# SOUTH PACIFIC BOARD
# FOR
# EDUCATIONAL ASSESSMENT

## PACIFIC SENIOR SECONDARY CERTIFICATE

# PHYSICS
# SYLLABUS

(including the Assessment Prescription)

**Effective from January 2002.**

# Contents

## RATIONALE:

Physics as a field of study is the result of investigations of the fundamental behaviour patterns exhibited by energy, matter, waves and fields. The need for an understanding of these behaviour patterns must lie at the heart of any physics syllabus.

There has been a tendency however, for the student's concept of physics to be restricted to fundamental laws and relationships without any strong recognition for the way in which such laws and relationships have been used to:

(a) develop an understanding of the world.
(b) evolve a technology which affects every one of us in our daily lives.

There is pressure to open up science at the senior level to an increasing number of students throughout the Pacific region. Hopefully these students will leave school with a "science awareness" that will serve them well in their societies. In order to facilitate this hope, it is necessary for students to consolidate conceptual links between the basic ingredients of physics (the laws and relationships), and the way these relationships have been exploited in the development of our technological society. This involves regular searches of commonplace technology for ways in which the fundamental concepts of physics have been exploited. The presentation of the syllabus is such that it **encourages teachers to involve " living physics" in their teaching.**

Another feature of the worldwide move to make senior physics accessible to a greater number of students has been an attempt to describe relationships in such a way as to reduce **the level of mathematics** required by the student. Although the language of mathematics may clarify matters for the physicist, the use of descriptive narrative is sometimes more successful in securing understanding in the majority of students. For this reason, the level of mathematics expected in the treatment of topics and options in this syllabus is not higher than that normally acquired by the end of the pre-PSSC year.

The order in which the core topics are presented in this syllabus book is one possible teaching sequence for the course. However **teachers must feel free** to order the teaching of topics to suit their particular circumstances. Staffing, equipment, the weather, and a range of other features can influence the decision as to where to most sensibly place a particular topic in the teaching sequence.

## GENERAL AIMS:

This syllabus is designed to further develop students' interests in, and an enjoyment of, Physics through strengthening conceptual links between the basic laws and relationships of Physics and how they are applied to the development of technology in society. It requires contact with, and observation of, the functioning appliances for students to experience applications of "science in everyday situations".
The knowledge and skills gained can provide a foundation for further study, leading to a career in any of a number of Physics related areas.

The aims of studying this subject are to develop:

- an understanding of basic laws and relationships of Physics
- appreciate the application of Physics laws and relationships to the development of technology in society including home appliances
- problem-solving techniques using the knowledge and ideas of Physics
- skills in making deductions and drawing logical conclusions
- the ability to understand a concept through a study of models
- a "science awareness" for life after school
- an understanding of an area of interest in detail through the study of an elective
- an appreciation of the relevance of Physics for informed decision making in today's world.

## AN OVERVIEW OF THE NEW SYLLABUS

The new PSSC Physics course has 19 core topics that must be studied by all students and 5 electives, one of which will normally be studied by a classroom group. A classroom group could study more than one elective but this would require more teaching and learning time. Furthermore, students in the same classroom group could, conceivably study different electives, but this would also require more teaching time. Both these unusual situations are acceptable and are left to the discretion of the teacher given time and available resources.

**The Core Topic details** section describes the core.

- Each topic has a number (1 to 19) and **a descriptive title**.
- A 'box' that contains, in point form, a **summary of the topic content**.
- A list of objectives describing what a student should be able to do after studying the topic.
- A sub-section then follows entitled **common conceptual difficulties for students**. These brief descriptions are intended to alert teachers to ideas that they should pay particular attention to in their teaching.
- The brief descriptions in **practical suggestions** are meant to give teachers a lead on how they might involve their students in activities that are closely related to the physics content of the topic.
- **applications of topic concepts** provides a list of applications and phenomena that are directly associated with the areas focused on in the topic. The diagrams and figures in the margins are always related to something in one of the topic sub-sections and often provide further information to that in the text.

**The Elective details** is the next major section in the syllabus. The format of the elective descriptions is slightly different from that used for the core topics.

- Each elective begins with a letter (A to E) and a **descriptive title**
- A boxed **summary of the content** in point form
- The long list of **objectives** is then broken up into sub-sections – each with own title and a suggested time allocation.
- **The total suggested time for any elective is approximately 8 hours**.
- Objectives for each elective are of two types, **compulsory objectives** and **extension objectives**. The course material covered by the compulsory objectives must be taught in the case of each elective chosen. A time allocation of 3 hours is given to cover compulsory objectives. Teachers are free to choose from the remaining extension objectives in order to build up the remaining 5 hours allocated for the elective.
- **Practical suggestions** are listed after the objectives and they serve the same purpose as those for the core topics.
- Following these suggestions, **titles of possible text books** which provide elective support have been included, although teachers are advised to locate alternative texts as titles come into publication.
- Students will choose **ONLY ONE** of the electives for study.

The next main section in this document is the **Assessment Prescription**. This is where the details of the assessment process for PSSC Physics are described.

At the back of the book teachers will find physics symbols and equations, followed by Greek alphabet names and symbols that are relevant to the PSSC Physics course.

## A BRIEF LOOK AT THE ELECTIVES

A frequent feature of technological development is that it is rare for a single concept to be responsible for the functioning of an appliance. Far more common is the integration of many concepts; yet in physics syllabuses these concepts are generally presented in isolation. Take, for example, the following set:

- the pressure of a gas rises as its temperature rises,
- a high secondary voltage can be induced from a low primary voltage,
- combustion of a fuel releases energy as heat.

In the context of a physics syllabus, each of the above would fall neatly into its place with:

- the gas laws,
- induction and transformers
- energy considerations.

Yet in the context of a motorbike for example, they are all intricately related in the successful work output from the piston in the cylinder.

The development of the "Electives" section of the syllabus has resulted in different physics concepts being brought together under a common technological umbrella. It is important that each is taught with plenty of practical contact with the concepts involved.

The five electives attempt to relate physics to areas of life that may be now, or in the future, of particular importance to students. Some focus on areas that seem especially relevant to many Pacific-island students (e.g., Boat Physics), while others examine areas that are important in the world in general (e.g., Electronics). However, all the electives have been designed to enhance student learning of physics ideas through particular types of technology.

Students will be expected to choose **ONLY ONE** of the electives for study towards the internal assessment. It is left to the school to decide whether they are able to allow more than one elective to be followed within a particular set of students.

Careful consideration should be given to the elective content before selection is made. **Only those electives for which schools feel they can meet the <u>resource demand</u> of the content should be selected for study.**

### Elective A – Boat Physics

All nations participating in the PSSC system have strong links with boats and the ocean. Many students will use boats for transport, fishing or pleasure. This elective investigates some of the physical principles that are closely connected with the design, propulsion and general use of boats.

It is assumed that during the study of this elective, time will be spent "in or on the water", where students can experience the effects of the principles of physics that are operating.

### Elective B – Motor Vehicle Physics

Many students will, at some stage, be responsible for a motor vehicle. This unit involves the study of a selection of physical principles that are incorporated within the design and operation of motor vehicles. There needs to be an emphasis on contact between the student and the motor vehicle, in order that physical principles are clearly linked with the technology involved in the design and operation of motor vehicles.

**Elective C – Energy Extraction Systems**

Energy supply and use currently demand attention worldwide. It is hoped that students taking this elective will become familiar with the various forms of energy, and explore some of the ways in which that energy can be harnessed for use in a directed manner.

**Elective D – Electronics**

This elective assumes that students have had no previous experience of electronics. The elective attempts to cover a basic introduction to electronic components and the manner in which they operate. The constructions and behaviour of certain components is included, but the theory of operation is not included.

Having studied this elective, students should be in a position to recognize a variety of components and identify their function in simple circuits.

The whole of this elective should be tackled through practical experience.

**Elective E – Health Physics**

The elective covers physics of the circulatory system and then explores the use of physics in the design of equipment suitable for use in medical investigation and treatment. This elective would be a most suitable choice for schools that are situated close to a hospital that has reasonably up-to-date facilities.

It would be admirably suited for students who anticipate a career in medicine or one of the ancillary services.

## SUGGESTED TIME ALLOCATION FOR TOPICS AND ELECTIVE

| Topic No. | Core Topic Title | Hours | Weight (%) |
|---|---|---|---|
| **Topic 1** | Light: Propagation, Reflection, Refraction | 13 | 12 |
| **Topic 2** | Wave properties and propagation | 4 | 3 |
| **Topic 3** | Consideration of phenomena in terms of wave theory | 5 | 4 |
| **Topic 4** | The phenomena of diffraction and interference | 7 | 6 |
| **Topic 5** | Kinematics, with graphical representation and equation relationships. | 8 | 7 |
| **Topic 6** | Vectors – addition, subtraction and resolution | 4 | 3 |
| **Topic 7** | An introduction to dynamics | 6 | 5 |
| **Topic 8** | Momentum | 5 | 4 |
| **Topic 9** | Acceleration in gravitational fields | 2 | 2 |
| **Topic 10** | Kinematics of projectiles | 4 | 3 |
| **Topic 11** | Circular motion | 4 | 3 |
| **Topic 12** | Energy | 11 | 10 |
| **Topic 13** | Pressure, and its relationship with the volume and temperature of gases | 7 | 6 |
| **Topic 14** | Electrical principles relating to simple DC circuitry, and energy transfer | 10 | 10 |
| **Topic 15** | Charges, conductors and magnetic fields, leading to the motor effect | 5 | 4 |
| **Topic 16** | Magnetic fields surrounding current-carrying conductors | 3 | 3 |
| **Topic 17** | Electromagnetic induction | 4 | 3 |
| **Topic 18** | Electrostatics | 6 | 5 |
| **Topic 19** | The atom and radioactivity | 8 | 7 |
| **TOTAL** | | **116** | **100*** |
| **ELECTIVES** | | | |
| **Elective A** | Boat Physics | | |
| **Elective B** | Motor Vehicle physics | | |
| **Elective C** | Energy source and transfer | **8** | |
| **Elective D** | Electronics | | |
| **Elective E** | Health physics | | |
| **TOTAL** | | **124** | |

**Total time is approximately 124 hours.**

***** Represents the weighting of each Topic in the Examination. Electives are assessed totally through IA.

# THE ASSESSMENT PRESCRIPTION

The PSSC Physics course, with its content and skill objectives, comprises 19 core topics and 5 electives.

All students entering for PSSC Physics must complete all of the 19 core topics. The content and skill objectives listed in the 19 core units will form the basis for the construction of the written examination paper that students will sit at the end of their PSSC year.

All students entering for PSSC Physics must complete ONE of the five electives in the syllabus document.

The objectives listed in each of the electives are of two types, **compulsory** and **extension**. Students following an elective must study the work implied by the compulsory electives. A total of 8 hours teaching time should be devoted to the elective; 3 hours given to compulsory objectives and 5 hours given to extension objectives.

The written examination will assess only the core topics 1 to 19. The Electives will be assessed completely through the Internal Assessment Programme.

## A. <u>THE EXAMINATION PAPER</u> – 60% of the total assessment for the course.

**General**

The **Topic details** given in the core of the syllabus will form the basis for questions in the PSSC Physics examination.

Examination questions will be designed to test:

(a) knowledge and understanding of the basic facts, principles, generalizations and theories of physics,

(b) ability to apply knowledge and understanding to familiar situations within the bounds of the prescription,

(c) familiarity with the experimental procedures and laboratory skills associated with the subject.

Students will be expected to understand the meaning of those technical terms used in the topic objective lists.

Both multiple-choice and supply (i.e., students supply their answer rather than select one) questions will be included on the examination paper in the following weighting:

- Supply questions based on the core topics 1 to 19, **80%**
- Multiple-choice questions based on the core, **20%**

Regardless of the sections in which questions appear, and regardless of the question style, the following restrictions will apply.

1. Questions will **not** require the candidates themselves to supply from memory formal definitions of physical ideas or formal statements of physical laws.
2. Questions will, in general, **avoid** the use of proper names as the sole indication of some physical principle (as in "Boyle's law" or "Snell's law").
3. Questions will **not** require candidates to write from memory an account of some experiment. Questions might present a selection of apparatus and ask how it could be used to achieve a desired result.
4. Questions will **not** require candidates to use a level of mathematics beyond that acquired in the pre PSSC year.

Quantitative questions will use, as fundamental units, the metre (m), kilogram (kg), second (s), and ampere (A) and will use the international (SI) system of symbols and nomenclature.

Standard equations will be supplied in a booklet accompanying the examination paper.

**Question Weightings**

The time allowed for the examination will be three hours. The relative weightings of topics examined will reflect the times allocated to these topics in the syllabus. All questions in the Examination Paper will be compulsory.

## B. THE INTERNAL ASSESSMENT PROGRAMME – 40% of the total assessment of the course

The Internal Assessment Programme comprises of the following components:

- **Practical Experiments and Reports** **60%**
- **Skills Task** **20%**
- **Written Tests** **10%**
- **Other Tasks** **10%**

**1. PRACTICALS** **(60% of IA)**

- **Core-based practicals** **50%**

  **A minimum of 10 core-based practicals must be completed, of which 5 will be summatively assessed. The 5 summatively assessed practicals must be nominated when the school assessment programme is submitted for approval, and must be the same 5 for all students in the school. The focus of the practicals must ensure that there is wide coverage of the core topics of the course.**

- **Elective-based practicals** **10%***

  **At least 1 elective-based practical must be completed for summative assessment, and must be focussed on the compulsory objectives of the elective. Further practicals may be included and may be based on the extension objectives of the Elective.**

**2. SKILL TASKS (20% of IA)**

Tasks that assess practical skills must be devised by teachers and must be included in the submitted assessment programme. The timing of the tasks should take into consideration the development of the student skills. Teachers may either test all skills at one time in a station type set of activities, or, test single skills on separate occasions during the course of the year.

The skills that must be covered are:

- observation with interpretation
- equipment handling
- data collection with ordered presentation
- data interpretation and graphing

**The skill tasks must be completed by June 30$^{th}$.** Since the skill of "equipment handling" has no paper record produced by the student, the teacher is expected to maintain a record of the precise task expectation and marking scheme relating to this skill.
**The Marking Scheme for this task is in Appendix 1 (Page 95).**

**3. WRITTEN TESTS (10% of IA)**

- **Core-based tests 5%**

  An allowance of 10% for this part of the internal assessment programme is available for examinations and/or topic tests.

- **Elective-based tests 5% ***

  A written test based on the compulsory objectives of the chosen elective must be included in the school based assessment programme.

** A combined value of 15% of the I.A. programme MUST be given to the elective through elective-based practicals and the elective-based test.*

**4. OTHER TASKS (10% of IA)**

***Only tasks other than written tests*** may be selected for this portion of the I.A. programme.

**The teacher may either construct a single "substantial" task, which is valued at 10%, or alternatively may construct two or three smaller tasks with a combined value of 10%.**

A possible task that would be considered as "substantial" could be a thoroughly framed project that required students to complete over an extended period of typically 2 to 6 weeks.

Teachers would be required to submit a well-developed frame for such a project at the beginning of the year, and this should clearly show how periodic checks are built into the frame in order to monitor student progress to completion, and to monitor authenticity of student work.

Possible tasks that would be considered “smaller” could include:

- model making
- field trip reporting
- poster production
- group debate
- seminar presentation
- and other possibilities envisaged by teacher that could be submitted for approval

| Summary Detail of I. A. Programme | | |
|---|---|---|
| **Task Style** | **Task Weighting** | |
| 1. **Practicals** | | 60 |
| • Core-based | 50 | |
| • Elective-based | 10 | |
| **2. Skills Tasks** | | 20 |
| **3. Written Tests** | | 10 |
| • Core-based | 5 | |
| • Elective-based | 5 | |
| **4. Other Tasks** | | 10 |
| **TOTAL** | | **100** |

When structuring the school IA programme, the weighting of tasks must be adhered to.

## Topic 1 - Light: Propagation, Reflection, Refraction (13 hours)

- Rectilinear propagation of light
- Inverse square law of illumination
- Use of binocular vision in image location
- Images formed in plane mirrors
- Focusing effect of a concave mirror
- Radius of curvature, pole, focus and focal length of a concave and a convex spherical mirror
- Real and virtual images formed of real objects
- The properties of concave and convex mirrors compared and contrasted qualitatively.
- Refraction of light at a plane boundary
- Refractive index
- Total internal reflection
- Focus and focal length of converging and diverging lenses
- Real and virtual images produced of a real object
- The properties of converging and diverging lenses compared and contrasted
- Magnification during image formation.

*Objectives 1 – 18*

Students should be able to:

1. explain the production of shadows in terms of rectilinear propagation,
2. construct ray diagrams which locate images produced by plane and curved mirrors,
3. use the relationship: $s_i s_o = f^2$ or $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ to calculate the position of an image,
4. distinguish between real and virtual images in concave mirrors,
5. recognize and apply the terms lateral inversion, pole, focus, focal length and radius of curvature,
6. compare and contrast the properties of concave and convex mirrors.
7. state that a light ray will tend towards the normal as it enters an optically denser material,
8. plot a graph of $\sin q_1$ against $\sin q_2$ and interpret the gradient as the relative refractive index for the two materials,
9. solve problems that involve using the relationships: $n_1 \sin q_1 = n_2 \sin q_2$ or $n_{21} = \frac{\sin q_1}{\sin q_2}$,
10. observe the partial reflection that occurs as light rays are mainly refracted at the boundary between two media of differing optical densities,
11. observe the condition of critical angle within an optically denser medium when a ray meets the boundary with an optically less dense medium,
12. realise that when $q_1$ is critical angle, then $q_2$ is $90^o$,
13. calculate the critical angle for a given pair of substances and describe total internal reflection,
14. use and draw ray diagrams to determine the position of images formed by single converging or diverging lenses,
15. use one of the lens relationships to determine the position of images:

$$s_i s_o = f^2 \quad \text{or} \quad \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

16. distinguish between real and virtual images formed by converging lenses,
17. compare and contrast the properties of converging and diverging lenses,
18. determine magnification of images from:

$$M = \frac{v}{u} \quad \text{or} \quad M = \frac{h_i}{h_o}$$

**Common Conceptual Difficulties For Students**

1. The distinction between what constitutes a real image and what constitutes a virtual image.
2. The physical position of an image in a plane mirror.
3. That distant objects produce such small angles of convergence that light may be regarded as comprising parallel rays.
4. The virtual focus of the convex mirror and the attributing of the negative sign in the mirror equation.
5. The squared influence on intensity by making linear changes in distance. e.g. reducing a distance to one third of the original produces an intensity increases of x9 (3 squared).
6. The distinction between what constitutes a real image and what constitutes a virtual image.
7. The virtual focal point of a diverging lens.
8. The negative attribute in the lens equation.

**Practical Suggestions**

1. Observation of shadows cast by sunlight.
2. Use of a torch to shine onto close and distant screens allowing students to appreciate reduction in intensity with increasing distance.
3. Distance judgement by locating the head of a pin held with one eye closed.
4. Locating the image of a pin or object in a plane mirror.
5. Observing images produced of an object when two plane mirrors are placed;
   - Parallel to each other.
   - At right angles to each other.
   - At an angle less than $90^o$ to each other.
6. Focussing a distant tree or building using a concave mirror (thus estimating its focal length).
7. Observing images formed by concave and convex mirrors.
8. Using ray box and scaled bench to determine focal length of the concave mirror.
9. Ray diagram construction work for plane and curved mirrors.
10. Focussing a distant tree or building using a converging lens (thus estimating its focal length).
11. Using a steady converging lens to concentrate solar energy in order to set fire to paper.
12. Using ray box and scaled bench to determine image position and size using a converging lens and screen.
13. Observing various lens shapes, both converging and diverging, of differing thicknesses.
14. Comparing appearances of objective and eye piece lenses in a compound microscope.
15. Correct use of a simple microscope or hand lens.

16. Observing eye lenses from fish and pig.
17. Using ray box, rectangular and triangular glass prisms to observe and measure angles of incidence and refraction.
18. Viewing a submerged coin through an air/water boundary.
19. Observing the refraction effect on a semi-immersed stick or pencil.

**Applications Of Topic Concepts**

1. Creation of shadows
2. Eclipse of the moon and the sun.
3. Binocular vision in predators.
4. Plane mirrors used for creating illusion of depth in rooms.
5. Multiple plane mirrors for creating large curved reflectors.
6. Convex mirrors used in motoring, security mirrors in stores.
7. Concave mirrors used in shaving.
8. Concave mirrors as focusing reflectors for solar energy.
9. The parabolic reflector for solar energy collection.
10. Mirrors in lasers.
11. Mirrors in microscopes, which rely on reflected light sources, dental mirrors.
12. Reflection in optical fibres.
13. The shiny reflectors of lamp-shades and headlamps.
14. Absorbing surfaces as in the flat solar panel.
15. Laterally inverted letters used in AMBULANCE and optician tests.
16. Dish aerial for reception of TV signals.
17. Hand lenses as simple microscopes.
18. Refracting properties of eye cornea and eye lens.
19. Spectacle lenses for correction of eye defects.
20. Camera lens.
21. Security spy holes in doors.
22. Magnifying display covers on wrist watches.
23. The fisherman-fish effect of apparent depth.
24. Mirages.
25. Production of the rainbow.
26. Total internal reflection in prism binoculars.
27. Total internal reflection in the fibre optic endoscope.
28. Movie projectors (producing a real image).

## Topic 2 - Wave Properties And Propagation (4 hours)

- The propagation of pulses and periodic waves.
- Longitudinal and transverse vibration illustrated by springs
- Relationship between the frequency, wavelength and speed of a periodic travelling wave.
- Sound in air described as a longitudinal wave
- Waves as energy carriers, amplitude.
- Propagation of waves in two dimensions illustrated in water.
- The ripple tank idea of wave fronts and rays.

*Objectives 1 – 8*

Students should be able to:

1. realize that waves carry energy from one position to another,
2. understand and demonstrate the difference between longitudinal and transverse waves,
3. describe the ideas of amplitude, wavelength and frequency,
4. establish and use the relationship $v = fl$ ,
5. illustrate the propagation of waves in water,
6. realise that the wave front is perpendicular to the direction of travel,
7. understand that the average displacement of vibrating particles involved in wave progress is zero,
8. associate differing speeds of sound propagation with qualities of the transporting medium.

### Common Conceptual Difficulties For Students

1. The depicting of a sound wave as a series of compressions and rarefactions and deducing wavelength from such a representation.
2. The progress of electromagnetic waves such as light, in the absence of a material medium.

### Practical Suggestions

1. Use of slinky springs to illustrate both transverse and longitudinal wave types.
2. Timing the travel of a longitudinal pulse along a stretched slinky and thus determine the pulse velocity.
3. Observation of the vibrating cone of a loudspeaker.
4. Using a guitar to illustrate the influence of string material, length and tension on the frequency of emitted notes.
5. Setting up a stationary wave in a length of fishing line attached to the vibrating blade of a ticker timer. Altering wavelength by adjusting tension.
6. Observation of waves from the beach, and devising methods of determining wave speed.
7. Use of a vibrator and ripple tank to illustrate circular waves.
8. Altering vibrator frequency in a ripple tank and observing change in wavelength.
9. Use of distant breaking sea waves to make qualitative comparison of speeds of sound and light.

**Applications Of Topic Concepts**

1. Wave arrangements in musical instruments such as guitar strings and recorder pipes.
2. Velocity and frequency of water waves at the beach.
3. Use of wave reflection for depth sounding and locating fish schools.
4. Heart beat as an example of a pulse, with exercise altering pulse frequency
5. Pulsing of the eye blink.
6. A child's swing as typical of the vibration of particles in waves.
7. Vibration of vocal chords setting up longitudinal waves.
8. Cathode Ray Oscilloscope providing a picture of wave shape.
9. Electromagnetic radiation yielding different frequencies, each with their associated wave type.
10. Phenomena or uses associated with different sections of the electromagnetic spectrum:

| | | |
|---|---|---|
| Gamma rays | - | radio activity |
| x-rays | - | medical investigation. |
| U.V. | - | filtering effect of the atmosphere. |
| Visible | - | the eye |
| Infra red | - | detectors |
| Microwaves | - | cookers, radar |
| Radio & TV | - | communication networks. |

11. Earthquake vibrations initiating waves.
12. Changing engine pitch (frequency) with changing engine revolutions.

## Topic 3 - Consideration Of Phenomena In Terms Of Wave Theory (5 hours)

- Laws of reflection and refraction deduced from arguments of wave speed.
- Idea of dispersion.
- Spectral dispersion.
- Particles and waves as alternative models for light.
- The current wave-particle theory.

*Objectives 1 – 7*

Students should be able to:

1. reveal an understanding of reflection and refraction portrayed by the effect of boundaries on incident wave fronts,
2. demonstrate dispersion of different frequencies present in white light,
3. recall that refraction is greatest in the higher frequency ranges; blue light bends more than red light,
4. discuss the failure of the corpuscular light model,
5. discuss the wave light model,
6. discuss the photon light model,
7. understand the dual nature of light.

**Common Conceptual Difficulties For Students**

1. Clarification of the angle of incidence in the case of an incident ray, and the angle of incidence in the case of an incident wave front.
2. Similarly for angles of reflection and refraction.
3. That dispersion forces us to the conclusion that the refractive index of a material is different for the different wave frequencies, and that the index usually presented is an average value.
4. When depicting dispersion through a triangular prism, that dispersion begins at the entry face and continues at the exit face (students should be encouraged to draw the normal at each boundary and “bend” the ray in the correct direction).

**Practical Suggestions**

1. Ripple tank observations of incident straight wave fronts being reflected at both flat surfaces and curved surfaces.
2. Ripple tank observations of incident circular wave fronts being reflected at a flat surface.
3. Ripple tank observations of refraction simulated by a depth-change boundary, and the observed change in wavelength.
4. Projection of a white light source through a triangular glass prism onto a screen.
5. Use of coloured celluloid filters to change the frequency composition of the incident light on the glass prism.
6. Dispersion by a water prism with a submerged mirror to reflect solar energy.
7. A bouncing tennis or golf ball to support the corpuscular model of reflection.

8. Rolling a ball bearing or marble across a flat surface, down a slope to a second flat surface, to reveal the failing of the corpuscular model of refraction.

**Application Of Topic Concepts**

1. Influence of wave fronts on beach and shoreline erosion.
2. Construction of suitable barriers to dissipate wave energy.
3. Parabolic reflectors for solar energy collection.

## Topic 4 - The Phenomena Of Diffraction And Interference (7 hours)

- Superposition of pulses and waves.
- Diffraction.
- Interference of light in Young's double slit experiment and the support this offers to the wave model of light.
- Use of double slits to estimate the wavelength of light.

*Objectives 1 – 8*

Students should be able to:

1. use the superposition principle to draw the resultant shape when two waves or pulses are wholly or partly superimposed,
2. predict situations in which diffraction is likely to occur,
3. predict what will happen when two diffraction patterns overlap,
4. know the value of interference patterns as support for the wave model,
5. recognize double slit arrangements from which wavelengths may be estimated,
6. use the relationships: $l = \frac{d\Delta x}{L}$ and $(n - \frac{1}{2})\, l = d \sin q$
7. understand the term *coherent* as applied to a light source,
8. understand the importance of path difference from two sources to a point under consideration in determining the cancellation or reinforcement of light waves (nodal or antinodal quality).

**Common Conceptual Difficulties For Students**

1. A clear understanding of the difference between diffraction and interference.
2. The significance of path difference from two point sources in determining interference effects.
3. "In phase" or "out of phase" generation of waves from two sources.

**Practical Suggestions**

1. Observation of sea waves passing through each other- reflected waves from the beach serve as waves travelling in opposite direction.
2. Pulses generated simultaneously at each end of a long slinky spring.
3. Use of the ripple tank to observe diffraction following parallel wave front approach to a gap in a reflecting wall. Effect of altering:
    i. gap size
    ii. wavelength
4. Observe diffraction effect by viewing a light source through a single narrow slit.
5. Observe diffraction effect at the edge of cast shadows.
6. Use of ripple tank to observe interference from two point sources.
7. Observing the effects of interference in thin films such as soap bubbles and oil films on water or trapped between two microscope slides.

8. Measurement of wavelength of different frequencies of light using a light source.
9. Construction diagrams simulating wave generation from two point sources in order to determine points of constructive and destructive interference.
10. Setting up two loudspeakers to act as sources for interference. Determining the positions along a "screen" which yield maxima and minima sound levels.
11. Young's slit experiment, using appropriate light source, slit and screen.

**Applications Of Optic Concepts**

1. Seashore observation of superposition.
2. Interference of radio signals – e.g. crackle when a light is switched on or near a radio.
3. Placement of loudspeakers in stereo systems.
4. Fading interference in radio reception due to path differences between ground signal and ionosphere signal.

## Topic 5 - Kinematics, With Graphical Representation And Equation Relationships. (8 hours)

- A one-dimension treatment of kinematics.
- Use of displacement-time and velocity-time graphs.
- Average velocity.
- Kinematics equations for the case of constant acceleration.
- Average velocity *versus* Instantaneous velocity

*Objectives 1- 8*

Students should be able to:

1. understand the concepts of displacement, velocity and acceleration,
2. draw and interpret displacement-time and velocity-time graphs,
3. interpret and determine the gradient of both $s\text{–}t$ and $v\text{–}t$ graphs,
4. establish that the area under a $v\text{–}t$ graph represents displacement,
5. correctly interpret the meaning of negative values attributed to displacements and velocities,
6. use the kinematic equations for solving problems,

$$v_f = v_i + at$$
$$s = v_i t + \tfrac{1}{2}at^2$$
$$s = \tfrac{1}{2}(v_i + v_f)t$$
$$v^2{}_f = v_i{}^2 + 2as$$

7. determine an average velocity over a particular time period.
8. understand the difference between an *instantaneous velocity* and an *average velocity.*

$$v_{av} = \frac{total\ distance}{total\ time}$$

**Common Conceptual Difficulties**

1. The important distinction between distance and displacement.
2. The important distinction between speed and velocity, and, average speed or velocity and instantaneous speed or velocity.
3. Intuitive awareness that a body is changing its velocity during an acceleration, and expecting the numerical value of the acceleration to also be changing.
4. Recognising when there is a need to consider different time portions of the movement of an object separately in order to correctly apply kinematic equations.
5. The meaning of an acceleration value such as $5ms^{-2}$. (It is helpful if this is read as "a change of $5ms^{-1}$ every second").
6. The inclusion of a negative stem to the $y$ axis of $s\text{–}t$ and $v\text{–}t$ graphs.
7. Failure to relate graph gradients to the axis graduations.

**Practical Suggestions**

1. Estimating a velocity by timing a steady straight line walk over a measured distance.
2. Determining an average velocity for a fluctuating straight line journey over a measured distance. 1 and 2 can be carried out simultaneously with the fluctuating person contriving to finish their journey at the same instant as the steady walker. The shape of the *s–t* and *v–t* graphs can then be compared.
3. Introduction to the ticker timer in producing velocity tapes, with emphasis on the regular time intervals between dots.
4. Use of a trolley and attached tapes to show patterns for:
   i. constant velocity
   ii. changing velocity
5. Compiling a *v–t* graph by chopping a recorded tape into dot interval lengths, with each length representing the displacement for the interval.
6. Use of a tape pulled by a falling weight to produce a trace from which "g" can be determined.
7. Use of a falling weight to accelerate a trolley with tape attached, followed by trolley movement with constant speed after the weight has hit the ground. Bench-trolley friction can be compensated for by raising one end of the bench appropriately.

**Applications Of Topic Concepts**

1. Displacement during a fishing trip; a comparison of distance and displacement relative to home base.
2. The manner in which displacement changes with time during a shopping trip.
3. Displacement–time for a piston head inside the cylinder of a car engine.
4. Athletic events:
   a. 100 metres with its average velocity
   b. 400 metres with its average speed
   c. 100 metres with 100 m displacement
   d. 400 metres with 0 m displacement.
5. Advertising blurb for cars: "Zero to 80 km hour in 10 seconds."

## Topic 6 - Vectors: Addition, Subtraction And Resolution (4 hours)

- Vector quantities.
- Addition and subtraction of vectors in two dimensions both by graphical and numerical methods.
- Resolution of vectors.

*Objectives 1 – 10*

Students should be able to:

1. distinguish between scalar and vector quantities,
2. understand the importance of the direction property of a vector,
3. represent vectors by scaled lines,
4. represent vectors numerically,
5. add vectors to get a resultant,
6. subtract vectors to get a resultant,
7. resolve single vectors into two components at right angles to each other by construction,
8. resolve by trigonometry,
9. interpret vector diagrams,
10. determine a change value in a vector during a particular period.

### Common Conceptual Difficulties For Students

1. The reversing of the drawn vector during a graphical subtraction.
2. The attributing of + or – signs to vectors before adding or subtracting them numerically.

### Practical Suggestions

1. Pacing out designated displacement vectors.
2. Pacing out more than one designated vector resulting in a vector addition.
3. Determining resultant of paced out vectors by considering start and finish points.
4. Graphical construction of vectors with due consideration to scaling.
5. A consideration of the order of addition of say four vectors, to determine any influence that order has on the resultant.
6. Use of Newton spring balances to provide values of three force vectors pulling on a common unfixed yet stationary point. Demonstrating that the resultant of adding any two vectors gives the negative value of the third.

### Applications Of Topic Concepts

1. Direction of forces resulting in rotation of the coil in a motor.
2. Resultants of velocity vectors involved in navigation of planes and boats.
3. Acceleration vector for a satellite directed towards the earth.

## Topic 7 - An Introduction To Dynamics (6 Hours)

- The concept of force.
- Frictional forces but not the coefficient of friction.
- The relationship between force, mass and acceleration.
- The Newton and the kilogram.
- The torque that a force exerts about a perpendicular axis.
- The equilibrium of a body under the influence of parallel forces.
- Force as a vector quantity.
- Vector sum of forces on a particle including the equilibrium case.

*Objectives 1 – 10*

Students should be able to:

1. understand that force **is not** a general prerequisite for continuing motion,
2. understand that the $F$ in the relationship $F = ma$ is a **net** force applied to a body,
3. experimentally verify $F = ma$ ,
4. calculate a resultant or unbalanced force,
5. solve problems involving $F = ma$ ,
6. calculate the torque of a force, but only in the perpendicular case,
7. solve problems where torques act in opposition, and where equilibrium is established,
8. interpret "$m$" as the gradient of a force versus acceleration graph,
9. define the Newton in terms of the acceleration given to a unit mass,
10. apply vector qualities to forces.

**Common Conceptual Difficulties For Students**

1. That only the initiation of motion requires force, and that once motion is established it will continue when the force is removed. The presence of opposing friction forces lead students to intuitively mistrust Newton's first law.
2. Many students seek to apply $F = ma$ to situations where the $F$ being applied is not a net force.
3. Where an applied force results in the acceleration of a mass, but where only a component of the force is acting in the direction of the acceleration.
4. That friction only exists if an attempt is made to produce motion.
5. That the determination of a torque involves the product of a force and a distance, but that this is not the same as work.
6. A body need not be at rest to be in equilibrium.

**Practical Suggestions**

1. Spring balances and weighing machines registering downward forces acting on masses.
2. Determining the size of a frictional force opposing motion of a block down a slope until the component of the weight of the block down the slope is just enough to overcome friction
3. Accelerating different masses with a steady force while drawing a tape through a ticker timer. The force could be provided by a falling weight. Thus determining how changes in mass are reflected in changes of acceleration.
4. A similar arrangement as in 3 using the same mass but changing the accelerating force. Thus determining how changes in force are reflected in the changes of acceleration.
5. Use of Newton spring balances to provide values of three force vectors pulling on a common unfixed point so that the point is stationary. Demonstrating that the net force on the point is zero and in equilibrium.
6. Balancing a metre rule by hanging from any chosen position and loading appropriately with hanging weights. The individual torques provided by the weights can be calculated and the total turning effec t determined.

**Applications Of Topic Content.**

1. Advertising blurbs for car performance, and forces required to accelerate a car's mass.
2. Frictional forces providing the external force to accelerate vehicles,
3. Wheel spin resulting from internal forces greater than available frictional forces.
4. Safety angles on ladders.
5. Comparison of pushing a bicycle with pushing a car, each from a standing start.
6. Torque provided by bicycle pedals, screw drivers, spanners, around door hinges.
7. Use of extension bars on tools to increase the applied torque.
8. Importance of shape on stability in design of racing cars.
9. The "tug of war" providing a resultant of force vectors.

## Topic 8 - Momentum (5 hours)

- The concept of momentum.
- The vector quality of momentum.
- Conservation of momentum in 2 dimensions.
- Equal and opposite forces of interaction.

*Objectives 1 – 6*

Students should be able to:

1. calculate the momentum of an object,
2. realize that momentum is a vector quantity and hence calculate the total momentum of two objects,
3. recognize that in a collision or explosion momentum is conserved,
4. calculate the change in momentum of an object owing to an external force,
5. solve problems involving conservation of momentum in two dimensions,
6. recognize that it is the velocity which gives the vector quality to momentum.

**Common Conceptual Difficulties For Students**

1. The importance of giving a direction sign (+ or -) to the numerical value of momentum in order to show its vector quality.
2. Identifying the masses involved when there is an apparent "creation" of momentum.
   - a bullet leaving a rifle,
   - a paddle moving a canoe.
3. Identifying the force that causes a change in momentum. e.g. a ball bouncing off the floor.

**Practical Suggestions**

1. Observation of colliding marbles by rolling singly or in groups along a track. Two metre rules clamped side by side, with a small gap between them, makes a good track.
2. Observation of the release of a long type balloon stuck with tape to a drinking straw threaded on a long fishing line track stretched across a room.
3. Exploding trolleys whose masses can be adjusted to provide various convenient mass ratios. By placing fixed stops at each end of the bench, the position of the explosion can be adjusted so that both trolleys hit the end stops at the same instant. The distance travelled by each trolley is then representative of its velocity.
4. Dropping a plastic bag of sand onto a trolley that is pulling a tape through a ticker timer. Momentum before and after the mass change can be determined by using the tape to determine the velocity change.

5. Propelling a ball bearing along an "$x$-axis" line and glancing a second stationary ball bearing. The path length taken by each ball bearing after the glance is a measure of the velocity of each. The $y$-axis component of each ball bearing can be found by construction, and the sum of these can be verified as being zero, (i.e. as expected since the original ball bearing's $y$-axis velocity was zero).

**Applications Of Topic Contents**

1. Sliding after a tackle due to momentum, in a game of rugby.
2. Apparent "disappearance" of momentum in head on vehicle collisions.
3. Momentum changes in a tennis ball being returned with a racquet or off a wall.
4. Apparent "creation" of momentum when paddling a canoe from a starting point.
5. Rocket propulsion using exhaust gases.
6. Momentum of a flywheel smoothing individual cylinder contributions in an internal combustion engine.
7. Changes in momentum brought about by external forces which either change direction of movement (e.g. a ball being "flicked on" in soccer), or a change in speed of the movement (e.g. applying brakes to a moving car).
8. Pile driving.
9. Impact of a falling coconut.

## Topic 9 - Acceleration In Gravitational Fields (2 hours)

- Acceleration in free vertical fall.
- Deduction that force in a gravitational field is proportional to mass.
- The spring balance as a force meter.

*Objectives 1 – 4*

Students should be able to:

1. recognize that the acceleration of an object in free vertical fall is constant,
2. recognize that all objects dropped in the same gravitational field experience the same acceleration,
3. recognize that the force of gravity on an object is proportional to its mass, i.e. $F = mg$
4. understand that the weight of an object depends upon the gravitational field in which it is situated.

### Common Conceptual Difficulties For Students

1. That even if an object is not moving it still experiences an acceleration owing to the surrounding gravitational field.
2. That the direction of the acceleration is not necessarily in the direction of motion.

### Practical Suggestions

1. Successive addition of equal masses to a spring balance.
2. Subjective determination of the simultaneous impact of two objects dropped at the same instant from a high position.
3. Use a free falling mass to draw a tape through a ticker timer. Repeat with different masses and compare acceleration values determined from the ticker tape trace.
4. Diluting the gravitational field by allowing a ball to roll down various degrees of slope. Acceleration can be determined with a ticker timer trace. The $mg$ value should equate with the component of the "true" weight which acts down the slope.

### Applications Of Topic Contents

1. The falling coconut.
2. The lift (elevator) accelerating downwards leaving occupants with an apparent reduction in weight.
3. Mass of individual sky divers not influencing their fall velocity.

## Topic 10 - Kinematics Of Projectiles (4 hours)

- Motion of a body in two dimensions when the force is constant.
- Independence of the velocity component which is at right angles to the direction of the force.
- Application of this to projectiles.

*Objectives 1 – 5*

Students should be able to:

1. describe the motion of an object which moves horizontally into a vertical force field,
2. state that in the above case:
   a. the horizontal component of velocity remains constant,
   b. the vertical component of velocity increases or decreases uniformly with time,
3. sketch the path of an object travelling through a gravitational field,
4. calculate vertical and horizontal displacement or velocity,
5. use the kinematic equations to solve projectile problems.

**Common Conceptual Difficulties For Students**

1. That horizontal and vertical velocities can be considered independently.
2. That the horizontal velocity is not influenced by the vertical force.
3. That the time taken to fall a distance, $h$ metres, is not altered by the presence of a horizontal velocity.
4. That a knife dropped by a sailor at the top of a mast of a boat moving horizontally with constant velocity, will hit the deck directly below the sailor's new position.

   i.e. that both sailor and knife move horizontally by the same distance during the fall time. (This assumes that the influence of air resistance on the falling knife is negligible).

**Practical Suggestions**

1. An outdoor discussion session based on observations of the behaviour of a ball thrown through a series of varying trajectories.
2. Observation of a ball shooting horizontally off the edge of a table, and a second similar ball being dropped from the edge at the instant the first passes it. Noting the simultaneous contact the balls make with the ground.
3. Using a pool cue arrangement to propel a ball from a bench surface across a 100cm to 150cm space before hitting a screen. The amount of horizontal fall of the ball can be measured from the impact mark left on the screen. From this information the horizontal velocity given to the ball by the cue can be calculated.

**Applications Of Topic Contents**

1. Skilful players using experience of trajectory in accurately placing the ball in games like tennis and basketball.
2. Adjustment of trajectory on large guns firing shells over big distances.
3. The trajectory of electrons fired through a varying electric field in an oscilloscope.

| analogy: | **Field type** | **Influence on** |
|---|---|---|
| | Gravitational | mass |
| | Electric | charge |

# Topic 11 - Circular Motion (4 hours)

- Acceleration produced by a change of the direction parameter of a velocity.
- Circular motion, only for cases of constant speed.
- The changing force needed to keep an object in uniform circular motion – centripetal force.
- Universal Law of Gravitation.
- Circular orbits of moons, planets and satellites.

*Objectives 1 – 6*

Students should be able to:

1. understand that an object travelling in a path along the circumference of a circle, is accelerating, despite the fact that the speed may be constant,
2. use the relationship: $a = \frac{v^2}{r}$ and state that this represents a centripetal acceleration, with $v$ as the instantaneous velocity perpendicular to the acceleration,
3. state that the direction of the **net** centripetal force needed to keep an object in uniform circular motion is towards the centre of that motion,
4. solve problems involving objects in circular motion,
5. discuss the use of the Universal Law of Gravitation, and realize that it is an inverse square law,
6. understand that the centripetal force maintaining the circular motion of planets and satellites is a force of gravitational attraction.

**Common Conceptual Difficulties For Students**

1. Distinguishing between the apparent centrifugal force that the human body senses and the centripetal force which is insisting that the human body is pushed into a circular path. e.g. a passenger in a car entering a right hand bend, has a sense of being pushed to the left hand door because the left hand door is providing the centripetal force which pushes the passenger into the circular path.
2. The fact that the instantaneous direction of movement is not in the direction of the acceleration.
3. Discerning exactly what is providing the centripetal force in situations where there is circular motion.
4. Confusing circular motion with rotation.

**Practical Suggestions**

1. Observing and discussing situations in which circular motion is exhibited:
   - a child on a roundabout,
   - an object whirled around on the end of a string,
   - a marble travelling around the inside wall of a closed glass jar.

2. Determining the speed of a rubber bung tied to fishing line which is whirled in a horizontal circle. Use of: $v = \frac{2pr}{T}$ to determine speed by timing multiple revolutions to provide the period $T$.

3. Use of a 200g “weight”, tied to a fishing line that is threaded through a hollow plastic tube handle, to provide the force on rubber bung masses being whirled in a circle. The force and line length can be kept constant while $v$ is determined for different values of rubber bung mass.

4. The same arrangement as in 3 above can be used to investigate the change in $v$ when $r$ is varied (keeping $F$ and $m$ constant).

5. Using a record player turn-table to determine the maximum distance from the centre that a small mass (e.g. 100g mass) can be placed and still maintain circular motion. A larger mass can then be used and the new maximum compared.

6. By placing materials with different frictional qualities on the record player turn table, the role of friction as the supplier of the centripetal force can be reinforced.

**Applications Of Topic Contents**

1. Consideration of the friction of road surfaces near severe road bends.
2. The use of cambers on roads and race tracks to provide additional centripetal force.
3. Weather conditions changing the nature of a road surface, resulting in reduced friction and consequently “side slip” of vehicles.
4. Runners attempting to hold a curve on the athletics track.
5. The use of guards on circular saws and grind wheels to contain any shattered fragments.
6. The slipping rollers of a bicycle bell.
7. The increase in centripetal force provided by the inward lean of a motorcyclist.
8. Retention of satellites and planets in orbit by centripetal gravitational forces.
9. Pre-determining the precise orbits of satellites by consideration of their speed, mass and distance from the earth.
10. The special case of the “stationary” satellite.

## Topic 12 - Energy (11 hours)

- Work and the joule.
- Power and the watt.
- Kinetic energy.
- Potential energy in a uniform gravitational field.
- Energy stored as potential energy in a compressed or extended spring.
- Problems in which the sum of kinetic and potential energies is conserved.
- Energy manifested as heat when work is done against friction.
- Heat of fusion and heat of vaporisation.
- Problems involving conservation of energy when $E_k$ of whole bodies is transferred to molecules and manifested as heat.
- Specific heat capacity.

*Objectives 1 – 17*

Students should be able to:

1. calculate the work done using: $W = Fs$,
2. determine the component of the force which is in the direction of movement and thus contributing to the work done,
3. recognise that the area under a force-displacement graph identifies the work done,
4. determine power attributes relating to work activity and machines,
5. calculate kinetic energy using: $E_k = \frac{1}{2}mv^2$,
6. calculate gravitational potential energy using: $E_p = mgh$,
7. draw a graph of force versus extension in a spring and recognize the gradient to be the spring force constant, $k$, i.e.: $F = kx$,
8. calculate spring potential energy using: $E_s = \frac{1}{2}kx^2$ ,
9. recognize that when work is done on a body, energy is transferred to that body,
10. understand the term *elastic collision* during which there is a conservation of kinetic energy.
11. describe the requirement of energy change, described as *latent heat,* in order to produce a change of state,
12. recognize that no temperature change is associated with a change of state,
13. interpret temperature-time graphs for substances either gaining or losing energy at a steady rate,
14. use the relationship $H_L = mL$, and solve problems relating to energy supply and change of state,
15. use the relationship $H = mc\Delta T$, and solve problems involving the energy required to change the temperature of a particular substance,
16. determine specific heat capacity from information yielded by temperature-time graphs where energy change is at a steady rate.
17. solve problems involving the interchange of energy between energy manifestations where the sum is conserved.

**Common Conceptual Difficulties For Students**

1. Ensuring that the correct force value is applied when considering the work done for a given displacement.

   or

   Ensuring that the correct displacement is applied when considering the work done for a given force.
2. Identifying whether work is done **on** a body or **by** a body.
3. That a spring may store energy either in the extended or compressed state.
4. A freezing point involves a liquid to solid phase change, and this certainly does not imply a low temperature.

**Practical Suggestions**

1. Observing change in energy manifestation during swing of a pendulum, explosion of a trolley and compressed spring, a rolled ball being brought to a stop by friction.
2. Pulling a wooden block along a surface using a Newton meter to give the minimum motion. Deducing the opposing frictional force, and determining the work done during a one metre displacement.
3. Determining the frictional force and work done in bringing a pushed trolley to a standstill. The trolley can be exploded by its spring and the following retardation determined from a recorded ticker tape.
4. Comparing the potential energy held by a mass, with the kinetic energy it possesses at impact with the ground. A mass attached to a ticker tape can be allowed to fall freely to the ground. The velocity at impact can be determined from the tape.
5. Allowing a marble to roll down an incline and then rolling on along a horizontal surface until it stops. The distance of "roll on" $(s)$ and the height fallen through the incline $(h)$ can be measured. By changing the angle of incline, different values of $s$ and $h$ can be obtained. A graph of $s$ against $h$ can be produced and interpreted by students.
6. Graphing a force extension graph for a spring, and determining the spring constant and the energy stored for a given load.
7. Determining the melting point of candle wax.
8. Plotting a cooling curve for paraffin wax. The wax contained in a boiling tube with the bulb of a suitable thermometer immersed in the wax. Allow the wax temperature to fall from well above its melting point to about 20 degrees below melting point.
9. Comparing the cooling of equal masses of water and cooking oil by raising both to $90^{o}$C in a common water bath, and then removing the water bath and recording the temperature fall every minute until one liquid reaches about $35^{o}$C. Students can be encouraged to describe graph curve differences in terms of specific heat capacity.
10. Specific heat capacity of a metal.

**Applications Of Topic Contents**

1. Work done by the body on the body when climbing a coconut tree (energy transfer of chemical potential in the muscle cells to gravitational potential up the tree).

2. The zero work done on a box carried across a room (no net force in the direction of displacement).

3. The gravitational potential energy held by water ready to be fed to a hydroelectric turbine.

4. The maximum gravitational potential energy of a punted rugby ball held at the top of its trajectory.

5. Materials and appliances holding potential energy that may be transferred.

   *Gravitational*:
   - positioned pile driver,
   - water behind a dam,
   - brown coconut ready to fall,
   - guillotine!,
   - child swing at top of arc,

   *Chemical:*
   - car battery and dry cells,
   - all fuels,

   *Electrical:*
   - charge about to be released from a battery,
   - charge about to "fall" through an electric field,
   - thunder cloud before discharge,

   *Spring:*
   - catapult,
   - suspension of cars,
   - return mechanism on door handles,
   - chest expanders,
   - pushbike saddle
   - outboard motor starter rope return.

6. Kinetic energy held by moving vehicles.

7. Kinetic energy held by a fast moving rugby player with the ball, and the energy that has to be dissipated in order to stop him.

8. The boxer transfers more energy to the chin of his opponent if his fist is travelling faster!

9. $E_k$ transferred to a ball at moment of impact:

   e.g. - a free kick in soccer,
   - a serve in tennis.

   Most of transferred energy is displayed as $E_k$, (some as heat and sound).

10. $E_k$ is commonly reduced in moving objects by frictional forces:

    e.g. - free wheeling bicycle gradually stopping,
    - reducing speed of a tennis ball as it travels through the air,
    - the canoe that stops when paddling stops.

11. Work done on a turbine by falling water.

12. The zero work, done on a wall, by unsuccessfully attempting to push it over.

    e.g. - a tractor attempting to pull down a tree (the tractor may be expending fuel, but no work is done on the tree).

13. Work done by a thatcher on his thatch by lifting the thatch from ground to roof.

    e.g. - the thatcher transfers energy from himself to his thatch.

14. Power rating of commercial machines:

    - output of electric motors
    - horse power rating of outboard motors (where 1 HP approx = 750 Watt).

15. Work done on a fishing line by a hooked fish, resulting in “stretch”. The stretch energy is stored in the line.

16. Use of water or oil to cool drills which are working on solid materials and getting hot through the frictional forces involved.

17. Providing of a heat sink to prevent damage to transistors.

18. Design of thermos flasks and cool boxes.

19. The link between sweating and the use of body heat to evaporate sweat, resulting in cooling of the body.

20. The influence of specific heat capacity in determining the small change in temperature of sea water, compared with relatively big temperature changes in road surfaces and metal roofs.

## Topic 13 - Pressure, And Its Relationship With The Volume And Temperature Of Gases (7 hours)

- Concept of pressure as a force applied to a given area.
- Relationship between pressure and temperature of a gas when volume is held constant.
- Relationship between pressure and volume of a gas when temperature is held constant.
- Elementary kinetic theory of a gas.
- Pressure characteristic of equal masses of different gases.
- Absolute temperature scale.
- Conversion between Celsius and Absolute (Kelvin) temperature scales.
- Absolute temperature of a gas being proportional to the average molecular kinetic energy.

*Objectives 1 – 7*

Students should be able to:

1. recognize and use the Pascal unit,
2. recognize that the forces producing the pressure of a contained gas come from the collisions of moving gas molecules,
3. establish and know that the pressure of a gas is inversely proportional to its volume, with temperature held constant,
4. establish and know that the pressure of a gas varies directly with **absolute** temperature, with volume held constant,
5. recognize and use the combined relationship: $PV = nRT$,
6. convert Celsius to Kelvin and vice versa,
7. realize that temperature is a measure of the average kinetic energy of the particles of a gas.

**Common Conceptual Difficulties For Students**

1. That the velocities of gas molecules at a particular temperature are not all the same, but that at higher temperatures there are a greater proportion of faster moving molecules.
2. That in all gas law calculations, the temperature must be converted to, and written with, the Kelvin value.
3. The false concept that at high pressures the gas molecules are squeezed together.

**Practical Suggestions**

1. Observation of pressure effects with solids.

   e.g.
   - the impression made by a four legged stool on sand, and then inverted with the seat downwards,
   - comparison of flat basketball boots and studded rugby boots.

2. Observation of pressure effects with liquids.

   e.g.
   - comparing the jets coming out through top and bottom side holes in a tin can full of water.

3. Loading a 100 or 200mL syringe which has its nozzle closed. Recording and graphing the volume for given loads.

4. Constructing a simple water thermometer with a narrow tube inserted into a bunged test tube full of water. Graduating the tube from a pair of fixed points.

5. Constructing a constant mass and volume air thermometer with a large flask to which is connected a manometer via some thin tubing.

6. Demonstration of the collapsing tin, and discussion on the size of the atmospheric pressure on the tin.

**Applications Of Topic Contents**

1. Increasing pressure on the body of divers as they descend – the ear detects increases at relatively small depths.

2. Blowing up a car or bicycle tyre, by increasing the number of gas particles and therefore increasing the number of collisions on the tyre wall.

3. The aneroid and Fortin barometers.

4. Pressurisation of aircraft cabins when a plane is flying at high altitude.

5. Immense pressures suffered by divers at great depth, and the influence this pressure has on the dissolving of gases in the blood.

6. Compressed gases in cylinders, and the use of regulators to control the release force.

7. Danger of temperature rise of sealed containers with small volumes of volatile liquids:

   e.g.
   - a large sealed petrol drum with a small volume of liquid petrol inside,
   - careless discarding of empty aerosol cans onto fires.

## Topic 14 - Electrical Principles Relating To Simple DC Circuitry, And Energy Transfer (10 hours)

- Wires as conductors.
- Establishing an electric field.
- Current being a flow of charge.
- Conductors – solids, electrolytes and ionised gases – with charges free to move.
- Concept of electrical resistance.
- Ohm's law.
- Variation of resistance with temperature.
- e.m.f. of a battery.
- Conservation of charge in current circuits.
- Potential difference and energy transfer in resistances.
- Series and parallel resistance combinations.
- Concept of power as used in a circuit component.
- Energy carried and used in a circuit.

*Objectives 1 –18*

Students should be able to:

1. know that current results from movement of charge, $Qt^{-1}$, in an electric field,
2. recognize electrons as the conveyors (carriers) of charge,
3. distinguish between the directions of conventional current and electron flow,
4. know the qualities that make materials good or bad conductors,
5. interpret resistances as materials opposing charge movement, and receiving energy from passing charge,
6. identify the influence of temperature on resistance wires,
7. state that charge flows from higher to lower potentials,
8. draw a graph of potential difference across, versus current through, a conductor, and interpret the gradient,
9. use Ohm's law $V = IR$ in calculations,
10. know that the e.m.f. of a battery is the amount of energy it supplies to each unit of charge, $EQ^{-1}$,
11. recognize that charge and hence current is conserved at all points in a circuit,
12. calculate resistance of series and parallel combinations,
13. calculate potential differences between points in a circuit,
14. understand the concept of power as energy per unit time in an electrical context, $P = Et^{-1}$,
15. interpret the power ratings given to appliances,
16. calculate the power output of a resistance using: $P = I^2R$,
17. calculate the amount of energy carried by a current,
18. calculate the energy dissipated as heat in a resistance.

**Common Conceptual Difficulties For Students**

1. Current “exists”, whereas charge “flows”.
2. That potentials are not absolute, but represent difference between two points.
3. That two equal parallel resistances have a lower resistance value than one on its own.
4. The rise in potential inside a supply cell as electrons move from + to – in the cell.

**Practical Suggestions**

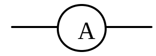
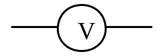
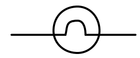
1. Set up black boxes (hidden conductors or insulators) and use a simple continuity circuit to separate into two groups.
2. Observe the e.m.f. or voltage values on various dry cells and batteries.
3. Set up a single resistance circuit with appropriately positioned ammeter and voltmeter, and vary supply voltage (or use a rheostat) to obtain pairs of $V-I$ values from which to construct and interpret a $V-I$ graph.
4. Monitor the current in a resistance immersed in water at several well dispersed temperatures.
5. Determine potential difference across:
   i. single light bulb,
   ii. two similar in series,
   iii. two similar in parallel.
6. Set up a long resistance wire (such as a potentiometer) and use a flying contact to relate wire length to the drop in potential.
7. Use an electrical heater of known output to warm an insulated known mass of water. Monitor temperature rise over a measured time period. Encourage students to determine energy supply by heater and energy gain by water from their knowledge of specific heat capacity.
8. Examining electrical appliances and costing their use.

**Applications Of Topic Contents**

1. Electrical wires chosen according to function:
   i. thick copper wires for large current supply,
   ii. thin nichrome for resistance.
2. Starter motor cable and battery straps in a car.
3. Tungsten filament of a light bulb.
4. Fluorescent strip lights containing ionised gases.
5. Choice of supply battery depending on energy requirement of the appliance;
   e.g. - small battery for low demand in calculators,
   - heavy duty for starting current of a lorry.
6. Parallel arrangement of appliances in a household circuit.
7. Ratings of appliances such as light bulbs, electric kettles, electric drills, refrigerators.
8. Electricity authorities billing their users for the energy consumption, from:

$$E = Pt$$

### *Electrical Symbols*

| | |
|---|---|
| Ammeter |  |
| Voltmeter |  |
| Switch | closed or open |
| Lamps |  or |
| Wires crossing *without* electrical contact | |
| Wires connected electrically | or |
| Cell | or |
| Battery (several cells in series) | or |
| Variable power supply (where the voltage can be varied) | |
| Resistor, usually low power electronic type (new standard symbol)<br><br>Resistor, usually high power type (old symbol for resistor)<br><br>Variable resistors (or potentiometers)<br><br>Variable power resistors (sometimes called potentiometers or rheostats) | <br><br><br><br>or<br><br>or |
| Diode and LED | and |
| Thermistor (temperature dependent resistor) | |
| LDR (light dependent resistor) | |

*Symbols for circuit diagrams*

## Topic 15 - Charges, Conductors And Magnetic Fields, Leading To The Motor Effect (5 hours)

- Qualitative treatment of magnetic fields near magnets, and the idea of magnetic flux.
- Direction of the magnetic field or vector, $B$.
- Force on a current-carrying conductor used to define the magnitude of $B$.
- Force on a charged particle moving in a magnetic field.
- Elementary theory of electric motors.
- Moving coil meter and the equilibrium of opposing torques.

*Objectives 1 – 7*

Students should be able to:

1. know that a current-carrying conductor placed in a magnetic field experiences a force,
2. recall that the magnetic force is perpendicular to the current and the field, as demonstrated by the right hand rule,
3. determine the direction of the force on a current-carrying conductor when it is in a magnetic field,
4. apply the principles of magnetic force to explain and predict the turning effect on a coil conductor mounted in a magnetic field,
5. describe the principle of the electric motor and explain how continuous rotation of the coil is achieved,
6. describe the moving coil galvanometer and the way it is adapted to offer a reading related to current size.

### Common Conceptual Difficulties For Students

1. Recalling that the field within a bar magnet is directed towards the N pole.
2. That as the motor coil leaves its position for maximum magnetic force, the turning component of the force gradually diminishes as the direction of movement is no longer at right angles to the magnetic field.
3. The reversal of current direction by the commutator in a DC motor.

### Practical Suggestions

1. Use of plotting compasses to determine the field surrounding a single bar magnet.
2. Investigating the field in the space between two opposite poles.
3. Locating a current-carrying conductor in between the opposing poles of two bar magnets in order to determine the direction of the force on the conductor:
   (i) observe effect of reversing current,
   (ii) observe effect of reversing field.
4. Measuring the value of magnetic force on a conductor using a current balance, and then calculating the magnetic field strength.
5. Constructing a *'simple motor'* from a small wound coil with its axis resting in the O loop of safety pins contacting the terminals of a dry cell. The magnetic field provided by directing the pole of a bar magnet at the coil.

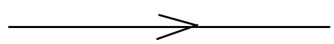
6. Assembling a laboratory designed motor, to experience the necessary considerations to successfully get the commutator to function and the coil to rotate.
7. Observation of a moving coil galvanometer and locating the essential components.

**Applications Of Topic Content**

1. Magnetic compasses used for navigation, responding to the earth's magnetic field.
2. Electromagnets created with their own field coils. Lifting steel objects such as girders or car bodies. Powerful directed electromagnets used for removing steel fragments from the eye.
3. The curved pole pieces of commercial motors which extend the period for which the rotating coil experiences a maximum force.
4. The complex windings of commercial motors to increase turning efficiency.
5. The spring loaded carbon brushes providing contact with the rotating coil.
6. Most electric motors, although many are AC design.
7. Use of moving coil mechanism in voltmeters, ammeters, analogue multimeters, consumer units metering electricity consumption.

***Conductor and Field Symbols***

Conductor



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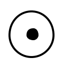

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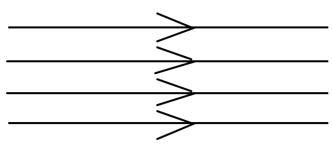
**into page**

Field



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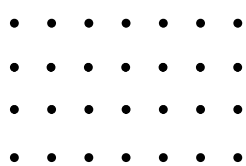

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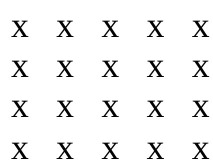

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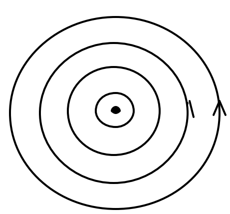

**surrounding a conductor**

# Topic 16 – Magnetic Fields Surrounding Current-Carrying Conductors (3 hours)

- Magnetic field surrounding a current-carrying long wire.
- Magnetic fields associated with two parallel current-carrying long wires.
- Direction of interactive forces between parallel current-carrying long wires.

*Objectives 1 – 5*

Students should be able to:

1. draw the magnetic field around a single long current-carrying wire,
2. recognize and use the normal symbols that describe the direction of conventional currents and magnetic fields, into or out of the page,
3. draw the magnetic field associated with two parallel long wires carrying currents and determine whether the force between the conductors is one of attraction or one of repulsion,
4. apply the relationship: $B = \frac{kI}{d}$ appropriately, and recognize $k$ as being a constant,
5. apply the relationship: $F = \frac{kI_1 I_2 \ell}{d}$ in order to determine the force on a length of conductor.

**Common Conceptual Difficulties For Students**

That in the case of parallel wires, the force experienced by one conductor is because of the presence of the field of the second conductor (the second conductor could well be replaced by a bar magnet).

**Practical Suggestions**

1. Set up a vertical conductor passing through a horizontal paper platform. Sprinkling iron filings around the conductor and onto the paper will reveal the magnetic field. A thick wire capable of carrying a large current is best, with a car battery source.
2. A similar arrangement to that in 1, but with two conductors passing through the paper platform, will reveal the combined magnetic fields surrounding the conductors.
3. The alternative shape of the combined magnetic field can be revealed by reversing the current direction in one conductor.
4. The existence of force between two conductors can be shown by suspending two adjacent aluminium foil strips, (30cm x 1cm) and establishing a momentary current in each by connecting through a DC supply. The strips should be separated by a small space. The effect of reversing the current in one strip can be observed.
5. Students could be encouraged to attempt a design that would allow the deflecting force between two conductors to be used to provide an estimate of the current in a conductor.

**Applications Of Topic Content**

1. The force existing between conductors is $2 \times 10^{-7} N$ for each metre length of conductor.
2. In practical applications of currents, forces are not usually of primary interest, although the number of amperes existing might be of interest.
3. Current established in a circuit determining the value of protecting fuses and circuit breakers.
4. The need to correctly match a conductor with the expected current.
5. The fact that large currents are potentially dangerous.

## Topic 17 - Electromagnetic Induction (4 hours)

- Electromagnetic induction.
- Lenz's law.
- Induced voltage and the current that may result.
- The transformer effect.

*Objectives 1 – 10*

Students should be able to:

1. state the conditions that are necessary to induce a voltage in a straight conductor or a coil,
2. predict the effect of changing:
   a. magnetic field strength,
   b. direction of field,
   c. rate of cutting through the magnetic field, $B$,
   d. direction of moving through the magnetic field, $B$,
3. understand that Lenz's law predicts a conservation of energy,
4. understand and apply the relationship: $V = B\ell v$,
5. understand that the induced current arises because of the magnetic force experienced by the electrons in the conductor,
6. know that the induced current itself produces a magnetic field,
7. recognize that as a conductor is pushed through a magnetic field, an opposing force develops as a result of the induced current,
8. relate the induced voltage in the secondary coil to the developing field around the primary coil,
9. relate the design of a transformer to induction in the secondary coil,
10. understand why commercial transformers cannot operate on DC supply.

**Common Conceptual Difficulties For Students**

1. The application of Lenz's law to various conditions leading to induced voltage and current.
2. The development of an opposing force to a conductor being pushed through a magnetic field.

**Practical Suggestions**

1. Using a sensitive galvanometer to detect induced current when a conductor is passed between the poles of a magnet. The investigation can check on:
   a. the effect of speed of movement of the conductor through the field,
   b. the effect of direction of movement of the conductor through the field,
   c. the effect of moving the magnet instead of the conductor,
   d. the effect of moving both conductor and magnet together.
2. Connecting a sensitive galvanometer to the terminals of a vertical coil and dropping a bar magnet into the centre of the coil. The investigation and check on the effect of reversing the pole first entering the coil.

3. Replacing the magnet with a large solenoid connected to a supply, and sliding a smaller solenoid in or out of the larger solenoid to observe the induced current developed in smaller solenoid. Again the deflection of a galvanometer needle can give information of the size and direction of the induced current.
4. Connecting the primary of a commercial transformer to a DC supply and the secondary to a galvanometer or light bulb. Students could be asked to account for the fact that induced current only shows during switch on and during switch off and not for the intervening period.
5. Turning a simple hand generator connected to a bulb. Allow students to compare the force required to turn the generator with the bulb in position and when the bulb is removed. A discussion on the reasons for the different forces encountered.

**Application Of Topic Content**

1. Simple generators on bicycles.
2. Steam and water driven generators for commercial power generation.
3. Transformers in mains operated radios and televisions.
4. Step down transformers in electricity sub-stations.
5. Ignition coils in cars.

## Topic 18 - Electrostatics (6 hours)

- Attraction and repulsion of static charges.
- Conductors and insulators.
- Conservation of charge.
- Positive and negative charge.
- Induced charge.
- The Coulomb.
- Concept of an electric field.
- Definition of vector $E$.
- Inverse square law of force between charges.
- Analogy between electric and gravitational fields.
- Potential energy of a charge in an electric field.
- Potential difference and the volt.
- Change of energy manifestation from potential to kinetic as a charge accelerates through an electric field.
- Deflection of moving charges by an electric field.

**OBJECTIVES**

*Objectives 1 – 6 (1 hour)*

**Some characteristics of charge.**

Students should be able to:

1. know the unit of charge as the coulomb,
2. represent diagrammatically the electric field that surrounds a positive and a negative charge,
3. draw the electric fields between like charges and between unlike charges,
4. identify the role that friction can play in the transfer of charge,
5. realise that a charged object holds an imbalance of charge,
6. describe the transfer of charge by rubbing.

*Objectives 7 – 11 (1 hour)*

**Behaviour of materials relating to charge.**

Students should be able to:

7. know that different materials have a natural tendency either to gain or to lose electrons,
8. determine whether two charged materials will attract or repel depending upon the charge type held,
9. know the behavioural differences between conductors and insulators,
10. know that the earth is a conductor of charge,
11. know that charged bodies discharge quickly in humid or salty conditions.

*Objectives 12 – 15* *(1 hour)*

**Coulomb's Law for charge.**

Students should be able to:

12. apply Coulomb's law to simple charge situations,
13. know that the electric force between two charges is proportional to the product of the charges,
14. know that the electric force varies inversely as the square of the distance between the charges,
15. identify the similarity between Newton's relationship for gravitation and that of Coulomb for electrical charge.

*Objectives 16 – 25* *(2 hours)*

**Characteristics of electric fields.**

Students should be able to:

16. understand the concept of an electric field,
17. draw the shape of an electric field between two parallel plates,
18. use the concept of electric field lines,
19. know the convention that establishes the direction of an electric field at a point,
20. know that the spacing of field lines is an indication of field strength,
21. know that field lines begin or end with charged particles,
22. know that the strength of an electric field is given by; $E = \frac{F}{Q}$
23. realise that the $E$ field is a vector,
24. use the relationship; $E = \frac{kQ}{r^2}$ to determine the field strength due to a charge,
25. find the combined influence of two charges at a point by finding the vector sum at the point.

*Objectives 26 – 29* *(1 hour)*

**Energy and potential in electric fields.**

Students should be able to:

26. determine the work done on a charge in moving it through an electric field, $W = EQd$ ,
27. understand that as a positive charge is moved against the field direction, it gains potential energy, which is stored in the field,
28. understand that there is a property associated with the field described as the electrical potential difference,
29. use the relationship: $V = Ed$ to determine the potential difference between two points in a field.

**Practical Suggestions**

***Note***: Most Pacific countries have climates which are both humid and often laden with salt ions. Both of these factors make electrostatic investigations difficult. The problem can be overcome if equipment is housed in an air-conditioned environment, and is prepared before investigations to ensure that it is free of moisture salts and dust.

1. Investigate the effect of rubbing together different materials and establish whether there has been a transfer of charge by holding the material close to small pieces of paper, polystyrene, grass seeds.
2. Charge a Van de Graaff generator and observe the discharge in a darkened room.
3. Observe the effect of a slow moving Van de Graaff generator on the clean hair of a person close by, but not touching the dome.
4. The electric field between parallel plates can be investigated by flooding a ripple tank with a 5 cm depth of dilute copper sulphate solution and connecting the plates to a low voltage supply. A two wire probe connected through a galvanometer can then investigate both the direction of the field and its strength. The vector quality of the field can be appreciated. (It is helpful to mark the plate of the ripple tank in a grid pattern.) Students can be encouraged to investigate other field shapes produced by varying plate position and shape.

## Topic 19 - The Atom And Radioactivity (8 hours)

- Descriptive treatment of Rutherford's experiments on the scattering of alpha particles by metal foil.
- Deduction that atoms have a very small dense nucleus.
- Description of the atom in terms of electrons in motion about a nucleus consisting of protons and neutrons.
- The photoelectric effect.
- Occurrence of isotopes and the manner in which isotopes differ in the number of neutrons.
- Nature of radioactivity.
- Half life.
- Radioactivity leading to the formation of new elements.
- Effects of radiation on living things.
- Uses of radioactivity.
- Safety precautions.
- Waste and fallout.

**Rutherford and the atom.** *Objectives 1 – 4* *(1 hour)*

Students should be able to:

1. give a brief description of the Rutherford model of the atom,
2. describe the causes of deflection of alpha particles fired at a thin metallic film,
3. know that deflection observations confirmed the presence of the dense nucleus,
4. describe the atom in terms of the nuclear bound protons and neutrons, and the electrons at varying energy levels in space around the nucleus.

**Photoelectric effects and consequences.** *Objectives 5 – 11* *(2 hours)*

Students should be able to:

5. describe the photoelectric effect,
6. recognize the support provided by the photoelectric phenomenon for a particle explanation of light,
7. use the term photon,
8. recognize that the frequency of a photon determines its associated energy,
9. use the relationship: $E = hf$ ,
10. understand the idea that different materials require different energy amounts to remove electrons away from the surface,
11. understand that both emitted photoelectrons and incoming photons possess momentum and that there is overall momentum conservation.

**Isotopes and radioactivity** *Objectives 12 – 22* *(3 hours)*

Students should be able to:

12. understand the term isotope, and distinguish between isotopes of an element in terms of its neutrons, with reference to mass number, $A$, and atomic number, $Z$, with ${}^{A}_{Z}X$ for element $X$,
13. understand that radioactivity involves the emission of particles or electromagnetic waves,
14. describe alpha and beta particles, $a = {}^{4}_{2}He$ $b = {}^{0}_{-1}e$
15. describe the characteristics of gamma rays, $g$,
16. recognize and use the symbols for alpha and beta particles, protons, neutrons and electrons,
17. determine the paths of alpha and beta particles, and neutrons travelling through a magnetic field of given direction,
18. compare the penetrating distances of alpha, beta particles and gamma rays,
19. understand the concept of half life,
20. determine the half life of a substance given its decay curve,
21. determine the particle emission during radio-active decay by applying conservation rules,
22. understand the manner in which radioactivity can lead to the formation of new elements.

**Radioactivity influences, useful and harmful.** *Objectives 23 – 28* *(2 hours)*

Students should be able to:

23. know that atomic radiation influences the structure of chemicals in living tissue,
24. describe the ways in which atomic radiation can be a valuable servant in medicine,
25. describe the way in which radiation can cause serious damage to organisms,
26. describe the precautions adopted in nuclear power generation plants and in hospitals where radiation equipment is used,
27. understand the strong arguments for caution in the increased use of atomic energy:
    a. danger in promoting nuclear reactions,
    b. radiation hazards,
    c. nuclear waste disposal,
    d. ingredients for weapons,
28. understand the reasons for the "Nuclear Free Pacific" policy and the counter arguments.

**Practical Suggestions**

1. Gather together articles from magazines and newspapers relating to:
    a. various attitudes to nuclear power,
    b. the problems relating to nuclear reactors and their waste,
    c. alternative energy initiatives in the Pacific region.
2. Simulate radioactive decay by tossing 100 coins (atoms) into the air (great fun), and representing all that land with heads up as being decayed atoms. The decayed "atoms" are removed and all remaining "atoms" are tossed. Again all "decayed atoms" are removed. Each tossing constitutes a half-life. Plot graph of "decay" against "half-life".

# ELECTIVE TOPICS

## ELECTIVE A - BOAT PHYSICS

- Density of solids and liquids.
- Conditions required to sink a body.
- Archimedes' principle.
- The law of flotation.
- Conditions required for flotation.
- Influence of hull shape on displacement.
- Change of hull density by loading.
- Centre of buoyancy.
- Centre of gravity, effect of high and low.
- Restoring couple.
- Loll, list and capsize.
- Canoes, twin hulls and outriggers.
- Displacement and planing hulls.
- Measurement of speed, the knot.
- Factors influencing hull speed.
- Forward propulsion from engines.
- Transom height.
- The propeller pitch, thrust and cavitation.
- Forward propulsion from sails.
- Sail curve and pressure difference.
- Sail size and sail shape, centre of effort.
- Resolution of lift force.
- Forward thrust and side thrust.
- Keels and centre boards, centre of lateral resistance.
- Running with the wind.
- Relative velocity, leeway from current and wind.
- Directing with the rudder.
- Anchor design and anchoring.
- The sea anchor.
- Block and tackle arrangements.
- Lines of latitude and longitude.
- Measurement of direction, the compass, variation.
- Operation of the two-stroke outboard.
- Fuel quality and supply to carburettor.
- Function and maintenance of the carburettor.
- Ignition, maintenance of plugs and points.

## Compulsory Objectives1 - 14 (3 hours)

**Density and flotation**

Students should be able to:

1. define density and apply the relationship: $r = \frac{m}{v}$

# determine densities of material by calculation,

2. understand that substances that sink in water have a greater density than water itself,
3. understand that substances that float in water have a density less than water itself,
4. determine the presence of an upthrust on a material which is in a liquid,
5. explain the meaning of an upthrust force,
6. describe the size of an upthrust in terms of displaced fluid,
7. understand a statement of Archimedes' Principle,
8. understand that the effective density of an object can be changed by including an enclosed or partially enclosed space in the object,
9. understand that although a material such as glass sinks in water, a closed glass bottle floats,
10. apply shape considerations of density to boat hulls,
11. understand the law of flotation,
12. understand that the loading of a boat hull influences the overall hull density,
13. understand that both hull shape and hull loading will influence the hull displacement.

## Extension Objectives 15 – 89

*Objectives 15 – 33* *(3 hours)* **The forces on a hull**

Students should be able to:

14. define "the centre of buoyancy",
15. understand that the location of the centre of buoyancy can change,
16. understand the term "centre of gravity",
17. locate the centre of gravity of regular solids such as a cube and rectangular prism,
18. observe the effect on stability of changing the height of the centre of gravity above an object's base,
19. understand the position of the centre of gravity above a supporting base in determining stability,
20. understand the concept of "a moment about a point",
21. know that as a hull rolls in one direction, there is a shift in the centre of buoyancy,
22. know that the upward buoyancy force tends to correct a roll,
23. understand that in a stable boat the centre of gravity and the centre of buoyancy tend to be in one vertical line,
24. understand that the upward force and the downward force are in one vertical line,
25. understand that shifts in the forces acting on a boat influence the stability momentarily or permanently,
26. realise that the manner in which a boat is loaded will determine its centre of gravity,
27. realise that a shift in the load of a boat will bring about a change in the position of the centre of gravity,

28. understand the meaning of "a couple",

29. know that the gravitational force downwards and the buoyancy force upwards produce a restoring couple,

30. understand that a **list** occurs when there is no righting couple formed,

31. understand the change in speed of righting a hull as the centre of gravity becomes higher,

32. describe the way in which a boat might capsize.

*Objectives 34 – 43* *(2 hours)* **Hull stability and movement**

Students should be able to:

33. understand that the shape of a hull has an influence on stability,

34. compare the natural stability of canoe, twin hulls, outrigger canoes, and flat bottomed planing hulls,

35. compare the displacements of different hull shapes,

36. understand the way in which hull shape and hull surface qualities influence the resistance by water to hull movement,

37. understand that moving hulls produce bow and stern waves,

38. understand the use of the knot as a measure of speed, where 1 knot is approximately 1850 m per hour (approx 0.5 $ms^{-1}$),

39. use the relationship:

$$Displacement\ speed\ (knots) = 2.4 \times \sqrt{waterline\ length\ (metres)}$$

to determine theoretical maximum hull speed for a displacement hull,

**40. deduce that theoretically, in the case of displacement hulls, longer boats are capable of greater hull speeds,**

41. understand the distinction between displacement progress and planing progress,

42. suggest advantages and disadvantages of the planing hull.

*Objectives 44 – 52* *(2 hours)* **Outboard motor forces**

Students should be able to:

43. identify an engine as transferring energy to the water behind the boat,

44. know that an outboard engine is mounted on a transom which needs to accept the thrust on the boat,

45. know that there will be an optimum height of transom for a particular length of motor, taking turbulences and drag into consideration,

46. know that the boat design will determine the maximum size of engine that can be safely accepted on the transom,

47. recognise the action of a propeller in providing a thrusting force onto the water,

48. know the meaning of propeller **pitch**,

49. know that the degree of pitch influences the thrust,

50. understand that the propeller thrust can be resolved into sideways and backwards components,

51. recognise the phenomenon of **cavitation** and the reasons for it.

*Objectives 53 – 66* *(3 hours)* **Wind and sails**

Students should be able to:

52. recognise the action of wind on the sail as providing a forward thrust on the boat,
53. describe the aerofoil action that develops a lifting force on the sail surface,
54. know that the resulting force on the sail is at right angles to the sail surface,
55. understand that the lifting force on the sail can be resolved into a forward thrusting component and into a sideways component,
56. know that it is the forward component which provides useful motion for the boat (headway),
57. understand that hulls, keels and centre boards offer opposing force to minimise leeway,
58. sketch the directions of the various forces acting on the sail and hull of the rigged sailing boat,
59. understand the concept of the position of the centre of effort of a sail and centre of lateral resistance of a hull,
60. understand that the relative positions of the centre of effort and the centre of lateral resistance will determine whether or not there is a tendency for the boat to swing around,
61. identify the couple formed by forces through the centre of effort and through the centre of lateral resistance,
62. know that the net headway force on a boat running with the wind is often smaller than when it is reaching,
63. understand the leeway that wind, and currents tend to create,
64. determine the resultant course of a boat when provided with both headway vectors and leeway vectors,
65. understand the function of a rudder of a boat and its action in turning a boat.

*Objectives 67 – 72* *(2 hours)* **Anchors and anchoring.**

Students should be able to:

66. understand the function of anchors in opposing forces attempting to carry a boat from its position,
67. consider the best position from which to attach a boat to its anchor,
68. understand why certain types of anchor are more suited to certain conditions than other types,
69. recognise the value of having adequate anchor chain and line length,
70. understand the nature of the forces along an anchor line for a vessel at anchor – including simple calculations.
71. understand the design and function of a sea anchor.

*Objectives 73 – 77* *(1 hour)* **Pulleys and reducing of effort**

Students should be able to:

72. understand the value of single fixed pulleys,
73. consider the action of a single moving pulley in reducing effort,
74. interpret pulley action in terms of mechanical advantage and velocity ratio,
75. understand that the pulley as a force reducer involves a greater travel,
76. understand that there is no saving in work when pulleys are used.

*Objectives 78 – 83* *(1 hour)* **Latitude, longitude and magnetic compasses**

Students should be able to:

77. recognise lines of latitude and longitude on a map,
78. understand the values given to lines of latitude and longitude,
79. know that boat speeds are usually stated in knots, and that this relates to the nautical mile,
80. recognise the value of a magnetic compass,
81. identify influences that can affect compass readings,
82. distinguish between true north and magnetic north.

*Objectives 84 – 89* *(3 hours)* **The outboard engine – how it functions**

Students should be able to:

83. understand the two stroke cycle typical of an outboard engine,
84. know the reasons for a correct oil-petrol fuel mix,
85. understand the danger of fuel being contaminated with water and the relative positions occupied by water and petrol in the fuel tank,
86. understand the function of the carburettor and apply that understanding to its maintenance,
87. understand the way in which ignition is achieved through the coil, points and plug,
88. effect maintenance on points and plug.

# PRACTICAL SUGGESTIONS

1. Determination of the density of blocks of steel and aluminium.
2. Determination of the density of a regular block of wood.
3. Determination of the density of an inconveniently shaped block of wood.
4. Determining the up thrust on various objects by weighing in air and then in water.
5. Investigating the depth of immersion of a rectangular wooden block depending upon the face offered for immersion. Comparing the volume of immersed block in each case. Students can be encouraged to apply this information to boat hull shape.
6. Observing the effect of "loading" an empty glass bottle with increasing amounts of water or sand and measuring the change in depth of immersion in a tank of water.
7. An open rectangular tin, such as a baking tin, can be used to represent a hull. A layer of sand evenly distributed over the bottom with a lead block embedded at the centre of gravity. The whole arrangement can be placed in a depth of water so that it floats. Observations can be made of the tin when:
   (i) it is disturbed to simulate a roll,
   (ii) the lead is placed to one side,
   (iii) a roll is simulated when the lead is placed to one side.
8. Students can be encouraged to design a way of raising the centre of gravity of a baking tin hull so that it can have a range of adjustments along a vertical line extending above the gunwales of the hull. This arrangement can then be used to study loll and capsize.

9. Plasticene can be used to create different hull shapes which can be drawn through the water with a spring balance on the end of a light fishing line. By trial and error, hull shapes which offer minimum resistance to progress through the water and still show a characteristic of stability can be determined.

10. A visit by students to look at a variety of hull shapes, sail size and shape. Information collected could lead to the production of a small test model for a single criterion.

11. The action of a rudder can be simulated by making an angle saw cut at the "stern" of a set of similar rectangular wooden blocks so that each block has a different angle cut. Into each cut a piece of masonite which can be adjusted to project below the bottom of the block will represent the rudder. The path taken by the block when it is pushed across the surface of level sand can be monitored for each of the rudder angles (each block say 15 cm x 6 cm x 2 cm).

12. Pulley systems can be used to investigate efforts required for given loads.

13. A session or two looking at maintenance features of an outboard motor.

14. Using a magnetic compass needle and observing the influence of metals and electrical appliances brought to the region of the compass.

**Text books which provide elective support.**

**1. Safety in Small Craft**
Scanlon
Royal New Zealand Coastguard Federation
P.O. Box 345, Manurewa, Auckland.
ISBN 0473007517
(Teacher reference and student use)
NZD approx $25

**2. GCSE Physics**
Tom Duncan
John Murray
ISBN 0719543800
AUSD approx $28

**3. Physics – A Textbook for Advanced Level**
Tom Duncan
John Murray
ISBN 0719543363
AUSD approx $38
(Teacher reference and student use)

**4. Service Manual**
Yamaha or Johnson outboards
Yamaha or Johnson distributor
(Teacher reference and student use)

## ELECTIVE B – MOTOR VEHICLE PHYSICS

- Theory of operation.
- The four stroke cycle with its valves.
- Piston design, head and rings.
- Piston stroke.
- Firing order.
- The two stroke cycle, with its ports.
- Expansion considerations.
- The flywheel.
- Comparison of petrol and diesel engines.
- Temperature control, cooling systems.
- Direct air cooling.
- Direct water cooling.
- The thermostat and radiator design.
- Fuels and combustion.
- Function of the carburettor.
- Float chamber and venturi.
- The choke and throttle valve.
- Idling.
- Ignition system, battery, coil.
- Ignition coil.
- Distributor, points and capacitor.
- Spark plugs.
- The battery design.
- Maintenance and charging.
- Relative density and the hydrometer.
- Battery rating.
- Engine capacity.
- Torque, energy and work.
- Power.
- Efficiency, thermal and mechanical.
- Friction and engine lubrication.
- Pressure and its transmission through liquids.
- Hydraulic braking system.
- Control of vehicle kinetic energy.

## Compulsory Objectives 1 – 14 (3 hours)

**Operation cycles in engines.**

Students should be able to:

1. know that internal combustion engines transfer energy from fuels to mechanical motion,
2. know that fuel is delivered to a cylinder in which it is exploded to force back a piston,
3. know that it is the motion of the piston that is transferred to other parts of the engine,
4. recognise a four stroke cycle,
5. recognise and sketch the order of operations in the four stroke cycle,
6. identify the strokes;
   - (i) intake,
   - (ii) compression,
   - (iii) power,
   - (iv) exhaust.
7. describe what happens inside the cylinder during each stroke,
8. comment on the action of the valves during the cycle,
9. recognise that engines often have several cylinders and that the same cycle has to occur in each cylinder,
10. understand that the cycle strokes in multicylinder engines are co-ordinated by having a firing order,
11. understand the need for a flywheel to smooth out the energy transfer between power strokes,
12. recognise a two stroke cycle,
13. recognise that intake, compression, ignition and exhaustion occur during a single revolution of the piston crankshaft in a two stroke engine,
14. understand that the ports have the same function as the valves of a four stroke engine.

## Extension Objectives 15 – 85

***Objectives 15 – 25*** *(3 hours)* **Temperature rise – the consequences**

Students should be able to:

15. know that during combustion the cylinder temperature is very high (about 250$^{o}$C) and this results in rapid expansion of the gases in the cylinder,
16. know that it is the expansion of the gases that drives the piston down the cylinder,
17. understand that the high temperatures also produce expansion of the cylinder and piston,
18. know that the design of pistons takes account of changes of size owing to expansion,
19. understand the function of the piston rings,
20. use the relationship; $l_f = l_i(1 + a\,\Delta T)$ for determining linear expansion,
21. understand that the coefficient of expansion expresses a fractional length change per degree temperature change,
22. understand how the materials chosen for pistons and cylinders allow operation without seizing or leaking,
23. know that the most common engine fuels are petrol and diesel, and that engines are designed for a particular fuel,

24. identify fundamental differences between the ignition process in petrol and diesel engines,
25. know that operating temperatures and pressures are far higher in diesel engines.

*Objectives 26 – 32* *(2 hours)* **Cooling systems**

Students should be able to:

26. understand that internal combustion engines require to be cooled during their operation,
27. know that cooling methods usually employ air or water,
28. explain direct air cooling as used in motorbikes,
29. explain direct water cooling as used in outboard motors,
30. explain indirect air cooling as used in motor cars,
31. compare the design of engine blocks which promote each particular type of cooling,
32. describe the working of a typical thermostat and radiator.

*Objectives 33 – 43* *(2 hours)* **Fuel system considerations**

Students should be able to:

33. know that petrol and diesel are hydrocarbon fuels,
34. know the possible products of combustion,
35. understand the system for providing fuel to the petrol engine,
36. know that fuels require the presence of oxygen before they will burn,
37. understand that the job of the carburettor is to provide the correct mixture of petrol and air for the cylinder,
38. recognise the various standard components of a carburettor,
39. identify problems that are linked with the carburettor:
    (i) clogged jets,
    (ii) stuck float,
    (iii) incorrect idle jet setting,
40. understand the purpose of the venturi and the influence they have on speed of air flow,
41. understand the conditions under which a choke would be used,
42. understand the function of the throttle valve and its adjustment,
43. recognise the requirement for an engine to idle.

*Objectives 44 – 59* *(3 hours)* **Ignition system and the battery**

Students should be able to:

44. identify the circuit components in a simple ignition system,
45. know that the battery provides the ignition coil with a primary current,
46. understand the role of the ignition coil as an inducer of high voltage,
47. understand that a changing magnetic field in the primary coil induces a large voltage in the secondary coil,
48. explain the role of the points in creating a collapse and rise of the magnetic field,
49. understand the role of the capacitor in storing charge that would otherwise cause sparking at the points,

50. recognise the need for a distributor in multicylinder four stroke engines,
51. describe the structure and function of the spark plug,
52. recognise the battery of a motor bike or car as a set of rechargeable cells,
53. describe the structure of a battery,
54. understand that the battery must be able to provide a large current for the starter motor,
55. understand the amp-hour rating attached to batteries,
56. know the maintenance considerations applying to a vehicle battery,
57. understand the process of charge and discharge of a lead-acid battery,
58. understand the use of a hydrometer for testing state of charge,
59. know that an installed battery has its own charging system through an alternator or generator.

*Objectives 60 – 78* *(4 hours)* **Work output from engines**

Students should be able to:

60. know that the capacity of an engine is determined by the volume swept out by the pistons in the cylinders,
61. know that the capacity of an engine is an indication of its power output,
62. know that the power output of an engine describes its rate of transfer of energy,
63. understand that horsepower ratings of engines describe the power output. (1 H.P.. approx represents 750 watt),
64. understand that the pressure in a cylinder after ignition results in a force on the surface of the piston,
65. calculate forces from information on pressure and piston size,
66. understand the terms top and bottom dead centre,
67. calculate the work done when a piston moves from t.d.c. to b.d.c.,
68. understand that the straight line displacement of the piston is translated into rotation of the crankshaft,
69. understand the concept of torque,
70. use the relationship for torque; $t = Fr$ ,
71. understand the term efficiency relating to inputs and outputs,
72. distinguish between thermal efficiency and mechanical efficiency,
73. know that there is a natural limit to thermal efficiency of any heat engine,
74. describe thermal efficiency in terms of the ratio of work output to the potential energy released from the fuel during combustion,
75. determine maximum thermal efficiency from the relationship:

$$Eff_{\max} = \frac{T_h - T_c}{T_h} \times 100$$ (where $T$ is in degrees Kelvin),

**76. describe ways in which mechanical efficiency is reduced, or can be improved, (increased and decreased friction),**

77. identify the need for lubrication to reduce frictional forces in transmission,
78. determine mechanical efficiency from;

$$h_c = \frac{work\ output\ at\ wheels}{work\ output\ at\ flywheels} \times 100$$

*Objectives 79 – 86* *(3 hours)* **Brakes and hydraulic considerations**

Students should be able to:

79. recognise a simplified braking system,
80. understand that forces can be transmitted through liquids,
81. understand the use of fluids in hydraulic braking systems,
82. understand the influence of surface area in magnifying force in hydraulic systems,
83. calculate forces resulting from hydraulic pressures,
84. understand the use of brakes to control the kinetic energy of a vehicle,
85. understand that the kinetic energy manifests as heat (and sometimes sound!) in the brakes,
86. calculate the energy transfer from kinetic energy of the vehicle to heat in brakes and tyres.

**PRACTICAL SUGGESTIONS**

1. Use a probe rod to follow the head of a piston through a single revolution.
2. Study the design of a piston and its ring extracted from a cylinder.
   Students can consider the way in which the design:
   - (i) ensures a gas tight seal,
   - (ii) reduces friction,
   - (iii) conducts heat from the piston,
   - (iv) copes with expansion changes.
3. Using a ball and ring, students can observe the failure of the hot iron ball to pass through the ring. Students can consider what effect this situation would have inside a cylinder.
4. An inverted bicycle can provide a wheel which can simulate a flywheel. The pedal can be used to provide different rotational speeds and then a steady retarding force can be applied through the brake blocks. The time required to stop the wheel can be compared for different values of initial rotational speed.
5. Students can study the fin structure of a motor bike block and the channel structure in a car or outboard engine block.
6. Equal volumes of boiling water can be poured into an empty aluminium soft drink can and into an aluminium tray. A thermometer can be used to record temperature changes in each with time. Cooling curves in each situation can then be plotted. Students can consider the implication of surface area in engine cooling.
7. Using a commercial thermostat, its opening and closing temperatures can be determined by placing into a heated beaker of water and making appropriate observations.
8. Students could be given the chance to disassemble and reassemble a carburettor.
9. A laboratory induction coil, or an ignition coil from a motor vehicle can be used to see how the size of a successful spark gap can be changed for a given primary voltage. Students need to be warned not to touch the secondary output. The gap can be provided by two steel nails pointing at each other.
10. The electrolyte of a battery can be tested with a hydrometer.
11. Students can be given a sulphated battery and asked to comment on its condition.
12. A model hydraulic system using different sized syringes can indicate the force changes associated with different cross sectional areas. By loading the plungers with known masses, the associated forces can be determined.

13. A motor cycle with a single fault that requires diagnosing. A whole range of simple faults can be introduced (but only one at a time!),

e.g.
- faulty spark plug (wrong gap size),
- faulty spark plug (insulation failed),
- spark plug lead faulty,
- breaker points not opening,
- condenser collapse,
- blocked carburettor,
- float stuck,
- no fuel.

**Text books which provide elective support.**

1. **Mechanics of the Motor Vehicle**
   New Zealand Technical Correspondence Institute
   Government Printers
   Wellington
   ISBN 0477013457
   (Teacher reference and student use)

2. **Automobile Construction and Operation**
   Stahn
   McGraw Hill
   ISBN 0070776962
   (Teacher reference and student use)

3. **The car and how it works**
   Emes and Emes
   Arnold
   ISBN 0713100044
   (Student use)

## ELECTIVE C - ENERGY SOURCE AND TRANSFER

- The Sun as the master source of terrestrial energy supplies.
- Nuclear reactions.
- Solar energy utilisation.
- Solar energy collectors, flat plate, focussing.
- Transfer and storage of energy.
- Wind power, wind mills, wind generators.
- Energy from movement of the sea.
- Conventional energy source from fossil fuels.
- Potential energy transfer.
- Efficiency and inefficiency of systems.
- Theoretical efficiency limits.
- Nuclear power generation.
- Arguments against nuclear power generation.
- The greenhouse effect.
- Solar cells, space located.
- Power input.
- Wave power, tidal power.
- Hydroelectric power.
- Disadvantages of coal and oil.
- Biofuels, digesters, sugar crops.
- Geothermal power.
- Ocean thermal energy conversion.

## Compulsory Objectives 1 - 16 (3 hours)

*Objectives 1 – 11* *(2 hours)*

**The Sun as an energy source**

Students should be able to:

1. recognize the Sun as the primary source of all the energy available on Earth,
2. describe the fusion reaction believed to provide solar energy
3. recognize the extremely high temperature required for fusion reactions
4. understand that energy from the sun arrives as electromagnetic radiation
5. describe natural solar energy collectors:
   (i) the oceans,
   (ii) photosynthesis in plants.
6. describe the principle of a solar energy collector,
7. know that the photovoltaic solar cell transfers radiant energy to electrical energy which can be stored (no detail of solar cell construction is expected)
8. know that a solar panel consists of many circuited photoelectric cells
9. describe the way in which the sun gives rise to winds,
10. understand the origin of sea swell and sea waves,
11. realize that the sun raises vast quantities of water from the oceans and dumps it as rain on the tops of mountain ranges,

*Objectives 12 – 16* *(1 hour)* **Efficiency**

Students should be able to:

12. recognize that all energy schemes ultimately are geared to the production of movement, heat or electricity which can be transferred immediately or stored for later transfer,
13. understand that the efficiency of energy transfer systems can never be 100%,
14. use information relating to input and output in order to determine efficiency,
15. interpret efficiency tables to determine the most economical energy transfer devices,
16. locate countries in the Pacific region which lend themselves to particular types of energy collection and distribution.

## Extension Objectives 17 – 25

*Objectives 17 – 25 (2 hours)* **Sun and nuclear fuels**

Students should be able to :

17. understand the origin of forces which prevent fusion at low temperatures,
18. understand the meaning of isotope in terms of an atom's particles,
19. realize that isotopes are naturally occurring,
20. describe the changes when one element form changes to an isotope,
21. understand that nuclear reactors promote changes within the atom,
22. name a fuel used in nuclear power generation and describe a fission reaction
23. describe the manner in which the nuclear reaction is controlled,

*24. understand the arguments for caution in the increased use of atomic energy
i.e. know about:
 (i) danger in promoting nuclear reactions,
 (ii) radiation hazards
 (iii) nuclear waster disposal
 (iv) ingredients for weapons

*25. understand the reasons for the "Nuclear Free Pacific" policy and the counter arguments.

* *These objectives also appear in the core.*

*Objectives 26 – 31 (2 hours)* **Solar radiation and atmosphere**

Students should be able to:

26. understand the influence of the ozone layer on arriving frequencies of this radiation,
27. know that some of the products of modern technology (e.g. CFC) are probable causes of the depletion of the ozone layer,
28. describe the valuable "greenhouse" influence of the Earth's atmosphere,
29. understand that it is **change** in the greenhouse influence that causes concern,
30. describe the suggested link between changes in the greenhouse effect and the use of fossil fuels and other products,
31. account for the manner in which solar energy is lost from or used by the Earth after arrival.

*Objectives 32 – 35 (2 hours)* **Solar plate collectors**

Students should be able to:

32. understand the design of a flat plate collector from physical principles,
33. name the medium to which energy is transferred in particular collectors,
34. consider conditions for optimum placement and direction for flat plate collector,
35. understand the design of focusing collectors from physical principles,
 (i) single parabolic mirror,
 (ii) multiple flat mirrors forming solar furnace
 (iii) lens

*Objectives 36 – 40 (1 hour)* **Solar photovoltaic collectors**

Students should be able to:

36. consider conditions for optimum placement of the solar panel,
37. understand the role of a battery in storing energy received from a photovoltaic solar panel, (calculations involving energy transfer to and from the battery should be covered),
38. understand the role of a diode in preventing discharge back through a solar panel,
39. know that solar radiation on the Earth's surface has a particular value (depending on conditions), in $Jm^{-2}$,
40. know of possibilities for locating solar cells in space as Earth-serving satellites.

*Objectives 41 – 45(2 hours)* **Wind energy**

Students should be able to:

41. understand that moving masses of air possess kinetic energy,
42. understand that part of the kinetic energy of the wind is transferred to the rotating portion of a windmill or wind generator,
43. use a power input relationship related to:
    - (i) wind speed,
    - (ii) area of sweep by blades,
    - (iii) density of wind air,
    - i.e. simple theory can be used to show that the power, $P$, contained in a cross-sectional area, $A$, of wind moving at a constant velocity, $v$, is given by: $P = \frac{1}{2} r v^3 A$ (where $r$ is air density)
44. **compare the axes of rotation in different wind generators e.g. compare propeller type with Savonius rotor.**
45. consider the appropriate siting for a wind generator.

*Objectives 46 – 58 (3 hours)* **Wave and hydro energy**

Students should be able to:

46. understand the research efforts into harnessing energy from waves,
47. understand that the up and down motion of the medium as the wave passes is the energy feature that could be exploited,
48. understand that the water in the crest of a wave is at a higher potential than the trough of the wave and that this presents an opportunity for harnessing energy,
49. discuss the technical difficulties in using wave power,
50. understand the action of wave devices: (i) the duck, (ii) oscillating water column,
51. understand that tidal changes result in gravitational potential changes of huge masses of water,
52. understand the role of the Sun and the Moon in the phenomenon of tides,
53. understand the possibility of damming quantities of water at high tide, to be released through turbines at low tide
54. consider the ecological problems posed by tidal energy projects.
55. understand that lakes and rivers at high altitude offer a source of gravitational potential energy,
56. calculate the gain in kinetic energy as a mass of water falls,
57. calculate the power input to a turbine from a moving mass of water.

*Objectives 58 – 64 (2 hours)* **Energy and organic fuels**

Students should be able to:

58. list conventional energy sources, both at industrial and village level,
59. identify combustion products of fossil fuels,
60. write representative equations for the combustion of hydrocarbons,
61. comment on the pollution influences resulting from the combustion of hydrocarbons or their derivatives,
62. discuss the use of wood as a viable fuel,
63. discuss the biodigester as a producer of methane,
64. discuss the use of sugar from crops as a producer of alcohol which can be used as fuel.

*Objectives 65 – 68(1 hour)* **Geothermal energy and OTEC**

Students should be able to:

65. describe the use of geothermal energy to drive steam generators,
66. explain why heat is generated in the Earth's core,
67. consider the possibilities of ocean thermal energy conversion,
68. understand the principles involved in an OTEC scheme.

*Objectives 69 – 71 (1 hour)* **More efficiency**

Students should be able to:

69. understand the reasons for the limit of efficiency imposed on heat engines such as a steam turbine, in terms of the heat loss in waste gases and the work needed to return an engine to the start of its power stroke,
70. determine maximum thermal efficiency through the use of the relationship:

$$Eff_{\max} = \frac{T_h - T_c}{T_h} \times 100$$

    (where temperature $T$ is in degrees Kelvin)
71. understand that mechanical efficiency can be improved by attention to lowering frictional loss in transmission.

**PRACTICAL SUGGESTION**

1. Gather together articles from magazines and newspapers relating to:
    - i. the Pacific attitude to nuclear power,
    - ii. the problems relating to nuclear reactors and their waste,
    - iii. alternative energy initiatives in the Pacific region.
2. Conduct a survey on the use of solar energy in your town, island, country.
3. Design and produce an experimental version of a solar plate collector using materials such as: glass and butyl tubing, thermos flask, black paint, perspex or glass sheet.

4. Use an experimental collector to monitor temperature rise in contained water following a specified exposure to the sun. Compare temperature rises with:
   i. collector facing different directions,
   ii. different times of the day.
5. Use data from an experimental solar collector to determine energy input and power input to the collector. Compare this to an estimate of the radiated energy incident on the collector. Consider ways in which the collector could have its efficiency improved.
6. Many Pacific countries use solar energy to promote the drying of foods such as fish and coconut. Students can design and build a solar drier suitable for use in food preservation.
7. Design and set up a digester charged with organic matter in order to collect and verify the production of combustible fuel gases.
8. Use rigidly positioned match heads at the focal point of convex lens and a concave mirror to see if solar ignition of the head is possible – use matches, which can be struck by rubbing on any rough surface. Determine the conditions which bring about successful ignition.
9. In coastal areas, students can monitor the rise and fall of a float, such as a balanced tin can moving against a rigid vertical rod which has been calibrated. The average rise and fall can be determined. The potential energy delivered to the tin with each rise can be determined, and the total energy delivered per minute calculated. The power input from the wave can be calculated, this being for a length of wave front, equivalent to the diameter of the tin.
10. Small toy windmills made from pieces of coconut frond, fashioned into a windmill sail design, are commonly seen in Pacific Islands. Study a toy such as this and attempt to see what conditions appear to be necessary for the most successful revolution of the sails. Try small alterations in design to see how they influence the turn of the sails.
11. A carefully cut tin will provide the two halves of a Savonius rotor. If they are glued to a bicycle spoke or similar straight rod, the bottom of the rod can then be inserted inside a drinking straw which passes through the hole of a rubber bung into a test tube. A small volume of oil at the bottom of the test tube will reduce friction at the bottom of the rod.
12. A report on a visit to see any commercial wind machines in operation, and the manner in which the harnessed energy is ultimately used.

**Text books which provide elective support.**

**1. GSCE Physics**
Tom Duncan
John Murray
ISBN 0719543800
AUSD approx $28
(Student use)

**2. Physics – A Textbook for Advancce Level**
Tom Duncan
John Murray
ISBN 0719543363
AUSD approx $38
(Teacher reference and student use)

**3. The World of Physics**
Avison
Nelson
ISBN 0174382383
(Teacher reference and student use)

## ELECTIVE D - ELECTRONICS

- Resistors, the value code and tolerance.
- Potential dividers, the potentiometer.
- Capacitors, types and construction.
- Capacitance and the farad.
- Protection resistors.
- Cathode-ray oscilloscope.
- Diodes, construction and properties.
- Forward and reverse bias.
- Current-voltage characteristics for a diode.
- Diode resistance.
- The diode as a rectifier.
- Diode rectifier bridge.
- Simple rectifying circuits.
- The LED.
- Transistor types and construction, NPN and PNP.
- Current direction and conservation.
- Current gain.
- Saturation current.
- Transistor amplifier.
- Simple two bulb indicator circuit for amplification.
- Transistor switch.
- The light dependent resistor (LDR).
- The thermistor.
- LDR or thermistor used in conjunction with a transistor as a switch.
- Reed switch and relay.
- Simple circuits involving reed switch.
- Logic gates AND, OR, NOT.
- Logic gates NAND and NOR.
- Truth tables.
- Components involved in simple circuitry.
- The operational amplifier as an integrated circuit.
- The calculator display.

## Compulsory Objectives 1 – 15 (3 hours)

*Objectives 1 – 10 (2 hours)* **Resistors and their uses**

Students should be able to:

1. recognize components as being resistors,
2. know that the resistance value is displayed as a code,
3. interpret resistor values from supplied code sheets,
4. understand the tolerance value of the resistor,
5. understand that when resistors are connected in circuits there is a potential drop across the resistor,
6. understand the usefulness of resistors in protecting other components from big currents,
7. understand that the potential between two points can be split with the use of two resistors,
8. recognize a "pot" resistor as a potential divider,
9. calculate the influence that a voltmeter could have on the potential it is attempting to measure.

*Objectives 10 – 14(1 hour)* **Capacitors, their construction and use**

Students should be able to:

10. recognize components that are capacitors,
11. understand the construction of a capacitor and its function as a storer of charge,
12. understand the term capacitance as indicated in the relationship: $C = \frac{Q}{V}$,
13. know the unit of capacitance as being the farad, F, and that the capacitance determines how much charge can be stored at a particular voltage,
14. know that each capacitor is designed to operate at a particular voltage,
15. know that capacitors interrupt DC charge flow in a circuit, but do not interrupt AC flow.

## Extension Objectives 16 - 76

*Objectives 16 – 23(2 hours)* **The cathode-ray oscilloscope**

Students should be able to:

16. understand the release of electrons from a hot filament,
17. recognize an electron gun as accelerating electrons through an electric field,
18. know that the electrons are released from the negative plate (cathode) and are attracted to the anode,
19. understand the design of the anode in an oscilloscope to allow a beam of electrons to pass through,
20. know that in a cathode-ray oscilloscope two sets of plates set up electric fields, one vertical field $Y$, the other a horizontal field $X$,
21. understand that the electric fields formed by the plates will have a deflecting influence on any passing electrons,
22. know that an input voltage can be supplied to the plates of the vertical electric field, and that this will deflect the electrons by an amount which depends on the electric field strength,
23. understand that the C.R.O. can be used as a sensitive voltmeter.

## **Objectives 24 – 29(1 hour)** Diode properties

Students should be able to:

24. recognize components that are diodes,
25. know that diodes are sensitive to the direction of charge flow through them,
26. know that diodes permitting flow of charge are described as forward biased,
27. know that diodes restricting flow of charge are reversed biased,
28. understand that a diode characteristic indicates that it does not obey Ohm's law,
29. understand that the operating voltage across a diode needs to be at a certain minimum.

*Objectives 30 – 34(2 hours)* **Diode rectification**

Students should be able to:

30. understand the meaning of rectification,
31. recognize the rectifying affect of a single diode,
32. understand the rectifier bridge as a rectifier,
33. recognize voltage-time graphs for diode rectifiers,
34. know of the role of a smoothing capacitor in a rectification circuit.

*Objectives 35 – 41(1 hour)* **The LED, transistors and their construction**

Students should be able to:

35. recognize the light emitting diode,
36. understand the usefulness of LEDs as on/off indicators,
37. know that the LED requires the correct bias for operation,
38. know that transistors are constructed like a back to back diode,
39. know that a transistor has three points of connection:
    i. base,
    ii. collector,
    iii. emitter.
40. know that there are two forms of transistor, namely NPN and PNP,
41. understand how to determine transistor type from the code arrow between the base and emitter.

*Objectives 42 – 49(1 hour)* **Transistor properties**

Students should be able to:

42. understand that base current runs through the base to the emitter,
43. understand that the size of base current controls the size of the collector current,
44. realize that there is conservation of current value into and out of the transistor,
45. know that the ratio of collector current to base current is described as the current gain,

46. use the relationship: $b = \frac{I_c}{I_b}$ ,
47. understand the need for resistors to protect transistors from excessive loads,
48. understand that the maximum current output from the collector is limited by the resistance elements in the external circuit, this limit being the “saturation current”,
49. understand that feeding a signal into the base and obtaining a stronger signal from the emitter is the basis of current amplification.

*Objectives 50 – 62(4 hours)* **Developing circuits and switching**

Students should be able to:

50. interpret simple circuit diagrams which include resistors, transistors and signal input or output devices,
51. understand a circuit with similar LEDs or bulbs in the base and collector circuits to serve as an indicator of the amplification,
52. understand that a transistor can use its base current to trigger activity in a collector circuit, in which case the transistor is acting as a switching device,
53. know that a light dependent resistor has the property of changing its resistance value according to the light intensity reaching it,
54. know that the resistance of an LDR is highest in darkness and lowest in bright light,
55. understand that the properties of an LDR can be used to switch through a transistor base,
56. understand circuits in which an LDR is used to raise a base current or reduce a base current,
57. understand the place an LDR has in a potential divider,
58. understand that a thermistor is a resistor sensitive to temperature changes,
59. know that the resistance of many thermistors falls as the temperature rises,
60. recognize a reed switch and understand the way it operates in conjunction with a relay,
61. understand the closing of a reed switch with a magnet or with the magnetic field of a current carrying coil,
62. understand the way that a reed switch can link an input with a desired output.

*Objectives 63 – 71(2 hours)* **Logic gates and truth tables**

Students should be able to:

63. understand the concept of a logic gate being a set of input conditions met with a specific output,
64. know the logic “high” “1” “on” all describe a triggering input voltage,
65. know that logic “low” “0” “off” describe no triggering input voltage,
66. know three basic logic gates AND, OR and NOT,
67. draw truth tables for AND, OR and NOT gates,
68. understand the combination of a NOT AND into a NAND gate,
69. understand the combination of a NOT OR into a NOR gate,
70. recognize the presence of gates in circuits,
71. recognize situations where the use of gates might be appropriate.

*Objectives 72 – 76(2 hours)* **More circuits and their component symbols**

Students should be able to:

72. recognize symbols for all components met in the objective descriptions,
73. study **simple** circuit diagrams involving any of the components met in the preceding objectives and predict the circuit behaviour,
74. recognize the technique of integrating components into circuits, but will not be expected to know any detail,
75. recognize an op-amp as an example of an integrated circuit,
76. understand the manner in which electronic displays use LEDs to form numbers.

**PRACTICAL SUGGESTIONS**

1. An oscilloscope can be used to display a variety of inputs to give students the opportunity of making control adjustments and interpreting the screen values displayed.
   e.g. - connecting one or two DC 1.5V cells across the input,
   - connecting a low voltage AC supply across the input,
   - connecting a microphone or signal generator across the input.
2. Provide students with a whole range of different resistors from which they can determine resistor values from their codes.
3. Build simple series and parallel resistor circuits and measure potential drops with a voltmeter or a CRO. A multimeter tester offers a quick way of moving about a circuit.
4. Investigate the importance of polarity in the placement of diodes and LEDs.
5. Determine the $V-I$ characteristic for a diode using a sliding resistance to vary voltage across the diode.
6. Provide students with a range of capacitors from which they can read off capacitance, polarity and recommended voltage.
7. Use suitably placed LEDs as indicators of current in both a low voltage AC and DC circuit containing a capacitor.
8. Investigate the rectification ability of the diode by comparing the effect of its inclusion and exclusion with a resistor in a low voltage AC circuit, and monitoring the voltage across the resistor with a CRO.
9. Students can build a full wave rectifier using diodes to form the bridge. The resulting output can be monitored on the CRO.
10. An extension of practical suggestion 9 can involve the inclusion of a capacitor to show the smoothing effect produced.
11. Students could observe a range of different transistors and be encouraged to look for the similarities and differences between each.
12. A transistor circuit with protection resistors and indicator LEDs in both the base line and the collector line. The similar LEDs give a visual impression of the difference between the base and collector currents. By including a switch in the base line, students can see the effect that reducing base current has on the collector and emitter currents.
13. By measuring the current in base and collector lines, the gain for a transistor can be determined.

14. Investigating the response of an LDR to light intensity change, and the response of a thermistor to temperature changes.

15. Building a simple circuit where an LDR switches on the base of a transistor allowing a collector current to operate a device such as an LED or buzzer.

16. Using understanding, students can be encouraged to design and build circuits such as:
    i. a continuity tester,
    ii. a fire alarm light or buzzer,
    iii. relay operated bell,
    iv. a salinity tester,
    v. a red-green flasher unit.

**Text books which provide elective support**

**1. GCSE Physics**
Tom Duncan
John Murray
ISBN 0719543800
AUSD approx $28
(Student use)

**2. Physics – A textbook for Advanced Level**
Tom Duncan
John Murray
ISBN 0719543363
AUSD approx $38
(Teacher reference and student use)

**3. Fun Way into Electronics**
Dick Smith
ISBN 0959508007
AUSD approx $5
(Student use for practicals)

## ELECTIVE E: HEALTH PHYSICS

- Blood pressure
- Blood pump and transport system
- Pressure differences in circulation
- Interpreting blood pressure values
- Work done by the heart
- The manometer and the sphygmomanometer
- The stethoscope
- Effect of radius on speed of blood flow
- Ultrasound, frequency and range
- Conditions determining velocity
- Reflection and echo
- Acoustic impedance
- Attenuation and half value thickness.
- A scan, B scan, and real time image display
- M scan
- Doppler Effect
- Benefits of ultrasound
- Radiotherapy
- Electromagnetic radiation, scatter, photoelectric effect, Compton effect, pair production
- Penetration ; alpha, beta, gamma rays.
- Cell growth, normal and abnormal.
- Radio sensitivity
- Cell irradiation.
- Dose measure in $Jkg^{-1}$ or grays.
- The simple x-ray tube, production of x-rays.
- The laser
- Properties of laser light
- Laser action and the laser box.
- Laser power, time and spot size.
- Reflection and absorption
- Biological effects of laser heat.
- Refracting structure of the eye
- Eye defects and their correction
- Heating and cooling
- Basic metabolic rate and size
- Heat production, fever, and cooling mechanisms.

## Compulsory Objectives 1 – 18 (3 hours)

*Objectives 1-10 (2 hours)* **Blood pressure and its measurement.**

**Students sh ould be able to:**

1. understand that pressure describes a force on a unit of area
2. know that blood pressure is the force exerted by the blood on the artery wall, and that pressure changes arise owing to heart beat,
3. know that blood pressure is a useful guiding indicator of general health status,
4. know the manner in which body blood vessels are arranged in circulation,
5. understand the reasons for blood pressure being different at various positions in the body,
6. understand the expressions of pressure in terms of mm of Hg,
7. use a manometer and understand its theory of operation,
8. use the relationship for determining the pressure $P$, at a depth $h$, in a liquid of density $r$, is given by: $P = rgh$
9. recognize a sphygmomanometer and understand how it works,
10. understand the 120/80 type expression resulting from a sphygmomanometer reading.

*Objectives 11-18(1 hour)* **Cardiac output and blood vessels**

Students should be able to:

11. understand the stroke vo lume as the volume of blood leaving one side of the heart at each beat,
12. understand that cardiac output describes the amount of blood leaving one side of the heart in one minute,
13. understand that the potential energy of the heart tissue is transferred to the blood as kinetic energy on contraction,
14. apply $\frac{1}{2}mv^2$ to the mass of blood in order to determine energy transfer,
15. understand that the average force on the blood in the aorta can be determined from the pressure difference at diastole and systole when the cross section area of the vessel is known, $F = PA$
16. understand that as blood vessels get narrow the speed of blood flow increases,
17. explain the apparent anomaly of small blood flow speeds in the capillaries,
18. understand that for a given pressure, halving the radius of a vessel reduces speed by a factor of sixteen: $v \; a \; r^4$

## Extension Objectives 19 - 89

*Objectives 19-24 (1 hour)* **Introduction to ultrasound.**

Students should be able to:

19. know that ultrasound has a use in medical diagnostics and treatment
20. know that ultrasound frequencies are above those detectable by the human ear usually in ranges above 20 000 $Hz$
21. understand that frequencies used in medical applications are generally above $10^6$ $Hz$,
22. use the relationship $v = fl$,

23. know that the velocity of sound in a substance depends upon the properties of the substance,

24. understand that velocities tend to be higher as the density of the medium increases, and deduce that usually velocity in a solid is greater than in a liquid or a gas.

*Objectives 25-38 (3 hours)* **Tissue penetration, reflection, transmission and absorption.**

Students should be able to:

25. understand that different body tissues will transmit ultrasound with differing velocities,
26. understand that at boundaries between different materials there will be a certain amount of transmission and a certain amount of reflection,
27. understand that the angle and smoothness of the boundary will influence the angle of the reflected wave,
28. understand that reflected waves can be detected as echoes,
29. know that the probe of an ultrasound device acts as an emitter and as a receiver,
30. know that tissues which transmit sound well are said to have a high acoustic impedance,
31. understand that the amount of reflection and transmission at a boundary also depends on the acoustic impedances of the two materials,
32. use acoustic impedance values to determine the amount of reflection or transmission at a boundary, using the relationship: $\frac{R}{I} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$ where $R$ and $I$ are the reflected and the incident intensities of the ultrasound wave, and the $Z_1$ and $Z_2$ are the acoustic impedances of the two media,
33. understand that when impedance values of two media at a boundary are similar, reflection is poor,
34. understand why a gel is used on the skin before a scan is taken,
35. understand that tissues also absorb some of the energy of the wave as it passes through the tissue,
36. interpret the term attenuation in terms of energy transfer,
37. understand the **half value thickness** of a tissue in terms of intensity drop,
38. understand that the half value thickness is also influenced by the frequency of the ultra wave.

*Objectives 39-44 (2 hours)* **Types of scan and Doppler shift**

Students should be able to:

39. understand the differences of image production from an A scan and a B scan,
40. understand that a real time scanner can image moving tissues,
41. understand that the M scan provides information about moving tissues,
42. understand the phenomenon of Doppler shift in frequency,
43. understand the value of Doppler shift in determining the velocity of a substance, and use the following relationship to determine the velocity, $v$, of a moving tissue: $v = \frac{c\Delta f}{2f}$ where $c$ and $f$ are the velocity and the frequency of the ultrasound wave, respectively,
44. list the benefits of using ultrasound in medical investigation.

*Objectives 45-48 (1 hour)* **Introduction to radiation**

Students should be able to:

45. understand that radiation is used both for diagnosis and treatment,
46. know that radiotherapy involves the use of X-rays and electrons, principally in the treatment of cancer,
47. know the role of X-rays in diagnosis, particularly of bone fractures and lung damage, and CAT scanning.
48. know that X-rays and gamma rays are forms of electromagnetic radiation in which photons interact with atoms with which they collide.

*Objectives 49-53 (1 hour)* **Photon - atom interactions**

Students should be able to:

49. understand scattering with a failure to ionize because of insufficient energy
50. understand the photoelectric effect as an emitted electron leaving behind an ion,
51. understand the Compton effect of emitted electron and a reduced-energy photon,
52. understand pair production leading to electron and positron formation with the ultimate production of two photons and further interactions,
53. know how to use the relationship $E = mc^2$ in simple energy-mass conversion.

*Objectives 54-62 (2 hours)* **Radiation type and therapy**

Students should be able to:

54. understand that alpha, beta and gamma rays do not have the same penetrating power of tissues,
55. understand that the penetrating radiation of body tissue causes ionization of body molecules,
56. understand that cells, whose chemical structure is changed by radiation, are likely to die,
57. understand that cancerous cells have rapid division which is out of control, and that these cells are more susceptible to damage from radiation than dormant cells,
58. understand the possible outcome that can result from the irradiation of cells,
59. understand the more serious consequences if meiotic, rather than mitotic, division changes occur as a result of radiation,
60. recognize the gray as the unit of dosed radiation which is expressed in $Jkg^{-1}$,
61. use the relationships: $E = hf$ and $E = eV$ in order to determine the energy of an $X$-ray,
62. recognize the general structure of a simple $X$-ray tube.

*Objective 63-73 (2 hours)* **Laser properties**

Students should be able to:

63. understand the properties associated with laser light in terms of the phase and wavelength.
64. understand a simplified description of the construction and function of a laser,
65. know that photons of the same frequency have the same energy,

66. understand the “ground state” of an atom, and that an atom can be excited by changing energy levels of electrons,
67. understand that an inverted population has a majority of atoms in an excited state,
68. understand that a photon arriving in an inverted population can cause an avalanche of emitted photons,
69. understand that the energy obtained from the laser is dependent on the medium supplying the excited atoms,
70. understand that the amount of energy hitting a target depends on the power of the laser, length of time of exposure and the size of the target,
71. understand that the laser beam can be focused at a target,
72. understand that intensity changes as the target is moved away from the focus,
73. understand that movement resulting in a doubling of spot size reduces energy absorbed by the target by a factor of four.

*Objectives 74-78 (1 hour)* **Lasers and tissues**

Students should be able to:

74. understand that different substances have different absorption properties,
75. understand that tissues may reflect, transmit, scatter, or absorb incident laser energy,
76. understand that tissues absorbing laser energy will suffer a temperature change,
77. list the ways in which medical lasers are used,
78. interpret information about different types of laser and apply this to a practical situation.

*Objectives 79 – 81 (1 hour)* **The eye and refraction**

Students should be able to:

79. understand the manner in which a normal eye is capable of focusing images on its retina,
80. understand the refracting defects which lead to failure of focus,
81. know how to use correcting lenses in order to correct focus (no calculations relating to lens power)

*Objectives 82-89 (2 hours)* **Body temperature and its control**

Students should be able to:

82. understand that body metabolism results in heat production,
83. understand the need for the body to have control mechanisms for maintaining body temperature
84. know the routes by which heat is lost from the body,
85. understand the importance of surface area in cooling,
86. understand that the metabolic volume to surface area ration differs from one mammal to another,
87. know the construction of a clinical thermometer
88. understand the role that shivering plays in heat generation,
89. understand the role that sweating plays in heat loss.

## PRACTICAL SUGGESTIONS

1. Use a stethoscope to listen for the characteristic sounds of heartbeat. Find the best position for the loudest sound.
2. Arrange for instruction in the use of a sphygmomanometer. Determine blood pressure values for class students. Compare blood pressures of students and discuss possible reasons for differences.
3. Use a frequency generator to establish upper audio limit of students. if possible follow the frequency changes with a CRO display
4. Visit a hospital that uses scanners, x-ray equipment or lasers and see the machines preferably during use. Students can report on their findings
5. Observe the apparent frequency changes occurring, as vehicles both approach the student, and move away from the student.
6. If possible arrange for a viewing of a police radar arrangement which often use the Doppler shift to assess speed of oncoming vehicles.
7. Make a survey of newspaper or magazine articles which discuss issues on radioactivity
8. Find out the wavelength and energy at which the school laser operates.
9. Direct a school laser beam onto a bulb of a clinical thermometer which has been dipped in a water colour paint. Record any temperature change against time. Repeat for different coloured paints. Determine relative energy absorptions.
10. Observe various pairs of spectacles to see how the physical shapes of the lenses differ.

**Text books which provide elective support**

**1. People, Probes and Pulses**
Barlow
Longman Paul
ISBN 0582859654
(Teacher reference and student use)

**2. Science Now – Health Physics**
McCormick and Elliott
Stanley Thornes
ISBN 0748702059
(Student use)

**3. Medical Physics**
Hart and Armes
Stanley Thornes
ISBN 0750102292
(Teacher reference)

## Equations associated with the syllabus

**Notes**:

1. The S.I. system of units is used throughout.

2. Students are expected to be familiar with the use of negative indices in equations and in the description of units.

3. Students are expected to be able to use standard form notation and be familiar with the prefixes kilo, mega, milli, micro.

4. Students are expected to be familiar with the $\Delta$ (delta) notation.

5. Examination questions may require the use of any of the equations included in this syllabus document.

6. All equations will be provided with the examination paper for selected use by candidates.

**Mirrors, lenses, reflection and refraction:**

| Variables defined as: | | Unit |
|---|---|---|
| $M$ | = magnification | |
| $u$ | = object distance | $m$ |
| $v$ | = image distance | $m$ |
| $f$ | = focal length | $m$ |
| $s_i$ | = distance from image to focus | $m$ |
| $s_o$ | = distance from object to focus | $m$ |
| $n_i$ | = refractive index medium 1 | |
| $n_2$ | = refractive index medium 2 | |
| $q_1$ | = angle of incidence in 1 | $\circ$ |
| $q_2$ | = angle of refraction in 2 | $\circ$ |
| $h_i$ | = height of image | $m$ |
| $h_o$ | = height of object | $m$ |

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

$$s_i s_o = f^2$$

$$M=\frac{v}{u}$$

$$n_1 \sin q_1 = n_2 \sin q_2$$

$$M = \frac{h_i}{h_o}$$

$$n_{21}=\frac{\sin q_1}{\sin q_2}$$

**Wave diffraction and interference:**

| Variables defined as: | | Unit |
|---|---|---|
| $T$ = | period | $s$ |
| $l$ = | wavelength | $m$ |
| $f$ = | frequency | $Hz$ |
| $v$ = | velocity | $ms^{-1}$ |
| $d$ = | slit separation | $m$ |
| $x$ = | fringe separation | $m$ |
| $L$ = | slit-screen separation | $m$ |
| $n$ = | fringe number | |
| $q$ = | diffraction angle | $\circ$ |

$$v = fl \qquad l = \frac{d\Delta x}{L}$$

$$T = \frac{1}{f} \qquad (n - \tfrac{1}{2})\, l = d \sin q$$

**Force and momentum:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $F$ | = | force | $N$ |
| $m$ | = | mass | $kg$ |
| $a$ | = | acceleration | $ms^{-2}$ |
| $p$ | = | momentum | $kgms^{-1}$ |
| $t$ | = | time | $s$ |
| $v$ | = | velocity | $ms^{-1}$ |
| $\Delta v$ | = | change in velocity | $ms^{-1}$ |
| $\Delta t$ | = | time interval | $s$ |
| $r$ | = | distance | $m$ |
| $t$ | = | torque | $Nm$ |

$$F = ma \qquad F\Delta t = m\Delta v$$

$$p = mv \qquad t = Fr$$

**Kinematics:**

Variables defined as: Unit

| | | | |
|---|---|---|---|
| $t$ | = | time | $s$ |
| $s$ | = | displacement | $m$ |
| $v$ | = | velocity | $ms^{-1}$ |
| $v_i$ | = | initial velocity | $ms^{-1}$ |
| $v_f$ | = | final velocity | $ms^{-1}$ |
| $a$ | = | acceleration | $ms^{-2}$ |

$$v_f = v_i + at \qquad s = v_i t + \tfrac{1}{2}at^2$$

$$s = \tfrac{1}{2}(v_i + v_f)t \qquad v_f^{\,2} = v_i^{\,2} + 2as$$

**Circular motion:**

Variables defined as: Unit

| | | | |
|---|---|---|---|
| $v$ | = | speed | $ms^{-1}$ |
| $r$ | = | radius of motion | $m$ |
| $T$ | = | period of motion | $s$ |
| $a$ | = | centripetal acceleration | $ms^{-2}$ |
| $F$ | = | force | $N$ |
| $G$ | = | Universal Gravitational constant | $m^3 s^{-2} kg^{-1}$ |

$$v = \frac{2pr}{T} \qquad a = \frac{v^2}{r} \qquad F = \frac{Gm_1 m_2}{r^2}$$

$$a = \frac{4p^2 r}{T^2} \qquad T = \frac{1}{f}$$

**Energy:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $E$ | = | energy | $J$ |
| $E_p$ | = | potential energy | $J$ |
| $E_k$ | = | kinetic energy | $J$ |
| $k$ | = | spring constant | $Nm^{-1}$ |
| $x$ | = | displacement | $m$ |
| $m$ | = | mass | $kg$ |
| $g$ | = | gravitational field strength near Earth's surface | $Nkg^{-1}$ |
| | | or acceleration due to gravity near Earth's surface | $ms^{-2}$ |
| $h$ | = | displacement (in $E_p = mgh$) | $m$ |
| $v$ | = | velocity | $ms^{-1}$ |
| $h$ | = | Planck's constant (in $E = mc^2$) | $Js$ |
| $f$ | = | frequency | $Hz$ |
| $e$ | = | charge on an electron | $C$ |
| $V$ | = | potential difference | $V$ |
| $c$ | = | speed of electromagnetic waves | $ms^{-1}$ |
| $l$ | = | wavelength | $m$ |
| $A$ | = | amplitude | $m$ |

$E_p = mgh$ $\qquad$ $E_k = \frac{1}{2}mv^2$

$E_p = \frac{1}{2}kx^2$ $\qquad$ $E = mc^2$

$E = hf$ $\qquad$ $E = eV$

**Relationship associated with heat and temperature:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $H_L$ | = | latent heat (heat of transformation for mass m) | $J$ |
| $m$ | = | mass | $kg$ |
| $\Delta T$ | = | temperature change | $^oC$ or $K$ |
| $T_c$ | = | lower operating temperature | $K$ |
| $T_h$ | = | upper operating temperature | $K$ |
| $c$ | = | specific heat capacity | $Jkg^{-1}\,^oC^{-1}$ |
| $L$ | = | latent heat capacity | $JKg^{-1}$ |
| $l_i$ | = | initial length | $m$ |
| $l_f$ | = | final length | $m$ |
| $a$ | = | coefficient of linear expansion | |
| $Eff_{\max}$ | = | maximum thermal efficiency | |

$H = mc\Delta T$ $\qquad$ $H_L = mL$

$l_f = l_i(1 + a\Delta T)$ $\qquad$ $Eff_{\max} = \frac{T_h - T_c}{T_h} \times 100$

**Pressure in liquids and gases:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $P$ | = | pressure | $Nm^{-2}$ $(Pa)$ |
| $V$ | = | volume | $m^3$ |
| $T$ | = | absolute temperature | $K$ |
| $k$ | = | a constant | |
| $n$ | = | number of moles | |
| $R$ | = | universal gas constant | $Jmol^{-1}K^{-1}$ |
| $r$ | = | density of a liquid | $kgm^{-3}$ |
| $g$ | = | gravitational field strength near Earth's surface | $Nkg^{-1}$ |
| | | or | |
| | | acceleration due to gravity near Earth's surface | $ms^{-2}$ |
| $h$ | = | depth in a liquid | $m$ |
| $A$ | = | area | $m^2$ |
| $W$ | = | work done on a gas | $J$ |
| $\Delta V$ | = | change in gas volume | $m^3$ |
| $F$ | = | force | $N$ |

$PV = kT$ $\qquad$ $PV = nRT$

$P = rgh$ $\qquad$ $F = PA$ $\qquad$ $W = P\Delta V$

**Currents and magnetic fields:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $V$ | = | voltage or potential difference | $V$ |
| $I$ | = | current | $A$ |
| $R$ | = | resistance | $\Omega$ (Ohm) |
| $P$ | = | power | $W$ |
| $B$ | = | magnetic field | $T$ |
| $k$ | = | electromagnetic constant | $NmA^{-2}$ |
| $d$ | = | distance | $m$ |
| $\ell$ | = | length | $m$ |
| $v$ | = | velocity | $ms^{-1}$ |
| $F$ | = | force | $N$ |
| $t$ | = | torque | $Nm$ |
| $A$ | = | area | $m^2$ |
| $N$ | = | number of turns | |
| $r$ | = | distance between conductors | $m$ |
| $Q$ | = | charge | $C$ |
| $E$ | = | energy | $J$ |

$$V = IR \qquad P = VI \qquad P = I^2 R$$

$$P = \frac{E}{t} \qquad F = \frac{kI_1 I_2}{d} \qquad B = \frac{kI}{d}$$

$$V = B\ell v \quad F = BQv \qquad t = BANI \qquad F = BI\ell$$

**Electrostatics, electric fields and capacitors:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $F$ | = | force | $N$ |
| $E$ | = | electric field strength | $NC^{-1}$ or $Vm^{-1}$ |
| $k$ | = | Coulomb's constant | $Nm^2C^{-2}$ |
| $r$ | = | distance | $m$ |
| $W$ | = | work | $J$ |
| $Q$ | = | point charge | $C$ |
| $V$ | = | potential difference | $V$ |
| $I$ | = | current | $A$ |
| $t$ | = | time | $s$ |
| $C$ | = | capacitance | $F$ |
| $R$ | = | resistance | $\Omega$ (ohm) |
| $d$ | = | displacement of charge | $m$ |

$$F = \frac{kQ_1Q_2}{r^2} \qquad E = \frac{F}{Q}$$

$$V = Ed \qquad E = \frac{kQ}{r^2}$$

$$W = EQd \qquad Q = It$$

$$C = \frac{Q}{V} \qquad W = VQ$$

**Boat displacement hulls:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $s_{\max}$ | = | theoretical maximum hull speed | $knot$ |
| $\ell_w$ | = | length of hull waterline | $m$ |
| $m$ | = | mass | $kg$ |
| $V$ | = | volume | $m^3$ |
| $r$ | = | density | $kgm^{-3}$ |

$$s_{\max} = 2.4 \times \sqrt{\ell_w} \qquad r = \frac{m}{V}$$

**Mechanical work and power:**

| Variables defined as: | | | Unit |
|---|---|---|---|
| $W$ | = | work | $J$ |
| $F$ | = | force | $N$ |
| $s$ | = | displacement | $m$ |
| $P$ | = | power | $W$ |
| $t$ | = | time | $s$ |
| $A$ | = | area | $m^2$ |
| $r$ | = | density of air | $kgm^{-3}$ |
| $v$ | = | velocity | $ms^{-1}$ |
| $h_c$ | = | mechanical efficiency of a car | |

$$W = Fs \qquad P = \frac{W}{t}$$

$$P = \tfrac{1}{2} r v^3 A \qquad h_c = \frac{work\ output at\ wheels}{work\ output at\ flywheel} \times 100$$

**Transistors:**

Variables defined as: Unit

| | | | |
|---|---|---|---|
| $b$ | = | current gain | |
| $I_c$ | = | collector current | $A$ |
| $I_b$ | = | base current | $A$ |

$$b = \frac{I_c}{I_b}$$

**Relationships associated with ultrasound:**

Variables defined as: Unit

| | | | |
|---|---|---|---|
| $R$ | = | reflected intensity | $Wm^{-2}$ |
| $I$ | = | incident intensity | $Wm^{-2}$ |
| $Z$ | = | acoustic impedance | $kgm^2 s$ |
| $v$ | = | speed of moving surface | $ms^{-1}$ |
| $c$ | = | speed of ultrasound | $ms^{-1}$ |
| $\Delta f$ | = | Doppler shift | $Hz$ |
| $f$ | = | frequency | $Hz$ |

$$\frac{R}{I} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2 \qquad v = \frac{c\Delta f}{2f}$$

**Greek alphabet names and symbols**

| | | |
|---|---|---|
| alpha | $a$ | lower case |
| beta | $b$ | lower case |
| gamma | $g$ | lower case |
| delta | $\Delta$ | upper case |
| eta | $d$ | lower case |
| lamda | $l$ | lower case |
| mu | $m$ | lower case |
| pi | $p$ | lower case |
| rho | $r$ | lower case |
| sigma | $\Sigma$ | upper case |
| sigma | $s$ | lower case |
| tau | $t$ | lower case |
| phi | $f$ | upper case |
| omega | $\Omega$ | upper case |
| omega | $w$ | lower case |

**Appendix 1**

## Mark Scheme

**Skill Tasks 20%**

**A. Observation with interpretation: 5%**

A task must be devised which requires students to make observation, and from that observation to make an interpretation. The context of the observation may be novel but students should be expected to draw upon physics concepts covered by the course in order to make an appropriate interpretation. At least two observations should be expected from the task, each of which requires an interpretation. The expected observations and interpretations must be non-trivial.

**5 marks:** **Makes two meaningful observations** and **successfully interprets both observations.**

**4 marks:** **Makes two meaningful observations** and **successfully interprets only one of the observations.**

**3 marks:** **Makes one meaningful observation** and **successfully interprets that observation.**

**2 marks:** **Makes two meaningful observations but fails to interpret either observation.**

**1 mark:** **Makes one meaningful observation but fails to interpret the observation.**

**0 mark:** **No success with any observation**

**B. Equipment handling: 5%**

A task must be devised which offers equipment to the student and requires the student, in accordance with the task instructions, to do **one** of the following;

- choose and assemble from the equipment supplied,
  e.g.: producing an electrical circuit with bulbs in parallel
- construct from materials supplied,
  e.g.: an arm balance capable of measuring the value of an unknown mass
- calibrate or prepare the piece of apparatus supplied.
  e.g.: an oscilloscope, a frequency generator, a ticker timer,

The student must have previously met and handled all specialist equipment offered.

**5 marks:** **Successfully completes the task with no assistance, demonstrating thoughtful organisation (through choice and/or design), and demonstrates safe practice through patience and care.**

**4 marks:** **Successfully completes the task with no assistance, but has weaknesses in organisation (shown through choice and/or design), though demonstrates safe practice through patience and care.**

**3 marks:** **Successfully completes the task with minimal assistance, demonstrating thoughtful organisation (through choice and/or design), and demonstrates safe practice through patience and care.**

**2 marks:** **Successfully completes the task with minimal assistance, but has weaknesses in organisation (shown through choice and/or design), though demonstrates safe practice through patience and care.**

**1 mark:** **Unsuccessful in completing the task, though demonstrates safe practice through patience and care.**

**0 Mark:** **Unsuccessful in completing the task, impatient and/or careless.**

**C. Data Collection with Ordered Presentation: 5%**

A task must be devised which requires students to collect data through some form of measurement, and for the data to be ordered and presented in a logical tabulated form. The data must constitute a minimum of six collected values. There must be an indication of the error present in the collected values. Each collected value must relate to an accompanying partner value that is known but not necessarily measured by the student.

For example: The force value causing spring extension might be known, but it is the extension that is actually measured by the student.

**5 marks:** **A tabulated set of at least six values with accompanying partner values. The tabulation is neatly constructed with appropriate headings for columns or rows and where the units of measurement are clearly present and correct. The error value in the measurements is stated.**

**4 marks:** **A tabulated set of at least six values with accompanying partner values. The tabulation is roughly constructed but with appropriate headings for columns or rows and where the units of measurement are clearly present and correct. The error value in the measurements is stated.**

**3 marks:** **A tabulated set of at least four values with accompanying partner values. The tabulation is neatly constructed with appropriate headings for columns or rows and where the units of measurement are clearly present and correct. The error value in the measurements is stated.**

**2 marks:** **A tabulated set of at least four values with accompanying partner values. The tabulation is neatly constructed but with inappropriate heading for at least one column or row, and where the units of measurement or the error value are absent.**

**1 mark:** **A tabulated set of at least four values with accompanying partner values. The tabulation is neatly constructed with inappropriate heading for at least one column or row, but where the units of measurement and the error value are absent.**

**0 mark:** **Failure to produce four data values.**

**D. Data Interpretation and Graphing 5%**

A task must be devised that requires students to interpret data, identify a trend or relationship, and to support that identification with a plotted line graph. The teacher may provide the data in the form of tabulation. There should be six pieces of data. The relationship evident from the data may either be novel to students, or, may support previously covered physical relationships.

**5 marks:** **Makes a valid statement of trend based upon the data, and supports it with a graph with all the following characteristics:**

- **valid heading**
- **correctly labelled axes**
- **appropriately graduated axes**
- **correctly plotted points**
- **line of best fit drawn**

**4 marks:** **Makes a valid statement of trend based upon the data, and supports it with a graph with four of the above characteristics.**

**3 marks:** **Fails to make a valid statement of trend based upon the data, but produces a graph with all of the above characteristics**

**2 marks:** **Fails to make a valid statement of trend based upon the data, but produces a graph with three of the above characteristics.**

**1 mark:** **Makes a valid statement but produces no graph.**

**0 mark:** **Fails to make a valid statement and the graph attempt has fewer than three of the above characteristics.**

**Pacific Senior Secondary Certificate**

# PHYSICS

## Internal Assessment Work Programme Summary Form

*Country*: ______________________   *School*: _________________________________________

| Topic | Task | Tick (? ) | Completion Month | Task Weight % | |
|---|---|---|---|---|---|
| | **Practicals (60%)**<br>• ***Core-based*** *(50%)* *(tick **included** tasks)* | | | | |
| | 1. | | | | |
| | 2. | | | | |
| | 3. | | | | |
| | 4. | | | | |
| | 5. | | | | 50 |
| | 6. | | | | |
| | 7. | | | | |
| | 8. | | | | |
| | 9. | | | | |
| | 10. | | | | |
| ☐ | • ***Elective-based (10%)*** | | | | 10 |
| | **Skill Task (20%)** | | | | 20 |
| | **Written Test (10%)**<br>• ***Core-based (5%)***<br>• ***Elective based (5%)*** | | | | 10 |
| | **Other Tasks (10%)**<br>1. | | | | |
| | 2. | | | | 10 |
| | 3. | | | | |

**100%**

<u>**Note**</u>: **1.** **Task outlines <u>for all tasks</u> must be submitted together with this completed IA Summary form.**

**2.** **Detailed marking schemes for the 5 included core practicals - the 1 included elective practical, the skill tasks (if different from the one in the Prescription), and all "other tasks" must be submitted together with this completed IA Summary Form.**

*Teacher*: …………………………………………….   *Date*: ……………………….