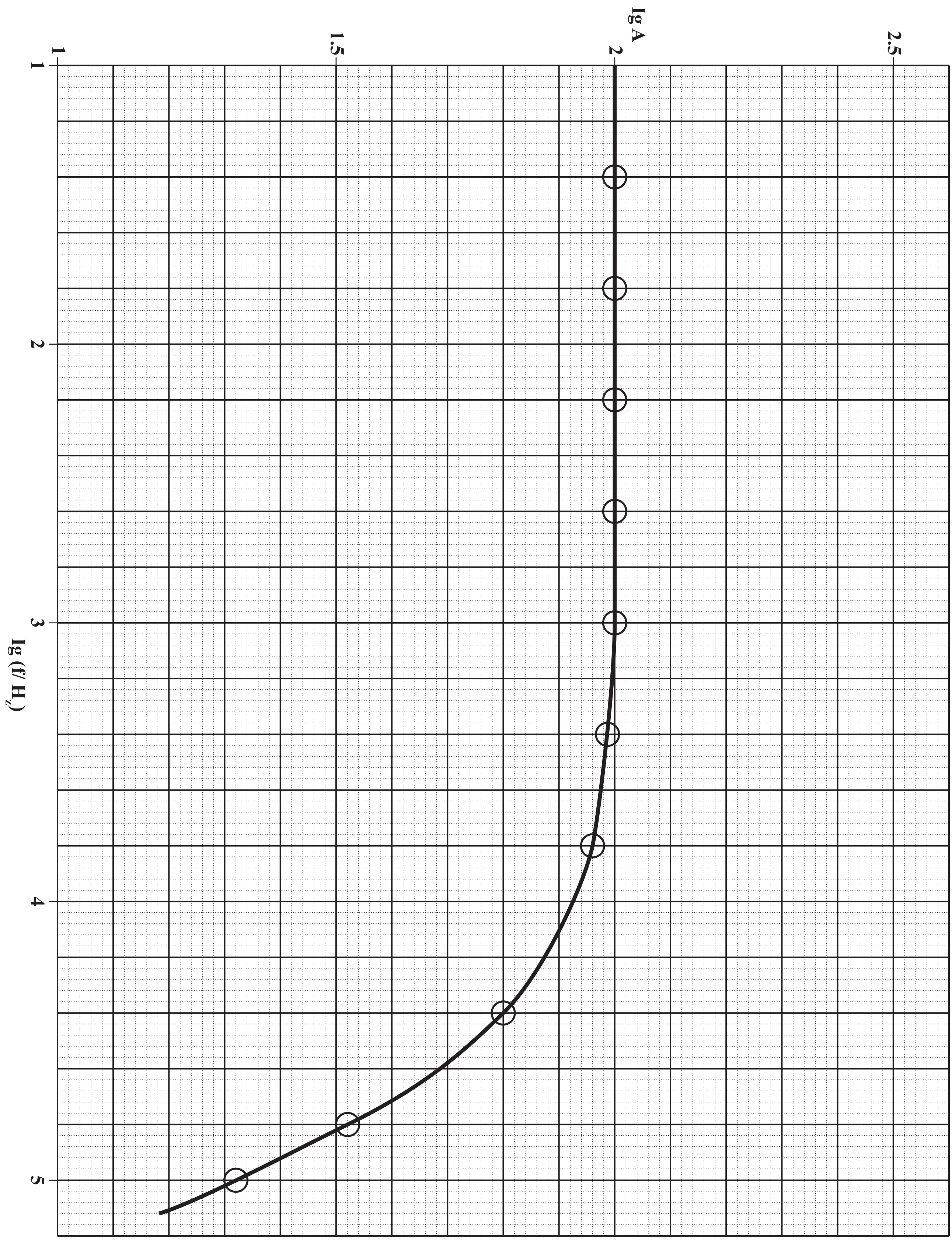
2 marks]



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(e) Figure 3 shows a logic circuit with TWO inputs, R and S, and TWO outputs Q and Q'.

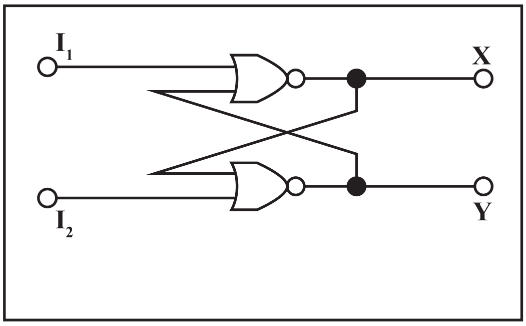

Figure 3

(i) Name the type of circuit shown in Figure 3.

....

....

[**1 mark**]

(ii) Name the logic gate used in the circuit.

....

....

[**1 mark**]

(iii) Copy and complete the sequential truth table given in Table 1 to show the action of the circuit in Figure 3.

[**2 marks**]

Sequence	I_1	I_2	**X**	**Y**
1	0	1	1	0
2	0	0	1	0
3	1	0		
4	0	0		
5	0	1		
6	0	0		

GO ON TO THE NEXT PAGE

(iv) By considering the role of feedback in the circuit and the condition for the type of gate in (e) (ii) to have a logic 0 output, explain why the output does NOT change when the input changes in the second step of the sequence (Row 2) as shown in Table 1.

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[**3 marks**]

(f) (i) Draw the circuit for a half-adder. Explain, with the aid of a truth table, what its function is and how it performs that function.

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[**5 marks**]

(ii) TWO half-adders can be connected to form a full-adder as shown in Figure 4. This circuit has THREE inputs.

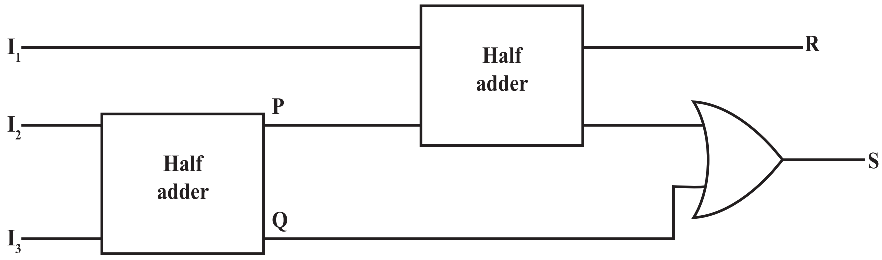

Figure 4.

Draw a table to show the outputs at points P, Q, R and S for the following input states:

A. 11 = 1 I2 = 0 I3 = 1
B. 11 = 1 I2 = 1 I3 = 1

[2 marks]
Total 30 marks

3. (a) (i) State what is meant by 'ware-particle duality'.

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[**2 marks**]

(ii) Write the de-Broglie equation.

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[**1 mark**]

(b) Sodium has a work function of 2.2 eV. Find

(i) its threshold wavelength

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[**2 marks**]

(ii) the maximum energy of the photoelectrons when the metal is illuminated by light of wavelength 4×10^{-7}m

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[**2 marks**]

(iii) the stopping potential.

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....

[1 mark]

(c) For the following equation, determine the energy released, in Joules.

$$^{2}_{1}He + ^{1}_{1}H \rightarrow ^{3}_{2}He$$

Mass of $^{2}_{1}H = 2.015\,\mu$

Mass of $^{1}_{1}He = 1.008\,\mu$

Mass of $^{3}_{2}H = 3.017\,\mu$

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[4 marks]

(d) (i) Define the 'half-life' and 'decay constant' of a radioactive substance.

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[2 marks]

GO ON TO THE NEXT PAGE

(ii) Radium has a half-life of 1.6×10^3 years. What is its decay constant?

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[3 marks]

(iii) For a sample of 5.0×10^{16} radium nuclei at time zero, what is its activity?

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[2 marks]

(iv) Write down the equation showing the decay of $^{226}_{88}Ra$ that produces both alpha and gamma decay.

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[2 marks]

(e) Another radioactive sample's activity was obtained for a 10-hour period.

Time/min	Activity/Cpm
60	3100
120	2450
240	1480
360	910
480	545
600	330

(i) On the grid provided on page 20, display the above results on a graph to indicate an exponential decay.

[5 marks]

GO ON TO THE NEXT PAGE

(ii) Use your graph to determine the half-life of the sample.

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[1 mark]

(iii) What will be the activity at time 900 minutes?

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[3 marks]

Total 30 marks

EXTRA SPACE

If you use this extra page, you MUST write the question number clearly in the box provided.

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Date: ______________________________

C A R I B B E A N E X A M I N A T I O N S C O U N C I L

ADVANCED PROFICIENCY EXAMINATION

PHYSICS

UNIT 2 - PAPER 02

MARK SCHEME

2017

Question 1.

(a) The capacitor is connected to the power supply. An electric field is set up across the plates of the capacitor **(1)**. The plates become charged as electrons are attracted from the positive plates and simultaneously repelled from the negative terminal to the negative plate **(1)**

KC	UK	XS
2		

(b)

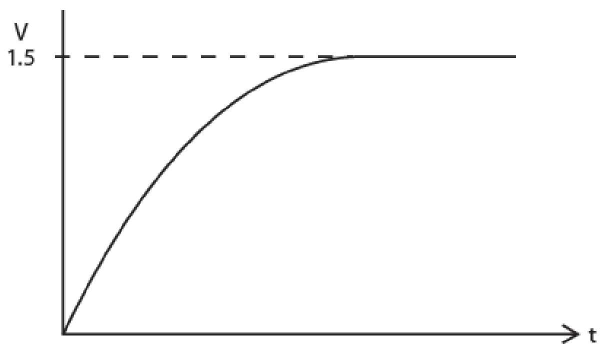
$E = \frac{1}{2} CV^2$ **(1)**

$= \frac{1}{2} \times 1000 \times 1.5^2$ **(1)**

$= 1.13$ m J **(1)**

KC	UK	XS
1	2	

(c)



Shape **(2)**- Increasing portion **(1)**, saturation portion **(1)**
Correctly labelled axes **(1)**

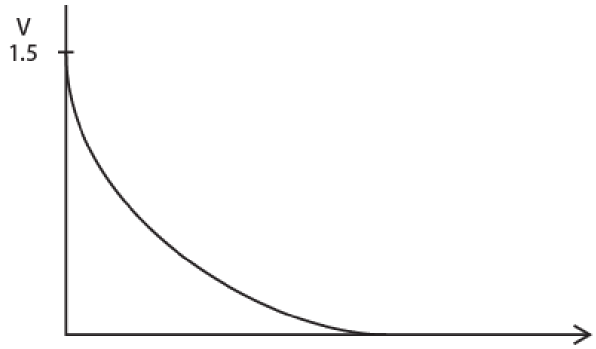
KC	UK	XS
	2	1

Question 1 continued

(d)
(i)

KC	UK	XS
		1

Question 1 continued

		KC	UK	XS
(ii)			2	
	Shape **(2)**- Increasing portion **(1)**, saturation portion **(1)**	1		
(iii)	Correctly labelled axes **(1)**	1		
	$I = I_0 (1 - e^{-t/CR})$ **(1)**		2	
(e) (i)	T = C R **(1)** = $1000 \times 10^{-6} \times 47 \times 10^{3}$ = 47 sec **(1)** **(1)**			
(ii)		2		
(f)	Free electrons are in random motion before the current is switched on. Collisions between electrons are common **(1)**.	1		
	After the current is switched on, electrons are guided by the electric field. They travel towards the positive potential **(1)**.			
	The drift velocity is average velocity of particles as they are attracted to the positive potential. There are many collisions **(1)**.			
(g)				
	Consider a segment of a conductor length L and cross-	2		

Question 1 continued

Question	Mark scheme	KC	UK	XS
	sectional area A. The volume of the segment is L x A.		1	
(h)	The charge carriers travel at speed v Then speed = dist/time $\Rightarrow$ V = L/t			
(i)	Number of charge carriers per unit volume = n			
(ii)	The total charge in the segment is enVtA **(1)**	1	1	
(iii)	The current flowing in charge passed/time i.e. I = enVtA/t = enVA **(1)**	1	1	
	hence V = I/neA **(1)**	1		
(i)	I = P/V **(1)** = 500/100 = 5 A **(1)**		2	
	$R = \frac{V}{I}$ **(1)** $= \frac{100}{5} = 20\Omega$ **(1)**			
	$R = \frac{\rho L}{A}$ **(1)** $L = \frac{RA}{\rho}$		2	
	$= \frac{20 \times 2.6 \times 10^{-6}}{5.0 \times 10^{-7}}$ **(1)** = 104 m **(1)**	13	15	2
	$V = \frac{I}{neA}$ Volume of conductor = 104 x 2.6 x 10^{-6} = 2.704 x 10^{-4} m^3			
	n = 2.704 x 10^{-4} x 9.0 x 10^{28} = 2.43 x 10^{25}			
	$V = \frac{5}{2.43 \times 10^{25} \times 1.6 \times 10^{-19} \times 2.6 \times 10^{-6}}$ **(1)**			
	= 0.49 ms^{-1} **(1)**			

Total 30 marks

Question 2

KC	UK	XS

(a) $\text{output} = \frac{V_2}{V_1} = -\frac{R_2}{R_1}$

$= -\frac{1\ 000\ 000}{10\ 000} = -10$ **(1)**

UK: 2

(b) (i) When V1 = 0.5V then V2 = 5V **(1)**

XS: 2

f(Hz)	Log$_{10}$f	Log$_{10}$A	A
100	2.0	2.00	100
1000	3.0	2.00	100
10,000	4.0	1.94	87.0
33,000	4.5	1.75	56.0
100,000	5.0	1.32	20.9

UK: 2

Columns 2 and 4 - all correct 2UK (-1 for each error)
Column 3 - all correct 2XS (-1 for each error)

(ii)

KC: 1

Band width = Range of operating frequencies for the amplifier **(1)** OR

Range of frequencies for which the voltage gain does not fall below a specified fraction of the nominal gain **(1)**

(iii)

KC: 2

Logarithmic scale more suitable for showing large range of frequencies encountered with op-amps (horizontal scale) **(1)**

Logarithmic scale more suitable for showing large range of gains encountered with op-amps OR

amplifiers widely used in audio applications and response of the ear is logarithmic hence logarithmic gain scale (vertical scales) **(1)**

(c)

XS: 3

(d) (i) Drawing two accurate tangents **(2)**
Read-off from intersection of tangents (**1)**

UK: 1

(ii) At intersection log10f BW = 4.2 hence BW = antilog104.2 = 15.85 kHz **(1)**

UK: 2

Question 2

(e)

If R1 = 1.0k gain becomes $-\frac{100}{1}$

$$= -100$$

The gain increases to 100 or by a factor of 10 **(1).**

Band width will be 1/10th as large since gain x BW is constant = 1.585 kHz **(1)**

(iii)

(i) R- S flip flop **(1)**

(ii) NOR gate **(1)**

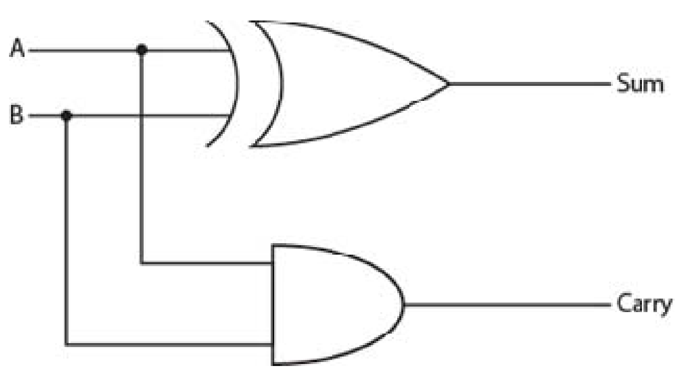
(iv)

Sequence	R	S	Q	Q’
1	0	1	1	0
2	0	0	1	0
3	1	0	0	1
4	0	0	0	1
5	0	1	1	0
6	0	0	1	0

(f) (i)

The circuit is an R-S FLIP-FLOP **(1).** The present output is determined by the previous value of the outputs and the present values of inputs **(1).** 0-0 on the input is compatible with any combination of outputs hence the output does not change when 0-0 is asserted at the input **(1).**

The Half Adder



KC	UK	XS
1		
1	3	
	3	
2		
2		
1		

Question 2

KC	UK	XS
	2	
10	15	5

(ii)

A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

1 mark for Sum column, 1 mark for Carry column

When the result of binary addition produces a sum that cannot be accommodated by one column, the carry is necessary to report the result **(1).**

The Ex OR Gate produces the sum and the AND Gate produces the carry.

	I_1	I_2	I_3	P	Q	R	S
A	1	0	1	1	0	0	1
B	1	1	1	0	1	1	1

Total 30 marks

Question 3	KC	UK	XS
(a) (i) A theory that seeks to explain the behaviour of light as waves **(1)** and in some cases as particles **(1)**.	2		
(ii) $\lambda = \frac{h}{P}$	1		
(b) (i) $\Phi = 2.2$ eV			
$f_0 = \frac{W}{h}$ **(1)** $= \frac{2.2 \times 1.6 \times 15^{-19}}{6.55 \times 10^{-34}\ Js} = 5.37 \times 10^{14}$ Hz **(1)**	1	1	
(ii)			
KE max $E = hf + \Phi$ $E = \frac{hc}{\lambda} + \Phi$ **(1)**	1		
$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8} + 2.2 \times 10^{-19}}{4 \times 10^{-7}}$		1	
(iii) $= 7.17 \times 10^{-19}$J **(1)**			
Stopping potential $eV_s = hf - W$ $= \frac{6.63 \times 10^{-34} \times 3 \times 0.10^{8}}{4 \times 10^{-7}} - 2.2 \times 10^{-19}$		1	
$eV_s = 4.12 \times 10^{-15}$			
$V_s = \frac{4.12 \times 10^{-15}}{1.6 \times 10^{-19}}$ **(1)**			

Question 3

Answer	KC	UK	XS
(c) $E = \Delta mc^2$ **(1)**	1		
$\Delta m = 3.017\ u - (2.015\ u + 1.008\ u)$ $= -0.006\ u$ **(1)** $= 0.006 \times 1.66 \times 10^{-27}$ $= 9.96 \times 10^{-30}$ kg **(1)** $E = 9.96 \times 10^{-30} \times (3 \times 10^8)^2$ $= 8.97 \times 10^{-13}$J **(1)**		3	
(d) (i) Half-life is the time taken for half the number of particles to disintegrate **(1)**. Decay constant λ: is a characteristic of the atoms that decay such that $\lambda = -\frac{1}{N}\frac{dN}{dt}$ **(1)**	2		
(ii) $T_{½} = \frac{0.693}{\lambda}$ **(1)**	1		
$\lambda = \frac{0.693}{1.6 \times 10^3}$ **(1)** $= 4.33 \times 10^{-4}\ s^{-1}$ **(1)**		2	
(iii) $A = -\lambda N$ **(1)**	1		
$= -4.33 \times 10^{-4} \times 5 \times 10^{-4} \times 10^{16}$ $= 2.17 \times 10^{13}$ Bq **(1)**		1	
(iv) $^{226}_{88}Ra \rightarrow {}^{222}_{86}X + {}^{4}_{2}He$ **(1)** $^{226}_{88}Ra \rightarrow {}^{226}_{89}X + {}^{0}_{-1}e$ **(1)**		2	

KC	UK	XS

Question 3

(e)

(i) For plotting graph — XS: **5**

Suitable scales **(1)**
5-6 correct points **(3)**
3-4 correct points **(Award 2 marks only)**
1-2 correct points **(Award 1 mark only)**
<2 correct points **(Award 0 marks)**
Best fit line **(1)**

(ii) Half-life = 144 min $\therefore \lambda = \dfrac{0.693}{144 \times 60}$ **(1)** — UK: **1**

(iii) 900 min = $\dfrac{900}{144}$ = 6.25 half-lives. — UK: **3**

$T_{½}$ = 174 min
= 174 x 60 sec
= 10440 sec **(1)**

$\lambda = \dfrac{0.693}{T_{½}}$

$= \dfrac{0.693}{10440}$

$= 6.6 \times 10^{-5}$ **(1)**

$A = A_o e^{-\lambda t}$

After 900 mins i.e. 900 x 60 sec
= 54000 sec

$\text{Activity} = 3100 \times e^{-6.6 \times 10^{-5} \times 54000}$

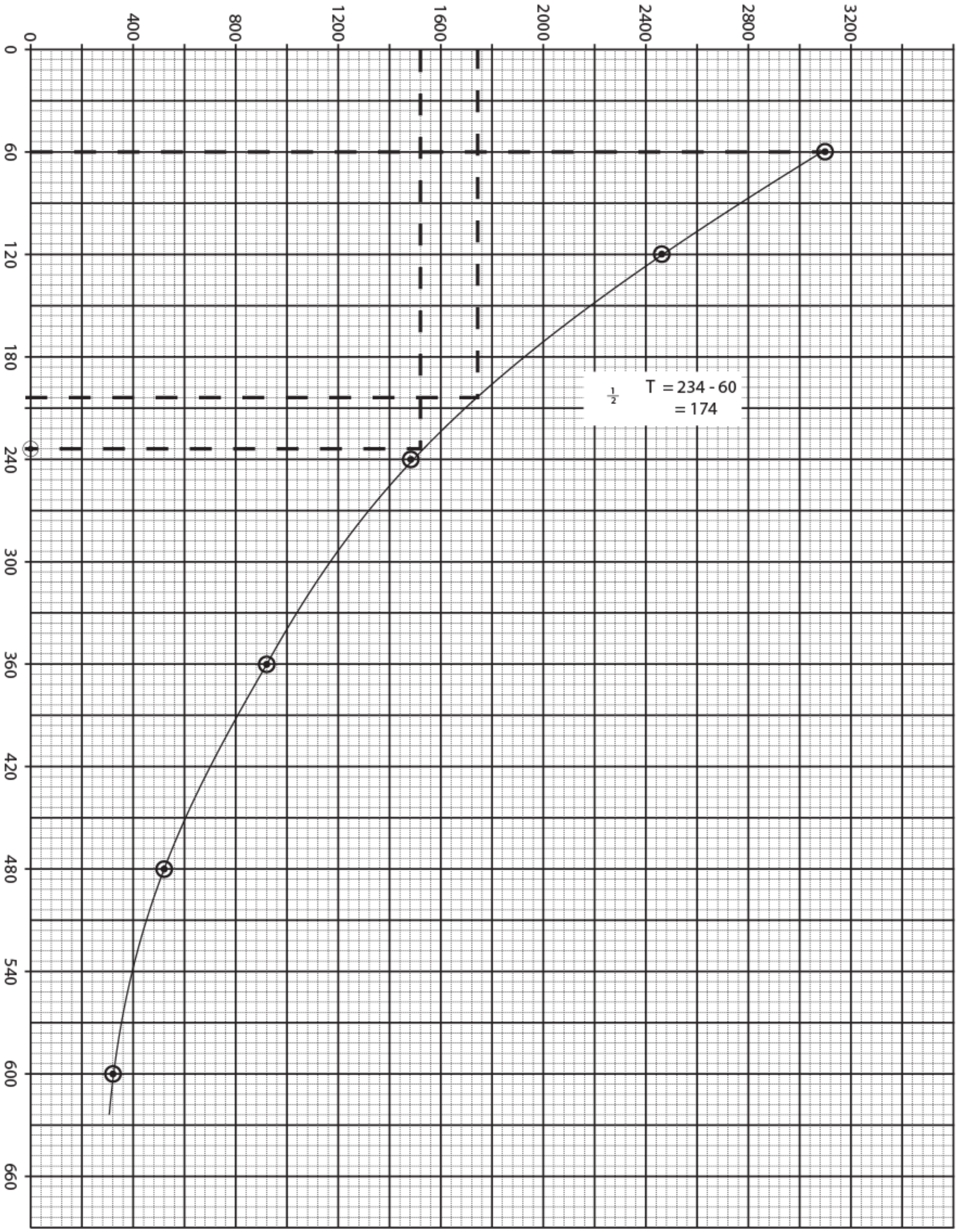
$= 3100 \times e^{-3.564}$

= 87.4 cpm **(1)**

Total 30 marks

KC	UK	XS
10	15	5

Graph for Question 3 (e) (i)



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SUBJECT PHYSICS – UNIT 2 – Paper 032

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CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

PHYSICS

UNIT 2 – Paper 032

ALTERNATIVE TO SCHOOL-BASED ASSESSMENT

2 hours

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of THREE questions. Answer ALL questions.
2. Write your answers in the spaces provided in this booklet.
3. Do NOT write in the margins.
4. Where appropriate, ALL WORKING MUST BE SHOWN in this booklet.
5. You may use a silent, non-programmable calculator to answer questions, but you should note that the use of an inappropriate number of figures in answers will be penalized.
6. You are advised to take some time to read through the paper and plan your answers.
7. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
8. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

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Answer ALL questions.

Write your answers in the spaces provided in this booklet.

1. (a) In this experiment, you will investigate the relationship between the peak-peak voltage of an alternating current waveform and its effective value in delivering power to a pure resistor.

You are provided with the following:

- 20Ω, 100W wire wound resistor
- Calorimeter
- Mercury in glass thermometer (0ºC - 100ºC)
- Stirrer
- Large beaker containing approximately 1.5 litres water maintained at constant temperature (ambient temp of tap water will suffice)
- Digital scale
- Oscilloscope
- 0-30V variable output voltage ac power supply (5A)
- Timer
- Calibrated digital multimeter

Procedure

1. Weigh the empty calorimeter and record its weight in Table 1.
2. Pour approximately 200 mL of water into the calorimeter and weigh calorimeter and the added water. Record this result in Table 1.
3. Determine, *m*, the mass of added water by subtraction and record this value in Table 1.
4. Using a calibrated multimeter, measure the true resistance, *R*, of the nominal 25Ω resistor and record this value in Table 1.
5. Set up the apparatus as shown in Figure 1.

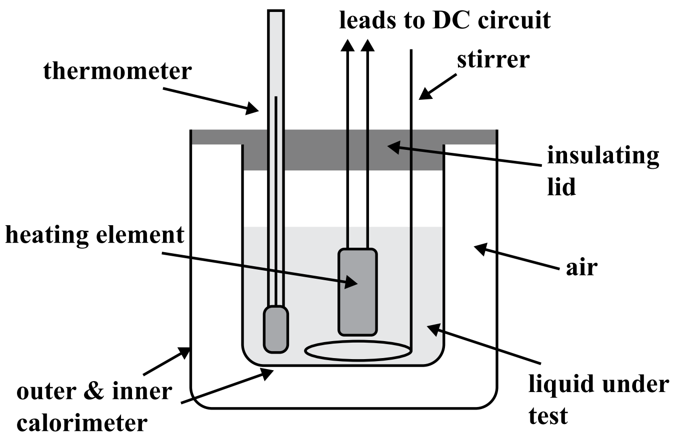

Figure 1. Diagram of apparatus

The heating element is the 20Ω resistor and the leads will be connected to the AC supply (instead of DC as shown in the diagram).

GO ON TO THE NEXT PAGE

6. Using the oscilloscope, adjust the output of the ac supply to a peak voltage of 30V.
7. Switch off the ac supply and connect its output to the 20Ω resistance heating element.
8. Record the initial temperature, *Ti*, of the water as indicated by the thermometer
9. Switch on the ac supply and start the timer.
10. Stir the water as continuously as is convenient and after 15 minutes (time interval Δt) switch off the ac supply and record the temperature.
11. Wait for the apparatus to cool.
12. Repeat steps (1) – (10) for a fresh quantity of water (mass of added water, m, should be the same throughout the experiment) and ac supply of 25V, 20V, 15V and 10V peak voltages.

TABLE 1: RESULTS OF EXPERIMENT

Mass of calorimeter	
Mass of calorimeter + water	
Mass of added water, *m*	
Resistance of heating resistor, *R*	
Time interval, Δt	

[3 marks]

(b) Using a suitable table, record the remainder of the results of the experiment in the space provided below. **[4 marks]**

(c) On the grid provided on page 6, plot a graph of the temperature change, ΔT, vs $(V_{pk}/\ \mathrm{sqrt}(2))^2$

[4 marks]

GO ON TO THE NEXT PAGE

(d) Determine the slope of your graph plotted in Part (c).

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....

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[2 marks]

(e) Compare the value obtained in Part (d) with the theoretical value, $S = \Delta t/mRC$, where C is the specific heat capacity of water. Comment on your result.

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....

....

[2 marks]

Total 15 marks

2. The circuit in Figure 2 has been set up with a cell of e.m.f, E, and internal resistance, r.

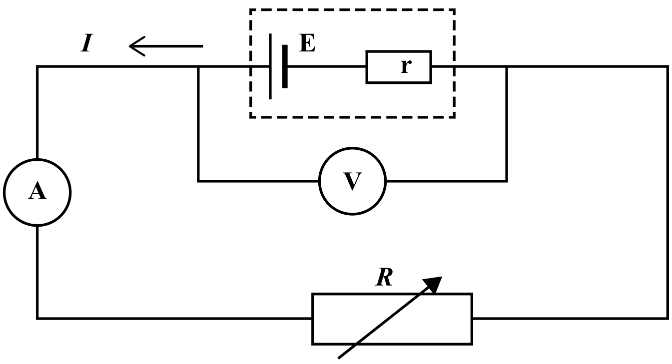

Figure 2. Circuit diagram

One equation that is relevant to the circuit is:

$$V = E - Ir$$

GO ON TO THE NEXT PAGE

(a) Several values of R and I are measured and plotted on a graph of R against $\frac{1}{I}$, shown in Figure 3. The equation of the graph is $R = \frac{E}{I} - r$.

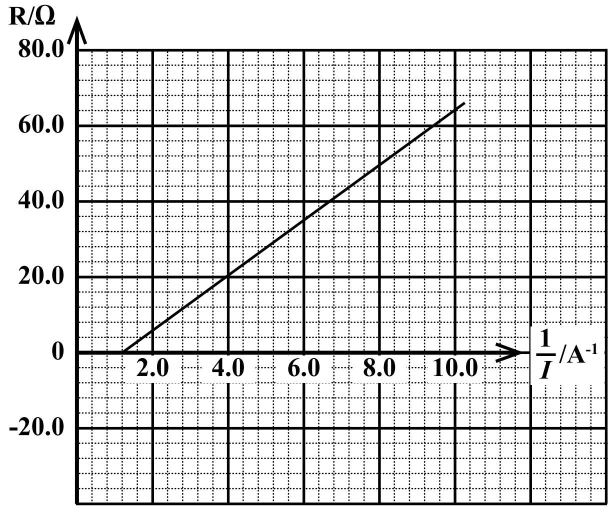

Figure 3. Graph of R against $\frac{1}{I}$

(i) Use the graph in Figure 3 to find the internal resistance, r, of the cell.

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[1 mark]

(ii) Determine the e.m.f of the cell.

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[2 marks]

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(iii) Using values obtained from the graph in Figure 3, calculate the power dissipated in the resistor *R*, when there is a current of 0.25 A.

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[3 marks]

(b) A second identical cell is added in series with the original cell and the experiment is repeated.

(i) Determine the new e.m.f and internal resistance of the combined cells.

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[2 marks]

(ii) Given an e.m.f. of 8 V and an internal resistance of 3 Ω, complete Table 2 using the equation for R given in Part (a).

TABLE 2: RESULTS OF EXPERIMENT

I (A)	1/I (A^{-1})	R (Ω)
0.1		
0.2		
0.5		
0.8		
1.0		

[3 marks]

(iii) On the grid provided on page 10, plot a graph of R against $\frac{1}{I}$, using the results of the experiment in Table 2. **[4 marks]**

Total 15 marks

3. A photocell generates electricity when it is exposed to light from the visible spectrum. The voltage produced in the photocell varies with the intensity of the light source. A student suggests that the voltage produced also varies with the colour of the light.

Assume that you are provided with the following apparatus

- Photocell
- Voltmeter
- Sheltered light intensity meter/photocell
- Selection of filters
- Light source of variable intensity
- Metre rule

Design an experiment to investigate the response of the photocell to the light of three different colours and the intensity of the light. Write your answers under the following headings.

(a) Identification of variables

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....

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[2 marks]

(b) Set-up of apparatus

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[3 marks]

GO ON TO THE NEXT PAGE

(c) Procedure

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[5 marks]

(d) Results and Conclusion

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[5 marks]

Total 15 marks

EXTRA SPACE

If you use this extra page, you MUST write the question number clearly in the box provided.

Question No.

EXTRA SPACE

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2. **Ensure that this slip is detached by the Supervisor or Invigilator and given to you when you hand in this booklet.**

3. **Keep it in a safe place until you have received your results.**

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Sign the declaration below, detach this slip and hand it to the candidate as his/her receipt for this booklet collected by you.

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SPECIMEN

PHYSICS

UNIT 2 – PAPER 032

KEY AND MARK SCHEME

MAY/JUNE 2017

PHYSICS
UNIT 2 — PAPER 032
MARK SCHEME

Question 1

(a) Table 1: Results of Experiment

Mass of calorimeter	0.62 kg
Mass of calorimeter + water	0.85 kg
Mass of added water, m	0.23 kg
Resistance of heating resistor, R	20.8Ω
Time interval, Δt	15 mins = 900s

2 XS for accurate recording of ALL results in Rows 1 – 4 (Deduct 1 XS if any row is incorrect.)

1 UK for accurate recording of result in Row 5.

[3 marks]

KC	UK	XS
	1	2

(b) Further results of experiment

V_{pk} (volts)	T_i	T_f	$\Delta T = T_f - T_i$	$(V_{pk}/\sqrt{2})^2$
30	27.0	50.2	23.2	450
25	28.3	44.4	16.1	313
20	28.5	38.8	10.3	200
15	29.3	35.1	5.80	113
10	28.4	30.9	2.50	50.0

For Columns 1 -3, award 2 **XS** for sensible results and correct sig. figs

For Columns 4 and 5 calculations, award **2 UK** for correct results, deduct 1 mark for each error

[4 marks]

KC	UK	XS
	2	2

(c) Plotting of Graph

Suitable scales **(1)**
Labelled axes (quantity and unit)**(1)**
All points accurately plotted **(1)**
Best-fit straight line**(1)**

[4 marks]

KC	UK	XS
		4

(d) Slope S, measured from graph $= \frac{21.9-0.0}{425-0.0} = 0.051\ ºC/Volt$

correct read off of points **(1 XS)**
correct calculated value **(1 UK)**

[2 marks]

KC	UK	XS
	1	1

PHYSICS
UNIT 2 — PAPER 032
MARK SCHEME

		KC	UK	XS
(e)	Theoretical value of slope $S = \frac{900}{0.23x20.8x4180} = 0.045\ ºC/Volt$ **(1 UK)** CONCLUSION: Relationship verified within the limits of experimental error. Cumulative experimental error substantial because of the large number of measurements.**(1 XS)** **[2 marks]**		1	1
	Total 15 marks		5	10

PHYSICS
UNIT 2 — PAPER 032
MARK SCHEME

Question **2**

(a) (i) By extrapolation, 8Ω **(1)**

[1 mark]

(ii) Reading off values from graph **(1 XS)**
Gradient, read off values and calculate, for example:
(64−0)/(10−1.2) = 7.2 V(**1 UK)**

[2 marks]

(iii) 1/I = 4 A
R = 20Ω (**1 XS)**
$P = I^2R$ or $P = IV$ or $P = V^2R$ (after finding V using equation given) **(1 UK)**
$P = (0.25)^2 \times 20 = 1.25$ W **(1 UK)**

[3 marks]

(b) (i) Both would double: E = 14.4 V; r = 16 V **(2)**

[2 marks]

(ii)

I (A)	1/I (A^{-1})	R (Ω)
0.1	10	77
0.2	5	37
0.5	2	13
0.8	1.25	7
1.0	1	5

1/I column correctly calculated **(1)**
R column correctly calculated **(2)**

[3 marks]

(iii) Plotting of graph

4 accurate points **(2)**
2-3 accurate points **(1)**
<2 accurate points **(0)**

Suitable scales **(1)**
Accurate labeling **(1)**

[4 marks]

Part	KC	UK	XS
(a)(i)			1
(a)(ii)		1	1
(a)(iii)		2	1
(b)(i)		2	
(b)(ii)			3
(b)(iii)			4
Total 15 marks		**5**	**10**

PHYSICS
UNIT 2 — PAPER 032
MARK SCHEME

Question **3**

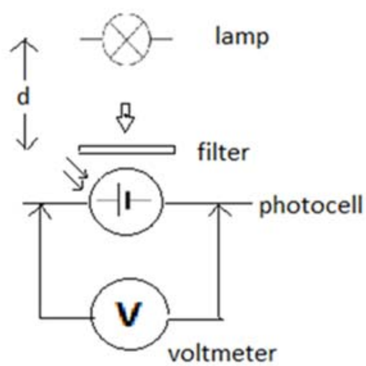
KC	UK	XS
		2
		3

(a)

Part	Relationship Tested	Dependent Variable	Independent Variable	Controlled Variable	Expected Results
1	Voltage/intensity	voltage	intensity	colour	
2	Voltage/colour	voltage	colour	intensity	

1 mark for each correct row **[2 marks]**

(b) Setup of apparatus



Proper arrangement as shown **(1)**
3-4 accurate labels **(2)**
1-2 accurate labels **(1)**

[3 marks]

PHYSICS
UNIT 2 — PAPER 032
MARK SCHEME

Question **3** continued

KC	UK	XS

(c) Procedure

(1) For Voltage/Intensity:

With no colour filters (or same colour filter) present **(1)** vary the distance of lamp (d) from photocell OR change vary lamp intensity for at least three positions **(1).**
Measure and record voltage **(1)**

(2) For Voltage/Colour:

With distance (d) fixed **(1),** measure and record the voltage for at least 3 different colours **(1)**

[5 marks]

XS: **5**

(d) Results and Conclusion

	Intensity	Voltage/V	Conclusion
1	low	V1	V depends on Intensity if $V_1 \neq V_2 \neq V_3$ **(1)**
	medium	V2	Inverse/proportional relationship **(1)**
	high	V3	V independent intensity if V1 = V2 = V3 **(1)**
2	Colour 1	V_1	V depends on colour if V1 ≠ V2 ≠ V3 **(1)**
	Colour 2	V_2	V independent colour if V1 = V2 = V3 **(1)**
	Colour 3	V_3	

XS: **5**

Total 15 marks

KC	UK	XS
		15