



# Physics

for Rwandan Secondary Schools

**Teacher's Guide**

**Senior Two**

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# Section I



# 1 General Introduction

## Introduction to the new curriculum

Physics is one of the natural science subjects and contributes significantly to global socioeconomic transformation through its discoveries. These have led to development of new technologies in all fields of production and are beneficial to mankind. Applications of Physics knowledge is evident in industries such as engineering, transport (automobiles, trains, planes, etc.), medicine and Information and Communication Technology (ICT).

Some of the discoveries based on Physics knowledge include televisions, computers, electrical appliances, and nuclear weapons advancements in thermodynamics and mechanics, which led to industrialisation.

The ambition to develop a skilled-based society and the growth of regional and global competition in the jobs market has necessitated the shift from knowledge based to a competence-based curriculum in pre-primary, primary and secondary schools. This new curriculum will address the issues of lack of appropriate skills that had cropped in the Rwandan education system.

## Competence-based curriculum

A Competence is defined as the ability to use appropriate combination of knowledge, skills, attitudes and, values in order to accomplish a particular task successfully. That is, the ability to apply learning with confidence in a range of situations.

### To be competent is, for example:

- to be able to prepare a balanced diet rather than making a list of components of a balanced diet only;
- to adopt good practices of preparing and drinking clean water rather than only listing the qualities of clean drinking water and;
- to be able to communicate fluently and accurately with others in everyday life situations rather than simply knowing grammatical rules and being able to produce lists of vocabulary.

A competence-based curriculum takes learning to higher levels by providing challenging and engaging learning experiences which require deep thinking rather than just memorisation. This means moving beyond the recall of information to a level of sufficient understanding for learners to apply their learning in practical situations.

A competence-based curriculum must address learner's individual needs, interests, abilities and backgrounds, creating an environment where learning activities are organised in a way that encourages learners to construct the knowledge either individually or in groups in an active manner.

### Categories of competences in Rwandan curriculum

The priority competences for the national curriculum as identified in various policy documents (Vision 2020, EDPRS 2, ESSP, 7YGP) include generic and basic competences. The description of each of the competences, whether generic or basic, provides insight into the broad learning outcomes expected for each of them, emphasising their relevance for each level of education.

#### Generic competences

Generic competences are transferrable and applicable to a range of situations including employment and it is through these competences that learners develop their higher order thinking and deepen their learning: Among them are Critical thinking, Creativity and innovation, Research and problem-solving, Communication, Co-operation, Interpersonal management and life skills, Lifelong learning.

**The table below provides generic competences and their descriptors:**

Generic Competences	Competence Descriptors
<b>Critical thinking</b>	<ul style="list-style-type: none"><li>➤ Think reflectively, broadly and logically about challenges encountered in all situations.</li><li>➤ Weigh up evidence and make appropriate decisions based on experience and relevant learning.</li><li>➤ Think imaginatively and evaluate ideas in a meaningful way before arriving at a conclusion.</li><li>➤ Explore and evaluate alternative explanations to those presented by others.</li></ul>

<b>Creativity and innovation</b>	<ul style="list-style-type: none"> <li>➤ Responding creatively to different challenges encountered in life.</li> <li>➤ Use imagination beyond knowledge provided to generate new ideas to enrich learning.</li> <li>➤ Take the initiative to explore challenges and ideas in order to construct new concepts.</li> <li>➤ Generate original ideas and apply them in learning situations.</li> <li>➤ Demonstrate resilience when faced with learning challenges.</li> </ul>
<b>Research and problem solving</b>	<ul style="list-style-type: none"> <li>➤ Be resourceful in finding answers to questions and solutions to problems.</li> <li>➤ Produce new knowledge based on research of existing information and concepts and sound judgment in developing viable solutions.</li> <li>➤ Explain phenomena based on findings from information gathered or provided.</li> </ul>
<b>Communication</b>	<ul style="list-style-type: none"> <li>➤ Communicating and conveying confidently and effectively information and ideas, through speaking and writing and other forms of communication, using correct language structures and relevant vocabulary in a range of social and cultural contexts.</li> <li>➤ Comprehending language through listening and reading.</li> <li>➤ Using oral and written language to discuss, argue and debate a variety of themes in a logical and appealing manner.</li> <li>➤ Communicate clearly and confidently using a range of linguistic, symbolic, representational and physical expression.</li> <li>➤ Developing and communicating formal messages and speech appropriate to the target recipient or audience.</li> </ul>

<p><b>Cooperation, interpersonal management, life skills</b></p>	<ul style="list-style-type: none"> <li>➤ Co-operating with others as a team in whatever task assigned.</li> <li>➤ Adapting to different situations including the world of work.</li> <li>➤ Demonstrating a sense of personal and social responsibility and making ethical decisions and judgments.</li> <li>➤ Respect others' rights, views and feelings.</li> <li>➤ Having positive ethical and moral attitudes with socially acceptable behaviour.</li> <li>➤ Perform practical activities related to environmental conservation and protection.</li> <li>➤ Advocating for personal, family and community health, hygiene and nutrition.</li> <li>➤ Developing motor skills to perform a variety of physical activities for fitness, health, leisure and social interaction.</li> </ul>
<p><b>Lifelong learning</b></p>	<ul style="list-style-type: none"> <li>➤ Taking the initiative to update knowledge and skills with minimum external support.</li> <li>➤ Coping with the evolution of knowledge and technology advances for personal fulfilment.</li> <li>➤ Seeking out acquaintances more knowledgeable in areas that need personal improvement and development.</li> <li>➤ Exploiting all opportunities available to improve on knowledge and skills.</li> </ul>

Table 1.1: Generic competence descriptors

### Basic competences

These are keys and essential competences highlighted in national policy documents. Their descriptors give an orientation about priority subjects to be taught, and the kind of learner envisaged at the end of every cycle, these are: Literacy, numeracy, ICT, Citizenship and national identity, entrepreneurship and business development, science and technology.

The table below provides basic competences and their descriptors:

Basic competences	Descriptors: What learners are able to demonstrate during the learning process
<b>Literacy</b>	<ul style="list-style-type: none"> <li>⦿ Reading a variety of texts accurately and fast.</li> <li>⦿ Expressing ideas, messages and events through writing legible texts in good hand-writing with correctly spelt words.</li> <li>⦿ Communicating ideas effectively through speaking using correct phonetics of words.</li> <li>⦿ Listening carefully for understanding and seeking clarification when necessary.</li> </ul>
<b>Numeracy</b>	<ul style="list-style-type: none"> <li>⦿ Computing accurately using the four mathematical operations.</li> <li>⦿ Manipulating numbers, mathematical symbols, quantities, shapes and figures to accomplish a task involving calculations, measurements and estimations.</li> <li>⦿ Use numerical patterns and relations to solve problems related to everyday activities like commercial context and financial management.</li> <li>⦿ Interpreting basic statistical data using tables, diagrams, charts and graphs.</li> </ul>
<b>ICT and digital competences</b>	<ul style="list-style-type: none"> <li>⦿ Locating, extracting, recording and interpreting information from various sources.</li> <li>⦿ Assessing, retrieving and exchanging information via internet or cell phones.</li> <li>⦿ Using cell phones and internet for leisure and for money transactions.</li> <li>⦿ Using computer keyboard and mouse to write and store information.</li> <li>⦿ Using information and communication technologies to enhance learning.</li> </ul>

<p><b>Citizenship and national identity</b></p>	<ul style="list-style-type: none"> <li>⦿ Relating the impact of historical events on past and present national and cultural identity.</li> <li>⦿ Understanding the historical and cultural roots of Rwandan society and how the local super structure functions in relation to the global environment.</li> <li>⦿ Demonstrating respect for cultural identities and expressing the role of the national language in social and cultural context.</li> <li>⦿ Advocating for the historical, cultural and geographical heritage of the nation within the global dimensions.</li> <li>⦿ Showing national awareness, a strong sense of belonging and patriotism.</li> <li>⦿ Advocating for a harmonious and cohesive society and working with people from diverse cultural backgrounds.</li> </ul>
<p><b>Entrepreneurship and business development</b></p>	<ul style="list-style-type: none"> <li>⦿ Applying entrepreneurial attitudes and approaches to challenges and opportunities in school and in life.</li> <li>⦿ Understanding obligations of parties involved in employment.</li> <li>⦿ Planning and managing micro projects and small and medium enterprises.</li> <li>⦿ Creation of employment and keeping proper books of accounts.</li> <li>⦿ Taking risks in business ventures and in other initiatives.</li> <li>⦿ Evaluating resources needed for a business.</li> </ul>
<p><b>Science and technology</b></p>	<ul style="list-style-type: none"> <li>⦿ Applying science and technology skills to solve practical problems encountered in everyday life including efficient and effective performance of a given task.</li> <li>⦿ Develop a sense of curiosity, inquisitiveness and research to explain theories, hypotheses and natural phenomena.</li> <li>⦿ Reasoning deductively and inductively in a logical manner.</li> <li>⦿ Using and experimenting with a range of objects and tools of science and technology and drawing appropriate conclusions.</li> </ul>

Table1.2: Basic competence descriptors

## Characteristics of competence-based curriculum

### Competence-based approach

This is an approach where teaching and learning is based on discrete skills rather than dwelling on only knowledge or cognitive domain of learning. Learners work on competences through units with specific learning outcomes broken down into knowledge, skills and attitude. The learner is evaluated against a set of standards to achieve before moving on. The learning activities are learner centered rather than the traditional didactic approach.

### Inclusive

The curriculum ensures that every individual is valued and there are high expectations of every learner. Learning is organised so that all learners thrive, including girls, learners with disabilities, learners with special educational needs and regardless of their background.

### Interconnected and crosscutting issues

The competence-based curriculum reflects the significance of connections between different subject areas, integrating them across years and cycles where applicable.

Crosscutting issues are integrated across learning areas appropriately. They are all important for learners to learn about, but they are not confined to one subject. Cross cutting issues are not stand alone subjects. They are issues which cut across the entire curriculum.

#### **There are eight (8) crosscutting issues:**

1. Peace and values education
2. Genocide studies
3. Gender education
4. Inclusive education
5. Comprehensive sexuality education
6. Financial education
7. Environment and sustainability
8. Standardisation culture

## **Flexible**

This caters for learner's individual needs and talents and ensure provision of a holistic education that include knowledge, skills, attitude and values and facilitates horizontal and vertical mobility within and across different education systems. This curriculum allows interactive teaching and learning involving all categories of learners to provide opportunities to nurture them.

## **Transparent and accountable**

Schools, learners and communities must communicate openly and honestly about the curriculum and learning in the school, to ensure successful teaching and learning. Parents and teachers and senior management staff in schools must be engaged together in supporting teaching and learning and holding each accountable for their contributions. School management must be open to stakeholders and policy makers to support efficient administration and effective teaching.

In competence based curriculum, learners will now get the opportunity to apply what they have learned in real life situations and to make a difference in their own life with the help of the teacher whose role is central to the success of the curriculum delivery.

This teacher's guide gives practical ideas about ways of implementing the Physics syllabus: suggestions about what to teach, strategies for facilitating learning and teaching, how to assess and suggested assessment tasks.

A variety of suggested learning and teaching activities provides teachers with ideas to motivate learners to learn, and make learning relevant, interesting and enjoyable. Teachers should relate learning Physics to real issues and the local environment. Teaching using meaningful contexts and making sure that learners participate in appropriate practical activities, assisting learners to gain knowledge and understanding, and demonstrate skills in Physics.

Teachers are encouraged to integrate Physics activities with other subjects, where appropriate, so that learners can see the interrelationships between subjects and that the course they are studying provides a holistic education and a pathway for the future.



## 2 Teaching Methods

### 2.1 Teacher centered method (Traditional teaching method)

Teachers are not required to teach the way they were taught. They must embrace the new approaches with the aim of developing competences in the learners. This requires them to shift from teacher-centered to learner-centered methods.

The teacher centered method is characterised by the teacher's central position. She/he/she is the controller of the learning environment, has the power and responsibility and he plays the role of instructor and decision maker (in regards to curriculum content and specific outcomes).

#### **Characteristics of the teacher centered method:**

- It is the teacher that causes learning to occur.
- By this method, knowledge is imposed on the learner without considering her his psychological level, interests and tendencies.
- It is the school where the teacher talks and learners listen passively.

#### **The traditional teaching method is accused of the following:**

- The teacher talks too much and neglects the learner.
- The learner is passive and does not participate actively in the teaching/learning process.
- It doesn't allow learners to share their knowledge and experience.
- It is boring.
- It doesn't allow learners to achieve major psychomotor or cognitive objectives.

### 2.2 Learner centered method (Active methods)

Educators commonly use three phrases (**Learner-centered/learning-centered teaching or learner-centered learning**) with this approach. Learner-centered teaching places the emphasis on the person who is doing the learning (Weimer, 2002). Learning-centered teaching focuses on the process of learning.

**Characteristics of the learner centered method:**

- The learner centered method is that type which lays emphasis on the learner as the center of all activities in the learning process.
- The learner is actively involved and sequencing of the learning experiences is based on the principle of experience and activity.
- According to the early educators like John Dewey, Rousseau, Montessori, John Dewey, Carapared,... a child is free to exercise his freedom.
- The school therefore considers the needs of individual learners, interests, background etc.

**Should or can all course be learner-centered?** Being a learner-centered instructor should be your goal, but it is not necessary or practical to be learner-centered on every component. Instructors should not expect their courses ever to be at the highest standard in all categories with every component.

**Distinctions between learner-centered method and teacher-centered method**

Teacher- centered method	Learner-centered method
Learners are often passive (No role in planning learning; apart from sitting in lectures).	Learner has responsible and active role (in planning his/her learning, interacting with teachers and other learners, researching, assessing).
Most decisions are made by the teacher.	Learners are required to make choices about and how to learn.
Emphasis is on learning the subject only.	Emphasis is on integrating learning across the curriculum.
Emphasis is on receiving information.	Emphasis is on enquiry-type activities
Teacher as expert dispenser of knowledge and controller of activities.	Teacher is a guide, mentor and facilitator of learning.
Extrinsic motivation (Grades, teacher praise).	Intrinsic motivation (Interest, curiosity, responsibility).
Individual learning and competition between learners	Focus is on cooperative learning.
Learning is confined to fixed teaching venues (lecture rooms, libraries, labs)	Learning can occur anywhere.

*Table 2.1: Distinctions between learner-centered method and teacher-centered method*

### 3 Teaching-learning techniques used in developing competences

In order to practice any teaching-and-learning procedures/approaches, there are techniques that the teacher or the learner may combine with different teaching-and-learning resources/aids so as to develop appropriate teaching-and-learning methods and strategies/tactics according to specific situations.

Active engagement in learning is crucial to the success of the competence-based curriculum. Learners need to be engaged in practical, contextualised and complex learning situations through which application of learning is constantly developed. It is therefore essential that teachers always have active techniques in mind when they are planning learning activities within a lesson.

**The following are examples of such techniques:**

Explanation; demonstration; observation; lecture; association; questioning and answering or dialogue; oral or written expression; repetition; review or rehearsal; reflection; experiment; analysis and synthesis; induction and deduction; brainstorming; discussion or debate; individual or team work; individual non-supervised work or assignment; supervised work; seminar or workshop; group work; case study; simulation, role playing or dramatisation; field trip; positive or negative reinforcement; and eclecticism.

Some examples of these techniques are briefly described below:

Techniques/ Strategies	Description
<b>Round Table</b>	This is a form of cooperative learning. A question is posed by the teacher to groups of learners. Each person in the group writes one answer on a paper and passes it to the next team member. The group looks at each answer and decides which one to present to the class. Each group shares/presents their answer to the entyre class. The suggestions are discussed by the class and conclusions drawn.
<b>Questions in Corners</b>	The teacher places questions in different corners of the classroom. Groups of 3-6 learners move from corner to corner as per signal given by the teacher. They discuss and write an answer to each question taking into account answers already written by previous groups. The use of different colored markers for each group helps to see what each group wrote for each question. Ideas for each question are discussed in plenary to come up with some conclusions at the end.
<b>Outdoor activities</b>	In field visits, learners go outside the classroom to observe specific organisms or phenomena, or to hear information from experts.
<b>Field visits</b>	<p>Before the visit, the teacher and learners;</p> <ul style="list-style-type: none"> <li>➤ agree on aims and objectives.</li> <li>➤ gather relevant information prior to visit.</li> <li>➤ brainstorm on key questions and share responsibilities.</li> <li>➤ discuss materials needed and other logistical issues.</li> <li>➤ discuss and agree on accepted behaviours during the visit.</li> </ul> <p><b>After the visit;</b></p> <ul style="list-style-type: none"> <li>➤ brief discussions of what was learnt and observed.</li> <li>➤ evaluation of all aspects of the visit.</li> <li>➤ reports, presentations prepared by learners.</li> </ul>

<b>Project work</b>	<p>Learners in groups or individually, are engaged in a self-directed work for an extended period of time to investigate and respond to a complex question, problem, or challenge. The work is presented to classmates and other people beyond the school. Projects are based on real-world problems that capture learner’s interest. This technique develops higher order thinking as learners acquire and apply new knowledge in a problem-solving context.</p> <p><b>The teacher plays the role of facilitator by;</b></p> <ul style="list-style-type: none"> <li>⦿ working with learners to frame worthwhile questions.</li> <li>⦿ setting relevant and meaningful tasks.</li> <li>⦿ availing resources needed.</li> <li>⦿ coaching both knowledge and skills development and social skills.</li> <li>⦿ assessing carefully what learners produced based on defined criteria.</li> </ul>
<b>Group work</b>	<p>This is a form of peer/cooperative/collaborative learning that values the learner-learner interaction. It is mutually beneficial and involves the sharing of knowledge, ideas and experience between learners. It offers learners opportunity to learn from each other.</p> <p>To be effective, teams should be heterogeneous in terms of ability levels, made of 3-4 learners in most tasks. Team members are assigned specific roles which are rotated. For elaborated work, assessment should be twofold: based on both the collective and individual work.</p>
<b>Role play</b>	<p>The role play is a special kind of case study in which there is an explicit situation established with learners playing specific roles, spontaneously saying and doing what they understand their “character” would do, in that situation. The case study differs from the role play because in the case study, learners read about situations and characters; in the role play, they find themselves what to say, how to play and which material to use.</p>

<p><b>Case study</b></p>	<p>Case study as a learning technique is a story either based on real events, or from a construction of events which could reasonably take place. It involves issues or conflicts which need to be resolved. The information contained in a case study can be complex or simple.</p> <p>The teacher presents a problem situation and indicates how to proceed.</p>
<p><b>Brainstorming</b></p>	<p>It is a technique used for creative exploration of options/ solutions in an environment free of criticism. It encourages creativity and a large number of ideas.</p> <p>Among ground rules there are: active participation by all members; no discussions, criticisms, compliments or other comments during the brainstorming stage. The teacher starts by reviewing the rules, sets a time limit; states and explains the question; collects and displays ideas; eliminates duplications and guides learners to draw a conclusion.</p>
<p><b>A learning centre /corner</b></p>	<p>It is a space set aside in the classroom that allows easy access to a variety of learning materials in an interesting and productive manner. Learners can work by themselves or with others in self- directed activities on a content related to the curriculum or not.</p> <p>These centres allow learners to deepen their understanding of subjects, apply their learning in a stimulating learning environment and engage in meaningful discoveries that match their individual interests. They provide learners with hands-on experiences they can pursue at their own pace and level of curiosity.</p>
<p><b>Games/play</b></p>	<p>Games are used to help learners to learn faster and better, and in an enjoyable manner. Games/plays help to create a classroom experience that actively engages learners. They develop communication and other important skills such as social skills, critical thinking, problem-solving, numeracy and literacy skills in different subjects.</p>
<p><b>Research work</b></p>	<p>Each learner or group of learners is given a research topic. They have to gather information or ask experienced people and then the results are presented and discussed in class.</p>

<b>Practical work</b>	Individually or in teams, learners are assigned practical tasks. To be effective, the task needs; a clear purpose with strong links and relevance to the curriculum; quality materials; learner's engagement; time for preparation and carrying out the work; support from the teacher or other experts. Such activities encourage deeper understanding of phenomena; develop skills such as observation, practical work, planning, reporting, etc
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Table 2.2: Technique descriptors

## 4 Teaching-learning resources/aids

Physics becomes more interesting and meaningful when you use a variety of resources and local materials in your teaching. You should always try to adapt, improvise, make, find or write materials that will be useful for lessons. Physics can be taught without expensive equipment by making use of what is around you, though there are some equipment and materials that are essential to teach the Physics syllabus.

Basically, the main teaching-and-learning resources/aids are the learners and the teacher themselves. In contrast to those, additional resources/aids that assist them for a better teaching-and-learning process are called auxiliary teaching-and-learning resources/aids and may be distributed into the following three major categories:

- **Concrete resources/aids** or real (i.e. real people, genuine things, situations or problems);
- **Semi-concrete or audio-visual resources/aids** (e.g. moving or fixed pictures, photographs, images, drawings, and/or recorded sounds);
- **Abstract resources/aids** such as verbal descriptions.

### General guidelines for selecting and using resources

How effective a resource is depends on whether it is suitable for the knowledge or skill to be learned and the attitude of the learners. Classroom organisation is the key to using resources successfully. You need to;

- Prepare thoroughly. Make sure that you are familiar with the resource so that you use it with confidence and assurance. If equipment is involved, check that it is in working order, make sure that you know how to operate it and that it is available when you need it.
- Use the resource at the right place and time—it should fit in with the flow and sequence of the lesson and serve a definite teaching purpose.
- If the resource is radio, film, video or television, introduce the program by outlining the content. You might also set some questions to guide listening or viewing. Follow up after using the resource, by discussing and drawing appropriate conclusions.



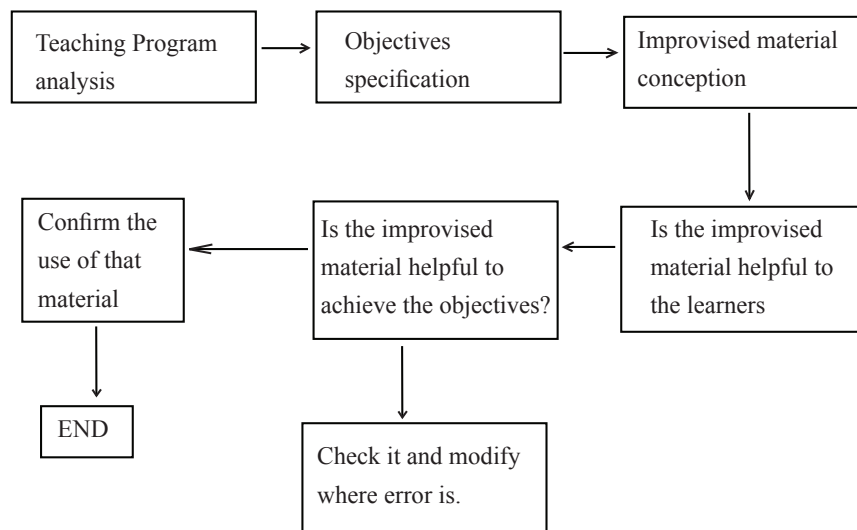
## 4.1 Improvisations when no lab

Improvisation is very important to our schools and for our country in general. To make a lab material using local available materials is very important for the development of scientific reflection and attitudes. Teachers of science should make a material and relate it to the lesson based on the objectives.

### 4.1.1 Characteristics of improvised material

1. Local make up of the improvised material should be available and easy to find.
2. Teachers of Sciences can make and maintain the improvised material.
3. Ensure learners on the new experiments done by themselves using local materials

### 4.1.2 Procedures of improvisation



### 4.1.3 Importance of improvisation:

1. Improvisation helps to promote the imagination for teachers and learners.
2. Improvisation help learners to have access on that improvised material.
3. It helps learners to use simple materials appropriate to their age group.
4. It helps learners to learn with their full participation and get opportunity to achieve learning objectives.
5. It reduces the cost of equipment of the laboratory.
6. Ensures a good and direct demonstration of the applied principle.
7. Improvisation gives a basic knowledge on the use of sophisticated material.

## 5 General Objectives

The syllabus learning outcomes describe what learners know and can do at the end of senior 2, 'OL'. The level of achievement of the learning outcome should improve during the three years of lower secondary study, and it is at the end of the study that learners are given a summative assessment on the level of achievement of the learning outcome.

**At the end of senior 2 the learner should be able to:**

- Validate basic formula based on dimensional analysis.
- Analyse the thermal expansion of solids, liquids and gases.
- Perform experiments on gas laws.
- Magnetise materials using magnets.
- Explain magnetisation and demagnetisation of magnets.
- Explain the applications of static electricity.
- Analyse resistor arrangement in electric circuits.
- Explain the functioning of basic electronic devices.

Clear informative, concise and understandable objectives are provided to give you what knowledge skills and attitudes you are expected to attain after studying the unit.

## 6 Education approach

### 6.1 The outcomes approach

An outcomes approach (learning objective) identifies the knowledge, skills, attitudes and values that all learners should achieve or demonstrate at a particular level in a particular subject (the learning outcomes). The teacher is responsible for identifying, selecting and using the most appropriate teaching methods and resources to achieve these learning outcomes.

Imagine the learner is on a learning journey, heading to a destination. The destination is the learning outcome described in the syllabus document. The learning experiences leading to the learning outcome are to be determined by the teacher. The teacher uses curriculum materials, such as syllabus documents and teacher guides, as well as textbooks or electronic media and assessment guidelines, to plan activities that will assist learners to achieve the learning outcomes. The outcomes approach has two purposes. They are;

- to equip all learners with knowledge, understanding, skills, attitudes and values needed for future success.
- to implement programs and opportunities that maximise learning.

#### **Three assumptions of outcomes-based education are:**

- all learners can learn and succeed (but not on the same day or in the same way).
- success breeds further success.
- schools can make a difference.

#### **The four principles of the outcomes approach are:**

##### **Clarity of focus through learning outcomes**

This means that everything teachers do must be clearly focused on what they want learners to be able to do successfully. For this to happen, the learning outcomes should be clearly expressed. If learners are expected to learn something, teachers must tell them what it is, and create appropriate opportunities for them to learn it and to demonstrate their learning.

By using a predictable sequence of activities, both the teacher and learners quickly become accustomed to the format of the activities and transitions between them,

and are therefore able to focus on learning rather than on the mechanics of the understanding instructions to new activities.

### **High expectations of all learners**

This means that teachers reject comparative forms of assessment and embrace criterion-referenced approaches. The ‘principle of high expectations’ is about insisting that work be at a very high standard before it is accepted as completed, while giving learners the time and support they need to reach this standard. At the same time, learners begin to realise that they are far capable more than before and this challenges them to aim even higher.

### **Expanded opportunities to learn**

This is based on the idea that not all learners can learn the same thing in the same way at the same time. Some achieve the learning outcomes sooner and others later. However, most learners can achieve high standards if they are given appropriate opportunities. Traditional ways of organising schools do not make it easy for teachers to provide expanded opportunities for all learners.

### **Planning and programming by ‘designing down’**

This means that the starting point for planning, programming and assessing must be the learning outcomes—the desired end results. All decisions on inputs and outputs are then traced back from the learning outcomes. The achievement of the outcome is demonstrated by the skills, knowledge and attitudes gained by the learner. The syllabuses and/or teacher guides or describes some ways in which learners can demonstrate the achievement of learning outcomes.

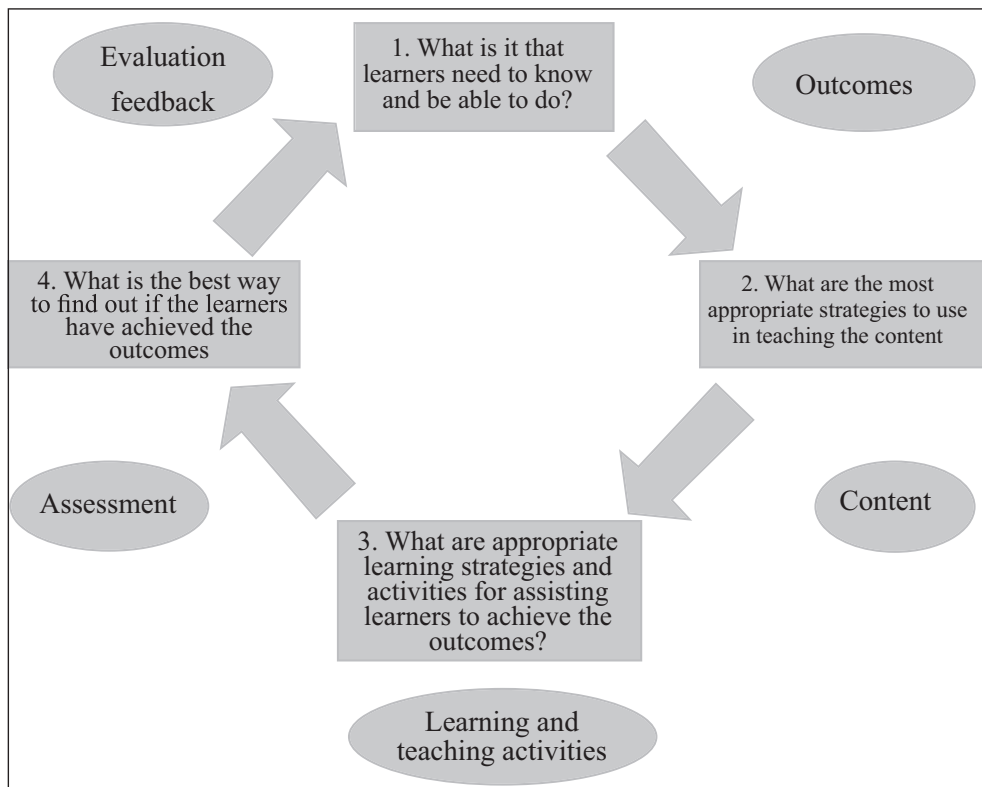


Figure 1: The outcomes-based approach

Learning outcomes provide teachers with a much clearer focus on what learners should learn. They also give teachers greater flexibility to decide what is the most appropriate way of achieving the learning outcomes and meeting the needs of their learners by developing programs to suit local content and involve the community.

**The outcomes approach means that learning.**

- ④ has a clearer purpose.
- ④ is more interactive — between teacher and learners, and learners to learners.
- ④ has a greater local context than before.
- ④ is more closely monitored and acted upon by the teacher.
- ④ uses the teacher as a facilitator of learning as well as an imparter of knowledge.

## 6.2 The Learning outcomes

The syllabus learning outcomes describe what learners know and can do at the end of senior two. The level of achievement of the learning outcome should improve during, and it is at the end of the study that learners are given a summative assessment on the level of achievement of the learning outcome.

**Learners can:**

- demonstrate understanding of fundamental physics principles and models.
- apply scientific inquiry and reasoning skills to find solutions to problems.
- communicate scientific data and information from investigations and laboratory work in different ways.
- analyse and interpret data and information.
- analyse and evaluate developments in physics from the past and present and its impacts on people and the environment; and use the information to support and make informed decisions.
- relate relevant traditional knowledge, beliefs, and skills to principles and concepts of physics.

## 6.3 Learning and teaching

You, as a teacher, must teach the knowledge that is included in the syllabus documents. Not only do you have to be able to teach what learners should know, you must also be able to interpret that knowledge for learners in a way that makes it relevant to them, and enables them to begin to acquire skills of analysis and problem solving, which will support learning and teaching.

You also need to give learners some opportunities to apply their knowledge, to be creative and to solve problems.

### Learning and teaching strategies

Learners who participate in guided instruction learn more than learners who are left to construct their own knowledge. You need to employ a variety of learning and teaching approaches because all learners do not learn in the same way. The 'auditory learner' prefers to use listening as the main way of learning new material whereas a 'visual learner' prefers to see things written down. They should be actively involved in their learning and therefore you need to design appropriate practical activities or experiments, using resources that can be found in your location.

You need to make use of your learners' experiences when designing and conducting learning in class; learning that is connected to your learners' world.

The following are some important learning and teaching strategies that can be used in implementing the Physics syllabus;

- Investigations and problem solving
- Inquiry
- Laboratory Experiments

- FieldWork
- Research
- Predict–Observe–Explain
- Use Of Analogies, Metaphors And Examples
- Group Work
- Cooperative Learning
- Tinkering Table
- Use Of Charts
- Mind Maps Or Concept Maps
- Models

The most efficient and long-lasting learning occurs when teachers encourage the development of higher-order thinking and critical analysis skills, which include applying, analysing, evaluation and creating. Attention should also be paid to developing learner’s affective and psychomotor skills.

## 6.4 Developing Physics skills

You must strive to provide opportunities for learners to develop life skills. Learner activities are designed to address the content knowledge that general science strands usually ignore.

The broad areas covered in this strand include knowledge, skills, attitudes and values. The knowledge obtained must be relevant, to bring about positive changes in attitudes and values that will have impact on society.

The opportunities provided through activities such as laboratory experiments, field work and research will lead to learners acquiring applicable knowledge and skills. Such knowledge and skills should enable individuals to participate effectively in this contemporary society.

## 6.5 Learner-centered, problem-solving based approach

The main part of each lesson (following a quick review and introduction to the lesson topic) starts with a problem-solving activity that learners first work out on their own. The teacher then provides assistance, modeling the process and giving more examples for learners to solve. Letting the learner tackle a problem first helps them draw upon math concepts they already know, increases their confidence in physics and stimulates their interest. This approach emphasises a variety of different

types of methods that shifts the role of the instructors from givers of information to facilitating student learning.

Learners enjoy learning when they are actively involved in the learning process with a high degree of participation, contribution and presentation. At the same time, each learner is an individual with their own needs, pace of learning, experiences and abilities. Teaching strategies must therefore be varied and flexible within well-structured sequences of lessons. Learner-centered education does not mean that the teacher is no longer responsible for learner learning.

Traditionally instructors focused on what they did, and not on what is being learnt. This emphasis on what instructors do often leads to producing of passive learners and who can not take responsibility for their own learning. Educators call this the traditional method, “instructor-centered teaching.” In contrast, “learner-centered teaching” occurs when instructors focus on learner learning.

### **6.5.1 Role of the learner**

The activities to engage the learner are indicated against each learning unit and reflect appropriate engagement of the learner in the learning process. The teaching/ learning process activities are tailored towards creating a learner friendly environment based on the abilities, needs, experiences and interests of the learner.

The learning activities are organised in such a way that they encourage learners to construct their own knowledge (minds-on and hands-on activities) either individually or in groups. The learner should suggest how to solve challenging problems exposed to them. Learners should work on one competence outcome at a time in the form of a concrete unit with specific learning objectives, which are broken into knowledge, skills and attitudes. In practical lessons, learners will work in groups depending on the availability of the apparatus, however if the apparatus numbers permit, then they work individually. Working on simple project work individually will be encouraged and emphasised. Learners should use textbooks and other resources for complementing the knowledge acquired in classroom. Learners should strive to become thinkers, inquirers, problem solvers, and communicators. Learners should be principled, open-minded, caring, risk takers, balanced in reflection.

#### **What do learners do in Physics?**

What follows is some elaboration of the competence that learners should develop through particular activities: Fieldwork, laboratory experiments and research.

Fieldwork, laboratory experiments and research are essential parts of the study of Physics. They are scientific tools that facilitate the understanding of scientific processes and inquiry. These can enhance learning opportunities for a wide range of learners because they cater for a variety of learning and teaching styles.



**Fieldwork enables learners to:**

- acquire knowledge about environments by hypothesising, observing, experimenting, measuring and recording phenomena in the real world in a variety of places, including the school.
- explore the scientific processes that form and transform lifestyles.
- use different kinds of scientific tools and approaches, including information and communication technology (ICT), to assist in the interpretation of, and decision-making about scientific phenomena.
- locate, select, organise and communicate scientific information.
- explore different perspectives on scientific issues.

**Laboratory experiments enable learners to:**

- identify problems, predict, test hypotheses by conducting experiments, observing, recording and analysing data.
- draw conclusions, recognising errors and make recommendations for improvement.
- communicate findings based on evidence.
- improve manipulative skills.

**Research enables learners to:**

- explore various media and sources of obtaining information.
- select relevant information and issues and make informed choices.
- improve research writing skills.
- design and develop models or experiments.

**6.5.2 Role of the teacher****Teachers are facilitators, not lecturers**

The lessons are set up to engage learners in learning activities through which they will master the skills and knowledge built into the course. The teacher's role is to facilitate these activities.

The change to a competence-based curriculum is about transforming learning by ensuring that learning is deep, enjoyable and habit-forming.

Teachers must shift from the traditional method of instruction to become facilitators in order to value and understand the learner's individual needs and expectations. The teacher must identify the needs of learners, the nature of the learning to be undertaken, and the means to shape learning experiences accordingly. The teacher's role is to organise learners in or outside the classroom, engaging them through

participatory and interactive methods. Learning processes should target individual learners, pairs of learners or large groups. This organisation ensures that learning is personalised, active, participatory and co-operative in nature.

The teacher should design and introduce tasks for the entire class to perform or for immediate discussion. The role of the teacher should be to guide learners in constructing their own knowledge. Learners should be taught how to use the textbooks and other resource materials as supplementary ways of acquiring knowledge. During research, learners should take summary notes of what they are reading. The teacher must select and develop appropriate teaching materials like models, charts, and ICT facilities such as the internet, videos, computers, simulations and so on. During practical lessons, the teacher should first demonstrate the experiment procedure and manipulation of the apparatus. For dangerous tasks teachers should give a demonstration of the experiment before exposing it to learners.

The teacher must devise remedial strategies in and outside the classroom to cater for low achievers and those with learning difficulties, in order to ensure they keep pace with other learners in acquiring the required competences.

### **Elaboration of activities and content**

Once you have mapped out your program for the term, you must then develop more detailed plans for each topic in the unit. All units require learners to be actively engaged in learning, not just copying from the board. Make sure you develop a range of activities that suit all learning needs—some reading and writing, some speaking and listening, some observing and doing.

Browse through the textbooks and teaching resources you have access to and list the chapters, pages or items that you will use for each topic in your program. The textbooks should also provide you with ideas for activities related to the topic. You may have to collect or develop some resources for yourself.

Once you have sorted out your ideas and information, you can then develop your more detailed weekly program and daily lesson plans.

## **What do teachers of Physics do?**

### **The Physics teacher:**

- ② is interested in and concerned about events and movements in the local, national and global community.
- ② actively seeks to keep informed while maintaining a critical stance towards sources of information.

- ② takes a principled stand, and supports others who do so, against injustices and inequalities relating to race, gender, class, physical or mental attributes.
- ② informs him or herself about environmental issues as they impact upon his or her community and on communities and ecological systems globally.
- ② values democratic processes as the best means of bringing about positive change.

**As a teacher, you will:**

- ② model democratic values of fairness, justice and equal respect.
- ② use a range of teaching styles that foster both individual development and group cooperation and enable learners to make the best use of their differing learning styles.
- ② encourage your learners to adopt a reflecting and questioning position in relation to geological knowledge.

### **6.5.3 Special needs education and inclusive approach**

All Rwandans have the right to access education regardless of their different needs. The underpinnings of this provision would naturally hold that all citizens benefit from the same menu of educational programs. The possibility of this assumption is the focus of special needs education. The critical issue is that we have persons/learners who are totally different in their ways of living and learning, as opposed to the majority. These differences can either be emotional, physical or sensory. Traditionally, intellectual learning challenges were known as mental retardation. Learners equally have the right to benefit from the free and compulsory basic education in nearby ordinary/mainstream schools. Therefore, the schools obligation is to enrol them and also set strategies to provide relevant education to them. The teacher therefore is requested to consider each learner's needs during the teaching and learning process. Assessment strategies and conditions should also be standardised to the needs of these learners.

## 7 Lesson Organisation

This teacher guide is to be used by teachers when implementing the Lower Secondary Physics Syllabus (S1, S2 and S3). The Physics syllabus identifies the learning outcomes and content of the subject as well as assessment requirements. The teacher guide gives practical ideas about ways of implementing the syllabus: suggestions about what to teach, strategies for facilitating learning and teaching, how to assess and suggest assessment tasks. The **Learner's Book** contains the objectives, the physics activities, physics theories and summaries.

A variety of suggested learning and teaching activities provide teachers with ideas to motivate learners to learn, and make learning relevant, interesting and enjoyable. Teachers should relate learning in Physics to real issues and the local environment. Teaching using meaningful contexts and making sure that learners participate in appropriate practical activities, assists them to gain knowledge and understanding, and demonstrate skills in Physics.

Teachers are encouraged to integrate Physics activities with other subjects, where appropriate, so that learners can see the interrelationships between subjects and that the course they are studying provides a holistic education and a pathway for the future.

### Planning and programming units

The main purpose of planning and programming is to help you to arrange the presentation of the unit in an organised manner. This will help you to know what to teach and when to teach it. It is strongly recommended that you make plans with the other teachers who teach the same subject. By planning together, you will *all* have better lessons and make better use of your limited resources.

#### Points to consider when programming;

- ④ Which outcomes are learners working towards?
- ④ What is the purpose of this unit or topic or learning experience?
- ④ Which learning experiences will assist learners to develop their knowledge and understanding, skills, values and attitudes in Physics?
- ④ What are the indicators of learner learning that you would expect to observe?
- ④ How can the learning experiences be sequenced?
- ④ How do the learning experiences in the unit relate to the learners' existing knowledge and skills?
- ④ How are individual learning needs to be catered for?

- ② What are the literacy demands of this unit or learning experience?
- ② What authentic links can be made with the content of other subjects?
- ② How can school events and practices be incorporated into the program?
- ② Do the assessment methods address the outcomes and enhance the learning?
- ② How can the assessment be part of the learning and teaching program?

### **The planning process**

In this teachers' guide, ideas for programming and organising have been provided. These have been arranged in steps to help you teach the unit. The steps follow the thinking processes involved in the outcomes approach.

#### **Step 1: Interpreting the learning outcomes**

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The first step is to read the description in the syllabus. Then study the learning outcomes and what learners do to achieve the learning outcomes, in order to determine what learners will know and be able to do by the end of the unit.

You need to look at the action verb, concept and context of each learning outcome. This will help you to see what skills and knowledge are embedded in the outcome.

#### **Step 2: Planning for assessment**

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It is necessary to plan for assessment early to ensure that you teach the content and skills the learners need for them to achieve the learning outcomes.

You will have to decide when to schedule assessment tasks to allow yourself time to teach the required content and time for learners to develop the necessary skills. You will also need time to mark the task and provide feedback. Practical tasks may, for example, be broken into a series of stages that are marked over several weeks as learners progress with making their product. It is not appropriate to leave all assessment until the end of the unit.

#### **Step 3: Programming a learning sequence**

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This step requires you to develop a program outlining a sequence of topics and the amount of time spent on each topic. If the unit involves a project, for example, you may plan to teach some theory at appropriate stages during the project, rather than teaching all the theory before the learners start the project.

To develop your program you need to study the topics listed in the syllabus and to think about which learning activities will best provide learners with the opportunity to learn the content and practise the appropriate skills, and how long the activities will take. You will have to think about some major activities that last several weeks and smaller activities that may be completed in a single lesson.

#### **Step 4: Elaboration of activities and content**

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Once you have mapped out your program for the term, you must then develop more detailed plans for each topic in the unit. All units require learners to be actively engaged in learning, not just copying from the board. Make sure you develop a range of activities that suit all learning needs—some reading and writing, some speaking and listening, some observing and doing.

Browse through the textbooks and teaching resources you have access to and list the chapters, pages or items that you will use for each topic in your program. The textbooks should also provide you with ideas for activities related to the topic. You may have to collect or develop some resources for yourself.

Once you have sorted out your ideas and information, you can then develop your more detailed weekly program and daily lesson plans.

This teacher guide gives some suggested learning and teaching activities for each unit.

#### **Using the internet for classroom activities**

##### **Planning**

- ② Where appropriate, incorporate computer sessions as part of planned learning experiences.
- ② Be aware that computers can be time-consuming and may require extra teacher support at unexpected times.
- ② Consider methods of troubleshooting, such as having learners with computer expertise designated as computer assistants.
- ② Design activities that provide the opportunity for learners to access, compare and evaluate information from different sources.
- ② Check protocols, procedures and policies of your school and system regarding the use of the internet.

##### **Managing**

- ② Ensure that all learners have the opportunity to explore and familiarise themselves with the technologies, navigation tools, e-mail facilities and texts on the internet. It is likely that learners will have varying degrees of expertise in searching for information and navigating the internet. They will also have varying experiences of, and be more or less familiar with, the way texts are presented on the World Wide Web.
- ② Ensure that all learners understand how to access the internet and perform basic functions such as searching, sending and receiving e-mail.

- Learners with more experience in using the internet may have information that will benefit the whole class. Provide opportunities for learners to share their experiences, interests, information and understandings. As well as planning lessons to instruct learners in these skills, pairing learners and peer tutoring on the computer can enable more experienced learners to assist others.
- Ensure that learners critically analyse Physics information gathered on the internet, just as they would for any other text. They should be aware that material posted on the Web is not necessarily subject to the conventional editorial checks and processes generally applied to print based publications.

### **Assessing learner work containing material from the internet**

- Learners can download large quantities of information from the internet. In itself, such information provides very little evidence of learner effort or learner achievement. Learners must make judgments about the validity and safety of information when working from the Web. They must consider the purpose of the text, identify bias, and consider the validity of arguments presented and the nature and quality of the evidence provided.
- When assessing learner's work that includes material drawn from the internet, it is important to recognise how they have accessed the information, what value they place on it and how they have used it for the topic being studied in class. It is useful to look for evidence of critical evaluation, and the development of learner's capacities to access, manipulate, create, restore and retrieve information.

## 8 Assessment approach

Assessment is the process of evaluating teaching and learning processes, by collecting and interpreting evidence of an individual learner's progress and to make a judgment about a learner's achievements measured against defined standards. Assessment is an integral part of the teaching and learning process. As opposed to the misconception most people have always had that assessment comes after teaching, assessment is an integral part of teaching and learning. In the new competence-based curriculum, assessment must also be competence-based; where a learner is given a complex situation related to their everyday life and asked to try to overcome the situation by applying what they have learned (knowledge, skills, competences and attitudes).

Classroom assessment is an integral part of science instruction. Assessment could be described as the systematic process of gathering information about what a learner knows, is able to do, and is learning to do. The primary purpose of classroom assessment is not to evaluate and classify learner performance, but to inform teaching and improve learning, and to monitor learner's progress in achieving year-end learning outcomes.

The pre-assessment questions help you to identify what you know and what you need to know, so that your level of concern will be raised and you can judge your level of mastery.

### 8.1 Types of assessment

#### 8.1.1 Formative and continuous assessment (Assessment for learning)

Continuous assessment involves formal and informal methods used by schools to check whether learning is taking place. When you are planning a lesson, you should establish criteria for performance and behaviour changes at the beginning of a unit. At the end of every unit, you should ensure that all the learners have mastered the stated key unit competences based on the criteria stated, before going to the next unit. You should assess how well each learner masters both the subject and the generic competences described in the syllabus. From this, you will gain a picture of the overall progress of the learner. You will use one or a combination of the following: (a) observation (b) pen and paper (c) oral questioning and d) experimentation. A change of behaviour (values, attitudes, beliefs and balance of norms) is the major indicator ensuring that teaching and learning has taken place. Therefore the set of mastery criterion should also reflect the change in behaviour of the learner.



### 8.1.2 Summative assessment (Assessment of learning)

When assessment is used to record a judgment of a competence or performance of the learner, it serves a summative purpose. Summative assessment gives a picture of a learner's competence or progress at any specific moment. The main purpose of summative assessment is to evaluate whether learning objectives have been achieved and to use the results for the ranking or grading of learners. The assessment is used for deciding on progression, for selection into the next level of education and for certification. This assessment should have an integrative aspect whereby a learner must be able to show mastery of all competences.

Assessment is an important part of learning and teaching. How you assess your learners will impact how and what they learn. Assessment is used to:

- evaluate and improve learning and teaching.
- report achievement.
- provide feedback to learners on their progress.

## 8.2 Assessing Physics units

In Physics, the learning outcomes are assessed using the range of assessment methods specified in the syllabus. In deciding what to assess, the starting point is 'what do you want learners to do and/or learn?' and following from this 'how will they engage with the material?' which in turn leads to the design and development of learning tasks and activities. It is crucial that at this point the assessment tasks clearly link back to the learning outcomes and are appropriate for the learning activities. The assessment can be used for formative and summative purposes.

**Assessment can be represented as follows:**

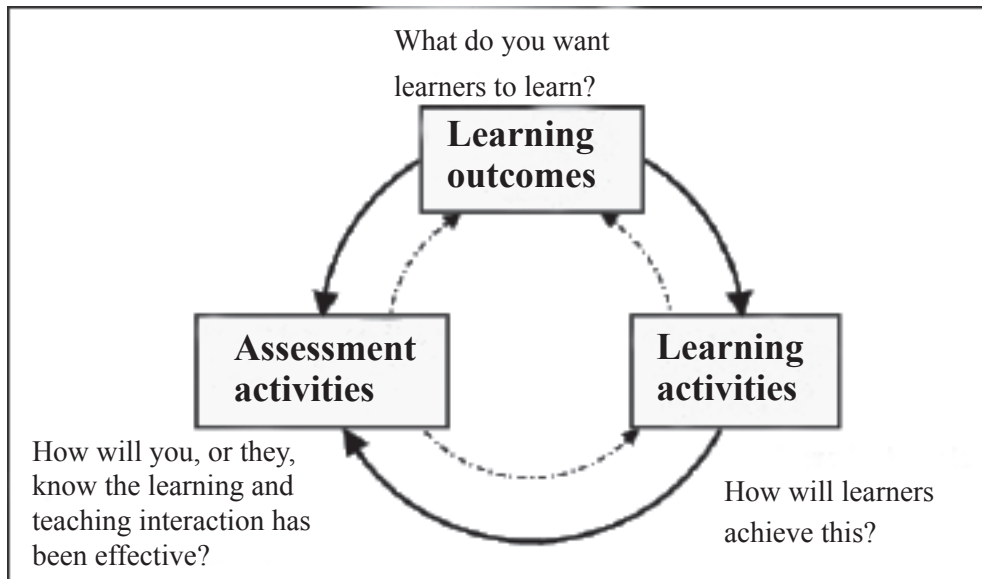


Figure 2: The assessment process

There are many types of assessment tasks that can be implemented; the factors that will determine choices include:

- the learners—how many are they, what is expected of them, how long will the assessment task take?
- the learning outcomes of the subject and how they might be best achieved.

During the year you must set assessment tasks that ensure that all the learning outcomes of the subject have been assessed internally. Each task you set must include assessment criteria that provide clear guidelines to learners as to how, and to what extent, the achievement of the learning outcomes may be demonstrated. Marking guides and assessment criteria help you with the marking process and ensure that your assessment is consistent across classes. It is important that marking guides and assessment criteria are collectively developed.

Learners must complete the assessment tasks set. Each task must provide clear guidelines to learners for how the task will be completed and how the criteria will be applied. When you set a task, make sure that:

- ↑ the requirements of the task are made as clear as possible to the learner.
- ↑ the assessment criteria and performance standards or marking guides are provided to learners so that they know what it is that they have to do.
- ↑ any sources or stimulus material used are clear and appropriate to the task.

- ④ instructions are clear and concise.
- ④ the language level is appropriate for the grade.
- ④ it does not contain gender, cultural or any other bias.
- ④ materials and equipment needed are available to learners.
- ④ adequate time is allowed for completion of the task.

### 8.3 Feedback

When you assess the task, remember that feedback will help the learner understand why he or she received the result and how to do better next time. Feedback should be:

- ④ constructive, so that learners will feel encouraged and motivated to improve.
- ④ timely, so that learners can use it for subsequent learning prompt, that they can remember what they did and thought at the time.
- ④ focused on achievement, not effort. The work, not the learner, should be assessed.
- ④ specific to the unit learning outcomes, so that assessment is clearly linked to learning.

# 9 Physics overview and content map

## 9.1 Physics overview

Basic Physics skills are essential for everyday life and are necessary to help out of school youth get back into the formal school system, prepare them for understanding other subjects; Physics is regarded as the most basic Science subject whose laws and inventions are widely used in the study of other subjects. A great many laws of physics are used to explain reactions in Chemistry. Besides, physical methods are used to determine the shapes of complex substances such as vitamins, proteins, chlorophyll and DNA. It is based on the Rwanda Ministry of Education's Physics curriculum for Upper Secondary Education, written by Rwanda Education Board (REB), and includes practical and the practical problems that people might experience at home, in the market, or on the job. The following table lays out the lessons, general topics and prerequisites to be obtained for each topic.

TOPIC	SUB-TOPIC Units	Unit and periods			
		Senior 1	Senior 2	Senior 3	
MECHANICS	Introduction to physics	<b>Unit 1:</b> Laboratory safety rules and measurements of physical quantities <b>(15 periods)</b>			
	Physical quantities		<b>Unit 1:</b> Sources of errors in measurement of physical quantities <b>(12 periods)</b>		
	Motion	<b>Unit 2:</b> Quantitative analysis of linear motion <b>(15 periods)</b>	<b>Unit 2:</b> Quantitative analysis of linear motion <b>(12 periods)</b>	<b>Unit 1:</b> Graphs of linear motion <b>(8 periods)</b>	
	Force		<b>Unit 3:</b> Force (I) <b>(10 periods)</b>	<b>Unit 3:</b> Friction Force <b>(12 periods)</b>	
			<b>Unit 4:</b> Newton's Laws of Motion (I) <b>(10 periods)</b>		<b>Unit 2:</b> Friction force and Newton's laws of motion <b>(10 periods)</b>
			<b>Unit 5:</b> Centre of gravity <b>(10 periods)</b>		
	Pressure			<b>UNIT 4:</b> Density and Pressure in Solids and Fluids <b>(9 periods)</b>	
				<b>Unit 5:</b> Measuring liquid Pressure with a Manometer <b>(9 periods)</b>	
				<b>Unit 6:</b> Application of Pascal's principle <b>(10 periods)</b>	
				<b>Unit 7:</b> Archimedes principle and atmospheric pressure <b>(10 periods)</b>	<b>Unit 3:</b> Applications of atmospheric pressure <b>(10 periods)</b>

	Work, Power and Energy.	<b>Unit 6:</b> Work, Power and Energy(I) <b>(10 periods)</b>	<b>Unit 8:</b> Work, Power and Energy. (II) <b>(9 periods)</b>	<b>Unit 4:</b> Renewable and non-renewable energy sources <b>(10 periods)</b>
		<b>Unit 7:</b> Simple Machines (I) <b>(10 periods)</b>	<b>Unit 9:</b> Conservation of mechanical energy in isolated systems <b>(10 periods)</b>	
<b>THERMAL PHYSICS</b>	Basic properties of matter	<b>Unit 8:</b> Kinetic theory and states of matter <b>(10 periods)</b>		<b>Unit 5:</b> Heat transfer and quantity of heat <b>(9 periods)</b>
	Thermometry	<b>Unit 9:</b> Heat and temperature <b>(10 periods)</b>		
<b>THERMO-DYNAMICS</b>		<b>Unit 10:</b> Gas laws' experiments <b>(10 periods)</b>	<b>Unit 10:</b> Gas laws' experiments <b>(10 periods)</b>	<b>Unit 6:</b> Laws of thermodynamics <b>(9 periods)</b>
<b>ELECTRICITY AND MAGNETISM</b>	Magnetism	<b>Unit 10:</b> Magnetism (1) <b>(10 periods)</b>	<b>Unit 11:</b> Magnetisation and Demagnetisation <b>(7 periods)</b>	
	Electromagnetic induction			<b>Unit 7:</b> Introduction to electromagnetic induction <b>(9 periods)</b>
				<b>Unit 8:</b> Electrical power transmission <b>(10 periods)</b>
	Electrostatics	<b>Unit 11:</b> Electrostatics (I) <b>(10 periods)</b>	<b>Unit 12:</b> Applications of Electrostatics <b>(10 periods)</b>	<b>Unit 9:</b> Electric field intensity <b>(9 periods)</b>
	Direct current	<b>Unit 12:</b> Current Electricity (I) <b>(10 periods)</b>	<b>Unit 13:</b> Arrangement of resistors in electric circuit <b>(10 periods)</b>	<b>Unit 10:</b> House electric installation <b>(12 periods)</b>
				<b>Unit 11:</b> Basic alternating current circuits. <b>(12 periods)</b>

	Nature of light	<b>Unit 13:</b> Rectilinear Propagation of light (10 periods).		
<b>LIGHT</b>	Reflection and refraction		<b>Unit 14:</b> Reflection of light in curved mirrors (10 periods)	<b>UNIT 12:</b> Refraction of light (9 periods)
ELECTRONICS	Electronic devices		<b>Unit 15:</b> Basic electronic components (10 periods)	
	Tele-communication			<b>Unit 13:</b> Tele-communication Channels. (9 periods)
Environmental Physics	Environmental factors			<b>Unit 14:</b> Properties of Physical processes affecting plant growth. (9 periods)
				<b>Unit 15:</b> Environmental phenomena and related physics concepts (9 periods)

Table 9.1: Physics overview for O.L

## 9.2 Content Map

This summarises every unit in the Learner's Book:

Unit	No. of Periods	Introduction	Classroom organisation
Unit 1	12	<p>↑ Teacher asks learners to explain what they understand by the word physical quantity; measurement of physical quantity, errors and sources of errors in physical quantity measurement in daily life.</p>	<p>↑ Whole-class orientation, then group work, each group should discuss various measuring physical quantity and providing their background in measuring and discussing errors of measurement.</p>
Unit 2	10	<p>↑ Learners show their explanation about what they know on motion such as types of linear motion, kinematics and free fall.</p>	<p>↑ Whole-class orientation, group work, each group should discuss different types of linear motion, kinematics and free fall motion under gravity.</p>
Unit 3	9	<p>↑ Learners should give the definitions of friction force, giving different examples of where friction is observed and applied, then stating different types of resistance forces with examples.</p>	<p>↑ Whole-class orientation, group work, each group should discuss different types of frictional forces and their applications.</p>
Unit 4	9	<p>↑ Learners should discuss the density of different substances and the pressure exerted by the solids on a surface area, the pressure exerted by the fluid on a solid.</p>	<p>↑ Whole-class orientation, group work, each group should discuss the density of substances, pressure of solids and the pressure in fluids such as atmospheric pressure, Archimedes principle.</p>



	<b>Equipment required</b>	<b>Activities</b>
	<ul style="list-style-type: none"> <li>↑ Ruler</li> <li>↑ Vernier calipers</li> <li>↑ Micrometer screw gauge</li> <li>↑ Meter rule</li> <li>↑ Balance</li> <li>↑ Watches</li> <li>↑ Ammeter</li> <li>↑ Voltmeter</li> <li>↑ Ohmmeter</li> <li>↑ Objects to be measured</li> </ul>	<ul style="list-style-type: none"> <li>↑ Group discussion on types of errors in experiment data.</li> <li>↑ Presentation of types of errors.</li> <li>↑ Learners work in groups to determine compound errors in single measured physical quantities such as surface area, volume, force etc.</li> <li>↑ Discuss in groups and report systematic errors found in measuring instruments.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Small mass (pop) stand and clamp</li> <li>↑ Inextensible string</li> <li>↑ Scientific calculator</li> <li>↑ Meter ruler and stop watch/digital watch.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Observe and discuss linear motion and report.</li> <li>↑ Discuss linear motion in groups, share ideas and make presentations.</li> <li>↑ Work in groups, interpret an equation of free fall.</li> <li>↑ Carry out experiment to determine acceleration due to gravity.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Wooden block (with smooth and rough surfaces)</li> <li>↑ Spring balance</li> <li>↑ Thread</li> <li>↑ Single pulleys and standard mass</li> <li>↑ Lubricants.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Perform group experiments to illustrate types of friction forces.</li> <li>↑ Discuss in groups factors affecting it and report to class.</li> <li>↑ Demonstrate and experiment determination of coefficient of friction force(static and dynamic).</li> <li>↑ Learners to work in pairs to solve problems related to friction force.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Sponge,</li> <li>↑ Nail/pins</li> <li>↑ Wooden surface</li> <li>↑ Two identical bricks</li> <li>↑ Fine sand</li> <li>↑ Spring balance</li> <li>↑ U-tube, tin/cans/plastic bottle with holes on the side (vertical and level).</li> </ul>	<ul style="list-style-type: none"> <li>↑ Working in groups, learners determine pressure exerted on a wooden surface by given forces.</li> <li>↑ Discuss and explain the relationship between pressure, force and contact area.</li> <li>↑ Carry out experiments in groups to determine the pressure exerted on the surface area and report.</li> </ul>

<p><b>Unit 5</b></p>	<p>9</p>	<p>↑ Learners should discuss pressure in liquids and determining pressure of liquids in equilibrium using a manometer</p>	<p>↑ Whole-class orientation then group work, each group should perform and discuss different activities on finding the pressure in liquids.</p>	
<p><b>Unit 6</b></p>	<p>10</p>	<p>↑ Learners should discuss the application of pressure, Pascal's principle and its application in daily life.</p>	<p>↑ Whole-class orientation, group work, each group should perform and discuss different applications of transmission of pressure in fluids.</p>	
<p><b>Unit 7</b></p>	<p>10</p>	<p>↑ Learners should discuss their explanation about atmospheric pressure and Archimedes principle application in fluids.</p>	<p>↑ Whole-class orientation, group work, each group should perform and discuss how the atmosphere exerts pressure on everything on earth.</p>	
<p><b>Unit 8</b></p>	<p>9</p>	<p>↑ Learners should discuss what they understand by the term work, power and energy.</p>	<p>↑ Whole-class orientation, group work, each group should perform and discuss work, energy and power and the relationship between them.</p>	
<p><b>Unit 9</b></p>	<p>10</p>	<p>↑ Learners should discuss what they understand about the mechanical energy and its conservation</p>	<p>↑ Whole-class orientation, group work, each group should discuss and investigate the conservation of mechanical energy of a system.</p>	

<ul style="list-style-type: none"> <li>↑ Level indicator</li> <li>↑ Manometer</li> <li>↑ Pascal's vessel</li> <li>↑ Gas</li> <li>↑ Water</li> <li>↑ Mercury</li> <li>↑ Alcohol.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Perform the experiment in groups to demonstrate that pressure in fluids depends on the height/ column not on the shape of the vessels.</li> <li>↑ Make a group demonstration.</li> <li>↑ The existence of pressure in a fluid at rest in a container.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Pascal's vessels</li> <li>↑ Gas</li> <li>↑ Water</li> <li>↑ Alcohol</li> <li>↑ Hydraulic press</li> <li>↑ Car jack</li> <li>↑ Syringe.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Demonstrate Pascal's principle using enclosed fluid.</li> <li>↑ Devise an experiment to illustrate the functioning of hydraulic brakes.</li> <li>↑ Discuss in groups the functioning of a hydraulic car jack.</li> <li>↑ Discuss how pressure is transmitted in fluids.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Mercury and open glass tube about 1 metre long</li> <li>↑ Hydrometer</li> <li>↑ Barometers</li> <li>↑ Balloons</li> <li>↑ Magdeburg hemispheres</li> <li>↑ Metal can/plastic container</li> <li>↑ Drinking straws</li> <li>↑ Spring balance</li> <li>↑ Spirit</li> <li>↑ Water</li> <li>↑ Electronic balance.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Devise an experiment to demonstrate the existence of atmospheric pressure.</li> <li>↑ Investigate the operation of a Barometer and use it to measure atmospheric pressure.</li> <li>↑ Make group discussions and presentations on Torricelli's experiment on a barometer.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Pulleys</li> <li>↑ Levers</li> <li>↑ Wedge</li> <li>↑ Screws</li> <li>↑ Compound machines (an apple peeler)</li> <li>↑ Masses and inclined plane.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Discuss in groups and make presentations on the relation between work, power, and energy.</li> <li>↑ Solve in groups, problems on work, power and energy.</li> <li>↑ In groups, estimate personal power, discuss and present results.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Simple pendulum</li> <li>↑ Masses</li> <li>↑ Bow</li> <li>↑ and catapult.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Working in groups, carry out experiments to demonstrate conservation of mechanical energy and report.</li> <li>↑ Discuss in groups energy conservation and make presentations.</li> <li>↑ Perform experiments on energy conversion (potential energy into kinetic energy and vice versa) and report.</li> </ul>

<p><b>Unit 10</b></p>	<p><b>10</b></p>	<p>↑ Teacher asks learners to discuss about properties of gas, then gas laws of gas and their application.</p>	<p>↑ Whole-class orientation then group work, each group should discuss on the three main gas laws and then the Dalton's law of partial pressure.</p>	
<p><b>Unit 11</b></p>	<p><b>7</b></p>	<p>↑ Learners should discuss on what they know about electricity magnetism, then discuss on magnetisation and demagnetisation process</p>	<p>↑ Whole-class orientation, group work, each group should discuss magnetisation and demagnetisation of a ferromagnetic material and they understand the process by which a magnet is made and a magnet is destroyed.</p>	
<p><b>Unit 12</b></p>	<p><b>10</b></p>	<p>↑ Learners should discuss about electric charges then properties of electric charges. They should discuss also some application of electrostatic in daily life.</p>	<p>↑ Whole-class orientation, group work, each group should discuss about what they understand on properties of electric charges and their application.</p>	

<ul style="list-style-type: none"> <li>↑ Glass tube</li> <li>↑ Mercury</li> <li>↑ Barometer</li> <li>↑ Rubber tube or plastic tube</li> <li>↑ Gas</li> <li>↑ Burette</li> <li>↑ Glass beaker</li> <li>↑ Calcium chloride (drying agent)</li> <li>↑ Thermometer</li> <li>↑ Clip</li> <li>↑ Concentrated sulphuric acid</li> <li>↑ Bunsen</li> <li>↑ Pipette</li> <li>↑ Hydrogen balloon</li> <li>↑ Glass bulb</li> <li>↑ Capillary tube</li> <li>↑ Tap air</li> <li>↑ Pump.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Perform experiments to verify Boyle's law, Charles's law and Pressure law and report results.</li> <li>↑ Perform experiments to verify Dalton's law of partial pressure and report.</li> <li>↑ Solve problems on gas laws.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Magnet</li> <li>↑ Hammer</li> <li>↑ Iron filings</li> <li>↑ Soft iron</li> <li>↑ Steel metal</li> <li>↑ Computer CDs</li> <li>↑ Magnetic tapes</li> <li>↑ Metallic wrist watches</li> <li>AC and DC power supplies.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Discuss in groups magnetisation of ferromagnetic materials and report.</li> <li>↑ Group discussion and presentations on demagnetisation.</li> <li>↑ Create sculpture from magnets and suggest how other materials can be used.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Electroscopes</li> <li>↑ Van de Graff generator</li> <li>↑ Ebonite rods</li> <li>↑ Glass rods</li> <li>↑ Treads</li> <li>↑ Silk</li> <li>↑ Animal fur and photocopy machine.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Work in groups and make presentations on experiments illustrating electric force, electric field and electric potential.</li> <li>↑ Discuss in groups ways of separating a mixture by applying an electric field.</li> <li>↑ Discuss in pairs various applications of electrostatics.</li> </ul>

<p><b>Unit 13</b></p>	<p><b>10</b></p>	<p>↑ Learners should discuss what they know about electric resistance and their arrangement.</p> <p>↑ And the teachers asks them some questions on the different ways of arranging resistors (in series, in parallel and in mixture)</p>	<p>↑ Whole-class orientation, then group work, each group should arrange resistors in either parallel or series and discuss the resulting circuit. Hence, they present what they have learnt from the activity.</p>	
<p><b>Unit 14</b></p>	<p><b>10</b></p>	<p>↑ Learners should discuss what they know about light reflection.</p> <p>↑ Teacher asks them some questions on the reflection of light in plane and spherical mirrors.</p>	<p>↑ Whole-class orientation, then group work, each group should use a spherical mirror, changing the distance and comment on their observations. Hence, they present what they have learnt from the activity.</p>	
<p><b>Unit 15</b></p>	<p><b>9</b></p>	<p>↑ Learners should discuss about what they know about electronic devices, then the teacher helps them to present what they know about components of some electronic devices such as a radio, telephone, computer and so on.</p>	<p>↑ Whole-class orientation, then group work, each group should use a spherical mirror, changing the distance and comment on their observations. Hence, they present what they have learnt from the activity.</p>	

	<ul style="list-style-type: none"> <li>↑ Battery</li> <li>↑ Bulb</li> <li>↑ Connecting wire</li> <li>↑ Magnetised needle</li> <li>↑ Insulated copper wire</li> <li>↑ Ammeter</li> <li>↑ Voltmeter</li> <li>↑ Ohmmeter</li> <li>↑ Resistors</li> <li>↑ Electrolytic cell (Voltammeter).</li> </ul>	<ul style="list-style-type: none"> <li>↑ Construct simple electric circuit with resistors in series and parallel, ammeter and voltmeter.</li> <li>↑ Discuss in groups the characteristics of a magnetic field produced by a current and make presentation.</li> <li>↑ Perform experiment to investigate the heating and magnetic effect of an electric current and report.</li> <li>↑ Carryout an investigation on chemical effect of current ie Electrolysis.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Curved mirrors,</li> <li>↑ Spoon</li> <li>↑ Light source</li> <li>↑ Concave</li> <li>↑ Convex mirror</li> <li>↑ Optical pins</li> <li>↑ Small movable screen.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Perform an experiment to verify laws of reflection for plane mirrors.</li> <li>↑ Perform an experiment to determine the focal length of spherical mirrors.</li> <li>↑ Work in groups and make presentations on applications of curved mirrors.</li> <li>↑ Solve problems requiring mirror and magnification formulae.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Inductors</li> <li>↑ Resistors</li> <li>↑ Capacitors</li> <li>↑ Ordinary diodes</li> <li>↑ Zener diode</li> <li>↑ Transistors.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Observe different electronic components on an electronic motherboard.</li> <li>↑ Use computer simulations to demonstrate the operational principles of electronic devices.</li> <li>↑ Discuss in groups the importance of electronic devices in everyday life.</li> <li>↑ Suggest some electronic devices with different electronic components.</li> </ul>

Unit	No. of periods	Competence practiced	Language Practice	Vocabulary Acquisition	
<b>Unit 1</b>	<b>12</b>	<ul style="list-style-type: none"> <li>↑ Team work</li> <li>↑ Using measuring instruments</li> <li>↑ Research on the internet for information on measurement of physical quantities</li> <li>↑ Communication skills</li> <li>↑ Recording experiment and reporting</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Accuracy</li> <li>↑ Precision</li> <li>↑ Random error</li> <li>↑ Uncertainty</li> <li>↑ Systematic error</li> <li>↑ Rounding off</li> <li>↑ Significant figure</li> <li>↑ Range</li> <li>↑ Mean</li> <li>↑ Average mean.</li> </ul>	
<b>Unit 2</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Interpretation of rectilinear motion.</li> <li>↑ Analysing velocity and acceleration.</li> <li>↑ Analysing equations of motion.</li> <li>↑ The use of ICT to evaluate motion.</li> <li>↑ Communication skills.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Kinematics</li> <li>↑ Trajectory</li> <li>↑ Curvilinear motion</li> <li>↑ Translational motion</li> <li>↑ Instantaneous velocity</li> <li>↑ Instantaneous acceleration.</li> </ul>	
<b>Unit 3</b>	<b>9</b>	<ul style="list-style-type: none"> <li>↑ ICT use in research about use of force.</li> <li>↑ Team work.</li> <li>↑ Interpretation of friction forces and other resistance forces.</li> <li>↑ Applied, magnetic and gravitational forces analysis.</li> <li>↑ communication skills.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Frictional force</li> <li>↑ Other resistance force</li> <li>↑ Weight</li> <li>↑ Roughness</li> <li>↑ Smoothness</li> <li>↑ Coefficient of frictions</li> <li>↑ Viscosity</li> <li>↑ Air resistance.</li> </ul>	
<b>Unit 4</b>	<b>9</b>	<ul style="list-style-type: none"> <li>↑ Interpretation of pressure</li> <li>↑ Communication skills.</li> <li>↑ Calculate relative density of different bodies.</li> <li>↑ Search internet for more applications of pressure.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Pressure</li> <li>↑ Atmospheric pressure</li> <li>↑ Fluids</li> <li>↑ Hydrostatic pressure.</li> </ul>	



	<b>Numeracy</b>	<b>Study Skills</b>	<b>Assessments</b>	<b>Learning outcomes</b>
	<ul style="list-style-type: none"> <li>↑ Performance of calculation of errors, uncertainty, range and averages.</li> <li>↑ Use of metric prefixes and metric calculation.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Distinguish random and systematic errors.</li> <li>↑ Choose appropriate measuring instruments.</li> <li>↑ Report measured physical quantities accurately.</li> <li>↑ Reduce random and systematic errors while performing experiments.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To determine the uncertainty in measurement.</li> <li>↑ Explain propagated errors and derived physical quantity and report results appropriately.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to identify and explain sources of error in measurements and report.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Improving in calculation on linear motion, and free fall motion</li> <li>↑ Graphic representation.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Derive equations of linear motion.</li> <li>↑ State conditions applicable to equations of uniformly accelerated motion.</li> <li>↑ Solve problems related to linear motion.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To analyse and solve problems related to linear motion correctly.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of the this unit, the learner should be able to analyse and solve problems related to linear motion.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Drawing free body diagram involving friction force.</li> <li>↑ Calculation of coefficient of friction.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Convey the nature of friction force.</li> <li>↑ Measure static and dynamic friction.</li> <li>↑ Identify factors affecting friction force.</li> <li>↑ Methods of reducing friction force.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To describe and explain clearly friction force and its applications.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to explain the effects of a force and its importance in life.</li> </ul>
	<ul style="list-style-type: none"> <li>↑ Calculations on pressure.</li> <li>↑ Drawing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Explain change in pressure by reducing or increasing area of contact and vice versa.</li> <li>↑ Measure pressure air using a simple manometer.</li> <li>↑ Measure atmospheric pressure using a barometer.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To explain the relationship between pressure, force and area of contact, can solve problems involving pressure, force and area, can conduct experiments on pressure and report.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to define pressure and explain factors affecting it.</li> </ul>

<b>Unit 5</b>	<b>9</b>	<ul style="list-style-type: none"> <li>↑ Appreciate the role of pressure in liquids.</li> <li>↑ Use the internet to search for information on application of pressure in liquids.</li> <li>↑ Communication skills.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ U-tube</li> <li>↑ Miscible and non miscible liquids</li> <li>↑ Hydrostatic pressure</li> <li>↑ Isobar</li> </ul>	
<b>Unit 6</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Appreciate the application of pressure with Pascal's principle.</li> <li>↑ Communication skills.</li> <li>↑ Team work and research on internet for more applications of pressure.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Hydraulic press</li> <li>↑ Water tower</li> <li>↑ Cylinder</li> <li>↑ Piston</li> <li>↑ Liquids in equilibrium</li> </ul>	
<b>Unit 7</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Analysis of simple mercury barometer.</li> <li>↑ Team work and research.</li> <li>↑ Communication skills.</li> <li>↑ Use of internet to access information on atmospheric pressure</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Barometer</li> <li>↑ Upthrust force</li> <li>↑ Floating</li> <li>↑ Sinking</li> <li>↑ Aerostat</li> <li>↑ Atmospheric pressure</li> </ul>	
<b>Unit 8</b>	<b>9</b>	<ul style="list-style-type: none"> <li>↑ Analysing of work, energy and power.</li> <li>↑ Team work.</li> <li>↑ Search Internet for simulations on machines performing work.</li> <li>↑ Communication skills.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Work</li> <li>↑ Energy</li> <li>↑ Power, Potential energy</li> <li>↑ Kinetic energy</li> <li>↑ Mechanical energy.</li> </ul>	

<ul style="list-style-type: none"> <li>↑ Calculation on pressure in liquids</li> <li>↑ Drawing</li> </ul>	<ul style="list-style-type: none"> <li>↑ Explain why a liquid surface is an isobar and state its application.</li> <li>↑ Analyse the equilibrium of non-miscible liquids in a container and in a communicating container.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To explain clearly the working principle of a Manometer and use it to determine pressure of a liquid.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to explain the working principle of manometer use to measure the pressure in fluids.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Performance of calculations of Pascal's principle.</li> <li>↑ Drawing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Explain transmission of pressure in fluids at rest.</li> <li>↑ Explain Pascal's principle.</li> <li>↑ Explain the functioning of hydraulic jack. Lift and dump it truck and car brakes.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To explain clearly transmission of pressure in fluids at rest and describe related applications.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of the unit the learner should be able to explain transmission of pressure in fluids at rest and describe its applications.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Performance in problem solving about atmospheric pressure.</li> <li>↑ Drawing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Existence of atmospheric pressure.</li> <li>↑ S.I. units of atmospheric pressure.</li> <li>↑ Applications of atmospheric pressure.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Learner can demonstrate clearly the existence of atmospheric pressure and verify Archimedes principle.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of the unit, the learner should be able to determine atmospheric pressure using barometer.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Performing calculations on work, energy and power.</li> <li>↑ Drawing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Derive the equations relating work and power.</li> <li>↑ Analyse relationship between work and power.</li> <li>↑ Relate power and energy.</li> <li>↑ Compare work, power and energy.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To establish correctly the relationship between work, power and energy, and solve related problems.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of the unit, the learner should be able to relate work, power and energy.</li> </ul>

<b>Unit 9</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Group discussions on advantages of different types of thermometric liquids.</li> <li>↑ Team work and group presentation.</li> <li>↑ Communication skills.</li> <li>↑ Search the internet for details on the principle of energy conservation for an isolated system.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Energy conservation</li> <li>↑ Isolated system</li> <li>↑ Open system</li> <li>↑ Closed system,</li> </ul>	
<b>Unit 10</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Appreciate the application of gas laws.</li> <li>↑ Search internet for simulations on gas laws.</li> <li>↑ Communication skills.</li> <li>↑ Team work.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Ideal gas or perfect gas</li> <li>↑ Partial prssure</li> <li>↑ Real gas</li> <li>↑ Gas constant</li> </ul>	
<b>Unit 11</b>	<b>7</b>	<ul style="list-style-type: none"> <li>↑ Interpretation of magnetisation and demagnetisation processes</li> <li>↑ Search the internet for additional information on magnetisation and demagnetsation of magnets.</li> <li>↑ Demonstrate the ways of making a magnet.</li> <li>↑ Communication skills and team work.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Magnetisation</li> <li>↑ Demagnetisation</li> <li>↑ Hummaring</li> <li>↑ Strocking</li> <li>↑ Heating</li> </ul>	
<b>Unit 12</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Interpretation of properties of electric charges.</li> <li>↑ Search the internet for electrostatic and its applications.</li> <li>↑ Team work and communication skills.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Electric field</li> <li>↑ Electric potential</li> <li>↑ Lightning arrestors</li> <li>↑ Paint spray</li> <li>↑ Laser printer</li> <li>↑ Electrostatic precipitator</li> <li>↑ Photocopy machine.</li> </ul>	

<ul style="list-style-type: none"> <li>↑ Calculations on mechanical energy and its conservation</li> <li>↑ Drawing</li> </ul>	<ul style="list-style-type: none"> <li>↑ Identify different forms of mechanical energy</li> <li>↑ Discuss applications of principle of conservation of mechanical energy to isolated system.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To explain clearly the principle of energy conservation and discuss implications of energy conservation in the environment.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to apply the principle of conservation of mechanical energy for isolated system.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Calculations of pressure, temperature and volume using gas laws</li> <li>↑ Drawing and graphing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Design experiment to verify Boyle's law, Charles's law and pressure law.</li> <li>↑ Explain equations of perfect gas. (Ideal gas)</li> <li>↑ Interpret experiments for gas laws.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To perform and describe experiments for Boyle's law, Charles law and Pressure law, solving problems involving gas law equations.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of the unit, the learner should be able to describe and analyse gas laws experiments.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Drawing</li> </ul>	<ul style="list-style-type: none"> <li>↑ Explain magnetisation using the domain theory.</li> <li>↑ Create temporary and permanent magnets.</li> <li>↑ Explain demagnetisation using the domain theory.</li> <li>↑ Discuss methods of storing magnets.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To explain and describe clearly the methods of magnetisation and demagnetisation.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to describe methods of magnetisation and demagnetisation</li> </ul>
<ul style="list-style-type: none"> <li>↑ Calculations on electric force.</li> <li>↑ Drawing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Relate electric field patterns and charge distribution on conductors of different shapes.</li> <li>↑ Evaluate applications of electrostatics in other fields (agriculture, environment, industry).</li> </ul>	<ul style="list-style-type: none"> <li>↑ To explain clearly the concept of electrostatics and its applications</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to explain applications static charges.</li> </ul>

<b>Unit 13</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Interpretation of an electric circuit.</li> <li>↑ Use the internet to search details on the different electric circuit arrangements.</li> <li>↑ Communication skills.</li> <li>↑ Team work.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Simple electric circuit</li> <li>↑ Electric potential</li> <li>↑ Potential difference</li> <li>↑ Electric bell</li> <li>↑ Electromagnet</li> <li>↑ Electrolysis</li> <li>↑ Heat effect</li> <li>↑ Chemical effect.</li> </ul>	
<b>Unit 14</b>	<b>10</b>	<ul style="list-style-type: none"> <li>↑ Interpretation of properties of a spherical mirror and their images.</li> <li>↑ Use the internet and computer simulations to illustrate reflection at a plane and curved surfaces.</li> <li>↑ Team work and communication skills.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Concave mirror</li> <li>↑ Convex mirror</li> <li>↑ Radius of curvature</li> <li>↑ Focal length</li> <li>↑ Pole, aperture</li> <li>↑ Principal axis</li> <li>↑ Centre of Curvature</li> <li>↑ Real image</li> <li>↑ Virtual image.</li> </ul>	
<b>Unit 15</b>	<b>9</b>	<ul style="list-style-type: none"> <li>↑ Interpretation of components of an electronic device.</li> <li>↑ Use the internet to search on the working principle of basic electronic devices.</li> <li>↑ Team work and communication skills.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Presentation and reporting of findings.</li> <li>↑ Roleplay and discussions.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Electronics</li> <li>↑ Motherboard</li> <li>↑ Forwarding bias</li> <li>↑ Reverse bias</li> <li>↑ Transistor</li> <li>↑ Diode</li> <li>↑ Capacitor</li> <li>↑ Inductor</li> <li>↑ Electronic devices</li> </ul>	

Table 6.2: Content map

<ul style="list-style-type: none"> <li>↑ Solve problems involving the arrangement of a resistor.</li> <li>↑ Solving problems involving the potential difference and electric potential.</li> <li>↑ Drawing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Construct a simple electric circuit with resistors in series and parallel, anammeter and voltmeter.</li> <li>↑ Predict what would happen in a house without a fuse or circuit breakers with an overloaded electric circuit.</li> <li>↑ Measure electric current and the potential difference using anammeter and voltammeter.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To construct a simple electric circuit with resistors in series and parallel, ammeter and voltmeter.</li> <li>↑ To perform an experiment to investigate the heating effect of an electric current.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to describe the arrangement of resistors in a simple electric circuit.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Solve problems involving spherical mirrors.</li> <li>↑ Drawing and graphing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Locate by construction of images formed in curved mirrors and state their characteristics.</li> <li>↑ Perform an experiment to determine the focal length of spherical mirrors.</li> <li>↑ Evaluate images formed by curved mirrors.</li> <li>↑ Discuss applications of curved mirrors.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To verify laws of reflection;</li> <li>↑ Describe images formed by spherical mirrors and to determine the focal length of spherical mirrors. Design a project to investigate applications of reflection of light.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end this unit the learner should be able to analyse applications of reflected light.</li> </ul>
<ul style="list-style-type: none"> <li>↑ Drawing.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Identify electronic components on an electronic motherboard.</li> <li>↑ Describe the electronic components of a motherboard.</li> <li>↑ Suggest the possible importance of electronic devices in everyday life.</li> </ul>	<ul style="list-style-type: none"> <li>↑ To explain clearly working principle of a basic semi-conductor devices.</li> <li>↑ Use computer simulations to demonstrate the operational principle of electronic devices.</li> </ul>	<ul style="list-style-type: none"> <li>↑ By the end of this unit, the learner should be able to explain the working principle of basic electronic devices.</li> </ul>

# 10. Competence – Based Lesson Plan

## 10.1 Planning of the lesson

- ⦿ A lesson plan must contain clear, realistic and **appropriate SMART** objectives reflected to the syllabus unit;
- ⦿ The planned lesson must be conducted within the time allocated in the lesson plan;
- ⦿ The management and control of the class must be effective and an indication of how to address the individual learner's needs is paramount.

## 10.2 Introduction of the lesson

- ⦿ The teacher must discuss lesson objectives or learning outcomes with the learners **and must reflect the rationale for learning the subject unit.**
- ⦿ The introduction must:
  - show the linkage between prior knowledge to new the concept and how learners demonstrate the existence of prior knowledge;
  - emphasise on how the new concept is applied in everyday life experience;
  - be stimulating enough to capture the learner's interest.

## 10.3 Pedagogical Approach

- ⦿ The teacher through questioning and provocation engages learners in active participation in the lesson.
- ⦿ The teacher encourages learners to work in groups to accomplish a given task.
- ⦿ The teacher encourages learners to ask questions and to give their views.
- ⦿ The teacher gives attention to time takers and those with special needs.
- ⦿ The teacher adapts to the needs of the learners.

## 10.4 Assessment Technique

- ⦿ The teacher asks questions as the lesson progresses.
- ⦿ The teacher gives class exercise and moves around to check the accuracy of the responses from learners.
- ⦿ The teacher sets tasks for small groups to work on.
- ⦿ The teacher involves learners in discussing the group findings.
- ⦿ The teacher discusses the exercise with learners.



- The teacher discusses responses with learners.
- The teacher gives home work or project work at the end of the lesson.

### **10.5 Instructional materials used**

- Learners make use of the text books during the lesson.
- Learners utilise other materials to facilitate their learning.
- The teacher makes use of the teacher's guide and other existing instructional materials relevant to the topic.
- Making use of charts, maps, common tools and models, overhead projector, flip board or whiteboard , reference books per subject, video and cassette player, computers, sufficient books in the library.

### **10.6 Conclusion of the lesson**

- The teacher summarises the lesson and encourages the learners to ask what was not clear.
- Teacher emphasises the relevance and applications of the concept in real life experiences.
- The teacher concludes by giving follow up assignment to learners.

### **10.7 Teacher competences required**

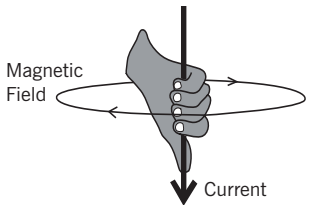
- The teacher adapts to the needs of learners.
- The teacher's communication skills in the language of instruction.
- The teacher's practical skills during the lesson.
- The teacher's management of relevant records.
- The teacher's ability to evaluate oneself and learners.

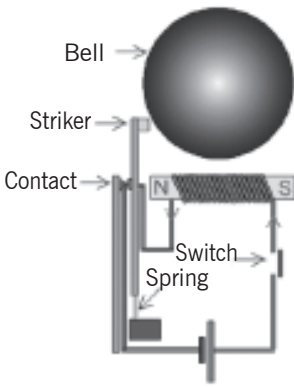
## Competence – based Lesson Plan

School Name:.....

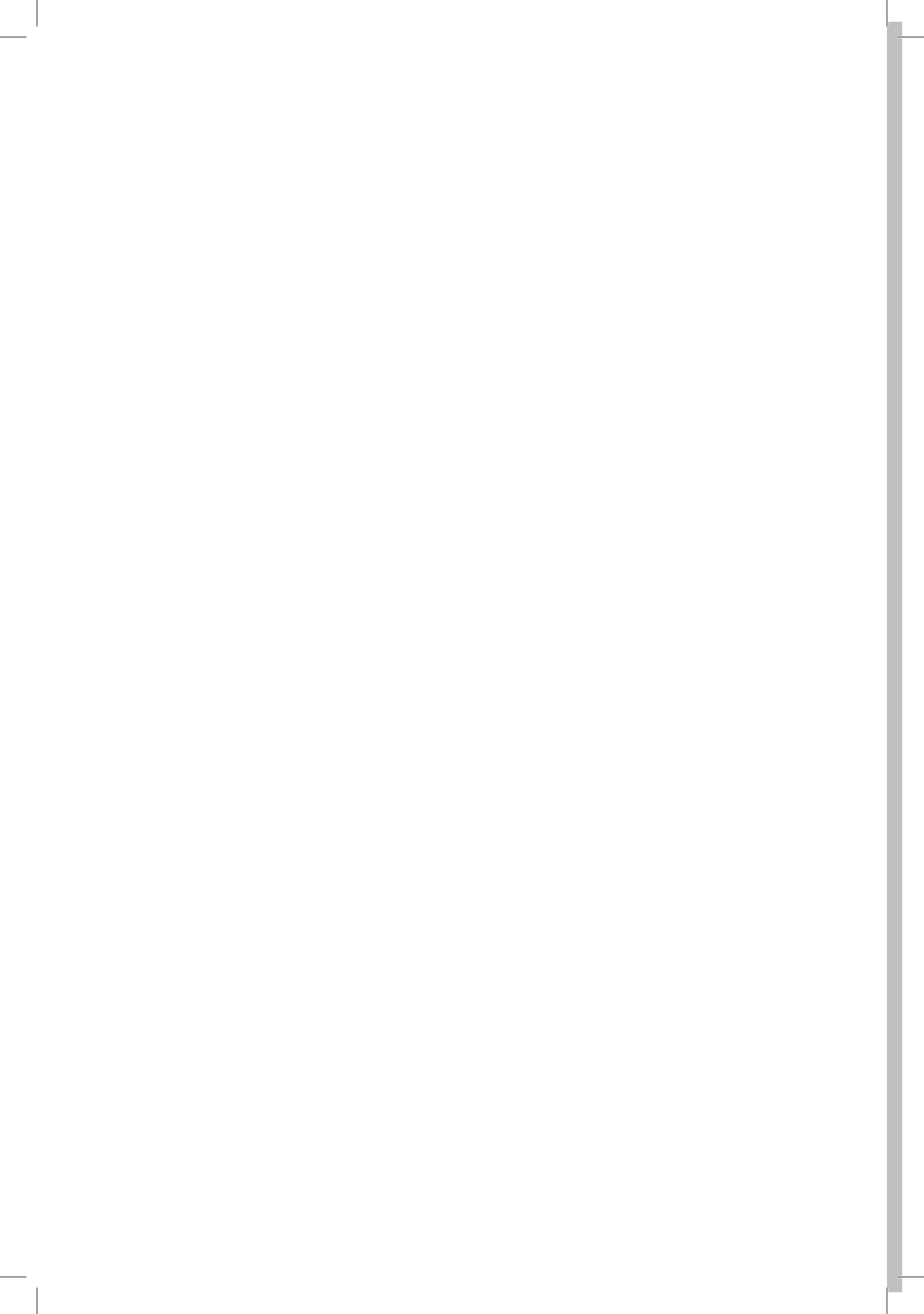
Teacher's name:.....

Term	Date	Subject	Class	Unit N°	Lesson N°	Duration	Class size
3rd	...../...../2017	Physics	S2	12	9 of 10	80 minutes	40
<b>Type of Special Educational Needs to be catered for in this lesson and number of learners in each category</b>				Learners with visual difficulties.			
<b>Unit title</b>		Arrangement of resistors in an electric circuit					
<b>Key unit competence</b>		By the end of this unit, the learner should be able to describe the arrangement of resistors in a simple electric circuit.					
<b>Title of the lesson</b>		Effects of an electric current.					
<b>Instructional Objective</b>		Given a coil, source of current 12V, wire, ferromagnetic bodies... learners will be able to create an electromagnet and explain how electricity and magnetism work together in the electric bell correctly.					
<b>Plan for this Class (location: in/ outside)</b>		Classroom					
<b>Learning materials (for all learners)</b>		Coil, Source of electric current 12V, Ferromagnetic body, Wire, Compass, Switch with holder					
<b>References</b>		<ol style="list-style-type: none"> <li>Breithaupt, J. (2000), Understanding Physics For Advanced Level (4, Ed.) Ellenborough House, Italy: Stanley Thorners;</li> <li>Abbot, A. F., &amp; Cockcroft, J. (1989). Physics. (5, Ed.) Heinemann: Educational Publishers.</li> </ol>					

Timing for each step	Description of the teaching and learning activity		Generic competences and Crosscutting issues to be addressed + a short explanation
	Teacher activities	Learner activities	
<b>Introduction</b> 10min	<ul style="list-style-type: none"> <li>↑ Begin by asking the class how they think electricity and magnetism are related.</li> <li>↑ Can you create a magnet using electricity? How Can you create electricity using a magnet?</li> <li>↑ Ask the learners to think about these answers as the lesson progresses.</li> </ul>	<ul style="list-style-type: none"> <li>↑ The answer is that a moving electric or magnetic field produces the other type of field, i.e. a moving magnetic field produces an electric field, and thus electricity, and vice versa.</li> </ul>	<b>Generic competences:</b> <ul style="list-style-type: none"> <li>↑ Communication</li> <li>↑ Cooperation</li> <li>↑ Critical thinking</li> </ul>
<b>Development of the lesson</b> 60min	<ul style="list-style-type: none"> <li>↑ Explain that, by the right hand rule, a coil of current carrying wire will create a magnetic field. (10 min.)</li> <li>↑ Ask the class to define and come up with examples of where both electricity and magnetism are present/used.</li> <li>↑ How are electromagnets used in everyday objects?</li> </ul>	<div style="text-align: center;">  </div> <ul style="list-style-type: none"> <li>↑ The electromagnet is a device that is used very often in everyday objects that exemplifies the relationship between electricity and magnetism.</li> <li>↑ The electromagnet is a widely used tool for converting electromagnetic energy into mechanical energy and back again</li> </ul>	<ul style="list-style-type: none"> <li>↑ Crosscutting issues to: Peace and value, inclusive education.</li> </ul> <b>Generic competences:</b> <ul style="list-style-type: none"> <li>↑ Communication.</li> <li>↑ Critical thinking.</li> <li>↑ Cooperation.</li> <li>↑ Creativity.</li> <li>↑ Collaborative grouping.</li> </ul>

	<ul style="list-style-type: none"> <li>↑ Explain the factors affecting the strength of an electromagnet.</li> <li>↑ Break the class into groups and begin the Electromagnet Activity.</li> <li>↑ Remember to reinforce the above concepts during the activity.</li> <li>↑ Ask the learners to use the right hand rule to describe what's going on with their nails and coils of wire.</li> <li>↑ Ask them if they think a striker will work as an electromagnet's core and why/ why not.</li> <li>↑ Ask them if they've seen electromagnets like this before and where.</li> </ul>	<ul style="list-style-type: none"> <li>↑ Motors and generators</li> <li>↑ Doorbells</li> <li>↑ Speakers</li> <li>↑ Hard drives</li> <li>↑ Audio tapes</li> <li>↑ Telephones</li> <li>↑ The strength of the magnetic field is based on 3 things:             <ul style="list-style-type: none"> <li>↑ The amount of current in the wire: the more current, the stronger the magnetic field.</li> <li>↑ The number of turns in the coil: the more turns, the stronger the magnetic field.</li> <li>↑ The material in the coil.</li> </ul> </li> <li>↑ Having a magnetic material such as iron or steel as the core of the coil works to magnify the effects of the coil, thus creating a stronger magnetic field.</li> <li>↑ Having nothing in the coil will still produce a magnetic field, though it will be very weak.</li> <li>↑ Learners create the electric bell and explain how it functions</li> </ul>	
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	<p>↑ Learners have learned about electricity, electric circuits, voltage, and current.</p> <p>↑ They are familiar with how to connect circuit elements.</p> <p>↑ Consider safety precaution when handling electrical appliances.</p>	<ol style="list-style-type: none"> <li>1. When the current flows through the circuit, the electromagnet makes a magnetic field.</li> <li>2. The electromagnet attracts the springy metal arm.</li> <li>3. The arm hits the gong, which makes a sound.</li> <li>4. The circuit is broken when the arm is out of position.</li> <li>5. The electromagnet is turned off and the springy metal arm moves back.</li> <li>6. The circuit is complete again.</li> <li>7. The cycle repeats as long as the switch is closed. When the switch is pushed/ closed, the circuit is completed and the current flows through the electromagnetic coil.</li> </ol>	
<p><b>Conclusion</b></p> <p>10 min</p>	<p><b>Summary.</b></p> <p>Correct and conclude.</p> <p><b>Assessment:</b></p> <p>Ask learners to suggest the next lesson by referring to the current lesson</p>	<p>↑ The learners harmonise the lesson. They examine and describe the function of the electric bell.</p> <p>↑ Imagine in connection with the current lesson what they think should follow as a next lesson.</p>	<p>↑ Critical thinking, analysis.</p>
<p><b>Teacher self-evaluation</b></p>			



# Section II

# Teaching and learning approaches for each unit

## General objectives

The syllabus learning outcomes describe what learners know and can do at the end of senior 2, OL. The level of achievement of the learning outcome should improve during the three years of lower Secondary study, and it is at the end of the study that learners are given a summative assessment on the level of achievement of the learning outcome.

**At the end of senior 2, the learner should be familiar with:**

- ④ Validate basic formula based on dimensional analysis.
- ④ Analyse the thermal expansion of solids, liquids and gases.
- ④ Perform experiments on gas laws.
- ④ Magnetise materials using magnets.
- ④ Explain magnetisation and demagnetisation of magnets.
- ④ Explain the applications of static electricity.
- ④ Analyse resistor arrangement in electric circuits.
- ④ Explain the functioning of basic electronic devices.

Clear informative, concise and understandable objectives are provided to give you what knowledge skills and attitudes you are expected to attain after studying the unit.



# Unit 1

## Sources of errors in measurement of physical quantities

### Key unit competence:

By the end of the unit, the learner should be able to identify and explain sources of error in measurements and report.

### Learning objectives:

By the end of this unit, learners should be able to;

- ④ State and explain types of errors in measurements.
- ④ Distinguish between precision and accuracy.
- ④ Explain the concept of significant figures.
- ④ Explain the error propagation in derived physical quantities.
- ④ Explain rounding off numbers.
- ④ Explain fundamental quantities and their dimensions.
- ④ State the fundamental and the derivate quantities and determine their dimensions.

## Resources:

Ruler, Vernier calipers, micrometer screw gauge, meter rule, balance, watches, ammeter, voltmeter, Ohmmeter, objects to be measured etc. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

### 1.1 Specific suggested methods/strategies/approaches of this unit.

Good teaching methods are those keeping learners motivated and engaged throughout the lesson. We then suggest practical (measurements), question and answer sessions, team work when demonstrating activities and solving problems throughout this unit.

The learner is actively involved in this learning. This teaching style we believe leaves no motivated learners and helps the teacher know learners who need to be helped more.

### 1.2 Support on assessment strategies and tasks of assessment

You may use some of the activities suggested in the learner's book, use formative assessment throughout this unit during each lesson, ask questions and interact with learners during activities.

You may also use multiple choice questions or other type of advanced questions at the end of the unit for summative assessment and home works.

### 1.3 Lessons and timing

This unit consists of 12 lessons and each lesson should be covered in 40 minutes.

	<b>Lessons</b>	<b>Periods</b>
1.	Dimensional analysis for given equations	2
2.	Fundamental quantities and their dimensions	2
3.	Significant figures and rounding off	2
4.	Compare uncertainty in measurements	2
5.	Types of errors and sources of compound error in simple equations	2
6.	General assessment	2

## 1.4 Solutions of unit activities

### Activity 1.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Tape measure is the most suitable instrument for the measurement of the length of a football field because the order of size of the field is within the accuracy which can be obtained from a tape measure and the tape measure measures up to 50m. To measure the diameter of a wire, you use a micrometer screw gauge because it gives the accuracy matching the order of size of the diameter of wire. To measure the width of a person, a meter rule would be the most suitable judging from the order of size of a finger.
2. The learner should select an appropriate measuring instrument and the teacher guides him or her.
3. In construction, sewing, cooking, carpentry, painting, etc.

### 1.1.5 Checking my progress

1.
  - (a) Volume  $L^3$
  - (b) Speed  $LT^{-1}$
  - (c) Acceleration  $LT^{-2}$
  - (d) Density  $ML^{-3}$
2. (b)  $kg^2ms^{-2}$
3. (a)  $L^3M^{-1}T^{-2}$
4. (a)  $K^{-1}$

### Activity 1.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

The results are different due to either human error or instrument error which might be random or systematic errors.

The results are different due to either human error or instrument error.

### 1.2.4 Checking my progress

1. (a) Ruler A: 2 cm (as it can measure up to the precision cm only)
- (b) Ruler B: 3.0 cm, 3.3 cm (as it can measure up to the precision of 0.1 cm only)

2. (a) The circumference  $circ = 2\pi r = 2 \times 3.14 \times (1.25 \pm 0.05) \text{ cm}$   
 $= (6.28 \times 1.25 \pm 6.28 \times 0.05) \text{ cm}$   
 $= (7.85 \pm 0.31) \text{ cm}$

$$A = \pi(r \pm \Delta r)^2$$

- (b) The area:  $= \pi(r^2 \pm 2 \frac{\Delta r}{r})$   
 $= 3.14[(1.25 \text{ cm})^2 \pm 2 \frac{0.05}{1.25}]$   
 $= 4.91 \text{ cm}^2 \pm 0.25$

3. (a)  $P = 2(l + w)$   
 $= 2[(7.3 \pm 0.1) \text{ cm} + (2.3 \pm 0.5) \text{ cm}]$   
 $= 2(9.6 \pm 0.6) \text{ cm}$   
 $= (19.2 \pm 1.2) \text{ cm}$

$$A = lw$$

- (b)  $= (7.3 \pm 0.1) \text{ cm} \times (2.3 \pm 0.5) \text{ cm}$   
 $= (7.3 \times 2.3) \text{ cm}^2 \pm (\frac{0.1}{7.3} + \frac{0.5}{2.3})$   
 $= 16.8 \text{ cm}^2 \pm 0.2$

4.

Accuracy	Precision
Accuracy refers to correctness and means how close the result is to the true value.	Experimental precision means the degree of exactness of the experiment or how well the result has been obtained.
Accuracy depends on how well the systematic errors are compensated.	Precision depends on how well random errors are reduced

5. A measurement is valid when it is both accurate and precise.

**Activity 1.3: Let learner's discuss and the teacher guides them**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Let learners discuss and you guide them

**Trial activity 1.1:**

Let learners try this and help them for correction:

You could express this error as a percentage of the length:

$$\frac{\Delta L}{L} \times 100 = \frac{0.2}{10.2} \times 100 = 1.961\% \quad \text{Where } \frac{\Delta L}{L} \text{ is the relative error.}$$

**Trial activity 1.2:**

Let learners try this and help them for correction:

The length of the object is just the difference:  $L = y - x = 10.34 - 0.10 = 10.24\text{cm}$ . The uncertainty is given by the rule for addition/subtraction:

$$\Delta L = \Delta y + \Delta x = 0.05 + 0.05 = 0.1\text{cm}$$

$$L \pm \Delta L = (10.2 \pm 0.1)\text{cm}$$

We round the absolute uncertainty to 1 sig fig and match precisions in our final answer.

**1.3.2 Checking my progress**

1. For the given table of length in cm:

The average

$$\begin{aligned} x_{avg} &= \frac{x_1 + x_2 + x_3 + x_4 + x_5 + x_6}{6} \\ &= \frac{23.53 + 24.10 + 24.65 + 25.32 + 25.48 + 25.87}{6} \\ &= \frac{148.95}{6} = \boxed{24.83 \text{ cm}} \end{aligned}$$

$$\text{Range } R = x_{\max} - x_{\min} = 25.87 - 23.53 = \boxed{2.34 \text{ cm}}$$

$$\text{Uncertainty in measurement } \Delta x = \frac{R}{2} = \frac{2.34 \text{ cm}}{2} = \boxed{1.17 \text{ cm}}$$

Uncertainty in the mean:

$$\begin{aligned}\Delta x_{avg} &= \frac{\Delta x}{\sqrt{N}} = \frac{R}{2\sqrt{N}} \quad (N = 6) \\ &= \frac{1.17 \text{ cm}}{\sqrt{6}} = \boxed{0.48 \text{ cm}}\end{aligned}$$

Measured value

$$\begin{aligned}x_m &= x_{avg} + \Delta x_{avg} \\ &= (24.83 \pm 0.48) \text{ cm}\end{aligned}$$

## 2. For the given table in °C

The average temperature

$$\begin{aligned}T_{avg} &= \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{7} \\ &= \frac{37.1 + 36.8 + 36.5 + 35.6 + 37.5 + 36.9 + 34.9}{7} \\ &= \frac{255.3}{7} = \boxed{36.5 \text{ }^\circ\text{C}}\end{aligned}$$

$$\text{Range } R = T_{\max} - T_{\min} = 37.5 - 34.9 = \boxed{2.6 \text{ }^\circ\text{C}}$$

$$\text{Uncertainty in measurement } \Delta T = \frac{R}{2} = \frac{2.6 \text{ }^\circ\text{C}}{2} = \boxed{1.3 \text{ }^\circ\text{C}}$$

Uncertainty in the mean:

$$\begin{aligned}\Delta T_{avg} &= \frac{\Delta T}{\sqrt{N}} = \frac{R}{2\sqrt{N}} \quad (N = 6) \\ &= \frac{1.3 \text{ }^\circ\text{C}}{\sqrt{7}} = \boxed{0.5 \text{ }^\circ\text{C}}\end{aligned}$$

### 1.4.3 Checking my progress

1. (a) 5    (b) 3    (c) 1    (d) 3
2. (2)    (b) 3    (c) 2    (d) 2

**Activity 1.5: Rounding off a number**

Group learners into groups of seven student mixing them respecting their gender balance with inclusive education for SEN. Guide them to measure one notebook's size (every student) and then let them follow instruction given in the LB.

Guide them to draw a suitable conclusion.

**1.5 Suggested answers for unit 1 Assessment**

1. (i) a) Rachel (ii) b) Daniel (iii) c) Leah
2. 0.006cm, 17.04cm, 342.0 cm, 843cm:
3. (a)  $6.8 = 7$ ,  $10.5 = 10$ ,  $801.625 = 802$   
 (b)  $5.83 = 5.8$ ,  $480.625 = 480.6$ ,  $0.234 = 0.2$ ,  $0.285 = 0.3$ ,  $6.58 = 6.6$ ,  $36.092 = 36.1$   
 (c)  $3.632 = 3.63$ ,  $812.097 = 812.10$ ,  $0.71 = 0.71$   
 (d)  $0.2827 = 0.283$ ,  $0.0066 = 0.007$   
 (e)  $56 = 60$ ,  $44 = 40$ ,  $17 = 20$ ,  $656 = 660$   
 (f)  $219 = 200$ ,  $256 = 300$ ,  $71 = 100$ ,  $550 = 600$ ,  $930.7 = 900$   
 (g)  $890 = 1000$ ,  $1600 = 2000$ ,  $10,500 = 10000$ ,  $13856 = 14000$ ,  
 $5420.5 = 5000$
4.  $468.5\text{m}$ ;  $0.00708\text{m} = 0.0\text{m}$ ;  $3.467\text{m} = 3.5\text{m}$ ;  $56.93\text{m} = 56.9\text{m}$ ;  $3.004\text{m} = 3.0\text{m}$
5. a) 41.14                      b) 806.9    c) -0.5    d) 42                      e) 75
6. a) 245100                      b) 407    c) 8470    d) 84
7. A. c) 4                      B. c) 0.28%    C. b)  $M^{-1}L^3T^{-2}$     D. b)  $M^0LT^0$
8. c) 6 s
9. b)  $L = 10.0\text{ m} \pm 0.2\text{ m}$

## 1.6 Additional information (content)

### Types of Errors

Measurement errors may be classified as either **random** or **systematic**, depending on how the measurement was obtained (an instrument could cause a random error in one situation and a systematic error in another).

**Random errors** are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device. Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations (see standard error).

**Systematic errors** are reproducible inaccuracies that are consistently in the same direction. These errors are difficult to detect and cannot be analysed statistically. If a systematic error is identified when calibrating against a standard, applying a correction or correction factor to compensate for the effect can reduce the bias. Unlike random errors, systematic errors cannot be detected or reduced by increasing the number of observations.

When making careful measurements, our goal is to reduce as many sources of error as possible and to keep track of those errors that we can not eliminate. It is useful to know the types of errors that may occur, so that we may recognise them when they arise.

#### Common sources of error in physics laboratory experiments:

**Incomplete definition** (may be systematic or random): One reason why it is impossible to make exact measurements is that the measurement is not always clearly defined. For example, if two different people measure the length of the same string, they would probably get different results because each person may stretch the string with a different tension. The best way to minimise definition errors is to carefully consider and specify the conditions that could affect the measurement.

**Failure to account for a factor** (usually systematic): The most challenging part of designing an experiment is trying to control or account for all possible factors except the one independent variable that is being analysed. For instance, you may inadvertently ignore air resistance when measuring free-fall acceleration, or you may fail to account for the effect of the Earth's magnetic field when measuring the field near a small magnet. The best way to account for these sources of error is to brainstorm with your peers about all the factors that could possibly affect your result. This brainstorm should be done **before** beginning the experiment in order to plan and account for the confounding factors before taking data. Sometimes a **correction** can be applied to a result **after** taking data to account for an error that was not detected earlier.



**Environmental factors** (systematic or random): Be aware of errors introduced by your immediate working environment. You may need to take account for or protect your experiment from vibrations, drafts, changes in temperature, and electronic noise or other effects from nearby apparatus.

**Instrument resolution** (random): All instruments have finite precision that limits the ability to resolve small measurement differences. For instance, a meter stick cannot be used to distinguish distances to a precision much better than about half of its smallest scale division (0.5 mm in this case). One of the best ways to obtain more precise measurements is to use a **null difference** method instead of measuring a quantity directly. **Null** or **balance** methods involve using instrumentation to measure the difference between two similar quantities, one of which is known very accurately and is adjustable. The adjustable reference quantity is varied until the difference is reduced to zero. The two quantities are then balanced and the magnitude of the unknown quantity can be found by comparison with a measurement standard. With this method, problems of source instability are eliminated, and the measuring instrument can be very sensitive and does not even need a scale.

**Calibration** (systematic): Whenever possible, the calibration of an instrument should be checked before taking data. If a calibration standard is not available, the accuracy of the instrument should be checked by comparing with another instrument that is at least as precise, or by consulting the technical data provided by the manufacturer. Calibration errors are usually linear (measured as a fraction of the full scale reading), so that larger values result in greater absolute errors.

**Zero offset** (systematic): When making a measurement with a micrometer caliper, electronic balance, or electrical meter, always check the zero reading first. Re-zero the instrument if possible, or at least measure and record the zero offset so that readings can be corrected later. It is also a good idea to check the zero reading throughout the experiment. Failure to zero a device will result in a constant error that is more significant for smaller measured values than for larger ones.

**Physical variations** (random): It is always wise to obtain multiple measurements over the widest range possible. Doing so often reveals variations that might otherwise go undetected. These variations may call for closer examination, or they may be combined to find an average value.

**Parallax** (systematic or random): This error can occur whenever there is some distance between the measuring scale and the indicator used to obtain a measurement. If the observer's eye is not squarely aligned with the pointer and scale, the reading may be too high or low (some analog meters have mirrors to help with this alignment).

**Instrument drift** (systematic): Most electronic instruments have readings that drift over time. The amount of drift is generally not a concern, but occasionally this source of error can be significant.

**Lag time and hysteresis** (systematic): Some measuring devices require time to reach equilibrium, and taking a measurement before the instrument is stable will result in a measurement that is too high or low. A common example is taking temperature readings with a thermometer that has not reached thermal equilibrium with its environment. A similar effect is **hysteresis** where the instrument readings lag behind and appear to have a “memory” effect, as data are taken sequentially moving up or down through a range of values. Hysteresis is most commonly associated with materials that become magnetised when a changing a magnetic field is applied.

**Personal errors** come from carelessness, poor technique, or bias on the part of the experimenter. The experimenter may measure incorrectly, or may use poor technique in taking a measurement, or may introduce a bias into measurements by expecting (and inadvertently forcing) the results to agree with the expected outcome.

## 1.7 Remedial and extension problem

- How many significant digits does  $L = 0.0254\text{m}$  have?
  - 3
  - 4
  - 5
- How do you write  $T = 1.25578\text{ s} \pm 0.1247\text{ s}$  keeping two significant digits in the error?
  - $1.3\text{s} \pm 0.1\text{s}$
  - $1.3\text{s} \pm 0.12\text{s}$
  - $1.26\text{s} \pm 0.12\text{s}$
- What is the relative error for  $v = 12.25\text{m/s} \pm 0.25\text{m/s}$ ?
  - 2%
  - 3%
  - 25%
- What are random errors? How can we minimise these errors?
- Show that  $\frac{1}{2}gt^2$  has the same dimensions of distance.
- What are the limitations of dimensional analysis?
- What are the uses of dimensional analysis? Explain with one example.
- Compute the following, rounding off each answer to the proper degree of accuracy.
  - $4.08 + 16.7$ ;
  - $74 \times 0.064$ ;
  - $8.72 - 2.8$ ;
  - $(0.8)^2$
- Answer each question yes or no. Must two quantities have the same dimensions:
  - if you are adding them?
  - If you are multiplying them?
  - If you are subtracting them?
  - If you are dividing them?
  - If you are equating them?
- What are the missing words in the following statements?

- (a) The dimensions of velocity are . .
- (b) The dimensions of force are . .
- (c) Using ‘vector’ or ‘scalar’, (i) mass is a . . . (ii) force is a . . . (iii) energy is a . . . (iv) momentum is a . .
- (d) Linear momentum is defined as . .
- (e) One newton x one metre =.....

**Answer**

1. 3
2. b
3. a
4. **Random errors** fluctuate from one measurement to another. A random error arises in any measurement, usually when the observer has to estimate the last figure possibly with an instrument that lacks sensitivity (poor instrument sensitivity). They may be due to random noise, random external disturbances, and statistical fluctuations (due to data sampling or counting). Random errors are small for a good experimenter and taking the mean of a number of separate measurements reduces them in all cases. A measurement with a small error is precise but it may not be accurate, as there may be a systematic error.
5.  $LT^2T^2 = L$ .
6. See LB Pages 5-6
7. See LB Pages 5-6
8. (a) 20.8                      (b) 4.7                      (c) 5.9                      (d) 0.6
9. **Answer**
  - (a) Yes. Three apples plus two avocados has no definable answer.
  - (b) No. One acre times one foot is one acre-foot, a quantity of floodwater.
  - (c) Yes. Three dollars minus six seconds has no definable answer.
  - (d) No. The gauge of a rich sausage can be 12kg divided by 4m, giving 3kg/m.
  - (e) Yes, as in the examples given for parts (b) and (d). Thus we have (a) yes (b) no (c) yes (d) no (e) yes
10. (a)  $LT^1$                       (b)  $MLT^2$ 
  - (c) i. Scalar                      ii. Vector                      iii. Scalar                      iv. Vector
  - (d) Product of mass and velocity    (e) J (joule)

# Unit 2

## Quantitative analysis of linear motion

### Key unit competence:

By the end of this unit the learner should be able to describe objects in motion in one dimension using the principles of kinematics.

### Learning objectives:

By the end of this unit, learners should be able to;

- ④ Define linear motion.
- ④ State examples of linear motions.
- ④ Explain the difference between instantaneous and average values of speed, velocity and acceleration.
- ④ Derive equations of linear motion.
- ④ Describe the acceleration of a free falling body near the earth's surface.
- ④ Recall the kinematic equations of rectilinear motions.
- ④ Explain effects of air resistance on moving object

### Resources

Metre rulers, stop watches, ticker tape timers, centisecond timers or digital timers, laboratory carts or trolleys, linear air tracks, suitable graph paper for plotting graphs. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

## 2.1 Specific suggested methods / strategies / approaches of the unit

Good teaching methods are those keeping learners motivated and engaged throughout the lesson.

We then suggest observation and demonstration activities, Experiment method, Cooperative learning, Questioning and answers and feedback.

## 2.2 Support on assessment strategies and tasks of assessment

You may use some of activities suggested in the learner's book, use formative assessment throughout this unit during each lesson, ask questions and interact with other learners during activities.

You may also use multiple choice questions or other type of advanced questions at the end of the unit for summative assessment and home works.

## 2.3 Lessons and timing

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	Lessons	Periods
1.	Definition and types of linear motion	1
2.	Equation for uniform acceleration in one direction	3
3.	Acceleration due to gravity and free fall motion	3
4.	Measurement of gravity using a simple pendulum	2
5.	Summative assessment	1

## 2.4 Solutions of unit activities

### Activity 2.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using the illustration from LB/ or using the guidance provided in the LB and help them to draw a suitable conclusion of their findings.

**Suggested answer to questions:**

1. There might be parts of the road which are rectilinear while others are curves. Assist learners to describe them.
2. Rectilinear motion
3. Curvilinear motion
4. Hands of a clock have periodic motion

**2.1.2 Checking my progress**

1. a. Rectilinear motion is the motion that a body moves in a straight path. Example, a plane running on its run way ready to takeoff or landing on airport.  
b. Curvilinear motion is the motion that a body moves when it takes a curved paths or change the direction of motion. Example, a car moving around a banked road.  
c. Rotatory motion is the motion that a body moves around at equal distance from a central point. Example, the motion of one point on wheel of a bicycle.
2. A bird takes a translational motion, i.e both rectilinear and curvilinear motion.
3. Rotatory motion
4. Oscillatory motion, Zig-Zag motion

**Activity 2.2**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1.  $\frac{1m}{t_1}$
2.  $\frac{2m}{t_2}$
3.  $\frac{3m}{t_3}$
4. At the end of the first 2m
5. Increasing on the inclined plane and decreasing on the horizontal part.

**Observation**

The average velocities are different i.e. the velocity is changing with time. The velocity increases as the marble goes down the plane.

## Conclusion

The acceleration of a body is the rate of change of its velocity with time. The SI unit of acceleration is the meter per square second abbreviated as  $ms^{-2}$ , like, velocity, acceleration is a vector quantity.

### 2.2.4 Check my progress

$$1. \quad v_{avg} = \frac{\text{total distance covered}}{\text{total time taken}} = \frac{65 \text{ m}}{3 \text{ s}} = 21.7 \text{ m/s}$$

$$2. \quad v_{avg} = \frac{15 \text{ km}}{0.5 \text{ h}} = 30 \text{ km/h} = 8.3 \text{ m/s}$$

$$3. \quad a = \frac{\Delta v}{t} = \frac{50 \text{ m/s} - 0 \text{ m/s}}{2 \text{ s}} = 25 \text{ m/s}^2$$

$$4. \quad \begin{aligned} v &= at + u \\ &= 4 \times 4 + 0 \\ &= 16 \text{ m/s}^2 \end{aligned}$$

$$5. \quad \begin{aligned} a &= \frac{\Delta v}{\Delta t} \\ \Delta t &= \frac{\Delta v}{a} = \frac{30 \text{ m/s} - 10 \text{ m/s}}{4 \text{ m/s}^2} = 5 \text{ s} \end{aligned}$$

$$6. \quad \begin{aligned} S &= \frac{1}{2} at^2 + ut + S_0 \\ &= \frac{1}{2} \times 6 \times 1^2 + 0 + 0 = 3 \text{ m} \end{aligned}$$

### Activity 2.3

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

$$v = 12 \text{ m/s} = 43.2 \text{ km/h}$$

The total distance is 426m

### Activity 2.4

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

The maximum height reached is  $h_{\max} = 10\text{m}$  and the time taken is  $t = 2.86\text{s}$

### Activity 2.5

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

- ④ You should notice that when you drop the cup, the water no longer spills out of the cup. Can you guess why?
- ④ First off, when you just held the cup and let your finger off the hole, the water was pulled down by gravity and thus water pressure pushes it out the hole.
- ④ So what changes when you drop the cup and water? The cup and water begin falling at the same speed, and are actually weightless as they fall.
- ④ There is no water pressure on the cup as it falls because both the water and the cup are moving at the same speed.

### Activity 2.6

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

### Activity 2.7

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

#### 2.3.4 Checking my progress

$$1. \quad (a) h_{\max} = \frac{u^2}{2g} = \frac{14^2}{2 \times 9.8} = 10 \text{ m} \qquad (b) t_{\text{tot}} = \frac{2u}{g} = \frac{28}{9.8} = 2.85 \text{ s} \approx 3 \text{ s}$$

$$2. \quad (a) h_{\max} = \frac{u^2}{2g} = \frac{15^2}{2 \times 9.8} = 11.4 \text{ m} \qquad (b) t_{\max} = \frac{u}{g} = \frac{15}{9.8} = 1.5 \text{ s}$$

$$(c) t_{\text{tot}} = \frac{2u}{g} = \frac{30}{9.8} = 3 \text{ s} \qquad (d) v = -gt_{\text{tot}} + u \\ = -9.8 \times 3 + 15 \\ = -14.4 \text{ m/s}$$



The negative sign means that the ball was on its way back

e) Using the equation of motion:

$$h = -\frac{1}{2}gt^2 + ut \quad \text{or}$$

$$\frac{1}{2}gt^2 - ut + h = 0$$

$$4.9t^2 - 15t + 8 = 0$$

$$t_1 = \frac{15 + \sqrt{15^2 - 4 \times 4.9 \times 8}}{2 \times 4.9} = 2.4 \text{ s}$$

$$t_2 = \frac{15 - \sqrt{15^2 - 4 \times 4.9 \times 8}}{2 \times 4.9} = 0.7 \text{ s}$$

$t_1$  is the time for which the ball passes 8 m when coming back while  $t_2$  is the time that the ball passes 8 m when going upward.

3. (a) Use the equation:

As the stone was released to fall freely,

$$v = gt + u$$

$$= 9.8 \times 10 + 0.2$$

$$= 98.2 \text{ m/s}$$

$$h = \frac{1}{2}gt^2 + ut$$

$$= \frac{1}{2} \times 9.8 \times 10^2 + 0.2 \times 10$$

$$= 492 \text{ m}$$

The stone will be at 508 m from the ground.

(b) As the balloon is moving upward, also the stone's initial velocity is 0.2 m/s upward:

$$v = -gt + u$$

$$= -9.8 \times 10 + 0.1$$

$$= -97.9 \text{ m/s}$$

Negative sign means that, the ball was moving downwards

$$v = -gt + u$$

$$= -9.8 \times 10 + 0.1$$

$$= -97.9 \text{ m/s}$$

Negative sign means that, the position of the stone is reduced of 489 m, hence, it is at 511 m from the ground

**Activity 2.8**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Follow the instructions, complete the table and put answers to questions that will help you to guide the learners.

**2.5 Suggested answers for unit 2 Assessment**

1. Yes. If the velocity of the particle is non zero, the particle is in motion. If the acceleration is zero, the velocity of the particle is unchanging, or is a constant.
2. Yes. If you drop a doughnut from rest ( $v = 0$ ), then its acceleration is not zero. A common misconception is that immediately after the doughnut is released, both the velocity and acceleration are zero. If the acceleration were zero, then the velocity would not change, leaving the doughnut floating at rest in mid-air.
3. No: Car A might have greater acceleration than B, but they might both have zero acceleration, or otherwise equal accelerations; or the driver of B might have tramped hard on the gas pedal in the recent past.
4. Using the equation  $S = \frac{1}{2}gt^2 + ut \Leftrightarrow S = \frac{1}{2}(-9.8)(4)^2 + (15)(4) = -18.48m$

The velocity is given by  $v = gt + u \Leftrightarrow v = (-10)(4)^2 + 15 = -24.24.24m$

The answer you should get is that the base of the cliff is 18.48m below you. In addition, the velocity of the ball is 24.24m/s downward at the base of the cliff.

5. We know that if we drop a coin and a feather from the same height, the coin will reach first the ground. In absence of air resistance all objects fall with the same uniform acceleration and then both objects hit the ground at the same time.
6. Quantities we need:  $v = +35m/s$   $u = +10m/s$   $a = +5m/s$

Formula using:  $t = \frac{v-u}{a}$  hence  $t = \frac{35m/s - 10m/s}{5m/s^2} = 5s$

7. Quantities we need:  $v = -25m/s$   $u = +5m/s$   $a = -10m/s^2$

$$t = \frac{-25m/s - 5m/s}{-10m/s^2} = 3s$$

8. The values you should have used are as follows.

$$v = -14m/s \quad u = +10m/s \quad t = 4s$$

$$a = \frac{-14\text{m/s} - 10\text{m/s}}{4\text{s}} = -6\text{m/s}^2$$

$$9. \quad a = \frac{75\text{km/h} - 0\text{km/h}}{5.0\text{s}} = 4.2\text{m/s}^2$$

$$10. \quad a = \frac{v-u}{\Delta t} \Leftrightarrow v = at + u = 19.30\text{m/s}$$

$$11. \quad v = 10\text{m/s}, a = -10\text{m/s}^2 \text{ and } t = 3\text{s}$$

$$u = v - at = 10 - (10)(3) = 40\text{m/s}$$

$$12. \quad v = \frac{23700}{3600} + 0.92 \times 3.6 = 9.9\text{m/s}$$

## 2.6 Additional information (content)

The kinematic equations are a set of four equations that can be utilised to predict unknown information about an object's motion if other information is known. The equations can be utilised for any motion that can be described as being either a constant velocity motion (an acceleration of  $0\text{m/s/s}$ ) or a constant acceleration motion. They can never be used over any time period during which the acceleration is changing. Each of the kinematic equations include four variables. If the values of three of the four variables are known, then the value of the fourth variable can be calculated. In this manner, the kinematic equations provide a useful means of predicting information about an object's motion if the other information is known. For example, if the acceleration value and the initial and final velocity values of a skidding car is known, then the displacement of the car and the time can be predicted using the kinematic equations. Lesson 6 of this unit will focus upon the use of the kinematic equations to predict the numerical values of unknown quantities for an object's motion.

The four kinematic equations that describe an object's motion are:

### The kinematics equations

$$d = v_i \times t + \frac{1}{2} at^2 \qquad v_f^2 = v_i^2 + 2ad$$

$$v_f = v_i + a \times t \qquad d = \frac{v_i + v_f}{2} \times t$$

There are a variety of symbols used in the above equations. Each symbol has its own specific meaning. The symbol  $d$  stands for the displacement of the object. The symbol  $t$  stands for the time for which the object moved. The symbol  $a$  stands for the acceleration of the object. And the symbol  $v$  stands for the velocity of the object; a subscript of  $i$  after the  $v$  (as in  $v_i$ ) indicates that the velocity value is the initial velocity value and a subscript of  $f$  (as in  $v_f$ ) indicates that the velocity value is the final velocity value.

Each of these four equations appropriately describes the mathematical relationship between the parameters of an object's motion. As such, they can be used to predict unknown information about an object's motion if the other information is known.

## 2.7 Remedial extension and consolidation activities

1. A cheetah is the fastest land mammal, and it can run at speeds of about 101km/h for a period of 20s. The next fastest land animal is an antelope, which can run at about 88km/h for a much longer time. Suppose a cheetah is chasing an antelope, and both are running at top speed.
  - (a) If the antelope has a 40cm head start, how long will it take the cheetah to catch him, and how far will the cheetah travel in this time?
  - (b) What is the maximum head start the antelope can have if the cheetah is to catch him within 20s (at which time the cheetah runs out of breath)?
2. The velocity of sound in air at sea level is about 343m/s. If a person hears a clap of thunder 3.00s after seeing a lightning flash, how far away was the lightning?
3. A man standing at the top of a building throws a ball vertically upward with a velocity of 14m/s. The ball reaches the ground 4.5s later.
  - (a) What is the maximum height reached by the ball?
  - (b) How high is the building?
  - (c) With what velocity will it reach the ground?
4. A stone is thrown upward with a speed of 20m/s. It is caught on its way down at a point 5.0m above where it was thrown. (a) How fast was it going when it was caught? (b) How long did the trip take?
5. What net force is needed to uniformly stop an automobile whose mass is 1500kg, from a velocity of 100km/h to rest, on a distance of 55m?
6. A car starts from rest and is accelerated uniformly at the rate of  $2\text{m/s}^2$  during 20s. It then maintains a constant speed for half a minute. The brakes are then applied and the vehicle uniformly retarded to rest in 10s. Find;
  - (a) The maximum speed reached in km/h

- (b) The total distance covered in meters.  
 (c) The average velocity
7. An automobile with an initial speed of 4.30m/s accelerates at the rate of 3.00m/s<sup>2</sup>. Find the final speed and the displacement after 5.0s.
  8. How far does a car travel in 10s if it undergoes a constant acceleration of 5m/s<sup>2</sup> to the right? Assume the car is initially at rest.
  9. Assume a ball has been thrown upwards with an initial velocity of 20m/s. While it is in the air, it experiences a constant downward acceleration of zero. What is the position of the ball after 2s?
  10. A body undergoing uniform acceleration has its velocity increased from 20cm/s to 50 cm/s, while it travels 500cm. What is its acceleration and how long does it take to travel the 500cm?
  11. A boy throws a stone vertically into the air and it returns to his hands in 4s.
    - (a) What was the velocity when it was thrown into the air?
    - (b) How high did the stone rise?
    - (c) What distance did it travel during the second (or quarter) of its flight?
  12. An aero-plane lands on the runway with a velocity of 50m/s and decelerates at 10m/s<sup>2</sup> to a velocity of 20m/s. Calculate the distance travelled on the runway.
  13. A car moving with a velocity of 15m/s accelerates uniformly at the rate of 2m/s<sup>2</sup> to reach a velocity of 20m/s. Find the time taken and the distance travelled in this time.

### Answers for additional problems

1. a) The speeds are constant, so  $x = vt$ . Both animals run for the same time, but the cheetah must run 40m extra. Thus  $x_c = v_c t$  and  $x_A = v_A t$

$$v_c t = v_A t + 40 \Leftrightarrow t = \frac{40}{x_c - x_A} = \frac{40}{45.1 - 39.3} = 6.9s$$

- b) Let  $h$  = head start distance and  $t = 20s$  for both animals. If the cheetah is to catch the antelope, then

$$x_c = x_A + h$$

$$\text{so } v_c t = v_A t + h \Leftrightarrow h = (v_c - v_A)t = (45.1 - 39.3)(20) = 116m$$

2. The velocity of light is so great compared with the velocity of sound that the time needed for the light of the flash to reach the person can be neglected. Hence  $s = vt = 343 \times 3 = 1029m = 1.03km$

3. a) Maximum height means  $v = 0$ . Then using  $v = v_i + at$ , and a vertical axis with origin at the top of the building pointing upward, with  $v = 0$ ,  $a = -9.8\text{m/s}^2$  and  $v_i = 14\text{ m/s}$ , the time to reach maximum height is  $t = -\frac{v_i}{a} = -\frac{14}{-9.8} = 1.43\text{s}$

Now, using  $y = y_i + v_i t + \frac{1}{2}at^2$

With the same vertical axis already mentioned,  $y_i = 0$ ,  $v_i = +14\text{m/s}$ ,  $a = -9.8\text{ms}^2$ ,

We get  $y_{\text{max}} = 0 + (14)(1.43) + (-9.8)(1.43)^2 = 10\text{m}$

- b) Keeping the same axis as before, and using  $v_i = +14\text{ m/s}$ ,  $a = -9.8\text{ m/s}^2$  and  $t = 4.5\text{s}$  in  $y = y_i + v_i t + \frac{1}{2}at^2 = 14 \times 4.5 - 49(4.5)^2 = -36.2\text{m}$

The result is negative as expected since the ground is in the negative side of the axis. The height of the building is then 36.2m.

- c) The velocity reaching the ground is  $v = u + gt = 14 - 9.8(4.5) = -30.1\text{m/s}$

4. a) We use:

$$v^2 - u^2 = 2gh \Leftrightarrow v \pm \sqrt{2gh + u^2} = \pm \sqrt{2(-9.80)(50) + 20^2} = -17\text{m/s}$$

We take the negative sign because the stone is moving downward, in the negative direction, at the final instant.

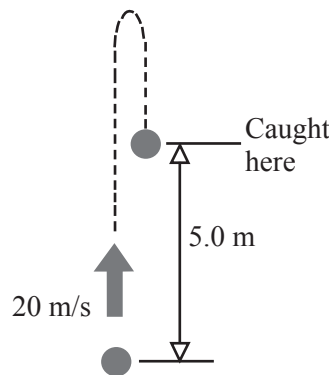


Fig. 2.1

- b) We use  $t = \frac{v - u}{g} = \frac{-17 - 20}{-9.80} = 3.8\text{s}$

5. To use  $F = ma$ , the acceleration should be calculated first. It is assumed that the movement is along the +x axis. The initial velocity is  $v_0 = 100\text{ km/h} = 28\text{m/s}$ , the final velocity is  $v_0 = 0$ , and the displacement is  $x = 55\text{m}$ .

From the kinematics equation  $v^2 = u^2 + 2ax$ , finding a:

$$a = \frac{v^2 - u^2}{2x} = \frac{0 - 28^2}{2 \times 55} = -7.1 \text{ m/s}^2$$

The necessary force is then:  $F = ma = (1500\text{kg})(-7.1\text{m/s}^2) = -1.1 \times 10^4\text{N}$ , acting in the  $-x$  sense.

6. a.  $v_1 = u + at_1$  but  $u = 0$  as the car starts from the rest.

$$\text{Thus } v_1 = at_1 = 2 \times 20 = 40 \text{ m/s}$$

b. The motion of the car comprises three phases:

$$\text{First phase: UARM (OA): } x_1 = \frac{at_1^2}{2} = \frac{2(20)^2}{2} = 400 \text{ m}$$

$$\text{Second phase: MRU (AB): } x_2 = v_2 t_2 = 40 \times 30 = 1200 \text{ m but } v_2 = v_1$$

Third phase: UARM (BC):

$$\begin{cases} x_3 = \frac{a_3 t_3^2}{2} + v_2 t_3 \\ v_3 = a_3 t_3 + v_2 = 0 \end{cases} \Leftrightarrow \begin{cases} x_3 = \frac{(-4)(10)^2}{2} + 40 \times 10 = 200 \text{ m} \\ a_3 = -\frac{v_2}{t_3} = -\frac{40}{10} = -4 \text{ m/s}^2 \end{cases}$$

$$\begin{aligned} \text{The total distance travelled by the car is } x &= x_1 + x_2 + x_3 = 400 + 1200 + 200 \\ &= 1800 \text{ m} \end{aligned}$$

### Alternative graphical solution

The graph below shows that the distance moved is numerically equal to the area of the area under the velocity-time graph in which OA, AB and BC represent the three stages of the motion respectively.

The area under velocity-time graph is numerically equal to the area of the figure OABC (trapezium):

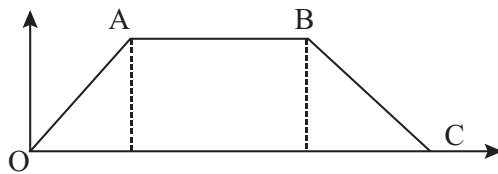


Fig.2.2: Velocity - Time graph

$$\text{Area OABC: } A_{OABC} = \frac{1}{2}(AB + OC) \times AD = \frac{1}{2}(30 + 60) \times 40 = 1800 \text{ m}$$

$$\text{(c) The average velocity will be given by: } \bar{v} = \frac{1800}{20 + 30 + 10} = 30 \text{ m/s}$$

7.  $v = 4.30 + 3.00 \times 5 = 19.3 \text{ m/s}$

$$S = \frac{1}{2} \times 3.00 \times 5.002 + 4.3 \times 5.0 = 59 \text{ m An}$$

8. Since it is always good to draw a picture, I have included one below.

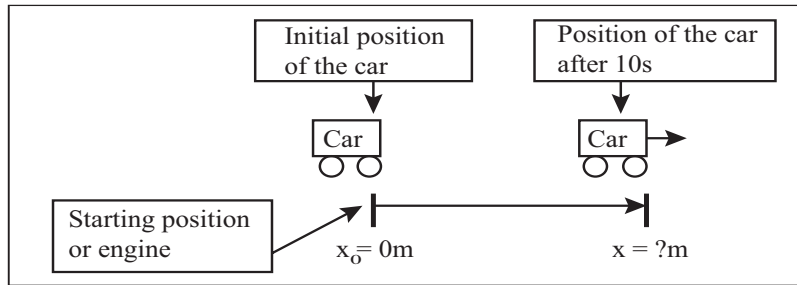


Fig. 2.3

Putting in the following values, we will be able to get the correct answer

$$S_0 = 0m$$

$$u = 0m/s \quad \text{we have } S = om + (0m/s \times 10s) + \frac{1}{2} \times 5m/s^2 \times 10^2 = 250m$$

$$a = +5m/s^2$$

$$t = 10s$$

Therefore, the answer is that the car is 250 m away from its initial position after undergoing a constant acceleration of 5 m/s<sup>2</sup> to the right for 10 s.

9. The values you should have used are as follows

$$u = 20m/s \quad a = -10m/s^2 \quad t = 2s \quad x_0 = 250m$$

$$x = 0m + (20m/s)(-10m/s^2) + \frac{1}{2}(-10m/s^2)(2s)^2 = 20m$$

10. Here we use the equation:  $v^2 - u^2 = 2as$ , because it relates with distance in the absence of time. So  $50^2 - 20^2 = 2a500$  gives  $a = 14.28m/s$

11. a) Using the equation  $v = at + u$ , at maximum height,  $v = 0$ ,  $a = -10m/s^2$  and  $t = 2s$  (i.e. half way through). This gives  $u = 20m/s$

- b) Using  $v^2 - u^2 = 2as$ , at a maximum height  $v = 0$  and  $u = 20m/s$ . This gives  $s = 20m$

c) For 1s,  $s = \frac{1}{2} \times (-10) \times 1^2 + 20 \times 1 = 15m$

For the first 2s,  $s = \frac{1}{2} \times (-10) \times 2^2 + 20 \times 2 = 20m$

In the second second, the stone traveled  $20 - 15 = 5m$

12.  $u = 50m/s \quad v = 20m/s \quad a = -10m/s^2$

No time is mentioned. So we use  $v^2 - u^2 = 2a(S - S_0) \Rightarrow S = 105m$

13. Using  $v = at + u \Rightarrow t = 2.5s$

Using  $v^2 - u^2 = 2aS \Rightarrow S = 43.75m$



# Unit 3

## Frictional Force

### Key unit uompetence:

By the end of this unit the learner should be able to define, explain and describe forces and their effects.

### Learning objectives:

By the end of this unit, Learners should be able to;

- State and explain the nature of frictional force.
- Describe types of frictional forces.
- Explain effects of frictional force.
- Discuss advantages and disadvantages of frictional forces.
- Determine the coefficient of friction.
- Describe technological applications of frictional force.
- Convey the nature of frictional force.
- Measure static and dynamic friction.
- Identify factors affecting frictional force.

### Resources:

Wooden block (with smooth and rough surfaces) spring balance, thread, single pulleys and standard mass, lubricants. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent..

### 3.1 Specific suggested methods/strategies/approaches of the unit

Good teaching methods are those keeping learners motivated and engaged throughout the lesson. We then suggest observation and demonstration activities, Question-answer sessions with immediate feedback.

Project-based instruction: Here, you may give work to be done in groups and ask learners to find and explain applications of friction force.

### 3.2 Support on assessment strategies and tasks of assessment

Use question-answer sessions, pair work and group work activities as a means of observing and evaluating your learners throughout this unit for formative assessments.

Good classroom practices such as direct and immediate feedback will help you to get a view of both individual and class performances while learners learn how well they have done.

You may also use multiple choice questions, completing statements and advanced questions at the end of the unit for summative assessments.

### 3.3 Lessons and periods

This unit consists of 9 lessons and each lesson should be covered in 40 minutes.

	<b>Lessons</b>	<b>Periods</b>
1.	Nature and types of friction forces	1
2.	Laws of solid friction	2
3.	Effects of friction	1
4.	Advantages and disadvantages of friction force	1
5.	Factors affecting friction and how to reduce it	2
6	Other resistance forces	1
7	Summative assessment	1

## 3.4 Solutions of unit activities

### Activity 3.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

#### Question/Answer:

Ask learners questions and have them raise their hands to respond. Write answers on the board and discuss as a class.

1. Have learners push on a heavy object (such as the teacher's desk). Ask learners what is balancing the force they exert on the desk. (Answer: Friction force balances the force they put on the desk.)
2. Ask learners what will happen if the force they exert on the desk becomes unbalanced with the friction force between the desk and the floor. (Answer: The desk will start moving.)
3. Ask learners to try to define friction. (Answer: The force that resists relative motion between two bodies in contact.) Have them give words that would describe friction. Write these words on the board. Work through the discussion with them until the class comes up with a good definition.
4. Ask learners if friction is a good thing or a bad thing; discuss as a class. (Answer: It is both good and bad! It is great for slowing things down, but it can also cause wear and tear in our bodies and in machines.)
5. As a class, brainstorm ideas to reduce friction between the desk and the floor. Have learners plan a way to reduce this friction. (One possible solution: Pour cooking oil on the floor beneath the desk.)

#### Activity 3.1: Experiencing the friction while pushing a desk

1. Have learners push on a heavy object (such as the teacher's desk). Ask learners what is balancing the force they exert on the desk. (Answer: Friction force balances the force they put on the desk.)
2. Ask learners to try to define friction. (Answer: The force that resists relative motion between two bodies in contact.) Have them give words that would describe friction. Write these words on the board. Work through the discussion with them until the class comes up with a good definition.
3. Ask learners if friction is a good thing or a bad thing; discuss as a class. (Answer: It is both good and bad! It is great for slowing things down, but it can also cause wear and tear in our bodies and in machines.)

4. As a class, brainstorm ideas to reduce friction between the desk and the floor. Have learners plan a way to reduce this friction. (One possible solution: Pour cooking oil on the floor beneath the desk.)

### 3.1.6 Check my progress

1. b.            2. c            3. d            4. a
5. **Advantages:** Friction is very important because it enables us to move. If there was no friction, our feet would slip, just as they do on smooth surface. Friction also enables us to write, to make fire, the brakes of cars or bicycles use friction to slow them down.

**Disadvantages:** It is also a nuisance because it wears the soles of our shoes and the car tyres, causes the unnecessary heat and undesirable noise, lowers efficiency of machines.

In a machine such as a bicycle, friction hinders the wheels from turning freely. This is also true in other machines like cars, lorries, buses. This means that they use more fuel in order to move because they have to Overcome friction.

### Activity 3.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Tension force
2. Force extend by the rope when a mass is raised by the rope, etc

### Activity 3.3

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Reaction of the meter ruler on the weight of books and reaction of the wooden block weight of books and the meter ruler applied on the wooden blocks, on the weight of books and meter ruler
2. The reaction is equal the weight of the books.

### Activity 3.4

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. The trees tend to be bent
2. Air resistance

### Activity 3.5

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Weight of the stone and resistive force of spring(elastic force)
2. Resistive force

### Activity 3.6

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. If a person is pushing a desk (Fig 3.8) across the room, then there is applied force acting upon the object.
2. Force  $F_p$  applied by the man and the resistive force  $f$  exerted by the inclined plane.
3. Action force  $F_p$

## 3.5 Suggested answers for End Unit 3 Assessment

1. (a) motion      (b) roughness    (c) unnecessary sound, heat  
(d) reduces      (e) less
2. (c) Static, sliding, rolling
3. (a) Wet marble floor, dry marble floor, newspaper, towel.
4. The direction of friction force should in opposite direction to the direction of motion. (You can use a diagram to show this).
5. It would be difficult to move on it due to less friction on the wet marble floor
6. Spikes on sports shoes helps athletes to move without slipping down as the friction force is very high.
7. Shema will use more effort than Ineza, as the Shema's box is very heavy, and the more pressing force, the more is the friction force.

8. When the body is not in motion, the friction force is equal but opposite to the applied force. Then, when the body starts to move, the friction force falls down to a new force (sliding friction force) which is less than the static friction force.
9. Friction force is a friend as it helps us to walk, to make fire, to produce music (violin)... Friction force is a foe because it tears the soles of our shoes or wheel of vehicles, produces heat, produces unnecessary sound, ...
10. They must heavy special shape in order to reduce friction force.
11. Consider the solution number 1 of TG (Pg 24 to 25)

$$F_{Gr} = mg = (5 \text{ kg})(9.8 \text{ m / s}^2) = 49 \text{ N}$$

12. When the velocity is constant,  $a = 0 \text{ m/s}^2$  and  $F_{\text{net}} = 0\text{N}$

Since the mass is known,  $F_{\text{grav}}$  can be found ( $F_{\text{grav}} = mg = (10\text{kg})(9.8\text{m/s}^2) = 98\text{N}$ ).

Since there is no vertical acceleration, normal force = gravity force. Once  $F_{\text{norm}}$  is known,  $F_{\text{frict}}$  can be found using  $F_{\text{frict}} = \mu F_{\text{nor}} = (0.2)(98\text{N}) = 19.6\text{N}$

Since there is no horizontal acceleration,  $F_{\text{frict}} = F_{\text{appl}} = 19.6\text{N}$

13.  $F_{\text{net}}$  can be found using,  $F_{\text{net}} = ma = (5\text{kg})(2\text{m/s}^2) = 10\text{N}$ , right.

Since the mass is known,  $F_{\text{grav}}$  can be found:  $F_{\text{Gra}} = mg = (5\text{kg})(9.8\text{m/s}^2) = 49\text{N}$

Since there is no vertical acceleration, the normal force equals the gravity force.

Once  $F_{\text{norm}}$  is known,  $F_{\text{frict}}$  can be found using  $F_{\text{frict}} = \mu F_{\text{nor}} = (0.1)(49\text{N}) = 4.9\text{N}$

Since the  $F_{\text{net}} = 10\text{N}$ , right, the rightward force ( $F_{\text{appl}}$ ) must be 10N more than the leftward force ( $F_{\text{frict}}$ ); thus,  $F_{\text{appl}}$  must be 14.9N.

14. Since there is no vertical acceleration, normal force = gravity force. Each of these forces can be determined using the equation:

$$F_{\text{Gra}} = mg = (0.765\text{kg})(9.8\text{m/s}^2) = 7.49\text{N}$$

The force of friction can be determined using the equation

$$F_{\text{frict}} = \mu F_{\text{nor}} = (0.410)(7.497) = 3.0737\text{N}$$

The  $F_{\text{net}}$  is the vector sum of all the forces: 4.25 N, right plus 3.0737N, left = 1.176N, right.

$$\text{Finally, } a = \frac{F_{\text{net}}}{m} = 1.54\text{m / s}^2$$

15.  $F_{\text{net}}$  can be found using,  $F_{\text{net}} = ma = (4\text{kg})(2.5\text{m/s}^2) = 10\text{N}$ , right.

Since the mass is known,  $F_{\text{grav}}$  can be found:  $F_{\text{Gra}} = mg = (4\text{kg})(9.8\text{m/s}^2) = 39.2\text{N}$

Since there is no vertical acceleration, the normal force equals the gravity force.

Since the  $F_{\text{net}} = 10\text{N}$ , right, the rightward force ( $F_{\text{app}}$ ) must be 10N more than the leftward force ( $F_{\text{frict}}$ ); thus,  $F_{\text{frict}}$  must be 15N.

$$\text{Finally, } \mu = \frac{F_{\text{frict}}}{F_{\text{norm}}} = \frac{15\text{N}}{39.2\text{N}} = 0.383$$

### 3.6 Additional information (content)

#### Types of Forces

A force is a push or pull acting upon an object as a result of its interaction with another object. There are a variety of types of forces. Previously in this lesson, a variety of force types were placed into two broad category headings on the basis of whether the force resulted from the contact or non-contact of the two interacting objects.

Contact Forces	Action-at-a-Distance Forces
Frictional Force	Gravitational Force
Tension Force	Electrical Force
Normal Force	Magnetic Force
Air Resistance Force	
Applied Force	
Spring Force	

Table 3.1: Types of force

These types of individual forces will now be discussed in more detail. To read about each force listed above, continue scrolling through this page. Or to read about an individual force, click on its name from the list below.

Type of Force (and Symbol))	Description of Force
<b>Applied Force</b> $F_{\text{app}}$	An applied force is a force that is applied to an object by a person or another object. If a person is pushing a desk across the room, then there is an applied force acting upon the object. The applied force is the force exerted on the desk by the person.

<p><b>Gravity Force</b> (also known as Weight)</p> <p><math>F_{\text{grav}}</math></p>	<p>The force of gravity is the force with which the earth, moon, or other massively large object attracts another object towards itself. By definition, this is the weight of the object. All objects upon earth experience a force of gravity that is directed "downward" towards the center of the earth. The force of gravity on earth is always equal to the weight of the object as found by the equation:</p> <p><math>F_{\text{grav}} = m * g</math></p> <p>where <math>g = 9.8\text{N/kg}</math> (on Earth) and <math>m = \text{mass (in kg)}</math></p>
<p><b>Normal Force</b></p> <p><math>F_{\text{norm}}</math></p>	<p>The normal force is the support force exerted upon an object that is in contact with another stable object. For example, if a book is resting upon a surface, then the surface is exerting an upward force upon the book in order to support the weight of the book. On occasions, a normal force is exerted horizontally between two objects that are in contact with each other. For instance, if a person leans against a wall, the wall pushes horizontally on the person.</p>
<p><b>Friction Force</b></p> <p><math>F_{\text{frict}}</math></p>	<p>The friction force is the force exerted by a surface as an object moves across it or makes an effort to move across it. There are at least two types of friction force - sliding and static friction. Though it is not always the case, the friction force often opposes the motion of an object. For example, if a book slides across the surface of a desk, then the desk exerts a friction force in the opposite direction of its motion. Friction results from the two surfaces being pressed together closely, causing intermolecular attractive forces between molecules of different surfaces. As such, friction depends upon the nature of the two surfaces and upon the degree to which they are pressed together. The maximum amount of friction force that a surface can exert upon an object can be calculated using the formula below:</p> <p><math>F_{\text{frict}} = \mu \cdot F_{\text{norm}}</math></p>



<p><b>Air Resistance Force</b></p> <p><math>F_{\text{air}}</math></p>	<p>The air resistance is a special type of frictional force that acts upon objects as they travel through the air. The force of air resistance is often observed to oppose the motion of an object. This force will frequently be neglected due to its negligible magnitude (and due to the fact that it is mathematically difficult to predict its value). It is most noticeable for objects that travel at high speeds (e.g., a skydiver or a downhill skier) or for objects with large surface areas.</p>
<p><b>Tension Force</b></p> <p><math>F_{\text{tens}}</math></p>	<p>The tension force is the force that is transmitted through a string, rope, cable or wire when it is pulled tight by forces acting from opposite ends. The tension force is directed along the length of the wire and pulls equally on the objects on the opposite ends of the wire.</p>
<p><b>Spring Force</b></p> <p><math>F_{\text{spring}}</math></p>	<p>The spring force is the force exerted by a compressed or stretched spring upon any object that is attached to it. An object that compresses or stretches a spring is always acted upon by a force that restores the object to its rest or equilibrium position. For most springs (specifically, for those that are said to balance “Hooke’s Law”), the magnitude of the force is directly proportional to the amount of stretch or compression of the spring.</p>

Table 3.2: Other types of force

## Confusion of mass and weight

A few further comments should be added about the single force that is a source of much confusion to many learners of physics - the force of gravity. As mentioned above, the force of gravity acting upon an object is sometimes referred to as the **weight** of the object. Many learners of physics confuse weight with mass. The **mass** of an object refers to the amount of matter that is contained by the object; the weight of an object is the force of gravity acting upon that object. Mass is related to how much stuff is there and weight is related to the pull of the Earth (or any other planet) upon that stuff. The mass of an object (measured in kg) will be the same no matter where in the universe that object is located. Mass is never altered by location, the pull of gravity, speed or even the existence of other forces. For example, a 2-kg object will have a mass of 2kg whether it is located on Earth, the moon, or Jupiter; its mass will be 2kg whether it is moving or not (at least for purposes of our study); and its mass will be 2kg whether it is being pushed upon or not.

On the other hand, the weight of an object (measured in Newton) will vary according to where in the universe the object is. Weight depends upon which planet is exerting the force and the distance the object is from the planet. Weight, being equivalent to the force of gravity, is dependent upon the value of  $g$  the gravitational field strength. On the earth's surface  $g$  is  $9.8\text{N/kg}$  (often approximated as  $10\text{N/kg}$ ). On the moon's surface,  $g$  is  $1.7\text{N/kg}$ . Go to another planet, and there will be another  $g$  value. Furthermore, the  $g$  value is inversely proportional to the distance from the center of the planet. So if we were to measure  $g$  at a distance of  $400\text{km}$  above the earth's surface, then we would find the  $g$  value to be less than  $9.8\text{N/kg}$ . (The nature of the force of gravity will be discussed in more detail in a later unit of The Physics Classroom). Always be cautious of the distinction between mass and weight. It is the source of much confusion for many learners of physics.

### 3.7 Remedial extension and consolidation

1. A wooden pallet carrying a load of  $600\text{kg}$  rests on a wooden floor.
  - (a) A forklift driver decides to push it without lifting it. What force must be applied to just get the pallet moving?
  - (b) After a bit of time, the pallet begins to slide. How fast is the pallet moving after sliding under the same force you calculated in part a. for half a second?
  - (c) If the forklift stops pushing, how far does the pallet slide before coming to a stop?

**Solution:** Four forces are acting on the pallet: the downward pull of the earth's gravity, the normal force of the floor pushing up, the forward push of the forklift, and the backward resistance of friction. Weight and normal are equal throughout this example since the floor is level. Friction changes from static to kinetic-static friction since the pallet isn't moving, then kinetic friction once the pallet gets going. The push also changes from nothing to the value needed to get the pallet moving, and then back to nothing after  $0.5$  seconds of motion.

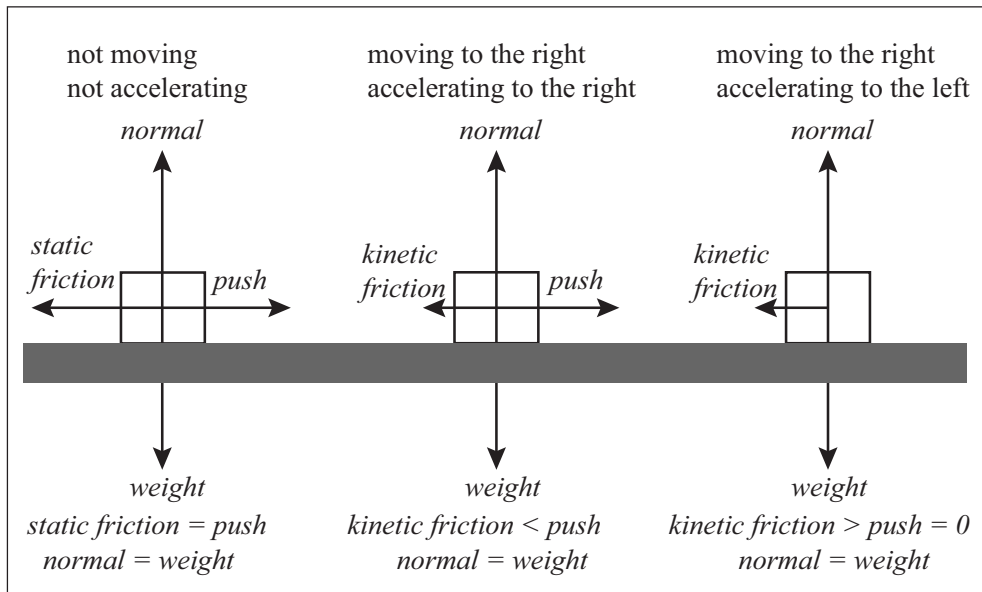


Fig.3.3: Friction force diagrams

- (a) To get the pallet started, the driver must push it with a force equal to the maximum static friction.  $P = f_s = \mu_s N = \mu_s mg$ ;  $P = (0.28) (600 \text{ kg}) (9.8 \text{ m/s}^2)$ ;  $P = 1,646 \text{ N}$
- (b) Once the pallet starts moving, the coefficient of friction drops from its static value to its kinetic value.  $f_k = \mu_k N = \mu_k mg$ ;  $f_k = (0.17) (600 \text{ kg}) (9.8 \text{ m/s}^2)$ ;  $f_k = 1,000 \text{ N}$

But the forklift is still pushing with 1,650N of force. Thus we have a non zero net force.  $\Sigma F = P - f_k$ ;  $\Sigma F = 1646 \text{ N} - 1000 \text{ N}$ ;  $\Sigma F = 646 \text{ N}$

A net force causes acceleration.  $a = \Sigma F/m$ ;  $a = (646 \text{ N})/(600 \text{ kg})$ ;  $a = 1.08 \text{ m/s}^2$

Acceleration goes with a change in velocity.  $v = v_0 + at$ ;  $v = (1.08 \text{ m/s}^2) (0.5 \text{ s})$ ;  $v = 0.54 \text{ m/s}$

- (c) Once the forklift stops pushing, kinetic friction becomes the net force. This net force will cause an acceleration opposite the direction of motion. When one vector is opposite another, one of the two needs to be negative. The convenient thing to do for this problem is to let friction be the negative one.

$$a = \Sigma F/m = f_k/m; a = (-1,000 \text{ N}) / (600 \text{ kg}); a = -1.67 \text{ m/s}^2$$

Pick the appropriate equation of motion  $v_2 = v_0^2 + 2a\Delta s$

Eliminate the zero term (final velocity), solve for distance, substitute, and calculate. Watch how the negative signs disappear. This has to happen. An object moving forward should be displaced forward.

$$\Delta S = \frac{-v_0^2}{2a}$$

$$\Delta S = \frac{-(0.54\text{m/s})^2}{2(-1.67\text{m/s}^2)} = 0.087\text{m}$$

2. Determine the following quantities for a car driving on a level surface with a coefficient of static friction of  $0.75(\frac{3}{4})$  and a coefficient of kinetic friction of  $0.67(\frac{2}{3})$ .
- Determine the car's maximum starting acceleration with and without "burning rubber". How do these two methods of starting a car compare?
  - Determine the car's minimum braking distance with normal brakes and antilock brakes as a function of initial speed. How do these two methods of stopping a car compare?

### Solution

- (a) The net external force propelling a car comes from the friction force between the tyres and pavement. When a driver starts a car by "flooring it" (pressing the accelerator to the floor) the tyres grind on the road producing a smoke of burning rubber and pavement. Since the tyres are slipping, the coefficient of kinetic friction determines the maximum acceleration. Under normal circumstances, however, most drivers are not willing to subject their tyres to such extreme punishment. Typical car tyres rotate over the surface of the road without slipping, thus the coefficient of static friction determines a car's maximum acceleration in most situations.

To solve this problem, set the frictional force on level ground equal to the net force of the second law of motion. Contrary to popular belief, flooring the accelerator is not an effective method of starting a car. Burning rubber is only about 90% as effective as accelerating a car normally from rest.

$$\sum F = ma$$

$$f = \mu mg = ma$$

$$a = \mu g$$

$$a_{\text{burnout}} = \frac{2}{3}(9.8\text{m/s}^2) = 6.54\text{m/s}^2$$

$$a_{\text{normal}} = \frac{3}{4}(9.8\text{m/s}^2) = 7.35\text{m/s}^2$$

- (b) The net external force stopping a car comes from the friction force between tyres and pavement. Stopping a car with ordinary brakes may result in wheel lock; that is, the wheels lock in position and are not able to rotate. When this happens, the tyres skid and the coefficient of kinetic friction determines the braking distance. Cars equipped with an antilock braking system (ABS) have a sensor that releases the brake pads the instant the wheel locks up. After a brief pause the brakes are then quickly re-engaged. If they don't lock up again, all is well. If they do, the ABS releases the brake pads again. These processes can repeat many times a second. In any case, the tyres are not allowed to lock for more than a few milliseconds. The car is then stopped using the force of static friction alone.

To solve this problem, determine acceleration using the displacement-velocity formula of kinematics. Set this equation equal to the formula for acceleration due to the friction derived above.

$$v_0^2 = 2a\Delta s = \mu g \Delta s$$

$$\Delta s = \frac{v^2}{2\mu g}$$

$$\frac{\Delta s_{\text{antilock}}}{\Delta s_{\text{normal}}} = \frac{v^2 / 2\mu_s g}{v^2 / 2\mu_k g} = \frac{\mu_k}{\mu_s} = \frac{3}{4} = 75\%$$

Antilock brakes need 75% of the distance of regular brakes to stop a car traveling at the same speed. This decrease in distance is certainly significant, but doesn't really seem all that great given the high cost of an ABS. In addition to reduced braking distance, however, antilock braking systems also increase performance during extreme braking. Locked brakes are useless for steering. ABS ensures that the wheels retain their static frictional grip on the road, which allows for maneuvering while braking in an emergency.

# Unit 4

## Density and Pressure in Solids and Fluid

### Key unit competence:

By the end of this unit the learner should be able to define pressure and explain factors affecting it.

### Learning objectives:

By the end of this unit, learners should be able to;

- ④ Outline common observations of pressure (ducks web legs, camel's/ elephant's wide pads, heavy lorries have many tyres).
- ④ Define and explain the pressure as a relationship of force acting on a surface area.
- ④ Identify force and area as factors affecting pressure in solids.
- ④ Give the relationship between force, pressure and area.
- ④ Explain how pressure varies with force and area of contact.
- ④ Describe liquid (mercury) in a glass barometer.
- ④ Explain the floating and sinking phenomena using density.
- ④ Explain measurement of atmospheric pressure using liquid in glass barometer.
- ④ Explain the functioning of an aneroid barometer.
- ④ Describe and explain pressure transmission in hydraulic systems.
- ④ Explain functioning of a hydraulic press and hydraulic brakes .

## Resources:

Sponge, nail/pins, wooden surface two identical bricks, fine sand, spring balance, u-tube, tin/cans/plastic bottle with holes on the side (vertical and level). Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

### 4.1 Specific suggested methods/strategies/approaches of the unit

Good teaching methods are those that keep learners motivated and engaged throughout the lesson. We then suggest observation and demonstration activities, and the learners decide whether objects will float or sink according to their density, relative to the surrounding medium. Question-answer sessions with immediate feedback are also good.

### 4.2 Support on assessment strategies and tasks of assessment

Throughout this unit, the formative assessment can be used as it can help the teacher to evaluate skills acquired by his learners before introducing a new lesson.

The teacher may also use multiple choice questions, completing statements at the end of the unit for summative assessment. Some of the advanced questions can be selected and given to learners as home work to be done in groups.

### 4.3 Lessons and timing

This unit consists of 9 lessons and each lesson should be covered in 40 minutes

	<b>Lessons</b>	<b>Periods</b>
1.	Force exerted by a solid on a surface	1
2.	Pressure and its unit	1
3.	Static fluid pressure	2
4.	Atmospheric pressure	2
5.	Archimedes' principle	1
6.	Common observation of pressure	1
7.	Assessment	1

## 4.4 Solutions of unit activities

### Activity 4.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Guide learners in the experiment and after work, ask learners to present the results obtained.

1. Learners will observe the change in the branches of manometer as they lower or make up the manometer in the liquid.
2. The change observed are due to pressure in the liquid
3. Use any material like, a plastic cup, invert it and the let them try to push it down in the liquid.

### 4.1.3 Check my progress

1. Pressure in solids depends on the pressing force (F), area (A) on which the force presses and the nature of the body.
2. Before cutting vegetables, before cutting meat, before fixing a nail into a tree or a wall, they have to be sharpened in order to increase pressure.
3. Every solid when laid on a surface area, exert pressure due to its pressing force (weight) and its base area

$$p = \frac{F}{A} = \frac{100 \text{ N}}{0.25 \text{ m}^2} = 400 \text{ Pa}$$

$$p = \frac{F}{A} = \frac{mg}{A} = \frac{1 \text{ kg} \times 9.8 \text{ m/s}^2}{0.02 \text{ m}^2}$$

$$= \frac{9.8 \text{ N}}{0.02 \text{ m}^2} = 490 \text{ Pa}$$

### Activity 4.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Guide learners in the experiment and after work, ask learners to present the results obtained.



**Solution to the activity 4.2**

(Add this text below under the paragraph 2 of the activity 4.2)

1. Learners will observe the change in the branches of manometer as they lower or make up the manometer in the liquid.
2. The change observed are due to pressure in the liquid
3. Use any material like, a plastic cup, invert it and the let them try to push it down in the liquid.

**4.2.1 Check my progress**

1. Pressure in liquids depends on depth and the density of the liquid.  $p = \rho g h$
2. Pressure in liquids increases with depth. The more go deep in a liquid, the more the pressure increases.
3. 
$$p = \rho g h$$

$$= 1030 \text{ kgm}^{-3} \times 9.8 \text{ ms}^{-2} \times 10 \text{ m}$$

$$= 100940 \text{ Pa}$$
4. 
$$p = \rho_{Hg} g h$$

$$= 13600 \text{ kgm}^{-3} \times 9.8 \text{ ms}^{-2} \times 10 \text{ m}$$

$$= 1332800 \text{ Pa}$$

**Solution to activity 4.3**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Guide them when answering to provided questions:

1. Forces pressing the liquid to squirt out are to the atmospheric pressure.
2. The atmosphere is composed by air which has mass. The mass of air over us, presses a force equivalent to its weight, by which create a pressure called atmospheric pressure.

**4.3.4 Check my progress**

1. The atmospheric pressure is the weight exerted by the overhead mass of air on a unit area of surface.
2. Atmospheric pressure depends on different factors including:
  - Altitude
  - Temperature
  - Moisture
  - Etc

1. (a)  $2.4 \text{ atm} = 20665200 \text{ Pa}$   
(b)  $196 \text{ kPa} = 1.93 \text{ atm}$   
(c)  $7.5 \text{ b} = 7.4 \text{ atm} = 750000 \text{ Pa}$
4. As an example, when air is compressed in a vehicle's wheel, it exerts high pressure to overcome the weight of the vehicle.

#### Activity 4.5

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. The water/juice is sucked from the glass
2. The water/juice doesn't suck from the closed bottle because there is not air pressure.
3. If you drink through a drinking straw you are making use of atmospheric pressure. You suck the air inside the straw and therefore the atmospheric pressure outside is greater than the pressure inside, and the liquid is pushed up.

#### Activity 4.6

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Different levels of water.
2. Atmospheric pressure upon the surface of the upper container forces water up the short tube to replace water flowing out of the long tube.
3. Removing an aquarium or petrol from the tank.

#### Activity 4.7

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. If you increase the area (number of tyres) that the load is distributed over, there will be less pressure (stress) on the pavement.
2. The area is increased and its weight is distributed over, there will be less pressure on the soil.
3. Webbed feet are useful on land as well as on water because they allow birds to walk more easily on mud. Most swimming or paddling birds have their legs and feet located at the rear of their body. This adaptation is an advantage on the water it helps to propel the birds along.

4. Those features help them walk across desert sands. So that they are able to walk across sand without sinking. To walk on sand they have a bigger surface area to handle their weight and the objects that are put on it to carry - so they don't sink into the sand. To spread their weight out over the sand, which helps to prevent them from sinking in to it. Camels are adapted to walking long distances in deserts, hence, they have evolved to form large, broad, flat feet. More surface area means less pressure exerted on that surface, and vice-versa as the pressure is distributed on a large area. Because it would give less pressure on the sand which prevents it from sinking.

## 4.5 Suggested answers for unit 4 Assessment

1. b
2. c
3. d
4. b

5.  $F = mg$

$$F = 3 \times 9 = 27N$$

$$p = \frac{F}{A} = \frac{27}{4^2} Pa$$

6. a. Pressure is the force acting normally to the unit area

b) Using relation:  $p = \frac{F}{A}$  and  $A = \frac{bh}{2} = \frac{5m \times 3m}{2} = \frac{15m^2}{2}$

We find.  $p = \frac{F}{A} = \frac{45 \times 2}{15} = 6Pa$

7.  $p = \frac{30}{0.2} = 150pa$

8. a) Pressure is defined as the force acting normally per unit area. The S.I unit for pressure is  $Nm^{-2}$

- b) i) The greatest pressure is exerted when the brick is placed on the smallest area.

Its smallest area is  $A = 3cm \times 4cm = 12cm^2$

$$p = \frac{F}{A} = \frac{3 \times 10}{12 \times 10^{-4}} = 25kPa$$

- ii) The least pressure will be exerted when the brick is placed on the largest area.

Largest area is given by:  $A = 6\text{cm} \times 4\text{cm} = 24\text{cm}^2 = 24 \times 10^{-4} \text{m}^2$

$$p = \frac{F}{A} = \frac{3 \times 10}{24 \times 10^{-4}} = 13\text{kPa}$$

9. Higher heeled shoes



Fig. 4.1: High heeled shoe

10. Copy and fill in the blanks of the missing words:

Pressure tells us how concentrated a .....force.....is. It is measured in ..... Pa.....or ..... $\text{N/m}^2$ ....., and is calculated using the equation:  $p = \frac{F}{A}$  ..... A force of 12 N acting over an area of 2  $\text{m}^2$  causes a pressure of .....6 Pa..... If the area were less, the pressure would be ..... increased ..... The dimensions of velocity are .....  $LT^{-2}$ ..... The dimensions of pressure are .....  $ML^{-2}T^{-2}$ .....

11. The weight of the book:  $W - mg = 0.5 \times 10 = 5\text{N}$

The area of the book:  $A = w \times l = 0.25 \times 0.20 = 0.05$

$$\text{Pressure: } p = \frac{W}{A} = \frac{5}{0.05} = 100\text{Pa}$$

## 4.6 Additional information (content)

### Pressure of solids versus liquids

Pressure is a very important concept in physics. The concept of pressure plays a very important role in applications such as thermodynamics, aerodynamics, fluid

mechanics, deformations and many more. It is vital to have a good understanding of pressure in order to excel in any field that uses pressure as a base concept. In this article, we are going to discuss what pressure is, what pressure on liquids and pressure of solids are, their applications, the definitions of these two, applications of pressure of liquids and pressure of solids, and finally the differences of pressure of solids and liquids.

## Pressure of liquids

To understand the concept of pressure of liquids, one must first understand the concept of pressure in general. The pressure of a static fluid is equal to the weight of the fluid column above the point the pressure is measured. Therefore, the pressure of a static (non-flowing) fluid is dependent only of the density of the fluid, the gravitational acceleration, the atmospheric pressure and the height of the liquid above the point the pressure is measured. The pressure can also be defined as the force exerted by the collisions of particles. In this sense, the pressure can be calculated using the molecular kinetic theory of gasses and the gas equation. The term “hydro” means water and the term “static” means non-changing. This means hydrostatic pressure is the pressure of the non-flowing water. However, this is also applicable to any fluid including gasses. Since the hydrostatic pressure is the weight of the fluid column above the measured point it can be formulated using:

$$P = hdg$$

Where P is the hydrostatic pressure, h is the height of the surface of the fluid from the measured point, d is the density of the fluid and g is the gravitational acceleration. The total pressure on the measured point is the unison of the hydrostatic pressure and the external pressure (i.e. atmospheric pressure) on the fluid surface. The pressure due to a moving fluid varies from that of a static fluid. **The Bernoulli theorem** is used to calculate the dynamic pressure of non-turbulent incompressible fluids.

## Pressure of solids

The pressure of a solid can also be interpreted using the argument based on liquid pressure. The atoms inside a solid can be considered static. Therefore, no pressure is created by the momentum change of a solid. But the weight of the solid column above a certain point is effective on the said point. Therefore, a pressure inside a solid can appear. However, solids do not expand or contract by large amounts due to this pressure. The pressure on the side of the solid normal to the weight vector is always zero. Therefore, the solid has its own shape unlike liquids, which take the shape of the container.

## 4.7 Remedial extension and consolidation

1. Calculate the pressure produced by a force of 800N acting on an area of 2.0m<sup>2</sup>.

**Answer:** Pressure is defined as force per unit area or;

$$P = F/A$$

$$P = (800N)/(2.0m^2)$$

$$P = 400N/m^2 = 400Pa$$

2. The pressure of a gas contained in a cylinder with a movable piston is 300Pa. The area of the piston is 0.5m<sup>2</sup>. Calculate the force that is exerted on the piston.

**Answer:** Pressure is defined as force per unit area or  $P = F/A$  We multiply both sides of the equation by the area to solve for the force as;

$$F = PA$$

$$F = (300Pa) (0.5m^2)$$

$$F = 150(Pa)m^2 = 150 (N/m^2)m^2$$

$$F = 150N$$

3. A swimming pool of width 9.0m and length 24.0m is filled with water to a depth of 3.0m. Calculate pressure on the bottom of the pool due to the water.

**Answer:** The pressure due to a column of fluid is calculated as the product of the height of the fluid times the density of the fluid times the acceleration due to gravity. For water the density is  $d = 1000kg/m^3$ .

$$\Delta P = dhg$$

$$\Delta P = (1000 kg/m^3)(3.0m) (9.8m/s^2)$$

$$\Delta P = 29400kg m^2/m^3s^2$$

To simplify the units we cancel onemterm in the m<sup>2</sup> term in the numerator and onemterm in the m<sup>3</sup> term in the denominator to get, We know that 1N = 1kg m/s<sup>2</sup> so we can write;

$$\Delta P = 29400kgm/s^2m^2$$

$$\Delta P = 29400N/m^2 = 29400Pa$$

4. What is the pressure on the side wall of the pool at the junction with the bottom of the pool in the previous problem?

**Answer:** According to Pascal's principle, the pressure on the bottom of the pool is the same as the pressure on the side of the pool at the same elevation; that is the pressure outward at the bottom of the pool is the same as the pressure downward at the bottom of the pool or in this case 29400Pa.

5. What is the total force on the bottom of the pool due to the water in the problem 3?

**Answer:** We can calculate the total force on the bottom of the pool in two equivalent ways. We may use the method of problem 2 above employing the pressure we calculated in problem 4.

$$F = P A$$

$$F = (29400\text{Pa}) (9.0\text{m} \times 24.0\text{m})$$

We know that  $1\text{Pa} = 1\text{N/m}^2$  so that we can write;

$$F = 6.35 \times 10^6 (\text{Pa}) \text{m}^2$$

$$F = 6.35 \times 10^6 (\text{N/m}^2) (\text{m}^2) F = 6.35 \times 10^6 \text{N}$$

In the second method we may calculate the total weight of the fluid using the definition of density as mass per unit volume in order to calculate the mass. We start with the definition of density as;

$$d = \frac{m}{v}$$

We multiply both sides of the equation by the volume to obtain the mass.

$$m = dV$$

$$m = (1000\text{kg/m}^3)(9.0\text{m} \times 24.0\text{m} \times 3.0\text{m})$$

$$m = 6.48 \times 10^5 \text{kg}$$

The weight of the water in the pool is calculated as the mass times the acceleration of gravity or;

$$w = mg$$

$$w = (6.48 \times 10^5 \text{kg}) (9.8\text{m/s}^2)$$

$$w = 6.35 \times 10^6 \text{N}$$

6. The pressure of a gas in a cylinder with a movable piston is increased from 40.0kPa to 60.0kPa while the temperature of the gas is held constant. If the original volume of the gas in the cylinder was  $0.9\text{m}^3$ , determine the final volume of the gas after the pressure is increased.

**Answer:** The temperature of the gas remains constant, so we can use Boyle's law to solve for the unknown volume.

$$P_1 V_1 = P_2 V_2$$

Divide both sides of the equation by  $P_2$  to get

$$V_2 = \frac{P_1 V_1}{P_2}$$

$$V_2 = (40.0\text{kPa}(0.90\text{ m}^3))/(60.0\text{kPa}) \quad V_2 = 0.60\text{m}^3$$

This conforms to our expectations that an increase in pressure should result in a decrease in the volume.

7. A block of wood of mass 3.5kg floats in water. Calculate the buoyant force on the block.

**Answer:** The wooden block is floating, so the buoyant force is equal to the weight of the block or;

$$F = mg$$

$$F = (3.5\text{kg})(9.8\text{m/s}^2)$$

$$F = 34.3\text{N}$$

8. A floating object displaces  $0.6\text{m}^3$  of water. Calculate the buoyant force on the object and the weight of the object.

**Answer:** According to Archimedes' principle the buoyant force is equal to the weight of the displaced fluid. We know the volume of fluid displaced, so we can calculate the mass of the displaced fluid by the second method used to solve problem 5.

$$m = dV$$

$$m = (1000\text{kg/m}^3)(0.6\text{m}^3)$$

$$m = 600\text{kg}$$

The weight is calculated as the product of mass times the acceleration due to gravity as

$$w = mg$$

$$w = (600\text{kg})(9.8\text{m/s}^2)$$

$$w = 5880\text{N}$$

The buoyant force is equal to the weight of the displaced fluid, so the buoyant force is 5880N. Because the problem stated that the object was floating, the



buoyant force must be equal to the weight of the object. Therefore the weight of the object is also 5880N.

9. A pipe of cross sectional area  $80\text{cm}^2$  has a constriction where the area is reduced to  $20\text{cm}^2$ . If the velocity of the fluid in the larger area is  $0.3\text{m/s}$  what is the velocity of the fluid in the constricted region?

**Answer:** The equation of continuity requires that  $V_1 A_1 = V_2 A_2$

We divide both sides of the equation by  $A_2$  to obtain an expression for  $V_2$ .

$$V_2 = \frac{V_1 A_1}{A_2}$$

$$V_2 = (0.3\text{m/s}) (80\text{cm}^2) / (20\text{cm}^2)$$

$$V_2 = 1.2\text{m/s}$$

Note that the velocity is greater in the constricted region of the pipe.

10. The pipe in the previous problem is horizontal. If the pressure in the larger area region is measured as  $20\text{kPa}$ , what is the pressure in the constricted region?

**Answer:** We use Bernoulli's law to calculate the pressure;

$$P_1 + \left(\frac{1}{2}\right) \rho g v^2 + \rho g h_1 = P_2 + \left(\frac{1}{2}\right) \rho g v^2 + \rho g h_2$$

The pipe is horizontal, so  $h_1 = h_2$ , and we may cancel the third term on each side of the equation:

$$P_1 + \left(\frac{1}{2}\right) \rho g v^2 = P_2 + \left(\frac{1}{2}\right) \rho g v^2$$

We subtract the second term on the right hand side of the equation from both sides of the equation to obtain  $P_2$  as:

$$P_1 + \left(\frac{1}{2}\right) \rho g v^2 - \left(\frac{1}{2}\right) \rho g v^2 = P_2$$

Using the information supplied in the statement of the problem and the value of  $V_2$  determined in problem 9, we can solve the problem, but we must be careful to use proper units. Thus the pressure must be expressed in Pascal, not kiloPascal.

$$P_2 = (20 \times 10^3 \text{Pa}) + \left(\frac{1}{2}\right)(1000 \text{kg/m}^3)(9.8 \text{m/s}^2)(0.3 \text{m/s})^2 - \left(\frac{1}{2}\right)(1000 \text{kg/m}^3)(9.8 \text{m/s}^2)(1.2 \text{m/s})^2$$

$$P_2 = (20,000 + 441 - 7056) \text{ Pa}$$

$$P_2 = 13,385 \text{ Pa} = 13.385 \text{ KiloPascal.}$$

# Unit 5

## Measuring liquid Pressure with Manometer

### Key unit competence:

By the end of the unit you should be able to determine the position of the centre of gravity of a body.

### Learning objectives:

By the end of this unit, learners should be able to;

- ④ Describe a manometer.
- ④ Explain the principle of a manometer.
- ④ Explain hydrostatic pressure and atmospheric pressure and their measurement.
- ④ Explain equilibrium of a liquid at rest in a vessel and communicating container.
- ④ Appreciate the benefits of pressure measurement.
- ④ Recognise the application of the same level of liquid in communicating vessels.
- ④ Appreciate the results of measurement of liquid pressure using a manometer.
- ④ Realise the use of pressure in everyday activities (aviation, automobile, sports).

## Resources:

Level indicator, manometer, Pascal's vessel, gas, water, mercury and alcohol. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

### 5.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching methods that keep learners motivated and engaged throughout the lesson. We then suggest observation and demonstration activities, question-answer sessions with immediate feedback.

### 5.2 Support on assessment strategies and tasks of assessment

Throughout this unit, the formative assessment can be used as it can help you to evaluate skills acquired by your learners before introducing a new lesson.

You may also use multiple choice questions, completing statements at the end of the unit for summative assessment.

Some of advanced questions can be selected and given to learners as home work to be done in groups.

### 5.3 Lessons and timing

This unit consists of 9 lessons and each lesson should be covered in 40 minutes.

	<b>Lessons</b>	<b>Periods</b>
1.	Pressure in liquids in equilibrium	1
2.	Equilibrium of liquid at rest	1
3.	Equilibrium of a liquid in communicating vessels	1
4.	Applications of hydrostatics	2
5.	Measuring pressure	2
6.	Summative assessment	2

## 5.4 Solutions of unit activities

### Activity 5.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Atmospheric pressure and pressure of liquid above the holes.
2. Because the pressure of liquid at greater depths is greater than the pressure of lower depths. Then at high depth, the water is falling at greater distance.
3. The pressure at a given depth in a static liquid is a result of the weight of the liquid acting on a unit area at that depth plus any pressure acting on the surface of the liquid.

#### 5.1.4 Check my progress

1. Pressure in liquids depends on the variation of the depth and the density of the liquid.
2. The pressure increases as one goes deep in the sea or lake
3. Unprotected human body can withstand a pressure equivalent to the depth of 45 m in flesh water:

$$\begin{aligned} p &= \rho_w gh \\ &= 1000 \text{ kgm}^{-3} \times 9.8 \text{ m / s}^2 \times 45 \text{ m} \\ &= 441000 \text{ Pa} \end{aligned}$$

$$\begin{aligned} 4. \quad p &= \rho gh \\ &= 1030 \text{ kgm}^{-3} \times 9.8 \text{ m / s}^2 \times 300 \text{ m} \\ &= 3028200 \text{ Pa} \end{aligned}$$

$$\begin{aligned} 5. \quad p &= \rho gh \\ h &= \frac{p}{\rho g} = \frac{196000 \text{ Pa}}{1030 \text{ kg / m}^3 \times 9.8 \text{ m / s}^2} = 19.42 \text{ m} \end{aligned}$$

$$\begin{aligned} 6. \quad p &= \rho gh \\ &= 1030 \text{ kgm}^{-3} \times 9.8 \text{ m / s}^2 \times 10 \text{ m} \\ &= 100940 \text{ Pa} \end{aligned}$$

### **Activity 5.2**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Water balances out to the same level in all of the branches of container regardless of the shape and volume of the branches.
2. Because the gravity is constant, it is one liquid(constant density) and the atmospheric pressure is the same at the end of each branch.

### **Activity 5.3**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Paraffin, glycerin, cooking oil, water.
2. In a container, immiscible fluids are superposed according to their decreasing relative densities from the bottom to the top.

### **Activity 5.4**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

### **Activity 5.5**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Let learners read carefully the instructions and then help them to find correct answers on their discussions and explanations.

### **Activity 5.6: Guide learners in doing this practical activity**

### Additional information (content)

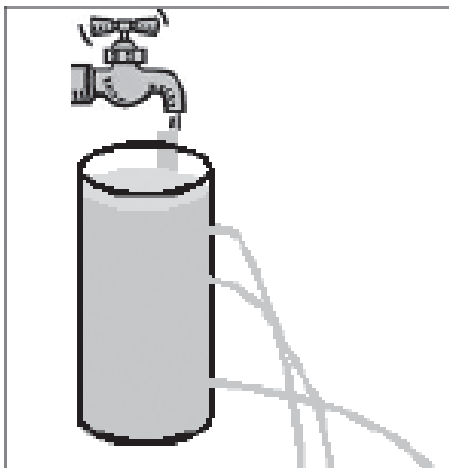


Fig. 5.1

A tall vessel is bored with three holes of equal size at different depth one near the top, the other in the middle and another at the bottom. The vessel is then filled with water using a supply water tap from above. It is observed that water flows furthest and slowest through the uppermost hole hence suggesting that pressure increases with depth. From that experiment we can conclude that:

- The pressure in water depends on the depth below the surface.
- The pressure is perpendicular to the surface of the can.
- At given depth in water, the pressure is the same in all directions.

## 5.5 Suggested answers for unit 5 Assessment

1. (a) If it is closed a manometer. We read 105mm which corresponds to 14.0kPa  
 (b) If it is an opened manometer. We read 1013kPa-655 mm=14.0kPa pressure of the gas.
2. a
3. c
4. The gauge pressure:

$$P_{\text{gauge}} = pgh \Leftrightarrow h = \frac{P_{\text{gauge}}}{\rho g} = \frac{2,5 \times 10^3}{9.8 \times 1.0 \times 10^3} = 0.255\text{m} = 25.5\text{cm}$$

5. A tube in a form of U with uniform section contains mercury. In one of the branches, they pour successively 8cm of water and 6cm of ether. Determine the difference in height between the two free levels; the volume weight of ether is  $711\text{N/m}^3$ , that of mercury is  $1333 \times 10^2 \text{N/m}^3$
6. In a tube in a form of U, they pour mercury. Then in one branch they pour 20cm of water and 20cm of naphtha in the other branch. Calculate the difference in height from the surfaces of separation. Volume weight of naphtha is  $6157\text{N/m}^3$

$$7. \quad p_A + (H_3 + H_2 + H_1)d_A\omega_A = p_B + H_2d_B\omega_B + H_1d_{Hg}\omega$$

$$p_A - p_B = (0.13 \times 0.8 + 0.08 \times 13.6 - 0.31 \times 0.70)9790 = 9545\text{Pa}$$

8. The two surfaces must undergo the same pressure. Let  $h_1$  be the height of oil column. Considering the fundamental principal of hydrostatics the pressure will be provided by:

$$p = \rho_1 g h_1 + p_{atm} = \rho_2 g h_2 + p_{atm} \Leftrightarrow \rho_1 h_1 = \rho_2 h_2$$

$$\text{We get: } 0.10 \times 9800 = h_1 \times 7752 \Rightarrow h_1 = 126 \times 10^{-3} \text{m}$$

Therefore the height of oil column is 12.6cm

9. Data and unknown:  $p = 1000\text{kg/m}^3$   $p = 10\text{m/s}^2$   $h = 2\text{m}$   $p = ?$

Using the relation:  $p = \rho g h = 20\text{kPa}$

10. Water and oil are poured into a U-shaped tube, open at both ends, and do not mix. They come to equilibrium as shown in the figure below. What is the density of the oil?

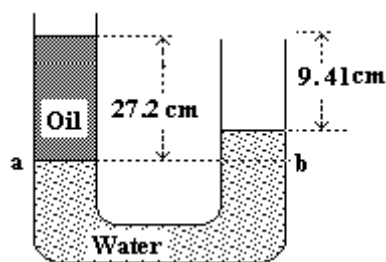


Fig. 5.3: U - Tube manometer

**Solution working to question 10:**

$$P_a = P_b$$

$$h_w = 27.2 \text{ cm} - 9.41 \text{ cm} = 17.8 \text{ cm}$$

$$P_{atm} + \rho_{oil} g h_{oil} = P_{atm} + \rho_w g h_w$$

$$\rho_{oil} g h_{oil} = \rho_w g h_w$$

$$\rho_{oil} h_{oil} = \rho_w h_w$$

$$\begin{aligned} \rho_{oil} &= \frac{\rho_w h_w}{h_{oil}} = \frac{1000 \text{ kg} / \text{m}^3 \times 17.8 \text{ cm}}{27.2 \text{ cm}} \\ &= 654.4 \text{ kg} / \text{m}^3 \end{aligned}$$

## 5.6 Additional information (contents)

Absolute, gauge and differential pressures — zero reference.

Everyday pressure measurements, such as for vehicle tyre pressure, are usually made relative to ambient air pressure. In other cases measurements are made relative to a vacuum or to some other specific reference. When distinguishing between these zero references, the following terms are used:

- ⦿ **Absolute pressure** is zero-referenced against a perfect vacuum, using an absolute scale, so it is equal to gauge pressure plus atmospheric pressure.
- ⦿ **Gauge pressure** is zero-referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure. Negative signs are usually omitted. To distinguish a negative pressure, the value may be appended with the word “vacuum” or the gauge may be labeled a “vacuum gauge.” These are further divided into two sub-categories: high and low vacuum (and sometimes ultra-high vacuum). The applicable pressure ranges of many of the techniques used to measure vacuums have an overlap. Hence, by combining several different types of gauge, it is possible to measure system pressure continuously from 10mbar down to  $10^{-11}$ mbar.
- ⦿ **Differential pressure** is the difference in pressure between two points.

The zero reference in use is usually implied by context, and these words are added only when clarification is needed. Tyre pressure and blood pressure are gauge pressures by convention, while atmospheric pressures, deep vacuum pressures, and altimeter pressures must be absolute.

For most working fluids where a fluid exists in a closed system, gauge pressure measurement prevails. Pressure instruments connected to the system will indicate



pressures relative to the current atmospheric pressure. The situation changes when extreme vacuum pressures are measured; absolute pressures are typically used instead.

Differential pressures are commonly used in industrial process systems. Differential pressure gauges have two inlet ports, each connected to one of the volumes whose pressure is to be monitored. In effect, such a gauge performs the mathematical operation of subtraction through mechanical means, obviating the need for an operator or control system to watch two separate gauges and determine the difference in readings.

Moderate vacuum pressure readings can be ambiguous without the proper context, as they may represent absolute pressure or gauge pressure without a negative sign. Thus a vacuum of 26 inHg gauge is equivalent to an absolute pressure of 30 inHg (typical atmospheric pressure)  $- 26 \text{ inHg} = 4 \text{ inHg}$ .

Atmospheric pressure is typically about 100 kPa at sea level, but is variable with altitude and weather. If the absolute pressure of a fluid stays constant, the gauge pressure of the same fluid will vary as atmospheric pressure changes. For example, when a car drives up a mountain, the (gauge) tyre pressure goes up because atmospheric pressure goes down. The absolute pressure in the tyre is essentially unchanged.

Using atmospheric pressure as reference is usually signified by a g for gauge after the pressure unit, e.g. 70psig, which means that the pressure measured is the total pressure minus atmospheric pressure. There are two types of gauge reference pressure: vented gauge (vg) and sealed gauge (sg).

A vented gauge pressure transmitter for example allows the outside air pressure to be exposed to the negative side of the pressure sensing diaphragm, via a vented cable or a hole on the side of the device, so that it always measures the pressure referred to ambient barometric pressure. Thus a vented gauge reference pressure sensor should always read zero pressure when the process pressure connection is held open to the air.

A sealed gauge reference is very similar except that atmospheric pressure is sealed on the negative side of the diaphragm. This is usually adopted on high pressure ranges such as hydraulics where atmospheric pressure changes will have a negligible effect on the accuracy of the reading, so venting is not necessary. This also allows some manufacturers to provide secondary pressure containment as an extra precaution for pressure equipment safety if the burst pressure of the primary pressure sensing diaphragm is exceeded.

There is another way of creating a sealed gauge reference and this is to seal a high vacuum on the reverse side of the sensing diaphragm. Then the output signal is offset so the pressure sensor reads close to zero when measuring atmospheric pressure.

A sealed gauge reference pressure transducer will never read exactly zero because atmospheric pressure is always changing and the reference in this case is fixed at 1 bar.

To produce an absolute pressure sensor, the manufacturer will seal a high vacuum behind the sensing diaphragm. If the process pressure connection of an absolute pressure transmitter is open to the air, it will read the actual barometric pressure.

### Static and dynamic pressure

Static pressure is uniform in all directions, so pressure measurements are independent of direction in an immovable (static) fluid. Flow, however, applies additional pressure on surfaces perpendicular to the flow direction, while having little impact on surfaces parallel to the flow direction. This directional component of pressure in a moving (dynamic) fluid is called dynamic pressure. An instrument facing the flow direction measures the sum of the static and dynamic pressures; this measurement is called the total pressure or stagnation pressure. Since dynamic pressure is referenced to static pressure, it is neither gauge nor absolute; it is a differential pressure.

While static gauge pressure is of primary importance to determining net loads on pipe walls, dynamic pressure is used to measure flow rates and airspeed. Dynamic pressure can be measured by taking the differential pressure between instruments parallel and perpendicular to the flow. Pitot-static tubes, for example perform this measurement on airplanes to determine airspeed. The presence of the measuring instrument inevitably acts to divert flow and create turbulence, so its shape is critical to accuracy and the calibration curves are often non-linear.

## 5.7 Remedial extension and consolidation

1. Convert a pressure head of 10m of water column to kerosene of specific gravity 0.8 and carbon-tetra-chloride of specific gravity of 1.62. **(Answer:12.5m and 6.17m)**
2. Determine (a) the gauge pressure and (b) The absolute pressure of water at a depth of 9 m from the surface.

**(Answers:** Case (a) as already discussed, gauge pressure is the pressure above the normal atmospheric pressure. Case (b) The standard atmospheric pressure is  $101.213\text{kN/m}^2$

Thus, the absolute pressure as  $P_{abs} = 88.131 + 101.213 = 189.344 \text{ kN/m}^2$

**Answer a) 88.131 kN/m<sup>2</sup> ; (b) 101.213 kN/m<sup>2</sup>**

3. Two pipes on the same elevation convey water and oil of specific gravity 0.88 respectively. They are connected by a U-tube manometer with the manometric liquid having a specific gravity of 1.25. If the manometric liquid in the limb connecting the water pipe is 2m higher than the other; find the pressure difference in two pipes. **(Answer: 10791 Pa)**
4. A two liquid double column enlarged-ends manometer is used to measure pressure difference between two points. The basins are partially filled with liquid of specific gravity 0.75 and the lower portion of U-tube is filled with mercury of specific gravity 13.6. The diameter of the basin is 20 times higher than that of the U-tube. Find the pressure difference if the U-tube reading is 25mm and the liquid in the pipe has a specific weight of  $0.475 \text{ N/m}^3$  **(Answer: 31.51 kPa)**
5. As shown in the figure below water flows through pipe A and B. The pressure difference of these two points is to be measured by multiple tube manometers. Oil with specific gravity 0.88 is in the upper portion of the inverted U-tube and mercury in the bottom of both bends. Determine the pressure difference. **(Answer: 10.131 kPa)**

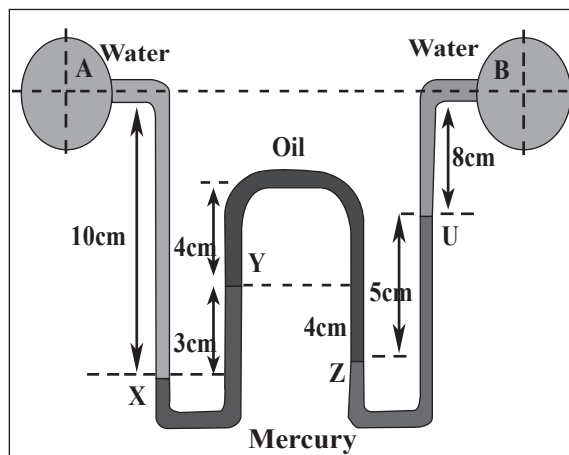


Fig.5.3: Pressure in the tube with non-miscible liquids

# Unit 6

## Pascal's principle and its applications

### Key unit competence:

By the end of this unit the learner should be able to analyse the process of energy transformations and conservation

### Learning objectives:

By the end of this unit, learners should be able to;

- Explain static pressure of fluids at rest.
- Describe transmission of pressure in static fluids.
- Explain Pascal's principle.
- State applications of Pascal's principle. (Hydraulic press, Hydraulic brake, Water Towers, Hydraulic jack.)
- Illustrate Pascal's principle.
- Explain transmission of pressure in fluid at rest.
- Explain the functioning of hydraulic jack.

### Resources:

Pascal's vessels, gas, water, alcohol, hydraulic press, car jack, syringe. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

## 6.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. We suggest observation and demonstration activities.

Divide the class into groups to discuss about the applications of Pascal's principle.

You can also interchange the brainstorming and question-and-answer methods when teaching. When they are in the lab, the teacher can lead (guide) learners to verify the Pascal's principle and let them discover why the principle can be used in elevation of the car. This increases the understanding and increases the creativity of learners.

## 6.2 Support on assessment strategies and tasks of assessment

Throughout this unit, you should use question-answer method as a formative assessment of your learners.

You may use multiple choice questions, completing statements and advanced questions at the end of the unit in the learner's book for summative assessment of your learners.

## 6.3 Lessons and timing

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	<b>Lessons</b>	<b>Periods</b>
1.	Fluid static and pressure in a fluid at rest	1
2.	Transmission of pressure in fluids	1
3.	Pascal's principle and Hydraulic press	3
4.	Hydraulic brakes and Hydraulic lift car	2
5.	Water tower Hydraulic paradox	1
6.	Summative assessment	2

## 6.4 Solutions of unit activities

### Activity 6.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. no
2. water is at rest
3. pressure at bottom of bath = density of water x acceleration due to gravity x depth of water.

### Activity 6.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. If air is not pumped into water bottle, the water falls at a different distance according to the level of hole. But if air is pumped into the water bottle from its opening, the water falls at the same distance.
2. The distances are equal.
3. When air is pumped on the water, the pressure exerted on the water is transmitted equally throughout the water so that water comes out of all the holes with equal force.

#### 6.2.2. Check my progress

$$1. \quad \frac{F_A}{A_A} = \frac{F_B}{A_B}$$

$$F_A = \frac{F_B \times A_A}{A_B} = \frac{16000 \text{ N} \times 50 \text{ cm}^2}{4000 \text{ cm}^2} = 200 \text{ N}$$

$$2. \quad \frac{F_A}{A_A} = \frac{F_B}{A_B}$$

$$F_A = \frac{F_B \times A_A}{A_B} = \frac{3500 \text{ N} \times 60 \text{ cm}^2}{4200 \text{ cm}^2} = 50 \text{ N}$$

$$3. \quad \frac{F_A}{A_A} = \frac{F_B}{A_B} \quad (A_B = 20A_A)$$

$$F_B = \frac{F_A \times A_B}{A_A} = \frac{F_A \times 20A_A}{A_A} = 20 F_A$$

$$F_B = 20 \times 25 \text{ N} = 500 \text{ N}$$

## 6.5 Suggested answers for unit 6 Assessment

$$1. \quad p = 18 \text{ atm} \times \frac{1.013 \times 10^5 \text{ Pa}}{1 \text{ atm}} = 1.82 \times 10^6 \text{ Pa}$$

$$d = 22 \text{ cm} = 0.22 \text{ m} \text{ gives } A = \frac{\pi d^2}{4} = 0.0380 \text{ m}^2$$

$$F = p \times A = 6.92 \times 10^2 \text{ N}$$

$$m = \frac{F}{g} = 7060 \text{ kg}$$

$$2. \quad \begin{aligned} P_t &= P_w + P_a \\ &= \rho gh + P_a \\ &= 1.025 \times 10^3 \times 9.8 \times 45.0 + 101300 = 5.53 \times 10^5 \text{ kPa} \end{aligned}$$

$$3. \quad \frac{F_{out}}{F_{in}} = \frac{A_{out}}{A_{in}} \Rightarrow F_{out} = \frac{F_{in} \times A_{out}}{A_{in}} = \frac{150 \times 4 \times \pi \times (4.00)^2}{\pi \times (0.100)^2} = 9.6 \times 10^5 \text{ N}$$

$$4. \quad p = \rho gh = 1000 \times 10 \times 8.0 = 80 \text{ kPa}$$

$$5. \quad \begin{aligned} A &= l \times w = 10 \text{ m}^2 \quad p = \rho gh = 1000 \times 10 \times 1 = 10^4 \text{ Pa} \\ F &= pA = 10^4 \times 10 = 100 \text{ kPa} \end{aligned}$$

6. 1

7. a) (iii)

b) (iv)

$$8. \quad h_2 g \rho_2 = h_1 g \rho_1 \Rightarrow h_2 = \frac{h_1 \rho_1}{\rho_2} = \frac{1000 \times 100}{13.6 \times 10^3} = 7.35 \text{ m}$$

$$9. \quad p = \rho gh = 1.00 \times 9.80 \times 100 = 9.80 \times 10^5 \text{ Pa} = 9.7 \text{ atm}$$

$$p_{tot} = p_{water} + p_{air} = 9.7 \text{ atm} + 1 \text{ atm} = 10.7 \text{ atm}$$

$$10. \quad (i) \quad p_A = \frac{F}{A} = \frac{8 \times 10}{16 \times 10^{-4}} = 50 \text{ KPa}$$

(ii) Pressure at A = Pressure at B i.e.  $p_A = p_B = 50 \text{ KPa}$  (By Pascal's law)

$$(iii) \quad \frac{x}{1600} = \frac{8}{16} \Rightarrow x = 800 \text{ kg}$$

13. (i)  $p_1 = h_1 g \rho = 0.1 \times 10 \times 1000 = 1 \text{KPa}$

$$p_2 = h_2 g \rho = 0.15 \times 10 \times 1000 = 1500 \text{Pa}$$

(ii) Resultant pressure on the object  $\Delta p = p_2 - p_1 = 500 \text{Pa}$

## 6.6 Additional information (content)

### Activity 1: Crushing can experiment

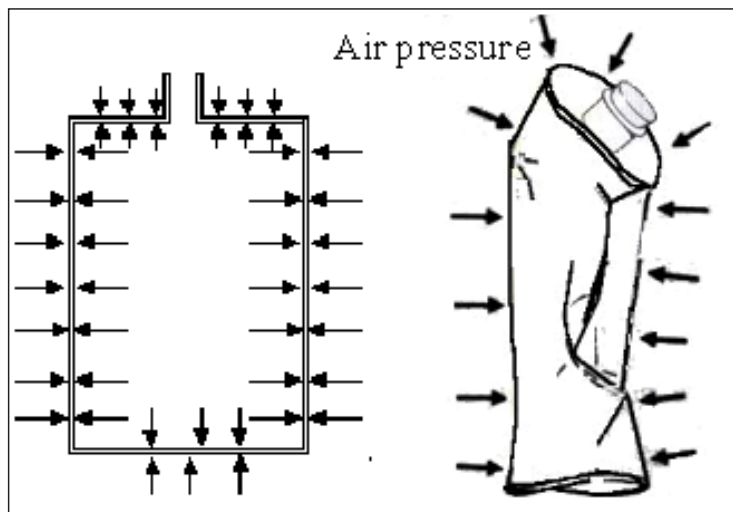


Fig. 6.1: Crushing can

#### Materials:

- Water in a big container,
- Heat source, empty bottle in aluminium
- Convenient pincers or any other tool that can be used to hold hot materials.

#### Procedure:

Put less water in a bottle; boil for a time keeping it with convenient pincers. Put now the bottle in a channel containing cold water.

#### Observations:

We notice that the bottle goes soft on a side. The external air pressure on the can is no longer counterbalanced by the pressure inside, causing the can to collapse.



## 6.7 Remedial extension and consolidation

### Additional information

- The diagram below shows a working model of a hydraulic jack.

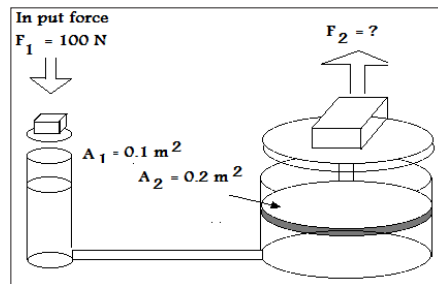


Fig. 6.2

- Why does the output piston rise when the input piston is pushed down?
  - Why does the output piston move a shorter distance than the input piston?
  - What is the oil pressure immediately under the input piston?
  - What is the oil pressure immediately under the output piston?
  - What is the upper force on the output piston?
  - Is this jack a force magnifier or a movement?
  - What change would you make to the hydraulic jack in order to produce a higher out force for the same input force?
- Why is water not suitable for use in a barometer? What property of mercury makes it suitable for use in a barometer?

### Answer:

Water has lower density, so the barometer needs to be 10m tall, Hg is much denser, so much shorter.

- The 70kg learner in figure below balances a 1200kg elephant on a hydraulic lift. What is the diameter of the piston the learner is standing on? (b) A second 70kg learner joins the first learner. How high do they lift the elephant?

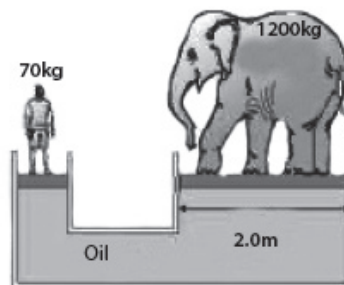


Fig. 6.3

# Unit 7

## Archimedes' principle and atmospheric pressure

### Key unit competence:

By the end of this unit, the learner should be able to explain the working principle of simple machines used in daily life

### Learning objectives:

By the end of this unit, the learner should be able to;

- ④ Explain atmospheric pressure and state its units.
- ④ Explain applications of atmospheric pressure.
- ④ Illustrate Archimedes principle in air.
- ④ Explain buoyant/up thrust force and Archimedes principle in liquid.
- ④ Realise the applications of Archimedes principle in air.
- ④ Explain the existence of atmospheric pressure.
- ④ Explain S.I units of atmospheric pressure.
- ④ Identify instruments for measuring atmospheric pressure.
- ④ Demonstrate applications of atmospheric pressure.
- ④ Explain the Archimedes principle in fluids: up thrust, factors affecting up thrust, state the principle and formula.
- ④ Demonstrate application of Archimedes principle: floating and sinking.
- ④ Discuss Archimedes principle in air
- ④ Discuss applications of Archimedes principle in air. (Aerostat, Baroscope)
- ④ Solve problems on Archimedes' principle.

## Resources:

Mercury and open glass tube about 1 metre long, Hydrometer, Barometers, balloons, Magdeburg hemispheres, metal can/plastic container, drinking straws, spring balance, spirit, water, electronic balance. Once materials are not available, you with learners should improvise the activity in order to make learners more competent.

### 7.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. We then suggest observation and demonstration activities. The teacher will introduce this unit by an activity: measuring of the force of upthrust. Debate, discussion and presentation. Teamwork, problem-solving.

### 7.2 Support on assessment strategies and tasks of assessment

Use formative assessment throughout each lesson in this unit through question-answer sessions and immediate feedback. You may also use multiple choice questions, completing statement and advanced questions at the end of the unit for summative assessment.

### 7.3 Lessons and timing

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	Lessons	Periods
1.	Existence of atmospheric pressure	1
2.	Atmospheric pressure units	1
3.	Instruments for measuring atmospheric pressure	2
4.	Application of atmospheric pressure	2
5.	Principle of buoyancy and factors affecting upthrust	2
6.	Summative assessment	2

## 7.4 Solutions of unit activities

### Activity 7.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. The can will collapse inside as the water cools down.
2. There is unbalance between external pressure and internal pressure.
3. This can be observed in different domain. Take an example of traditional banana beer in a jerrycan; the jerrycan appears tending to crash as it expands because of unbalance between internal pressure and external pressure. (You may provide different examples from those suggested by the learners).

### Activity 7.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

The force caused by atmospheric pressure acting on the surface of the cardboard is greater than the weight of the water in glass.

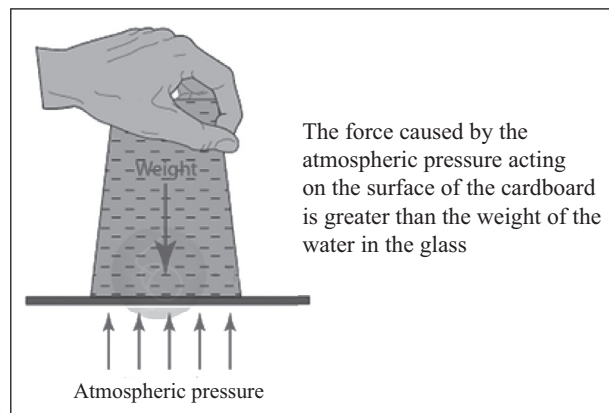


Fig. 7.1

### Activity 7.3

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

The force exerted by the atmosphere on the liquid, helps to make the sucking action easier.

#### Activity 7.4

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

When a rubber sucker is laid on the glass window and pushed slightly, some air gets out and leaves low pressure inside. Then, the unbalance of the pressure inside and the outside pressure (atmospheric pressure) cause the rubber sucker to stick on the glass window or on the phone.

#### Activity 7.5

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

The force exerted by the atmosphere on the liquid, helps to make the liquid coming out, as the liquid surface is pressurised by the atmospheric pressure.

#### Activity 7.6

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. The atmospheric pressure, acting on the surface of the water, forces water past the lower valve into the cylinder. Simultaneously, the water above the plunger is lifted and flows out through the spout. This process is repeated until sufficient water is obtained.
2. This is applied in different fields such as fetching water from the wells in lower altitudes.

#### 7.1.5 Check my progress

1. Rubber sucker as when pressed to a glass, the create unbalance of pressure inside and pressure out ( $p_{in} < p_{out} = p_{atm}$ ), this effect cause them to stick on glasses and get easily to be picked from their location.
2. Due to the unbalance in pressure ( $p_{in} > P_{out}$ ) this causes the door to fly out not inside the plane. The same, for passengers and cargo, the pressure inside starts to push them out.
3. It is too much smaller than the height of water. The column of water is at least 13.5 times the column of mercury.

4.  $p = \rho_w g h_w$

$$h_w = \frac{p}{\rho_w g} = \frac{100\,000 \text{ Pa}}{1000 \text{ kg/m}^3 \times 10 \text{ m/s}^2} = 10 \text{ m}$$

5. (a) The level, goes down  
 (b) The level goes up  
 (c) It falls down to the level of the dish, as that air also exert a pressure equivalent to atmospheric pressure  
 (d) The level falls down due to the fact that atmospheric pressure decreases with altitude.  
 (e) The level falls down, as the temperature increases, the atmospheric pressure decreases.
6. (a) *millibar* ( $mb$ ) =  $100 \text{ Pa}$   
 (b) An isobar, is a line in fluid on which you find the pressure is the same.

#### Activity 7.7

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1.  $w' = w_3$ .
2. The volume of the stone is equal to the volume of water displaced.
3. The weight of water displaced is equal to the upthrust force exerted by the liquid on the stone.

#### Activity 7.8

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Use the provided materials and guide learner to experience the Archimedes principle and assist them to calculate the buoyancy force

$$\text{Buoyance } (B) = \text{weight in air } (W_a) - \text{weight in fluid } (W_f)$$

## 7.2.2.3 Check my progress

$$1. \quad a) \quad W_{Al} = m_{Al} \times g = V_{Al} \times \rho_{Al} \times g \\ = 2 \times 10^{-4} \times 2700 \times 9.8 = 5.3 \text{ N}$$

$$W_k = V_k \rho_k g \\ = 2 \times 10^{-4} \times 800 \times 9.8 = 1.6 \text{ N}$$

$$\text{Upthrust } B = W_k = 1.6 \text{ N}$$

$$b) \text{ Apparent weight } W'_{Al} = W_{Al} - W_k = 5.3 \text{ N} - 1.6 \text{ N} = 3.7 \text{ N}$$

2. The buoyant force is the same since they displaced the same volume of water.

$$3. \quad R.D = \frac{W_a}{B} = \frac{m_s}{m_{oil}} = \frac{20 \text{ g}}{7.6 \text{ g}} = 2.63$$

$$R.D = \frac{\rho_s}{\rho_{oil}} = 2.63$$

$$\rho_s = 2.63 \rho_{oil} = 2.63 \times 0.83 \text{ gcm}^{-3} = 1.96 \text{ gcm}^{-3}$$

$$\rho_s = \frac{m_s}{V_s} \Leftrightarrow V_s = \frac{m_s}{\rho_s} = \frac{20 \text{ g}}{1.96 \text{ gcm}^{-3}} = 10.2 \text{ cm}^3$$

$$4. \quad a) \quad R.D = \frac{50 \text{ g}}{50 \text{ g} - 44 \text{ g}} = 8.33$$

$$b) \quad B = W_a - W_w = (m_a - m_w)g \\ = (50 - 44) \times 10^{-3} \text{ kg} \times 9.8 \text{ m/s}^2 \\ = 0.059 \text{ N}$$

b

$$c) \quad \rho_s = RD \times \rho_w = 8.33 \times 1 \text{ gcm}^{-3} = 8.33 \text{ gcm}^{-3} \\ \rho_s = 8.33 \text{ gcm}^{-3} \quad (\text{cgs}) \\ \rho_s = 8330 \text{ kgm}^{-3} \quad (\text{SI})$$

$$5. \quad a) \quad R.D = \frac{\text{weight of sinker in air}}{\text{loss of weight of sinker in water}} = \frac{W_a}{W_a - W_f} = \frac{m_a}{m_a - m_f} \\ R.D = \frac{m_a}{m_a - m_f} = \frac{20}{20 - 18} = 10$$

b)

$$R.D \text{ of the liquid} = \frac{\text{loss of weight of sinker in liquid}}{\text{loss of weight of sinker in water}} = \frac{W_a - W_{f2}}{W_a - W_{f1}} = \frac{m_a - m_{f2}}{m_a - m_{f1}}$$

$$R.D \text{ of the liquid} = \frac{m_a - m_{f2}}{m_a - m_{f1}} = \frac{20 - 18.2}{20 - 18} = 0.9$$

$$6. \quad R.D \text{ of the liquid} = \frac{\text{loss of weight of sinker in liquid}}{\text{loss of weight of sinker in water}} = 0.9 = \frac{x}{32 - 28.8}$$

$$\frac{x}{32 - 28.8} = 0.9 \quad \Leftrightarrow x = 2.88 \text{ g}$$

The mass of the solid in the liquid :  $m_l = 32 \text{ g} - 2.88 \text{ g} = 29.12 \text{ g}$

7. a) Upthrust is equals to the weight of the floating body

$$W_b = m_{tot}g = (85 + 35) \times 10^{-3} \times 9.8 = 1.176 \text{ N}$$

b)

$$V = \frac{m}{\rho} = \frac{(85 + 35)g}{1g / cm^3} = 120 \text{ cm}^3$$

$$V = Ah \quad \Leftrightarrow A = \frac{V}{h} = \frac{120 \text{ cm}^3}{10 \text{ cm}} = 12 \text{ cm}^2$$

c)

$$V' = \frac{m}{\rho'} = \frac{m}{RD \times \rho_w} = \frac{120 \text{ g}}{1.2 \times 1 \text{ g} / cm^3} = 100 \text{ cm}^3$$

$$h' = \frac{V'}{A} = \frac{100 \text{ cm}^3}{12 \text{ cm}^2} = 8.3 \text{ cm}$$

8. The buoyant force on the statue due to the water is equal to the weight of

$3.0 \times 10^4 \text{ cm}^3 = 3.0 \times 10^{-2} \text{ m}^3$  of water. (for sea water  $\rho = 1.025 \times 10^3 \text{ kg} / \text{m}^3$ )

$$B = \rho_w g V_d = 1025 \times 9.8 \times 3.0 \times 10^{-2} = 300 \text{ N}$$

$$W_{st} = m_{st} \times g = 70 \text{ kg} \times 9.8 \text{ m} / \text{s}^2 = 690 \text{ N}$$

The required force to lift it is  $690 \text{ N} - 300 \text{ N} = 390 \text{ N}$

9. Density of the block =  $900 \text{ kg} / \text{m}^3$  and density of water is  $1000 \text{ kg} / \text{m}^3$ . The block floats in water because its density is less than that of water.



10.

$$V_d = \frac{m_w}{\rho_w} \Leftrightarrow$$

$$m_w = m_{ice} = \rho_{ice} \times V_{ice} = 800 \times 0.9 = 720 \text{ g}$$

$$V_d = \frac{m_w}{\rho_w} = \frac{720}{1.1} = 654.54 \text{ cm}^3$$

The volume of water displaced is equal to the volume of part of ice under water.

The volume of ice above water is  $V'_{ice} = V_{ice} - V_d = 800 - 654.54 = 145.46 \text{ cm}^3$

The fraction of ice above the water is given by:

$$fr = \frac{V'_{ice}}{V_{ice}} = \frac{145.46}{800} = 0.182 = 18.2\%$$

$$11. \quad B = (11. \quad B = (m_{He} + 800) \Leftrightarrow \rho_{air} V g = (\rho_{He} V + 800) g \Leftrightarrow V = \frac{800}{\rho_{air} - \rho_{He}} = 720 \text{ m}^3$$

$$12. \quad a) \quad \text{mass of hydrogen in the balloon} = 15 \times 0.09 = 1.35 \text{ kg}$$

$$b) \quad \text{mass of hydrogen + balloon} = 1.35 + 7.15 = 8.50 \text{ kg}$$

$$c) \quad \text{mass of hydrogen + balloon + equipment} = ((8.50 + x) \text{ kg})$$

$$d) \quad \text{mass of air displaced} = 15 \times 1.3 = 19.5 \text{ kg}$$

$$e) \quad \text{Total mass of floating body} = \text{mass of air displaced.}$$

$$8.5 + x = 19.5 \Rightarrow x = 11 \text{ kg}$$

$$13. \quad \text{The hydrometer density: } \rho = \frac{m}{V} = \frac{45.0}{2.0 \times 25.0} = 0.9 \text{ g/cm}^3$$

Thus, when placed in water, it will come to equilibrium when  $\frac{V_d}{V} = \frac{\rho}{\rho_{H_2O}}$

$$\text{where } V_d \text{ is volume submerged i.e. } V_d = \frac{\rho}{\rho_{H_2O}} V = \frac{0.9}{1} V = 0.9V$$

Since it is of uniform cross section  $V_d = 0.9V = 0.9 \times 25.0 = 22.5 \text{ cm}$  of its length will be submerged.

### Activity 7.9

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

## 7.5 Suggested answers for unit 7 Assessment

### 7.5.1 Suggested answer for quick exercise

1. See learner's book.
2. Archimedes' principle allows us to calculate the mass of floating objects. For instance, if we place a block of wood in water and notice that it displaces 20cc of water (1cc = 1ml), then we know that the mass of 20cc of water must equal the mass of the block since it is floating. Since we know the density of water is 1g/cc and  $20\text{cc} \times 1\text{g/cc} = 20\text{g}$  then we know the mass of the object is 20g.
3. A cubical block made of a certain type of plastic has a density of 0.75g/cm<sup>3</sup>. The density of water is 1.0g/cm<sup>3</sup>. If the block is allowed to float in water, what fraction of the volume of the block would be below the water level?
  - (a) one quarter
  - (b) one half
  - (c) three quarters
  - (d) some other fraction
4. The secret lies in increasing the volume of the displaced water. You are reducing the density by increasing the volume. Remember, an object floats by displacing a volume of fluid which has a weight equal to the object's weight.

A ship will adjust to a depth in water for which its weight just equals the weight of water (and air) displaced. The contribution of the air to the buoyant force of a ship is a negligible amount and, therefore, disregarded. The dirigible is, however, totally supported by the buoyant force supplied by air displacement.

5. A glass beaker is filled with water and placed on a balance. A person holds a finger into the water. The reading on the balance will;
  - (a) go up
  - (b) go down
  - (c) stay the same
  - (d) can't tell.

## 7.6 Additional information (content)

### Vacuum Cleaner

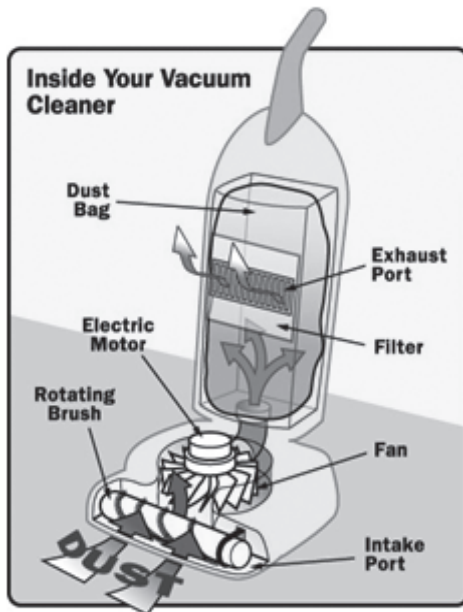


Fig. 7.2: Vacuum cleaner hovering dust from a dirty floor

Vacuum cleaner applies the principle of atmospheric pressure to remove dust particles. When it is switched on, the fan sucks out the air from space inside the vacuum (space A). Space A then becomes a partial vacuum. The atmospheric pressure outside, which is greater, then forces air and dust particles into the filter bag. This traps the dust particles but allows the air to flow through an exit at the back.

### Archimedes' Principle

The principle that the net force on a body submerged (or floating) in a stationary fluid is an upward force equal to the weight of the fluid displaced by the body. This concept, perhaps the oldest stated principle in fluid mechanics, was first put forth by Archimedes in the third century B.C. Archimedes was one of the greatest mathematicians of all time. Not only did he give his name to the principle we will be describing, but he also discovered the number pi, developed a method of calculation similar to today's integral calculus, invented Archimedes screw to lift water (Archimedes screws are found in most modern sewage and irrigation systems today), and discovered the law of levers. He is quoted as saying "Give me a lever long enough and where to stand and I will move the Earth".

Archimedes discovered that floating objects or objects that are fully or partially submerged in a fluid have a certain amount of upthrust, or buoyancy, acting on them. The size of this upthrust is equal to the weight of the fluid that the object displaces. Given that various fluids have differing densities, this upthrust changes accordingly. An object will seem lighter, in salt water than fresh. A ship will actually ride higher in the salt water.

## 7.7 Additional remedial and consolidation problems

1. A submarine floats at rest 50m deep in water. Without using the propeller, how can the captain make it surface? Make it sink?
2. A block of metal having a density of  $9.00\text{g/cm}^3$  has an apparent weight of 180g in water and 135g when submerged in a liquid. What is the density of the liquid?
3. Oil having a density of  $0.80\text{g/cm}^3$  floats on water of density  $1.0\text{g/cm}^3$ . A solid object which has an S.G of 0.90 is dropped into the container. Locate its exact position of rest.
4. A piece of copper whose density is  $8.93\text{g/cm}^3$  weighs 180g in air and 162g when submerged in a certain liquid. What is the density of the liquid?
5. A piece of glass of unknown density loses 43.71g when weighed in water and 80.36g when weighed in concentrated sulfuric acid. What is the specific gravity of the acid?
6. If in the determination of the density of a granular solid, half a cubic centimeter of air is left in the pycnometer when weighed with the solid, will the resulting value of the density be too large or too small? Explain
7. Consider a  $10\text{cm} \times 20\text{cm} \times 50\text{cm}$  ( $V = 0.01\text{m}^3$ ) lead brick that weighs 1100N in the air. How much will it weigh while submerged in water?
8. The water tank is 8m above the tap. What pressure forces the water out from the tap? (Density of water =  $1000\text{kgm}^{-3}$ ).
9. A bargain hunter purchased a gold crown, like the one shown in the figure at a free market. After she gets home, she hangs the crown from a scale and finds its weight to be 8.84N. She then weighs the crown while it is immersed in water, and the scale reads 6.86N. Is the crown made of pure gold? Explain.



Fig. 7.3: Gold crown

**Answer**

$$RD = \frac{\rho_o}{\rho_w} = \frac{W_a}{W_a - W_w} \Rightarrow \rho_o = \frac{7.84}{7.84 - 6.86} = 8.00 \times 10^3 \text{ kg/m}^3$$

We know the density of gold is  $\rho_g = 19.3 \times 10^3 \text{ kg/m}^3$ . Because  $\rho_o < \rho_g$ , the crown is either hallow or not pure gold.

# Unit 8

## Work, Power and Energy

### Key unit competence:

By the end of this unit the learner should be able to relate physical properties of solids, liquids and gases to temperature

### Learning objectives:

By the end of this unit, learners should be able to;

- Recall the knowledge on energy, work and power.
- Explain the terms work, power and energy.
- Describe notations/symbols used in relating work, power and energy.
- Explain the relationship between work, power and energy.
- Appreciate the importance of energy and power for efficiency working of machines.
- Show concern of work as a product of distance and energy.
- Be aware of the social, economical, environmental and technological implications of studying work, energy and power.
- Acquire an analytical mind to critically evaluate work, energy and power-related issues.

## Resources:

Pulleys, Levers, wedge, screws, compound machines (an apple peeler), masses and an inclined plane. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

### 8.1 Specific suggested methods/strategies approaches of the unit

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. We then suggest observation and demonstration activities.

Lecture-based method, questioning technique and immediate feedback. Debate, discussion and presentation. You should make sure that all learners feel supported in their learning so that they can understand the contribution of work, power and energy to society and in their lives.

### 8.2 Support on assessment strategies and tasks of assessment

Throughout this unit, the formative assessment can be used as it can help you to evaluate skills acquired by your learners before introducing a new lesson.

You may also use multiple choice questions, completing statements at the end of the unit for summative assessment. Some of the advanced questions can be selected and given to learners as home work to be done in groups.

### 8.3 Lessons and timing

This unit consists of 9 lessons and each lesson should be covered in 40 minutes.

	Lessons	Periods
1.	Relating Work, Energy and Power	2
2.	Categories of energy in our environment	1
3.	Relation between work, energy and power	2
4.	Measure personal power	2
5.	Summative assessment	2

## 8.4 Solutions of unit activities

### Activity 8.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. To take the box upon the table requires effort as well as taking it down; hence the difference should be that the box gains potential energy as it is being moved upward and lose it as it is being taken down .
2. It takes same energy.

#### 8.1.1 Check my progress

1. Work is a form of energy obtained from the product of force and the distance moved in the direction of force.
2. Energy is a general term to express different forms of work, when the work is done; there is a use of energy. Hence, work and energy are related.

$$3. \quad W = Fd = 20 \text{ N} \times 5 \text{ m} = 100 \text{ J}$$

$$4. \quad W = Fd \Leftrightarrow d = \frac{W}{F} = \frac{30 \text{ J}}{5 \text{ N}} = 6 \text{ m}$$

$$5. \quad W = Fd = 2000 \text{ N} \times 0 \text{ m} = 0 \text{ J}$$

### Activity 8.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide to activity using provided materials and help them to draw a suitable conclusion of their findings.

1. No.
2. Yes
3. Joseph has more power. Because he used his force in a short time compared to others.

#### 8.2.1 Check my progress

Consider the solution provided for activity 8.4 (Pg 74-75) in TG

1. 100 joules
2. 100 watts
3. 746 watts



**Activity 8.3**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. It comes from the elasticity of the lower limb and the upper together with the string.
2. Elastic energy.
3. It can be used in springs, elastic strings, etc.

**Activity 8.4**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. It is the lorry, because it has more mass as the Kinetic energy depends on mass and speed/velocity of a moving body.
2. Kinetic energy
3. In all moving bodies.

**8.3.3 Check my progress**

$$\begin{aligned}
 1. \quad W &= \Delta E_K = \frac{1}{2}m(v_2^2 - u_1^2) \\
 &= \frac{1}{2} \times 1000 \times (30^2 - 20^2) \text{ J} \\
 &= 250\,000 \text{ J}
 \end{aligned}$$

2. C. (as we the distance from Earth to moon is considered constant)

$$3. \quad E_p = mgh = 2.5 \times 9.8 \times 180 = 4410 \text{ J}$$

4.  $W = Fd = 2000 \text{ N} \times 0 \text{ m} = 0 \text{ J}$  as the distance moved is zero

**Activity 8.10**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Follow the provided instructions and workout the following:

1. Calculate the work done in climbing the stairs (work = force  $\times$  distance).
2. Finally, calculate the work done per second (i.e., the power at which you were working when climbing the stairs).

Here the result may depend on the stairs you have used. Try this with your learners and help them to draw a suitable conclusion.

### Answers

1. The net work needed is equal to increase in kinetic energy
2. The gravitational force on the Moon acts toward the Earth as a centripetal force, inward along the radius of the Moon's orbit. The Moon's displacement at any moment is along the circle, in the direction of its velocity, perpendicular to the radius and perpendicular to the force of gravity. Hence the angle between the force and the instantaneous displacement of the Moon is 90 and the work done by gravity is therefore zero.

## 8.5 Assessment answers for unit 8 Assessment

1. Given:  $m_b = 7.00\text{kg}$       $m_t = 2.45 \times 10^{-3}\text{kg}$       $v_b = 3.00\text{m/s}$

Unknown:  $KE_b = ?$

$$KE_b = \frac{1}{2} m_b v_b^2 = 31.5\text{J}$$

Use kinetic energy equation:

$$KE_t = \frac{1}{2} m_t v_t^2 \Leftrightarrow v_t = \sqrt{\frac{2KE_b}{m_t}} = 1.60 \times 10^2 \text{ m/s}$$

2. Given:  $m = 193\text{kg}$ ,  $\Delta t = 5.0\text{s}$ ;  $d = 7.5\text{m}$

Unknown:  $P = ?$

Use the power equation:  $P = \frac{W}{\Delta t} = \frac{Fd}{\Delta t} = \frac{mgd}{\Delta t}$   $P = 2.8\text{kW}$

The best motor to use is the 3.5 kW motor. The 1.0 kW motor will not lift the curtain fast enough, and the 5.5 kW motor will lift the curtain too fast.

3. The change in kinetic energy must be equal to the net work done on the car,  
 $W = Fd = 400 \times 5 = 2000\text{J}$

The final velocity is obtained from the equation

$$W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 \Leftrightarrow v_f = \sqrt{\frac{2W}{m}} = \sqrt{\frac{2 \times 2000}{1000}} = 2\text{m/s}$$

4. Energy: is the ability to do work such as moving matter over a distance or causing a heat transfer between two objects at different temperature. Example, Heat, Light, Electricity, Chemical energy.

(a) The energy contained in a moving body is called Kinetic Energy.

(b) Potential Energy is stored energy that is latent but available for use. Chemical energy stored in the food and gasoline are examples of Potential Energy.

(c) Power is the rate of doing work.

5. a) Force applied  $P = \frac{W}{t} = \frac{Fs}{t} = Fv$  d:  $F = 900\text{N}$ ,

$$\text{speed: } v = \frac{s}{t} = \frac{45000}{60 \times 60} = 12.5\text{m/s}$$

Work done is equal to force  $\times$  distance  $W = Fs$ . But distance is equal to speed  $\times$  time

$$s = vt \Rightarrow v = \frac{s}{t} \text{ and hence } P = 900 \times 12.5 = 11.25\text{KW}$$

- b) Force applied:  $F=1200\text{N}$ , speed:  $v = \frac{60000}{60 \times 60} = \frac{50}{3}\text{m/s}$

$$\text{using } P = Fv = 1200 \times \frac{50}{3} = 20\text{KW}$$

6. Kinetic (the energy of a moving object) is  $E_k = \frac{1}{2}mv^2$  ( $m$  = mass,  $v$  = speed)

Gravitational potential is  $E_p = mgh$ , ( $m$  = mass,  $g$  = gravitational acceleration,  $h$  = change in height). And work is  $Fs\cos\theta$  ( $F$  = force,  $s$  = displacement, and  $\theta$  = angle between  $F$  and  $s$ )

Finally, elastic potential (not in the data packet) is  $E_p = \frac{1}{2}kx^2$  ( $k$  = spring stiffness in  $\text{N/m}$ , and  $x$  = spring stretch or compression distance)

$$\text{Difference } \Delta E = \frac{1}{2}(5.2)(4.2)^2 - 3.12 = 21\text{J}$$

7. Power = (any change in energy)/(the time it took). It can also be written as:  
Power =  $Fv$ .

In this case, the work to be done is the change in the Land Rover's potential energy:

$$W = mgh = 1300 \times 9.81 \times 5.7 = 72692.1\text{J}$$

The power of the motor in Watts is  $P = 1.2 \times 745.7 = 894.84\text{W}$

And finally, the time: Power = (any change in energy) / (the time it took)

$$P = \frac{W}{t} \Leftrightarrow t = \frac{W}{P} = \frac{72692.1}{894.84} = 81\text{s}$$

8. Work done by  $F$ :  $W_F = Fs = 20 \times 5 = 100\text{J}$

Work done by friction force;  $W_{fr} = F_{fr}s = Kmg s = 0.3 \times 4 \times 10 \times 5 = 60\text{J}$

Work done by resultant force:

$$W_{net} = F_{net} s = (F - F_{fr}) s = (20 - 0.3 \times 4 \times 10) \times 5 = 40\text{J}$$

## 8.6 Additional information (content)

### Work, Energy and Power: Problem Set Overview

This set of 32 problems targets your ability to use equations related to work and power, to calculate the kinetic, potential and total mechanical energy, and to use the work-energy relationship in order to determine the final speed, stopping distance or final height of an object. The more difficult problems are colour-coded as blue problems.

#### Work

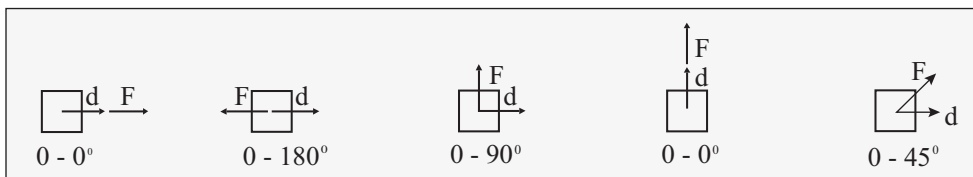
Work results when a force acts upon an object to cause a displacement (or a motion) or, in some instances, to hinder a motion. Three variables are of importance in this definition - force, displacement, and the extent to which the force causes or hinders the displacement. Each of these three variables find their way into the equation for work. That equation is:

**Work = Force • Displacement • Cosine(theta)**

$$W = F \cdot d \cos \theta$$

Since the standard metric unit of force is the Newton and the standard metric unit of displacement is the meter, then the standard metric unit of work is a Newton•meter, defined as a Joule and abbreviated with a J.

The most complicated part of the work equation and work calculations is the meaning of the angle theta in the above equation. The angle is not just any stated angle in the problem; it is the angle between the F and the d vectors. In solving work problems, one must always be aware of this definition - theta is the angle between the force and the displacement which it causes. If the force is in the same direction as the displacement, then the angle is 0 degrees. If the force is in the opposite direction as the displacement, then the angle is 180 degrees. If the force is up and the displacement is to the right, then the angle is 90 degrees. This is summarised in the graphic below.



## Power

Power is defined as the rate at which work is done upon an object. Like all rate quantities, power is a time-based quantity. Power is related to how fast a job is done. Two identical jobs or tasks can be done at different rates - one slowly or rapidly. The work is the same in each case (since they are identical jobs) but the power is different. The equation for power shows the importance of time:

$$\text{Power} = \frac{\text{Work}}{\text{time}}$$

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

The unit for standard metric work is the Joule and the standard metric unit for time is the second, so the standard metric unit for power is a Joule/second, defined as a Watt and abbreviated W. Special attention should be taken so as not to confuse the unit Watt, abbreviated W, with the quantity work, also abbreviated by the letter W.

Combining the equations for power and work can lead to a second equation for power. Power is  $W/t$  and work is  $F \cdot d \cdot \cos(\theta)$ . Substituting the expression for work into the power equation yields  $P = F \cdot d \cdot \cos(\theta) / t$ . If this equation is re-written as  $P = F \cos(\theta) \left( \frac{d}{t} \right)$

One notices a simplification which could be made. The  $d/t$  ratio is the speed value for a constant speed motion or the average speed for an accelerated motion. Thus, the equation can be re-written as;

$$P = F \times v \cos \theta$$

where  $v$  is the constant speed or the average speed value. A few of the problems in this set of problems will utilise this derived equation for power.

## Mechanical, Kinetic and Potential Energies

There are two forms of mechanical energy - potential energy and kinetic energy.

Potential energy is the stored energy of position. In this set of problems, we will be most concerned with the stored energy due to the vertical position of an object within the Earth's gravitational field. Such energy is known as the gravitational potential energy ( $PE_{\text{grav}}$ ) and is calculated using the equation;

$$PE_{\text{grav}} = mgh$$

where  $m$  is the mass of the object (with standard units of kilograms),  $g$  is the acceleration of gravity (9.8 m/s/s) and  $h$  is the height of the object (with standard units of meters) above some arbitrarily defined zero level (such as the ground or the top of a lab table in a physics room).

Kinetic energy is defined as the energy possessed by an object due to its motion. An object must be moving to possess kinetic energy. The amount of kinetic energy (KE) possessed by a moving object is dependent upon mass and speed. The equation for kinetic energy is;

$$KE = 0.5mv^2$$

**where  $m$  is the mass of the object (with standard units of kilograms) and  $v$  is the speed of the object (with standard units of m/s).**

The total mechanical energy possessed by an object is the sum of its kinetic and potential energies.

### Work-Energy Connection

There is a relationship between work and total mechanical energy. The relationship is best expressed by the equation;

$$TME_i + W_{\text{nc}} = TME_f$$

In words, this equation says that the initial amount of total mechanical energy ( $TME_i$ ) of a system is altered by the work which is done to it by non-conservative

forces ( $W_{nc}$ ). The final amount of total mechanical energy ( $TME_f$ ) possessed by the system is equivalent to the initial amount of energy ( $TME_i$ ) plus the work done by these non-conservative forces ( $W_{nc}$ ).

The mechanical energy possessed by a system is the sum of the kinetic energy and the potential energy. Thus the above equation can be re-arranged to the form of;

$$KE_i + PE_i + W_{nc} = KE_f + PE_f$$

$$0.5mvi^2 + mgh_i + Fdcos(\theta) = 0.5mv_f^2 + mgh_f$$

The work done to a system by non-conservative forces ( $W_{nc}$ ) can be described as either positive work or negative work. Positive work is done on a system when the force doing the work acts in the direction of the motion of the object. Negative work is done when the force doing the work opposes the motion of the object. When a positive value for work is substituted into the work-energy equation above, the final amount of energy will be greater than the initial amount of energy; the system is said to have gained mechanical energy. When a negative value for work is substituted into the work-energy equation above, the final amount of energy will be less than the initial amount of energy; the system is said to have lost mechanical energy. There are occasions in which the only forces doing work are conservative forces (sometimes referred to as internal forces). Typically, such conservative forces include gravitational forces, elastic or spring forces, electrical forces and magnetic forces. When the only forces doing work are conservative forces, then the  $W_{nc}$  term in the equation above is zero. In such instances, the system is said to have conserved its mechanical energy.

The proper approach to work-energy problem involves carefully reading the problem description and substituting values from it into the work-energy equation listed above. Inferences about certain terms will have to be made based on a conceptual understanding of kinetic and potential energy. For instance, if the object is initially on the ground, then it can be inferred that the  $PE_i$  is 0 and that term can be cancelled from the work-energy equation. In other instances, the height of the object is the same in the initial state as in the final state, so the  $PE_i$  and the  $PE_f$  terms are the same. As such, they can be mathematically canceled from each side of the equation. In other instances, the speed is constant during the motion, so the  $KE_i$  and  $KE_f$  terms are the same and can thus be mathematically cancelled from each side of the equation. Finally, there are instances in which the KE and or the PE terms are not stated; rather, the mass ( $m$ ), speed ( $v$ ), and height ( $h$ ) is given. In such instances, the KE and PE terms can be determined using their respective equations. Make it your habit from the beginning to simply start with the work and energy equation, to cancel terms which are zero or unchanging, to substitute values of energy and work into the equation and to solve for the stated unknown.

## Habits of an effective problem-solver

An effective problem solver by habit approaches a physics problem in a manner that reflects a collection of disciplined habits. While not every effective problem solver employs the same approach, they all have habits which they share in common. These habits are described briefly here. An effective problem-solver;

- ④ reads the problem carefully and develops a mental picture of the physical situation. If needed, they sketch a simple diagram of the physical situation to help visualise it.
- ④ identifies the known and unknown quantities in an organised manner, often times recording them on the diagram itself. They equate given values to the symbols used to represent the corresponding quantity (e.g.,  $m = 1.50\text{kg}$ ,  $v_i = 2.68\text{m/s}$ ,  $F = 4.98\text{N}$ ,  $t = 0.133\text{ s}$ ,  $v_f = ???$ ).
- ④ plots a strategy for solving for the unknown quantity; the strategy will typically center around the use of physics equations be heavily dependent upon an understanding of physics principles.
- ④ identifies the appropriate formula(s) to use, often times writing them down. Where needed, they perform the needed conversion of quantities into the proper unit.
- ④ performs substitutions and algebraic manipulations in order to solve for the unknown quantity.

## 8.7 Remedial extension and consolidation

1. Renatta Gass is out with her friends. Misfortune occurs and Renatta and her friends find themselves getting a workout. They apply a cumulative force of 1080N to push the car 218m to the nearest fuel station. Determine the work done on the car. **(Answer:  $2.35 \times 10^5\text{J}$ )**
2. Hans Full is pulling on a rope to drag his backpack to school across the ice. He pulls upwards and rightwards with a force of 22.9Newtons at an angle of 35degrees above the horizontal to drag his backpack a horizontal distance of 129 meters to the right. Determine the work (in Joules) done upon the backpack. **(Answer:  $2.42 \times 10^3\text{J}$ )**
3. Lamar Gant, U.S. powerlifting star, became the first man to deadlift five times his own body weight in 1985. Deadlifting involves raising a loaded barbell from the floor to a position above the head with outstretched arms. Determine the work done by Lamar in deadlifting 300kg to a height of 0.90m above the ground.**(Answer:  $2.6 \times 10^3\text{J}$ )**
4. Sheila has just arrived at the airport and is dragging her suitcase to the luggage check-in desk. She pulls on the strap with a force of 190N at an angle of  $35^\circ$  to the horizontal to displace it 45m to the desk. Determine the work done by Sheila on the suitcase.**(Answer:  $7.0 \times 10^3\text{J}$ )**



5. While training for breeding season, a 380gram male squirrel does 32 pushups in a minute, displacing its center of mass by a distance of 8.5cm for each pushup. Determine the total work done on the squirrel while moving upward (32 times). **(Answer: 10.J)**
6. During the Powerhouse lab, Jerome runs up the stairs, elevating his 102kg body a vertical distance of 2.29 meters in a time of 1.32 seconds at a constant speed.
  - (a) Determine the work done by Jerome in climbing the stair case.
  - (b) Determine the power generated by Jerome. **(Answers: a.  $2.30 \times 10^3\text{J}$   
b.  $1.73 \times 10^3\text{ W}$ )**
7. A new conveyor system at the local packaging plant will utilise a motor-powered mechanical arm to exert an average force of 890N to push large crates a distance of 12meters in 22seconds. Determine the power output required of such a motor. **(Answer: 490W (rounded from 485W))**
8. The Taipei 101 in Taiwan is a 555.7m tall, 101-story skyscraper. The skyscraper is the home of the world's fastest elevator. The elevators transport visitors from the ground floor to the Observation Deck on the 89th floor at speeds up to 16.8 m/s. Determine the power delivered by the motor to lift the 10 passengers at this speed. The combined mass of the passengers and cabin is 1250kg. **(Answer:  $2.06 \times 10^5\text{ W}$ )**
9. The ski slopes at Bluebird Mountain make use of tow ropes to transport snow boarders and skiers to the summit of the hill. One of the tow ropes is powered by a 22kW motor which pulls skiers along an icy incline of  $14^\circ$  at a constant speed. Suppose that 18 skiers with an average mass of 48 kg hold onto the rope and suppose that the motor operates at full power;
  - (a) Determine the cumulative weight of all these skiers.
  - (b) Determine the force required to pull this amount of weight up a  $14^\circ$  incline at a constant speed.
  - (c) Determine the speed at which the skiers will ascend the hill. **(Answers: (a)  $8.5 \times 10^3\text{ N}$  (b)  $2.0 \times 10^3\text{ N}$  (c)  $11\text{ m/s}$ )**
10. The first asteroid to be discovered is Ceres. It is the largest and most massive asteroid in our solar system's asteroid belt, having an estimated mass of  $3.0 \times 10^{21}\text{kg}$  and an orbital speed of 17900m/s. Determine the amount of kinetic energy possessed by Ceres. **(Answer:  $4.8 \times 10^{29}\text{J}$ )**
11. A bicycle has a kinetic energy of 124J. What kinetic energy would the bicycle have if it had;
  - (a) twice the mass and was moving at the same speed?
  - (b) the same mass and was moving with twice the speed?
  - (c) one-half of the mass and was moving with twice the speed?

- (d) the same mass and was moving with one-half of the speed?
- (e) three times the mass and was moving with one-half of the speed?

**(Answers: (a) 248J, (b) 496J, (c) 248J, (d) 31.0J, (e) 93.0J)**

12. A 78-kg skydiver has a speed of 62m/s at an altitude of 870m above the ground.
- (a) Determine the kinetic energy possessed by the skydiver.
  - (b) Determine the potential energy possessed by the skydiver.
  - (c) Determine the total mechanical energy possessed by the skydiver.

**(Answers: (a)  $1.5 \times 10^5\text{J}$ , (b)  $6.7 \times 10^5\text{J}$ , (c)  $8.1 \times 10^5\text{J}$ )**

13. Li Ping Phar, the esteemed Chinese ski jumper, has a mass of 59.6kg. He is moving with a speed of 23.4m/s at a height of 44.6meters above the ground. Determine the total mechanical energy of Li Ping Phar. **(Answers:  $4.24 \times 10^4\text{J}$ )**

14. Chloe leads South's varsity softball team in hitting. In a game against New Greer Academy this past weekend, Chloe slugged the 181 gram softball so hard that it cleared the outfield fence and landed on Lake Avenue. At one point in its trajectory, the ball was 28.8m above the ground and moving with a speed of 19.7m/s. Determine the total mechanical energy of the softball.

15. Olive Udadi is at the park with her father. The 26kg Olive is on a swing following the path as shown. Olive has a speed of 0m/s at position A and is a height of 3.0m above the ground. At position B, Olive is 1.2m above the ground. At position C (2.2m above the ground), Olive projects from the seat and travels as a projectile along the path shown. At point F, Olive is a mere picometer above the ground. Assume negligible air resistance throughout the motion. Use this information to fill in the table.

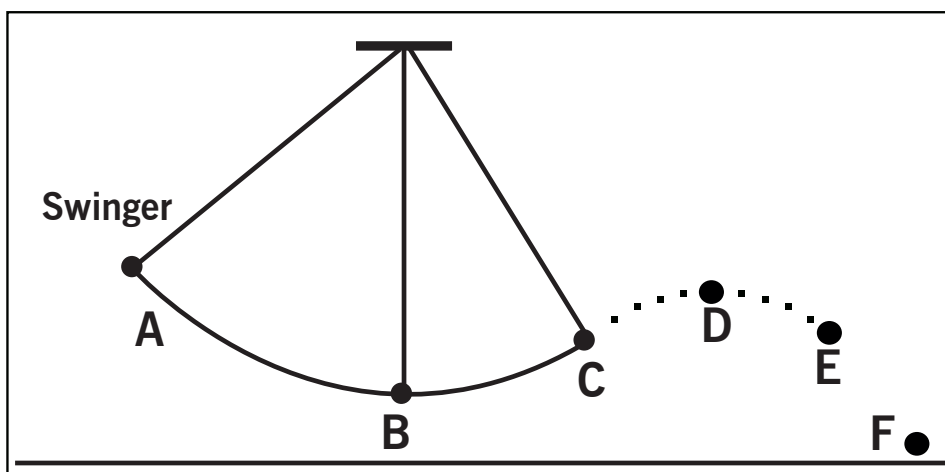


Fig. 8.2

Position	Height (m)	PE (J)	KE (J)	TME (J)	Speed (m/s)
A	3.0				0.0
B	1.2				
C	2.2				
F	0				

Table. 8.1

16. Suzie Lavtaski ( $m = 56\text{kg}$ ) is skiing at Bluebird Mountain. She is moving at  $16\text{m/s}$  across the crest of a ski hill located  $34\text{m}$  above ground level at the end of the run.
- Determine Suzie's kinetic energy.
  - Determine Suzie's potential energy relative to the height of the ground at the end of the run.
  - Determine Suzie's total mechanical energy at the crest of the hill.
  - If no energy is lost or gained between the top of the hill and her initial arrival at the end of the run, then what will be Suzie's total mechanical energy at the end of the run?
  - Determine Suzie's speed as she arrives at the end of the run and prior to braking at a stop.
17. Nicholas is at The Noah's Ark Amusement Park and preparing to ride on The Point of No Return racing slide. At the top of the slide, Nicholas ( $m = 72.6\text{kg}$ ) is  $28.5\text{m}$  above the ground.
- Determine Nicholas' potential energy at the top of the slide.
  - Determine Nicholas's kinetic energy at the top of the slide.
  - Assuming negligible losses of energy between the top of the slide and his approach to the bottom of the slide ( $h = 0\text{m}$ ), determine Nicholas's total mechanical energy as he arrives at the bottom of the slide.
  - Determine Nicholas' potential energy as he arrives at the bottom of the slide.
  - Determine Nicholas' kinetic energy as he arrives at the bottom of the slide.
  - Determine Nicholas' speed as he arrives at the bottom of the slide.
18. Ima Scaarred ( $m = 56.2\text{kg}$ ) is traveling at a speed of  $12.8\text{m/s}$  at the top of a  $19.5\text{m}$  high roller coaster loop.
- Determine Ima's kinetic energy at the top of the loop.
  - Determine Ima's potential energy at the top of the loop.

- (c) Assuming negligible losses of energy due to friction and air resistance, determine Ima's total mechanical energy at the bottom of the loop ( $h = 0\text{m}$ ).
- (d) Determine Ima's speed at the bottom of the loop.
19. Justin Thyme is traveling down Lake Avenue at  $32.8\text{m/s}$  in his  $1510\text{kg}$  1992 Camaro. He spots a police car with a radar gun and quickly slows down to a legal speed of  $20.1\text{m/s}$ .
- (a) Determine the initial kinetic energy of the Camaro.
- (b) Determine the kinetic energy of the Camaro after slowing down.
- (c) Determine the amount of work done on the Camaro during the deceleration.
20. Pete Zaria works on weekends at Barnaby's Pizza Parlor. His primary responsibility is to fill drink orders for customers. He fills a pitcher full of Cola, places it on the counter top and gives the  $2.6\text{kg}$  pitcher a  $8.8\text{N}$  forward push over a distance of  $48\text{cm}$  to send it to a customer at the end of the counter. The coefficient of friction between the pitcher and the counter top is  $0.28$ .
- (a) Determine the work done by Peter on the pitcher during the  $48\text{cm}$  push.
- (b) Determine the work done by friction upon the pitcher.
- (c) Determine the total work done upon the pitcher.
- (d) Determine the kinetic energy of the pitcher when Pete is done pushing it.
- (e) Determine the speed of the pitcher when Pete is done pushing it.
21. Gwen is baby-sitting for the Parker family. She takes 3-year old Allison to the neighborhood park and places her in the seat of the children's swing. Gwen pulls the  $1.8\text{m}$  long chain back to make a  $26^\circ$  angle with the vertical and lets the  $14\text{kg}$  Allison (swing mass included) go. Assuming negligible friction and air resistance, determine Allison's speed at the lowest point in the trajectory. **(Answers:  $1.9\text{m/s}$ )**

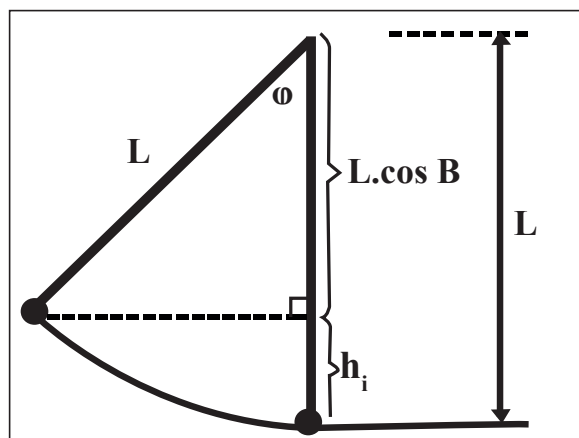


Fig. 8.3

# Unit 9

## Conservation of Mechanical Energy in isolated systems

### Key unit competence:

By the end of this unit, learners should be able to apply the principle of conservation of mechanical energy for isolated system.

### Learning objectives:

By the end of this unit, learners should be able to;

- Define terms associated with isolated system and open system.
- Describe an isolated and open system.
- State different forms of mechanical energy.
- Differentiate kinetic from potential energy.
- Explain conversion of kinetic energy into potential energy and vice versa.
- State the principle of conservation of energy.
- Appreciate the application of the principle of conservation of mechanical energy.
- Predict consequences of the law of conservation of mechanical energy on an isolated system.

## Resources:

Liquid in glass thermometer, thermocouple, pyrometer, Bunsen burner. Once materials are not available, you with learners should improvise the activity in order to make the learners more competent.

### 9.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching methods which will keep learners motivated and engaged throughout the lesson. We then suggest observation and demonstration activities.

Group discussion and presentation, question-answer with immediate feedback, solving problems in pairs or in group in order to help each other.

### 9.2 Support on assessment strategies and tasks of assessment

You may use multiple choice questions, completing the statement or table and advanced questions at the end of the unit to evaluate the learners through quizzes and home work for summative assessment without forgetting formative assessment throughout each lesson of the unit.

### 9.3 Lessons and timing

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	Lessons	Periods
1.	Isolated and open systems	1
2.	Kinetic and potential energy of a system	2
3.	Kinds of potential energy	1
4.	Conversion of potential energy into kinetic energy	2
5.	Mechanical energy and the law of conservation of energy	2
6.	Summative assessment	2

### 9.4 Solutions of unit activities

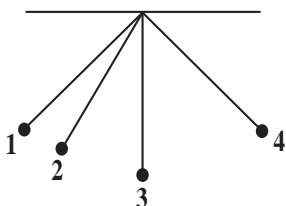
#### Activity 9.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. You find that the temperature  $t_1$  is greater than the  $t_2$ , which means that the vacuum flask has maintained the temperature of water (Closed system) while the vessel has lost part of the temperature (open system).
2. As the vessel was open, it exchanged with the surrounding, and as the flask was closed, it didn't exchange with the surrounding.
3. Temperatures are different because the flask is a closed system, while the vessel is an open system.

### Activity 9.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.



Position 1	Position 2	Position 3	Position 4
PE = 6J	PE = 3J	PE = 0J	PE = 6J
KE = 0J	KE = 3J	KE = 6J	KE = 0J
$h = \frac{A}{m}$	$h = \frac{B}{m}$	$h = \frac{D}{m}$	$h = \frac{F}{m}$
$v = 0\text{m/s}$	$v = \frac{C}{m/s}$	$v = \frac{E}{m/s}$	$v = 0\text{m/s}$

1. There is Kinetic energy and Potential energy.
2. The relationship is that, when the Kinetic energy decreases, the potential energy increases and vice versa.

### Activity 9.4

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. As one adds more mass on the mass hanger, the spring stretches more.
2. Potential energy.

### Activity 9.5

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Its the kinetic energy.
2. The kinetic energy has decreased as it moves upwards changing into Potential energy; when the kinetic energy becomes zero, it stops and by that point, the ball falls back.
3. Potential energy.

### Activity 9.6

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

This can be well observed; when the cyclist stops pedaling, the bicycle will move, which shows that it is the potential energy which is being converted into kinetic energy.

### Check my progress

1. Open system
2. Kinetic energy is given by  $KE = \frac{1}{2}mv^2 = 0.5 \times 0.18 \times 12^2 = 12.6 \approx 13J$
3. Using  $V = \sqrt{(2 \times 9.8 \times 12)} = 15.3m / s$
4. The answer is (b) It will never go beyond the original height.

## 9.5 Suggested answers for unit 9 Assessment

1. Before and after it has both kinetic and gravitational potential:

$$mgh_1 + \frac{1}{2}mv_1^2 = mgh_2 + \frac{1}{2}mv_2^2$$

$$\text{So, } v_2 = \sqrt{2\left(gh_1 + \frac{1}{2}v_1^2 - gh_2\right)}$$

$$= \sqrt{2\left(9.81 \times 1.2 + \frac{1}{2} \times 7.5^2 - 9.81 \times 3.5\right)}$$

$$= 3.3m/s$$

2. Components of the applied forces are equal to each other. Masses of the objects are also equal. Thus, acceleration of the objects and distances taken are also equal.

Since Work done:  $W = FS$  then  $W_1 = W_2 = W_3$



3. Since box moves from point A to B, only  $F_3$  does work.

$$W_3 = F_3 x = 30 \times 5 = 150 \text{ J}$$

4. By using work and energy theorem we say that; area under the graph gives us work done by the force i.e.  $\Delta K = W = \text{area under the graph.}$

$$\Delta K = \frac{8(8+4)}{2} + (-8)(12 - 8) = 16\text{J}$$

We use conservation of energy theorem.

5. Slope of the  $E_k$  vs. position graph gives applied force

I. interval:  $F_1 = (20 - 0) \div (5 - 0) = 4\text{N}$

II. Interval:  $F_2 = (30 - 20) \div (10 - 5) = 2\text{N}$

III. Interval:  $F_3 = (0 - 30) \div (15 - 10) = 6\text{N}$

$$F_{\text{III}} > F_{\text{I}} > F_{\text{II}}$$

6. Object has velocity at  $t = t$ ;  $v_1 = at$

Object has velocity at  $t = 2t$ ;  $v_2 = at + \frac{2a + a}{2}t = \frac{5}{2}at = \frac{5}{2}v_1$

$$\frac{E_2}{E_1} = \frac{v_2^2}{v_1^2} = \frac{25}{4}$$

7. Object lost  $2mgh$  potential energy from point A to C. According to conservation of energy theorem, this lost potential energy converted to the kinetic energy. Thus; we can say that kinetic energy of the object at point C is;  $K = 2mgh$

Total mechanical energy;  $E = 3mgh$

$$\frac{K}{E} = \frac{2mgh}{3mgh} = \frac{2}{3}$$

8. Work done by gravity is equal to change in potential energy of the object.

Interval AB:  $W_1 = \Delta E_p = mgh$

Interval BC:  $W_2 = \Delta E_p = mgh$

Interval CD:  $W_3 = \Delta E_p = 0$

$$W_1 = W_2 > W_3$$

9. The object has kinetic energy at point A;  $E_k = \frac{1}{2}vm^2$

Object stops at point A, which means that all energy is lost on friction.

$$E_k = F_f$$

10. Using conservation of energy theorem;

$$E = 2mgh + F_{fr} \times 2s \Leftrightarrow E = 2(mgh + F_{fr} s) \Leftrightarrow \frac{E}{2} = mgh + F_{fr} s$$

$$E' = 3mgh + F_{fr} \times 3x = 3(mgh + F_{fr} s) = 3 \frac{E}{2} = 1.5E$$

We must give 1.5E energy to make the object reach point D.

## 9.6 Additional information (content)

### The conservation of mechanical energy

Mechanical energy is the sum of the potential and kinetic energies in a system. The principle of the conservation of mechanical energy states that the total mechanical energy in a system (i.e., the sum of the potential plus kinetic energies) remains constant as long as the only forces acting are conservative forces. We could use a circular definition and say that a conservative force is a force which doesn't change the total mechanical energy, which is true, but might shed much light on what it means.

A good way to think of conservative forces is to consider what happens on a round trip. If the kinetic energy is the same after a round trip, the force is a conservative force, or at least is acting as a conservative force. Consider gravity; you throw a ball straight up, and it leaves your hand with a certain amount of kinetic energy. At the top of its path, it has no kinetic energy, but it has a potential energy equal to the kinetic energy it had when it left your hand. When you catch it again it will have the same kinetic energy as it had when it left your hand. All along the path, the sum of the kinetic and potential energy is a constant, and the kinetic energy at the end, when the ball is back at its starting point, is the same as the kinetic energy at the start, so gravity is a conservative force.

Kinetic friction, on the other hand, is a non-conservative force, because it acts to reduce the mechanical energy in a system. Note that non-conservative forces do not always reduce the mechanical energy; a non-conservative force changes the mechanical energy, so a force that increases the total mechanical energy, like the force provided by a motor or engine, is also a non-conservative force.

## 9.7 Remedial, extension and consolidation activities

1. The legend has it that Isaac Newton “discovered” gravity when an apple fell from a tree and hit him on the head. If a 0.20kg apple fell 7.0m before hitting Newton, what was its change in PE during the fall?
2. In a wild shot, Bo shoots a pool ball of mass  $m$  off a 0.68m high pool table, and the ball hits the floor with a speed of 6.0m/s. How fast was the ball moving when it left the pool table? (Use the law of conservation of energy.)
3. It is said that Galileo dropped objects off the Leaning Tower of Pisa to determine whether heavy or light objects fall faster. If Galileo had dropped a 5.0kg cannon ball to the ground from a height of 12m, what would have been the change in PE of the cannon ball?
4. On June 5, 2007, Rags to Riches, became the first filly to win the Belmont Stakes horse race since 1905, running with an average speed of 16.23m/s. If Rags to Riches and jockey Johnny Velazquez had a combined mass of 550.0kg, what was their KE as they crossed the finish line?
5. Brittany is changing the tyre of her car on a steep hill 20.0m high. She trips and drops the 10.0kg spare tyre, which rolls down the hill with an initial speed of 2.00m/s. What is the speed of the tyre at the top of the next hill, which is 5.00m high? (Ignore the effects of rotation KE and friction.)
6. A Mexican jumping bean jumps with the aid of a small worm that lives inside the bean.
  - (a) If a bean of mass 2.0g jumps 1.0cm from your hand into the air, how much potential energy has it gained in reaching its highest point.
  - (b) What is its speed as it (the bean) lands back in the palm of your hand?
7. A 500kg pig is standing at the top of a muddy hill on a rainy day. The hill is 100.0m long with a vertical drop of 30.0m. The pig slips and begins to slide down the hill. What is the pig’s speed at the bottom of the hill? Use the law of conservation of energy.
8. While on the moon, the Apollo astronauts enjoyed the effects of gravity much smaller than that on Earth. If Neil Armstrong jumped up on the moon with an initial speed of 1.51m/s to a height of 0.700m, what amount of gravitational acceleration did he experience?

# Unit 10

## Gas Laws' Experiments

### Key unit competence:

By the end of this unit the learner should be able to differentiate magnetic and non-magnetic materials.

### Learning objectives:

By the end of this unit, learners should be able to;

- State and explain the behaviour and properties of an ideal gas.
- Discuss the equation of perfect gas. (Ideal gas).
- Define Boyle's law, Charles's law, Pressure law, and Dalton's law.
- Recall the gas law equations.
- Design experiments to verify Boyle's law, Charles's law and pressure law.
- Explain equations of perfect gas. (Ideal gas)
- Discuss the gas laws.
- Interpret experiments for gas laws.
- Evaluate experiments to verify Dalton's law of partial pressure.
- Solve and interpret problems using gas law equations.

**Resources:**

Glass tube, mercury, barometer, rubber tube or plastic tube, gas, burette, glass beaker, calcium chloride (drying agent), thermometer, clip, concentrated sulphuric acid, Bunsen, pipette, hydrogen balloon, glass bulb, capillary tube, tap air, pump. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

**10.1 Specific suggested methods/strategies/approaches of the unit**

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. The most effective methodology in this unit seems to be the discussion led by the teacher and practical activities as proposed in the learner's book.

You should ask learners to make their own suggestions in order to improve the quality of practical activities. By systematic questions and answer method, you can gauge the understanding of learners to prove whether this method was really effective or not.

**10.2 Support on assessment strategies and tasks of assessment**

You may use the question-answer method throughout as formative assessment of your learners. You should also use multiple choice questions, completing statement, graphing and other advanced questions at the end of this unit for summative assessment of your learners.

**10.3 Lessons and timing**

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	<b>Lessons</b>	<b>Periods</b>
1.	Introduction to gas laws	2
2.	Three Gas laws	3
3.	Ideal gases	3
4.	Summative assessment	2

## 10.4 Solutions of unit activities

### Activity 10.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

What is happening is that the balloon trapped the water vapour in the bottle and as it cools the outside air pressure replaces the water vapour that is now condensing and emptying the inside of the bottle. Gas expands as it heats, and shrinks as it condenses, making the bottle “empty” compared to the exterior air pressure. The balloon expands inside the bottle to allow the exterior air pressure inward.

### Activity 10.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

**What happens:** When we place the bulb inside the syringe without squeezing the piston, the balloon remains the same as the air escapes from the front, keeping the atmospheric pressure the same. The moment we close the outlet of the syringe and squeeze the piston, the balloon becomes smaller under increased pressure.

**Why this happens:** The balloon remains the same size when the pressure decreases and the volume increases. But when pressure increases, the volume decreases therefore making the balloon compress to a smaller size. Boyle’s law describes the inversely proportional relationship between the absolute pressure and volume of a gas.

### Activity 10.3

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. You do not need to fill the flask. The less water you add, the faster you will be able to bring it to a boil. However, make sure that you do add enough water so that you don’t boil it off too quickly. About 75ml should do nicely.
2. This will serve as a heat source for your water. Make sure you heat the water to the boiling point. This will force air to expand out of the top of the flask and also generate water vapour to fill the balloon.
3. Remember that the flask is being heated. You should use gloves to avoid burning your hands as you secure the balloon over the opening of the flask. Make sure

that the balloon is far enough down on the neck of the flask that it does not pop off easily.

4. Securing the balloon over the top of the flask will create a seal and only allow the air to expand into the balloon. This expansion of air into the balloon will cause the balloon itself to expand. Do not let the balloon get so large that it pops.
5. To prepare the ice bath just put water and ice into a container. This is a very easy and fast way to cool the contents of the flask. Use gloves to transfer the flask from the heat source to the ice bath.
6. The rapid cooling of the gas inside of the flask and balloon will cause the volume of the gas to decrease. As the volume decreases, the volume of the balloon will also decrease, causing it to shrink. As the gas cools even more and contracts even more, the volume of the gas shrinks so much that the pressure outside the flask pushes the balloon completely inside the flask.

#### Activity 10.4

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Rinse a soda can with water, and leave approximately 15–30ml (1–2tbsp.) of water in the bottom of the can. If you don't have a measuring spoon, pour in just enough water to cover the bottom of the can.
2. Fill a bowl with cold water and ice, or with water that has been kept in a cold refrigerator. A bowl deep enough to hold the can might make it easier to conduct the experiment, but it is not necessary. A clear bowl will make it easier to watch the can get crushed.
3. Place the soda can upright on a stove burner, then turn the heat setting on low. Let the water boil outside the can, bubbling and letting out water vapour for about thirty seconds.

If you smell something strange or metallic, move on to the next section right away. The water might have boiled away, or the heat might have been too high, causing the ink or aluminum on the can to melt. If your stove burner cannot support the soda can, use a hot plate, or use tongs with heat-resistant handles to hold the soda can over the stove.

Hold the tongs with your palm facing upward. Use the tongs to pick up the can, then quickly turn it over above the cold water bath, plunging the can into the bowl of water. (Be prepared for a loud noise as the can is rapidly crushed!)

**Learn about air pressure.** The air around you is pressing against you and every other object, with a pressure as high as 101 kPa when you're at sea level. This would normally be enough to crush a can by itself, or even a person! This doesn't happen because the air inside the soda can (or the material inside your body) is pushing outward with equal pressure, and because the air pressure "cancels itself out" by pushing at us from every direction equally.

4. When the water in the can boils, you can see the water start to escape as little droplets in the air, or steam. Some of the air in the can gets pushed out when this happens, to make room for the expanding cloud of water droplets.
  - ⦿ Despite the can losing some of the air inside it, it doesn't get crushed yet, because the water vapour that took the place of the air is pushing from the inside instead.
  - ⦿ In general, the more you heat a liquid or a gas, the more it expands. If it is an enclosed container it can't keep expanding, it exerts more pressure.

**Understand how the can gets crushed.** When the can is turned upside down in the ice water, the situation changes in two ways. First, the can is no longer open to the air, since water is blocking the opening. Second, the water vapour inside the can rapidly cools down again. The water vapour once again shrinks down to its original volume, the tiny amount of water at the bottom of the can. Suddenly, most of the space inside the can has nothing in it at all – not even air! The air that's been pressing from the outside of the can this whole time suddenly has nothing on the other side to resist it, so it crushes the can inward.

- ⦿ Space that has nothing in it is called a vacuum.

**Watch the can closely to discover one more effect of the experiment.** The appearance of a vacuum, or empty space, inside the can has one other effect besides causing the can to be crushed. Watch the can carefully as you lower it into the water, and again as you lift it out. You might notice a small amount of water getting sucked up into the can, then trickling out again. This is because the water pressure is pushing against the opening of the can, but only hard enough to fill a little of the can before the aluminum is crushed.

### **Helping learners learn from the experiment**

**Ask the learners why the can was crushed.** See if they have any ideas about what happened to the can. Do not affirm or deny any of the answers at this stage. Acknowledge each idea, and ask them to explain their thought process.

**Help the learners come up with variations on the experiment.** Ask the learners to come up with new experiments to test their ideas, and ask them what they think will happen before they conduct the new experiment. If they have trouble coming up with a new experiment, help them out. Here are a couple variations that may be helpful:

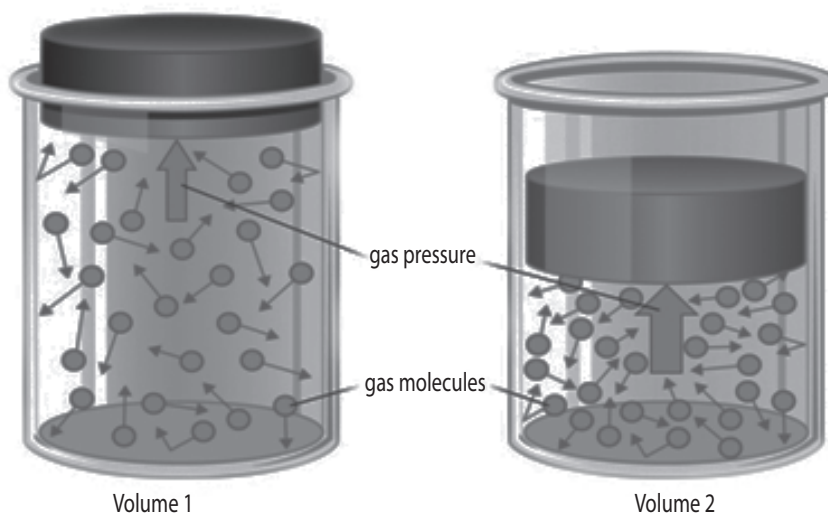


- ⦿ If a learner thinks the water (not the water vapour) inside the can was responsible for it getting crushed, have the learners fill an entire can with water, and see if it is crushed.
- ⦿ Try the same experiment with a sturdier container. The heavier material should take longer to be crushed, which will give the ice water more time to fill it.
- ⦿ Try letting the can cool for a short time before putting it in the ice bath. This will result in more air being present in the can, and thus less severe crushing.

**Explain the theory behind the experiment.** Use the information in the How it Works section to teach the learners why the can was crushed. Ask them whether that matches what they came up with in their experiments.

### Activity 10.6

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.



1. Molecules in Volume 1 are more distant from each other than in volume 2
2. In volume 2
3. Once the volume increase, the pressure decreases and vice versa.

**Activity 10.7**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Read the table 10.1 and use the given information, then guide learners in their discussions and help them to draw a good conclusion using the next example in the learner's book.

**Check my progress**

- (b) Molecules bounce off the walls of the containing vessel and their rate of change of momentum on a certain area causes a pressure.
- (c) Molecules bounce off the walls of the containing vessel and their rate of change of momentum on a certain area causes a pressure.
- (b) Pressure law
- (c)  $P_1V_1 = P_2V_2 \Rightarrow V_2 = \frac{P_1}{3P_2} \times V_1 = \frac{1}{3}V_1$  so,  $V_2 = \frac{V_1}{3}$
- (d) Momentum

**10.5 Suggested answers for unit 10 Assessment)**

- One atmosphere is equal to: 760mm Hg
- Density
- Dalton's Law of Partial Pressures states that: the total pressure exerted by a mixture of gases is equal to the sum of the pressures exerted by the individual components in the mixture.
- To convert centigrade temperature to Kelvin:  $^{\circ}\text{C} + 273.15$

$$\begin{array}{ll} P_1 = 755\text{mmHg} & P_2 = 760\text{mmHg} \\ V_1 = 125\text{cm}^3 & V_2 = ? \\ T_1 = (273 + 15)\text{K} = 288\text{K} & T_2 = 273 \end{array}$$

Since  $\frac{PV}{T} = C'$ , it follows that  $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Leftrightarrow V_2 = 118\text{cm}^3$

- Assuming the temperature remains constant, Boyle's law may be applied, i.e.,  
 $PV = C'$  or  $P_1V_1 = P_2V_2$
- The absolute pressure inside the tyre is  $(190 + 100) \text{ kPa} = 290 \text{ kPa}$

Applying the pressure law:  $\frac{P}{T} = C' \Leftrightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$  We have  $P_2 = 310\text{kPa}$

Therefore, new pressure as given by pressure gauge =  $310 - 100 = 210\text{kPa}$

7. Using idea gas law:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow T_2 = \frac{P_2V_2T_1}{P_1V_1} = 4.3 \times 10^2 \text{ K}$$

8. We solve for V: in equation:

$$V = \frac{nRT}{P} = \frac{1 \times 8.315 \times 273}{1.013 \times 10^5} = 22.4 \times 10^{-3} \text{ m}^3 = 22.4 \text{ L}$$

9. from  $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow V_2 = \frac{P_1T_2V_1}{P_2T_1} = 5.1 \text{ L}$

10. The total pressure in the bottle is:

$$P_{\text{tot}} = P_{\text{bar}} = P_{\text{H}_2\text{O}} + P_{\text{O}_2} \Rightarrow P_{\text{O}_2} = 757 - 19.8 = 737.2 \text{ torr}$$

## 10.6 Additional information (content)

### Gas laws

The **gas laws** were developed at the end of the 18<sup>th</sup> century, when scientists began to realise that relationships between the pressure, volume and temperature of a sample of gas could be obtained which would hold to a good approximation for all gases. Gases behave in a similar way over a wide variety of conditions because they all have molecules which are widely spaced, and the equation of state for an ideal gas is derived from kinetic theory. The earlier gas laws are now considered as special cases of the ideal gas equation, with one or more of the variables held constant.

### Boyle's Law

Boyle's Law, published in 1662, states that, at constant temperature, the product of the pressure and volume of a given mass of an ideal gas in a closed system is always constant. It can be verified experimentally using a pressure gauge and a variable volume container. It can also be derived from the kinetic theory of gases: if a container, with a fixed number of molecules inside, is reduced in volume, more molecules will strike a given area of the sides of the container per unit time, causing a greater pressure.

As a mathematical equation, Boyle's Law is written as either:

$$p \propto \frac{1}{V} \text{ or } pV = k \text{ or } P_1V_1 = P_2V_2$$

Where P is the pressure and V is the volume of a gas, and k1 is the constant in this equation (and is not the same as the proportionality constants in the other equations below). The statement of Boyle's law is as follows:

The volume of a given mass of a gas is inversely related to the pressure exerted on it at a given temperature and given number of moles.

### Charles's Law

Charles's Law, or the law of volumes, was found in 1787 by Jacques Charles. It states that, for a given mass of an ideal gas at constant pressure, the volume is directly proportional to its absolute temperature, assuming in a closed system.

As a mathematical equation, Charles's Law is written as either:

$$V \propto T = \frac{P}{T} = k \text{ or } \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Where V is the volume of a gas, T is the absolute temperature and K<sub>2</sub> is a proportionality constant (which is not the same as the proportionality constants in the other equations in this article).

### Gay-Lussac's Law

Gay-Lussac's Law, Amontons' Law or the Pressure Law, was found by Joseph Louis Gay-Lussac in 1809. It states that, for a given mass and constant volume of an ideal gas, the pressure exerted on the sides of its container is directly proportional to its absolute temperature.

As a mathematical equation, Gay-Lussac's Law is written as either:

$$P \propto T = \frac{P}{T} = k \text{ or } \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Where P is the pressure, T is the absolute temperature, and K<sub>3</sub> is another proportionality constant.

### Avogadro's Law

Avogadro's Law states that the volume occupied by an ideal gas is directly proportional to the number of molecules of the gas present in the container. This gives rise to the molar volume of a gas, which at STP (273.15K, 100kPa) is about 22.7l/mol. The relation is given by:

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

where  $n$  is equal to the number of molecules of gas (or the number of moles of gas).

### Combined and Ideal Gas Laws

The Combined Gas Law or General Gas Equation is obtained by combining Boyle's Law, Charles' Law, and Gay-Lussac's Law. It shows the relationship between the pressure, volume, and temperature for a fixed mass (quantity) of gas:

$$pV = k_s T$$

This can also be written as:

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

With the addition of Avogadro's Law, the combined gas law develops into the Ideal Gas Law:

$pV = nRT$  where  $P$  is pressure,  $V$  is volume,  $n$  is the number of moles,  $R$  is the universal gas constant and  $T$  is temperature (K); where the proportionality constant, now named  $R$ , is the universal gas constant with a value of  $0.083144598 \text{ (atm}\cdot\text{L)/(mol}\cdot\text{K)}$ .

An equivalent formulation of this Law is:  $pV = kNT$

Where  $P$  is the pressure,  $V$  is the volume,  $N$  is the number of gas molecules,  $K$  is the Boltzmann constant ( $1.381 \times 10^{-23} \text{ J}\cdot\text{K}^{-1}$  in SI units)  $T$  is the absolute temperature.

These equations are exact only for an ideal gas, which neglects various intermolecular effects (see real gas). However, the ideal gas law is a good approximation for most gases under moderate pressure and temperature.

#### **This law has the following important consequences:**

1. If temperature and pressure are kept constant, then the volume of the gas is directly proportional to the number of molecules of gas.
2. If the temperature and volume remain constant, then the pressure of the gas changes is directly proportional to the number of molecules of gas present.
3. If the number of gas molecules and the temperature remain constant, then the pressure is inversely proportional to the volume.
4. If the temperature changes and the number of gas molecules are kept constant, then either pressure or volume (or both) will change in direct proportion to the temperature.

## Other gas laws

- ④ Graham's law states that the rate at which gas molecules diffuse is inversely proportional to the square root of its density. Combined with Avogadro's law (i.e. since equal volumes have equal number of molecules); this is the same as being inversely proportional to the root of the molecular weight.
- ④ Dalton's law of partial pressures states that the pressure of a mixture of gases simply is the sum of the partial pressures of the individual components. Dalton's Law is as follows:
- ④ Henry's law states that:

At constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid.

## 10.7 Remedial extension and consolidation

1. Gas is confined in a tank at a pressure of  $1.0 \times 10^8 \text{ Pa}$  and a temperature of  $50^\circ \text{C}$ . If half the gas is withdrawn and the temperature is raised to  $65^\circ \text{C}$ , What is the new pressure in the tank?
2. Fixed mass of a perfect gas is held at  $27^\circ$ . It is heated so that its volume is doubled, but the pressure kept constant. Find the new temperature.
3.  $2.30 \text{ l}$  of a gas is at  $725.0 \text{ mmHg}$  pressure. What is its volume at standard pressure? Recall that standard pressure is  $760 \text{ mmHg}$ .

**Answer:** To solve this problem we first place given values into our Boyle's law equation,  $P_1 V_1 = P_2 V_2$  where X is the asked pressure:

$$725 \text{ mmHg} \times 2.30 \text{ l} = 760 \text{ mmHg} \times X$$

$$X = (725 \text{ mmHg} \times 2.30 \text{ l}) \div 760 \text{ mmHg}$$

4.  $4.35 \text{ l}$  of a gas is at  $1.16 \text{ atm}$ . What pressure is obtained when the volume is  $9.3 \text{ l}$ ?

**Answer:** So let's use the same method as we did for problem 1.

$$1.16 \text{ atm} \times 4.35 \text{ l} = X \times 9.3 \text{ l}$$

$$X = (1.16 \text{ atm} \times 4.35 \text{ l}) \div 9.3 \text{ l}$$

5. Let's say this time we have 3.68l of a gas which is at an unknown pressure. However, at standard pressure, its volume was determined to be 9.20l. We need to solve for the unknown pressure?

**Answer:** This time the units of pressure was not given. Before, in the above examples we used, mmHg (mm of Mercury) and atm (atmospheres). Since the units were not given, it's up to us and this time we'll use the kPa or "kiloPascal." value for standard pressure.

- ⦿ Just as before we insert into the  $P_1 \times V_1 = P_2 \times V_2$  relationship our values to calculate the solution.

$$(X) \times (3.68l) = (101.325kPa) \times (9.20l)$$

$$X = (101.325kPa \times 9.20l) \div (3.68l)$$

6. A gas is collected and found to fill 4.73l at 35.0°C. What will be its volume at standard temperature?

**Answer:** convert 35.0°C to Kelvin and you get 308°K.

- ⦿ Standard temperature is 273°K.  
 ⦿ Now we insert our given values into our Charles' law equation.

$$\frac{4.73l}{308K} = \frac{X}{273K}$$

- ⦿ Remember to keep the correct quantities paired up: in this case 4.73l and 308°K and the unknown x with 273°K
7. 8.00l of a gas is collected at 60.0°C. What will be its volume upon cooling to 30.0°C?

- ⦿ Here a wrong answer, 4.00l. We cannot just divide by 2 because 60.0°C is twice 30°C given that the temperature is given in Celsius; we could do it if the temperature were given in degrees Kelvin, however. But since we're starting with Celsius we can't simply divide and be done.

**Answer:** So first we convert 60.0°C to 333°K and 25.0°C to 303°K. We MUST always convert to KELVIN!! Then plug into the equation and solve for x, like this:

$$\frac{8.00l}{333K} = \frac{X}{303K}$$

- ⦿ Again notice that the °K units cancel out leaving X in the proper units of volume.

8. 5.00L of a gas is collected at 100K and then allowed to expand to 50.0L.

- ⦿ What is the new temperature in order to maintain the same pressure?
- ⦿ Here again we use Charles' Law.

**Answer:**

$$\frac{500l}{100K} = \frac{50.0l}{X}$$

9. 9.0L of a gas is found to exert 83.0 kPa at 35.0°C. What would be the required temperature (in Celsius) to change the pressure to standard pressure?

**Answer:** We must first change 35.0°C to 308.0K and remember that standard pressure in the kiloPascal unit (kPa) is 101.325. Insert values into the equation, giving us:

$$\frac{83Pa}{308K} = \frac{101.32kPa}{X}$$

The answer is 375.9°K, but the question asks for Celsius, so you subtract 273 to get the final answer of 102.9°C.

10. 4.73l of a gas is collected at 32.0°C and 625.0mmHg. When the temperature is changed to standard conditions, what is the new pressure?

**Answer:** Remember first to CONVERT TO KELVIN and insert:

$$\frac{625.0mm}{305K} = \frac{X}{273.0K}$$

11. This type of combined gas law problem is frequently encountered, especially when values are calculated at “standard temperature and pressure” or STP conditions.

- ⦿ So let's say that 3.00l of a gas is collected at 35.0°C and 705.0mmHg. What is the volume at STP?
- ⦿ Five values are provided in the problem and we need to figure our the sixth which is our X value. As usual we need to be sure to change any temperature presented in Celsius (or any other scale) temperatures to Kelvin.
- ⦿ This six variable problem can be set up with the P, V and T variables described in a table:

$P_1 =$	$P_2 =$
$V_1 =$	$V_2 =$



$T_1 =$	$T_2 =$
---------	---------

- ⦿ Then the table can be filled in with information provided in the text of the problem. First the right-hand side or answer side may be filled in with the STP values:

$P_1 =$	$P_2 = 760.0\text{mmHg}$
$V_1 =$	$V_2 = X$
$T_1 =$	$T_2 = 273\text{K}$

- ⦿ On test questions, STP or standard conditions or standard temperature and pressure will be used in the problem set up.
- ⦿ In the table below all the values except, of course, X are filled in.

$P_1 = 705\text{mmHg}$	$P_2 = 760.0\text{mmHg}$
$V_1 = 3.00\text{l}$	$V_2 = X$
$T_1 = 308\text{K}$	$T_2 = 273\text{K}$

- ⦿ Placing these values in their correct places in the combined gas law equation:

$$\frac{(P_1) \times (V_1)}{T_1} = \frac{(P_2) \times (X)}{T_2} \text{ allows solution for X, i.e. } V_2.$$

12. A sample of dry gas weighing 3.1134grams is found to occupy 3.650l at 22.0°C and 740.0mmHg.

- ⦿ How many moles of the gas are present?
- ⦿ The units for R require that the units for pressure MUST be in atm.
- ⦿ Therefore, the 740.0mmHg must be converted first.

$$740.0 \text{ mm Hg} \div 760.0\text{mmHg/atm} = 0.9737\text{atm.}$$

- ⦿ Use these values in the equation, solving for n:
- ⦿  $(0.9737 \text{ atm}) (3.65\text{l}) = (n) (0.08206\text{l/atm/molK}) (295.0\text{K})$

Abbreviations
atm (atmosphere)
mmHg (millimeters of mercury)
torr (same as mmHg)
Pa (Pascal; kPa = kiloPascal)
K (Kelvin)

$^{\circ}\text{C}$  = degrees Celsius

**Conversions**

$$\text{K} = ^{\circ}\text{C} + 273$$

$$1 \text{ cm}^3 \text{ (cubic centimeter)} = 1 \text{ ml (milliliter)}$$

$$1 \text{ dm}^3 \text{ (cubic decimeter)} = 1 \text{ l (liter)} = 1000 \text{ ml}$$

$$0.00^{\circ}\text{C} = 273 \text{ K}$$

$$1.00 \text{ atm} = 760.0 \text{ mmHg} = 101.325 \text{ kPa} = 101,325 \text{ Pa}$$

# Unit 11

## Magnetisation and Demagnetisation

### Key unit competence:

By the end of this unit the learner should be able to describe methods of magnetisation and demagnetisation.

### Learning objectives:

By the end of this unit, learners should be able to;

- ④ Review previous knowledge of magnets.
- ④ Describe the magnetic properties of iron and steel.
- ④ Describe the methods of magnetising and demagnetising of materials.
- ④ Explain use of keepers in storing magnets.
- ④ Explain magnetic shielding.
- ④ Explain magnetisation using the domain theory.
- ④ Create temporary and permanent magnets.
- ④ Describe methods demagnetising magnets.
- ④ Explain demagnetisation using the domain theory.
- ④ Discuss methods of storing magnets.

## Resources:

Magnet, hammer, iron filings, soft iron, steel metal, Computer CDs, magnetic tapes, metallic wrist watches AC and DC power supplies. Once materials are not available, you with learners should improvise the activity in order to make the learners more competent.

### 11.1 Specific suggested methods/strategies/approaches of the unit

Before introducing this unit, the teacher may first review and assess the understanding of learners on what they learned in the previous unit, about magnetism.

Magnetisation and demagnetisation involves many observations, practical activities. Some other methods you can use when teaching lessons in this unit may include:

- ↑ Demonstrations and observations
- ↑ Question-answer method with immediate feedback

You should make sure that all learners feel supported in their learning so that they can understand the contribution of magnetisation and demagnetisation to society and in their individual lives.

### 11.2 Support on assessment strategies and tasks of assessment

You may use question- answer method throughout as formative assessment of your learners. You can use multiple choice questions and advanced questions to assess and test the understanding of learners on magnetisation and demagnetisation for summative assessment.

### 11.3 Lessons and timing

This unit consists of 7 lessons and each lesson should be covered in 40 minutes.

	Lessons	Periods
1.	Structure of an atom and magnetism	3
2.	Magnetisation and demagnetisation	2
3.	Magnetic keepers and magnetic shielding	1
4.	Summative assessment	1

## 11.4 Solutions of unit activities

### Activity 11.1

Do the activity with the learners and guide them in their discussion and help them to draw a good conclusion.

#### Possible answers to the questions:

1.
  - (a) The compass needle is magnetic so, if you place a magnet near the compass, the needle will change direction either attracting or repelling.
  - (b) The compass needle is a magnet and as you have probably tried, a magnet will 'stick' to an Iron bar. Thus as you move the compass near the Iron, its magnetic field lines are bent by the Iron and become locally stronger than the field lines of the planet, deflecting the needle away from north.
2. This phenomenon is called magnetism. Where the magnets exert the magnetic fields on each other and also magnetic materials within their fields.

### Activity 11.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

You will notice that the metal rod in the coil will attract the paper clip as it has become a magnet.

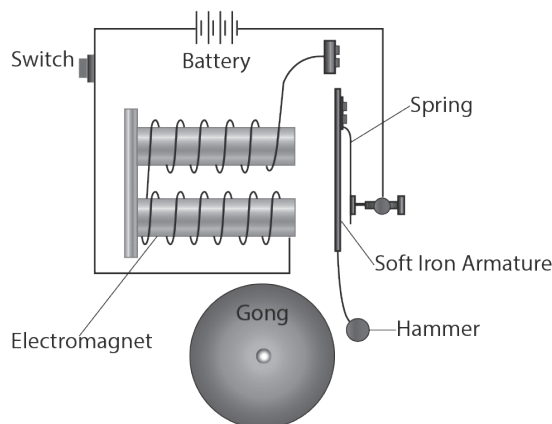
## 11.5 Suggested answers for unit 11 Assessment

1. Electrons are negatively charged and protons are positively charged. The neutrons do not have a charge.
2.
  - (a) **False.** Positively charged objects have electrons; they simply possess more protons than electrons.
  - (b) **False.** Negatively charged objects have protons; their number of electrons is greater than their number of protons.
  - (c) **False.** Electrically neutral atoms simply possess the same number of electrons as protons. This gives the objects a balance of both types of charge.
3. A is negative; B is neutral; C is positive. Determining whether a particle is + or - is a matter of comparing the number of electrons to the number of protons.

If there are more electrons than protons, then it is negative. If there are more protons than electrons, then it is positively charged.

4. From  $Q = ne$ ,  

$$n = \frac{Q}{e} = \frac{10}{1.6 \times 10^{-19}} = 6.25 \times 10^{19} \text{ electrons.}$$
5. Yes: Because the positive electron is also called positron or antielectron is the antiparticle or the antimatter counterpart of the electron. The positron has an electric charge of  $+1 e$ .
6. Magnetic domain alignment creates a stronger external magnetic field. The field of one piece of iron in turn can align domains in another iron sample. A non uniform magnetic field exerts a net force of attraction on magnetic dipoles aligned with the field.
7. The shock misaligns the domains. Heating will also decrease magnetism.
8. Electric bell



9. The cause of ferromagnetism is the electrons in the outer shells of each atom. Electrons moving round the nucleus create tiny magnetic fields because they are moving charges, and moving charges from electric currents. In ferromagnetic atoms, the electrons of each atom, produce zero resultant magnetic field. So ferromagnetic atoms are like tiny magnets.

Heating a bar magnet causes it to lose its magnetism. The effect is to give the atomic magnets enough energy to turn in random directions. For example, iron loses its magnetism if it is heated to a temperature of  $800^{\circ}\text{C}$ .

10. Temporary magnet is the body which is easily magnetised, but do not retain their magnetism (soft). An example is **mumetal**.

While permanent magnet is the body which retains its magnetism extremely well, and is therefore, said to be magnetically hard, examplealnico.

### **Summary of Various Applications and Uses of Magnets:**

We come across magnets in various forms such as computers, MRI machines or inside some appliances which are used in the house, business or medical industry. The size can be from very small to the large giant like structures. Some magnet uses at home, in laboratory and in daily life is provided in the points below.

- We might be using computers in our day to day lives but never wondered the presence of a magnet inside it. Magnetic elements present on a hard disk helps to represent computer data which is later ‘read’ by the computer to extract information.
- Magnets are used inside TVs, Sound speakers and radios. The small coil of wire and a magnet inside a speaker transforms the electronic signal to sound vibrations.
- Magnets are used inside a generator to transform mechanical energy to electrical energy where there are other kinds of motors which use magnets to change electrical energy to mechanical energy.
- Electrically charged magnets can help cranes to move large metal pieces.
- Magnets are used in filtering machines which separates metallic ores from crushed rocks.
- It is also used in food processing industries for separating small metallic pieces from grains etc.
- Magnets are used in MRI machines which are used to create an image of the bone structure, organs, and tissues. Even magnets are used to cure cancer.
- At home, you use magnets when you stick a paper on the refrigerator in order to remember something. Attaching a magnetic bottle opener to the fridge can come in handy.
- We often use pocket a compass to find out directions when we are on a trek. The pocket compass uses a magnetic needle to point north.
- The dark strip on the back of debit and credit cards is of magnetic nature and are used to store data just like computers’ hard drives.
- Magnets can help collect all the nails which are scattered on the ground after a repair job.

## **11.6 Additional information (content)**

### **When and how to use magnetic shielding**

When electronic equipment intended to handle certain precise levels of input, whether logic or continuous signal, picks up undesired inputs at the operating, triggering or higher levels, a dysfunction occurs. The sources of EMI/RFI include conducted interference via wire, cable, and/or induced voltage and current attributable to

electromagnetic fields that couple energy into the calibrated circuits. Sometimes the undesired source is obvious and can be subjected to line filtering or shielding suitable to the frequency and intensity encountered. However, unexpected and unpredicted sources and combinations may not be analysed so easily.

The earth's magnetic field, of course, is pervasive but not always taken into consideration.

Other unwanted fields including electromagnetic pulses of wide dynamic range can be caused by local severe thunderstorms and improperly grounded power cable systems acting as antennas for switching transients on the power lines, or for the low-frequency power currents. In aircraft, for example, instruments are closely packaged due to limited space. The radar tube's performance can be visibly distorted by nearby tachometers which may radiate a rotating magnetic field. The radar display is subject to some position shift each time the aircraft changes direction or attitude relative to the earth's field. A magnetic (i.e. permeable) shield enclosure minimises these effects as well as supporting and positioning the tube. Clear, sharp CRT readouts are vital in many applications. Yet, without magnetic shielding at the tube neck, this cannot be optimally achieved.

In electron microscopes, a magnetic shield around the vertical column prevents resolution deterioration caused by beam scattering, bending or displacement from normal optimum focus position. A sharp, clear focus is thus achieved, permitting full magnification.

Magnetic shielding is indispensable for providing an economical, repeatable controlled magnetic environment for determining response characteristics, sensitivity and orientation direction of magnetic sensor devices used for signature recognition, proximity sensing, etc. in a wide variety of industrial, military and commercial security applications. Complex, high resolution video recorded head assemblies must be shielded from a wide range of magnetic field interferences that may prevent full operational capability in recording/playback applications in television studio/mobile, closed circuit, professional home and other video display systems.

## 11.7 Remedial, Extension and consolidation

1. Which of these is NOT a basic component of an atom?  
(a) Electron (c) Proton  
(b) Quantum (d) Neutron
2. Do magnets lose their strength over time?
3. What might affect a magnet's strength?
4. How can you tell which is the "North" pole if it is not marked?
5. What are the different types of magnets available?
6. State at least three methods of magnetising a magnet.
7. State at least three methods of demagnetising a magnet



# Unit 12

## Applications of Electrostatic

### Key unit competence:

By the end of this unit the learner should be able to explain applications static charges.

### Learning objectives:

By the end of this unit, learners should be able to;

- Explain and describe distribution of electric charges in metallic conductors.
- Explain electric force, electric field and electric potentials.
- Discuss applications of electrostatic.
- Appreciate the applications of electrostatics.
- Appreciate the need to find other applications of electrostatics.
- Realise possible hazards related to electrostatic and how to avoid them.
- Define electric field strength.
- Relate electric field patterns and charge distribution on conductors of different shapes.
- Evaluate applications of electrostatics in other fields (agriculture, environment, industry).

### Resources:

Electroscopes, Van de Graff generator, ebonite rods, glass rods, treads, silk, animal fur and photocopy machine. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

## 12.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. We suggest experiments, observations and demonstration activities. Group discussion and presentation, Question-answer with immediate feedback, Solving problems in pairs or in groups will help each other.

## 13.2 Support on assessment strategies and tasks of assessment

You may use multiple choice questions, completing the statement for short assessment after covering each lesson with the unit and question-answer sessions during the lesson as formative assessment.

Advanced questions at the end of the unit may be used for summative assessment and home work.

## 12.3 Lessons and timing

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	Lessons	Periods
1.	Review to electrostatic and introduction to electric field	2
2.	Electric potential	1
3.	Charge distribution and gas law	2
4.	Application of electrostatics	3
5	Summative assessment	1

## 12.4 Solutions of unit activities

### Activity 12.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

### What's happening?

Rubbing the balloons against the woolen fabric or your hair creates static electricity. This involves negatively charged particles (electrons) jumping to positively charged objects. When you rub the balloons against your hair or the fabric they become negatively charged, they have taken some of the electrons from the hair/fabric and left them positively charged.

They say opposites attract and that is certainly the case in these experiments, your positively charged hair is attracted to the negatively charged balloon and starts to rise up to meet it. This is similar to the aluminum can which is drawn to the negatively charged balloon as the area near it becomes positively charged, once again opposites attract.

In the first experiment both the balloons were negatively charged after rubbing them against the woolen fabric, because of this they were unattached to each other.

### Activity 12.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

A compass allows us to observe the direction of a magnetic field: compass needles are just little magnets that are free to rotate. Normally, compasses respond to the Earth's magnetic field, orienting themselves parallel to the magnetic field lines. If we create a magnetic field that is stronger than **the Earth's field for example, by using electric currents, a compass needle will orient itself parallel to the new field.**

**Caution!** Working with electricity can really heat things up! Always be careful with hot wires. And be sure that you don't leave the clip leads connected too long, because the electric current will rapidly drain the battery and may cause it to overheat. A few seconds should be long enough to make good observations.

### Check my progress

1. Like charges ..... REPEL..... but unlike charges do ..... ATTRACT.....
2. (B) conserved
3. (A) Distance from the charge
4. (A) and (D) are wrong
5. (C) Like charges.

### Check my progress

1. (A) TRUE
2. (a) TRUE
3. (b) FALSE
4. (d)  $Potential = k \frac{q}{r} = 9 \times 10^9 \times \frac{11 \times 10^{-6}}{1} = 99000V = 99kV$

### **Activity 12.3**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Help them to answer the questions provided on lightening and thunder storm.

### **Activity 12.4**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. For the purpose of protecting their houses from electric short circuits which may result in the flow of charges from the clouds into the normal house circuit.
2. They carry electric charges from the clouds in the ground. They work in the time that a moving charged clouds meet a lightening arrestor; and then this end to carry those charges in the ground without damaging the house's installation.

### **Activity 12.5**

Using the available materials, group learners into different groups and make sure you balance gender and learners with disabilities. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

The teacher should visit the workshop before to make sure that all needed materials are there, hence using the internet research, you may find the function of the printer and a photocopier (how it functions). This will help you to guide learners in this activity.

### **Activity 12.6**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

### **Activity 12.7**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Read carefully the activity, do the activity with learners and they observe the changes produced.

**Activity 12.8**

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

- ⦿ Ask the learners: What is static electricity? Explain and give an example (e.g., clothes sticking together in the dryer). Ask learners to brainstorm ways static electricity can be used to clean air pollution.
- ⦿ Ask the learners to record their observations of the class demonstration. Instruct them to record anything that seems important.
- ⦿ Discuss student observations. Explain that electrostatic precipitators capture small particles (called particulate matter) from the polluted air before the air is released into the atmosphere. Describe the purposes for which we use an electrostatic precipitator.

**Questions**

1. Does the electrostatic precipitator remove all of the particulates? (Answer: No, not all of them. Electrostatic precipitators are about 98% efficient.)
2. How does this compare to the efficiency of a wet scrubber? Which one is better? (Answer: A wet scrubber is 94% efficient, so precipitators are more efficient).
3. If the precipitators are more efficient, why would you ever want to use a wet scrubber? (Answer: Wet scrubbers work better on gases.)

**12.5 Suggested answers for unit 12 assessment**

1. The Coulomb force between two equal charges (spheres) is  $F = k_e q^2 / r^2$

We know:  $F = 2.20 \times 10^{-21} \text{ N}$ ,  $r = 35 \text{ cm} = 0.35 \text{ m}$ , electrostatic constant:

$k_e = 8.988 \times 10^9 \text{ Nm}^2\text{C}^{-2}$ . Then we can find  $q$ :  $q = 0.17 \times 10^{-15} \text{ C}$

Then we can find the number of excess electrons (since we know the charge of a single electron:  $e = 1.6 \times 10^{-19}$ )

$$N = \frac{q}{e} = \frac{0.17 \times 10^{-15}}{1.6 \times 10^{-19}} = 1062$$

2. The magnitude of electric field due to charge 1 is;

$$E_1 = K_e \frac{q_1}{(x)^2 + (y)^2} = 8.988 \times 10^9 \frac{7 \times 10^{-2}}{0.6^2 + 0.8^2} = 20302 \text{ N/C}$$

The magnitude of electric field due to charge 2 is;

$$E_2 = K_e \frac{q_2}{(x)^2 + (y)^2} = 8.988 \times 10^9 \frac{4 \times 10^{-9}}{0.6^2 + 0^2} = 32226 \text{ N/C}$$

3. We have equilibrium. It means that the net force is 0. Then the gravitational force should be equal to electric force:

$$mg = /qE$$

From this equation we can find the charge of the particle;

$$(q) = \frac{mg}{E} = \frac{0.005 \times 9.8}{800} = 0.0000613 \text{ C}$$

The direction of electric force should be upward (since the gravitational force has downward direction). Since the direction of the electric field is downward then the electric charge should be negative:

$$q = - 0.0000613 \text{ C}$$

4. The electric force is equal to gravitation force. So we can write:

$$mg = qE$$

From this equation we can find the electric field;

$$E = \frac{mg}{q} = \frac{1.67 \times 10^{-27} \times 9.8}{1.6 \times 10^{-19}} = 10^{-6} \text{ N/C}$$

5. The magnitude of electric field due to point charge is given by the expression:

$$E = k_e \frac{q}{r^2} = k_e = 8.988 \times 10^9 \frac{8 \times 10^{-9}}{0.5^2} = 287 \text{ N/C}$$

Since the charge is negative then the direction of electric field is downward (toward the charge).

6. Introduce the distance from the charge 0.7nC to the point P, where the net electric field is 0. The net electric field at point P is the sum of two contributions: electric field due to charge 0.7nC and electric field due to charge 12nC. They have opposite directions (since both charges are positive). Then the condition that the net electric field is 0 is the following:

$$k_e \frac{q_1}{a^2} = k_e \frac{q_2}{(r-a)^2}$$

where  $r=2$  m is the distance between the charges. From this equation we can

$$\text{find the distance } a: a = \frac{rq_1^{\frac{1}{2}}}{q_1^{\frac{1}{2}} + q_2^{\frac{1}{2}}} = 0.39m$$

7. Electric field due to infinite plane:

$$E = 2\pi k_e \delta$$

Where  $K_e = 8.988 \times 10^9 \text{ Nm}^2\text{C}^{-2}$ . The surface charge density (charge density per square meter) is:

$$a = 4 \times 10^6 \times 10^4 \times 1.6 \times 10^{-19} \text{ C/m}^2 = 0.64 \times 10^{-8} \text{ C/m}^2$$

Then the magnitude of electric field is;

$$E = 2 \times 1314 \times 8.988 \times 10^{19} \times 0.64 \times 10^{-8} = 361 \text{ N/C}$$

The direction of electric field is towards the plane (since the plane is negatively charged).

$$8. \quad E = \frac{9.0 \times 10^9 \times 9.1 \times 10^{-9}}{(3.74 \times 10^{-2})^2} = 58551.9 \text{ N/C}$$

$$9. \quad d = \sqrt{\frac{kQ}{E}} = \sqrt{\frac{9.0 \times 10^9 \times 5.536 \times 10^{-9}}{1.9 \times 10^5}} = 0.016 \text{ m}$$

$$V = \frac{W}{Q} = \frac{88.3}{0.051} = 122.5 \text{ V}$$

$$10. \quad E = \frac{v}{d} = \frac{44.6}{0.051} = 874.5 \text{ N/C}$$

11.

12. Van De Graff generator is used to generate high potential differences of near about million volts. Then the generated potential differences are used to speed up the particles like ions etc.

13. Damages due to lightning flashes are very common. But with the help of a lightning conductor we can save our large buildings on which we have spent lots of money. The lightning conductor consists of a large no of conductors having sharp pointing heads.

14. The phenomenon of Thunderstorm and lightning is still unclear. Some experimental observations on this fact can be seen. It is said that during a

thunderstorm different, charged ions are separated from each other due to a complicated process. Explain the statement.

15. It is the best way to protect some area in the vacuum from the influence of the external electric field. As we have proved earlier that the electric field inside a conductor is ...
16. Those substances which have the ability to carry charge from one place to another are called conductors. Silver is one of the best conductors. There are lots of examples of conductors like aluminum, coal, iron, copper, etc. Some conductors are solid and some are liquids.
17. At any point; electric field intensity is the total sum of all the electric field intensities generated due to different charges at the same point. If other charges are absent then vectorially sum up their Electric field intensities. Here is the measure of the distance.
18. The inventions of electric lines of force were done by a famous scientist Michael Faraday. These do not provide the full info about electric field, but provide us with quantitative partial information. Def: Electric lines of force can be defined as a way or path, it may ...

## 12.6 Additional information (content)

### Electrostatics and everyday life



Fig. 12.1

1. When you take off a pullover over a nylon shirt there is a crackling sound.
2. A pen rubbed with a piece of cloth will pick up small pieces of paper.
3. A television screen collects dust easily.
4. If you roll over in bed you can sometimes see small sparks between the bed sheets.
5. Sellotape and cling film sticking to everything.
6. Getting a small electric shock from a cat that has rolled on a synthetic carpet
7. In a thunder storm there are huge flashes of lightening.



8. An electrostatic dust collector in a chimney.
9. Paint sprays can be charged and the object they are spraying earthed to attract the paint towards it.
10. Photocopiers use a charged sheet to attract fine carbon powder.
11. Charges build up when emptying oil tankers or refueling planes.

Have you ever thought about why the plastic bags from your lunches stick to your clothing or why lightning strikes? Well, these are just some of the many examples of electrostatic forces in our everyday lives.

**Plastic bags:** As you unwrap your lunch, the plastic bag gets charged with a positive charge, and is attracted to your negatively charged clothing. This is due to the fact that when one object is negatively charged and the other positively charged, they will be attracted to each other.

**Lightening** is another example of electrostatic forces in everyday life, but is shown on a massive scale. When clouds rub against each other, the particles will gain a charge, and these charges want to equalise. As the ground has a neutral force this is an ideal place for the particles to equalise their charge, the flash of lightening is the charges equalising with the ground.

**Woollen clothing:** When taking off woollen clothing, the rub against the other items of clothing makes the wool negatively charged. As the wool wants to equalise its charge this is the noise and slight zap that occurs.

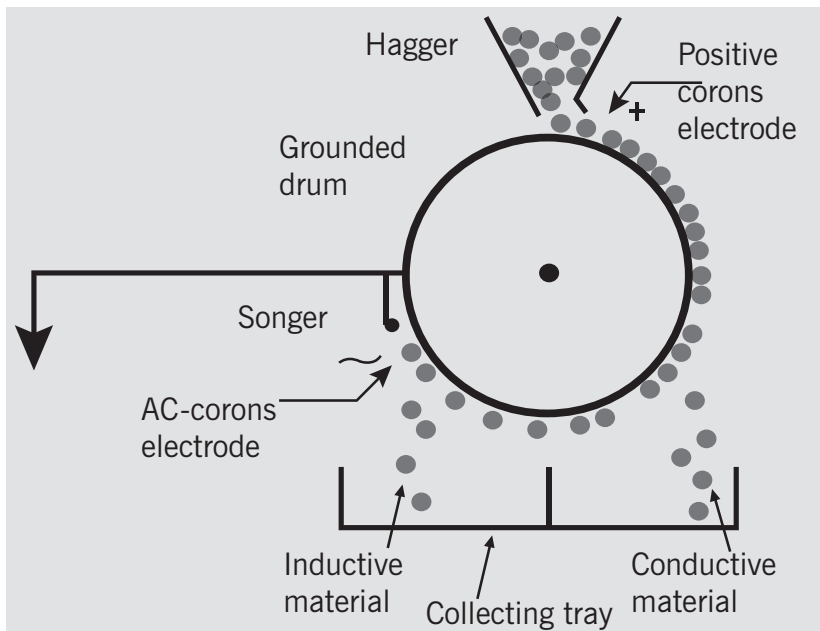


Fig. 12.2

**Photocopiers:** Photocopiers also need electrostatic forces to work. Inside the photocopier there is a special drum, charged with static electricity and the black ink commonly known as toner. This drum attracts the toner particles but the light allows the toner only to touch the marked parts of the paper.

## 12.7 Remedial extension and consolidation

1. Can we give any amount of charge to a capacitor?

**Answer:** No, on giving charge continuously to a capacitor, the p.d across its plates will go on rising and ultimately the insulation of the medium between the plates will break. Then the capacitor will be discharged giving sparking.

**2. Two statements:**

**Statement I:** A small metallic sphere is placed at the center of a large charged spherical shell and the two are connected by a wire. The charge will not flow from the outer sphere to the inner sphere.

**Statement II:** A charged conductor is placed inside the hollow conductor and two are connected by the wire. The whole charge will flow on the outer surface of the outer conductor;

- (a) Both the statement I and II are correct.
- (b) Statement I is correct only.
- (c) Statement II is correct only.
- (d) Both the statements are true.

**Solution: (1)**

3. Superposition principle cannot be applied to these quantities in electrostatics
- (a) Electrostatic energy
  - (b) Electric Field
  - (c) Electric Potential
  - (d) Electric force

**Solution:** (a) It can be applied to an electric field, electric potential and electric force.

4. What is electrostatic shielding?

**Solution** The absence of electric field inside the charged conductors means that electric lines of force cannot enter the empty space of any hollow conductor. Thus hollow conductor can be used to act as electrostatic shield. So sensitive electric instruments can be saved from external electric fields by covering them with hollow conductor.

5. Consider the electric field at the points A, B, C.

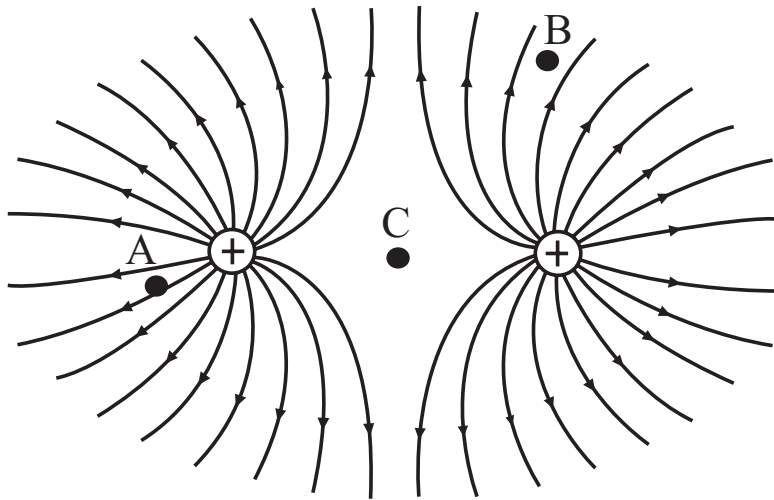


Fig. 12.3

List the points in increasing order of electric field strength

- (a)  $C > B > A$
- (b)  $C > A > B$
- (c)  $A > B > C$
- (d) None of these

**Solution: (a)**

6. Consider the system; which of the following is true?

- (a) Electric flux through surface A2 is zero
- (b) Electric Flux through surface A1 is not zero
- (c) Electric field at the surface A2 is not zero
- (d) None of these

**Solution: (a), (b) and (c)**

7. Two conducting charged spheres X and Y having unequal charges are connected by the wire. Which of the following is true?

- (a) Charge is conserved.
- (b) Electrostatic energy is conserved.
- (c) Both the charge and electrostatic energy is conserved.
- (d) Neither of these is conserved.

**Solution: (a)**

8. What is true of equipotential surface?
- (a) The PD between any two points on the surface is zero.
  - (b) The electric field is always perpendicular to the surface.
  - (c) Equipotential surface are always spherical.
  - (d) No work is done in moving a charge along the surface.

**Solution (a) (b) and (d)**

9. Kariza rubs two latex balloons against her hair, causing the balloons to become charged negatively with  $2.0 \times 10^{-6}\text{C}$ . She holds them a distance of 0.70m apart.
- (a) What is the electric force between the two balloons?
  - (b) Is it one of attraction or repulsion?

**Solution: a.** It is not necessary to carry the sign of the charge through out the entire exercise. However, when determining the direction of your final answer, it is important to remember the charge on each object.  $F=0.073\text{N}$

- c) Because both balloons are negatively charged, they will repel each other.
10. Two pieces of puffed rice become equally charged as they are poured out of the box and into Kirk's cereal bowl. If the force between the puffed rice pieces is  $4 \times 10^{-23}\text{N}$  when the pieces are 0.03m apart, what is the charge on each of the pieces?

**Solution:** Because both charges are the same, solve for both q's together. Then find the square root of that value to determine one of the charges.  $q = 2 \times 10^{-18}\text{C}$

11. When sugar is poured from the box into the sugar bowl, the rubbing of sugar grains creates a static electric charge that repels the grains, and causes sugar to go flying out in all directions. If each of the two sugar grains acquires a charge of  $3.0 \times 10^{-11}\text{C}$  at a separation of  $8.0 \times 10^{-5}\text{m}$ , with what force will they repel each other?

**Answer:  $1.3 \times 10^{-3}\text{N}$**

12. Boppe the clown carries two mylar balloons that rub against a circus elephant, causing the balloons to separate. Each balloon acquires  $2.0 \times 10^{-7}\text{C}$  of charge. How large is the electric force between them when they are separated by a distance of 0.50m?

**Answer:  $1.4 \times 10^{-3}\text{N}$**

13. Ineza uses hair spray on her hair each morning before going to school. The spray spreads out before reaching her hair partly because of the electrostatic charge on the hair spray droplets. If two drops of hair spray repel each other

with a force of  $9.0 \times 10^{-9} \text{ N}$  at a distance of  $0.070 \text{ cm}$ , what is the charge on each of the equally - charged drops of hair spray? Answer:  $7.0 \times 10^{-13} \text{ C}$

14. Bonnie is dusting the house and raises a cloud of dust particles as she wipes across a table. If two  $4.0 \times 10^{-14} \text{ C}$  pieces of dust exert an electrostatic force of  $2.0 \times 10^{-12} \text{ N}$  on each other, how far apart are the dust particles at that time?

**Answer:  $2.7 \times 10^{-3} \text{ m}$**

15. Each of the two hot-air balloons acquires a charge of  $3.0 \times 10^{-5} \text{ C}$  on its surface as it travels through the air. How far apart are the balloons if the electrostatic force between them is  $8.1 \times 10^{-2} \text{ N}$ ?

**Answer: 10m**

# Unit 13

## Arrangement of Resistors in Electric Circuit

### Key unit competence:

By the end of this unit the learner should be able to describe arrangement of resistors in a simple electric circuit.

### Learning objectives:

By the end of this unit, learners should be able to;

- Arrange resistors in a simple electric circuit.
- Explain the magnetic effect of electric current.
- Explain how grounding, fuses, and circuit breakers protect people against electrical shocks and short circuits.
- State and explain the effect of electric current.
- Analyse arrangement of resistors in simple electric circuit.
- Construct a simple electric circuit with resistors in series and parallel, ammeter and voltmeter.
- Illustrate the effect of electric current.
- Apply knowledge of safety to prevent circuits from overheating devices (fuses and circuit breakers).
- Predict what would happen in a house without a fuse or circuit breakers with overloaded electric circuit.
- Measure electric current and potential difference using an ammeter and voltmeter.

## Resources:

Battery, bulb, connecting wire, magnetised needle, insulated copper wire, Ammeter, Voltmeter, Ohmmeter, resistors, Electrolytic cell (Voltammeter). Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

### 13.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. We then suggest experiments observations and demonstration activities.

We suggest experiment methods, question-answer sessions with immediate feedback, demonstration activities, teamwork and presentation.

### 13.2 Support on assessment strategies and tasks of assessment

Use formative assessment during each lesson as they respond to questions, ask questions and interact with other learners during the activities.

You may also use multiple choice, completing the statements and advanced questions at the end of the unit for summative assessment and home work reporting by groups.

### 13.3 Lessons and timing

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	<b>Lessons</b>	<b>Periods</b>
1.	Simple circuit elements	1
2.	Arrangement of resistors	2
3.	Electric potential and electric potential difference	2
4.	Effects of electric current	2
5	Electromagnet and electric bell	2
6	Summative assessment	1

## 13.4 Solutions of unit activities

### Activity 13.1

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

From this experiment on, a multimeter is assumed to be necessary and will not be included in the required list of parts and materials. In all subsequent illustrations, a digital multimeter will be shown instead of an analog meter unless there is some particular reason to use an analog meter. You are encouraged to use both types of meters to gain familiarity with the operation of each in these experiments.

This is the simplest complete circuit in this collection of experiments; a battery and an incandescent lamp. Connect the lamp to the battery as shown in the illustration, and the lamp should light, assuming the battery and lamp are both in good condition and they are matched to one another in terms of voltage.

If there is a “break” (discontinuity) anywhere in the circuit, the lamp will fail to light. It does not matter where such a break occurs! Many learners assume that because electrons leave the negative (-) side of the battery and continue through the circuit to the positive (+) side, that the wire connecting the negative terminal of the battery to the lamp is more important to circuit operation than the other wire providing a return path for electrons back to the battery. This is not true!

### Answer to questions:

Follow instructions and do the same experiment and from your results, guide learners in taking conclusion of their results.

### Activity 13.2

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

The main objective of this is the use of a breadboard; help learners to accomplish the activity. Make sure you have done it before.

### Activity 13.3

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.



1. They all switch off because there is no continuity of the current.
2. When we keep the same source of voltage, the two bulbs bright more.
3. It will have more brightness.

#### Activity 13.4

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. When one bulb is removed, the other bulbs continue to light.
2. The brightness doesn't change.
3. The brightness doesn't change, but the time for one bulb is greater than the time with two or three bulbs.

#### Check my progress

1. (d)  $R = 2.5 + 3.5 + 4 = 10 \Omega$
2. (c) and (d) are correct. If two *identical* resistors are connected in series, they will have the same PD across them, and if these identical resistors are connected in parallel, they will always have the same current passing through them.
3. (d) Half one of the resistances.
4. (a) The smaller the resistance, the less it opposes the current therefore, much current will pass through it.

#### Activity 13.5

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. The potential difference across the resistor.
2. Potential difference (Voltage)
3. When the cells are arranged in series, the total p.d is the sum of all the individual cells.
4. The multimeter will read the same voltage as it is one cell used.

#### Activity 13.6

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide to activity using provided materials and help them to draw a suitable conclusion of their findings.

1. Is measuring the potential difference.

2. Is measuring the current flowing through the circuit.
3. Look at the result in activity 13.4 and 13.5.
4. Perform the ratio  $\frac{V}{I}$  in your experiment.

### Check my progress

1. The answer is either 100V or -100V. The potential difference  
 $V_{AB} = 20 - 120 = -100V$   
And  $V_{BA} = 120 - 20 = +100V$
2. (B) FALSE
3. ALL answer can change the resistance of the wire there fore they can make Ohm's law invalid
4.  $Energy = P.t = 40 \times 60 \times 60 = 144000J = 144k$

### Activity 13.7

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide to activity using provided materials and help them to draw a suitable conclusion of their findings.

It means that the electric current through the copper wire has produced a magnetic effect. Thus we can say that electricity and magnetism are linked to each other.

### Activity 13.8

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

They have the same observation and explanation as activity 13.7

### Activity 13.9

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. They represent the magnetic field lines.
2. Place a compass at a point (say P) over a circle. Observe the direction of the needle. The direction of the north pole of the compass needle would give the direction of the field lines produced by the electric current through the straight wire at point P. Show the direction by an arrow.

### Activity 13.10

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

Do the experiment and guide learners.

### Activity 13.11

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. When the kettle is connected, you will find water heated after a few minutes, the iron will also get hot, and the water in the bucket will also start to get hot.
2. Heat is being provided by the transformation of electric energy into heat energy.

### Activity 13.12

1. The passage of an electric current through a conducting solution causes chemical reactions. This is known as the chemical effect of an electric current. Some of the chemical effects of electric current are the following:
  - ⦿ Formation of bubbles of a gas on the electrodes
  - ⦿ Deposition of metal on electrodes.
  - ⦿ Change in colour of solutions.
2. Help learners to draw a suitable conclusion to their discussions.

### Activity 13.13

Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity using provided materials and help them to draw a suitable conclusion of their findings.

1. The electromagnet (iron rod) will attract the paperclip.
2. Help learners to draw a suitable conclusion to their discussions.

### Project 13.10

Form groups of four, and let them develop the project of making an electric bell. Guide them and help them to get what they need.

## 13.5 Suggested answers for unit 13 Assessment

1. The current outside the branches of a combination circuit is everywhere the same. The current inside of the branches is always less than that outside of the branches. When comparing the current of two parallel-connected resistors, the resistor with the least resistance will have the greatest current. The current within a single branch will be the same above and below the resistor.
  - (a) The current at location A is **equal to** the current at location B.
  - (b) The current at location B is **greater than** the current at location E.
  - (c) The current at location G is **less than** the current at location F.
  - (d) The current at location E is **greater than** the current at location G.
  - (e) The current at location B is **greater than** the current at location F.
  - (f) The current at location A is **equal to** the current at location L.
  - (g) The current at location H is **less than** the current at location I.
2. The voltage drop across a resistor is dependent upon the current in the resistor and the resistance of the resistor. In situations in which the current is the same for both resistors (such as for series-connected resistors), the resistor with the greatest resistance will have the greatest voltage drop.
  - (a) The electric potential difference (voltage drop) between points B and C is greater than the electric potential difference (voltage drop) between points J and K.
  - (b) The electric potential difference (voltage drop) between points B and K is greater than the electric potential difference (voltage drop) between points D and I.
  - (c) The electric potential difference (voltage drop) between points E and F is equal to the electric potential difference (voltage drop) between points G and H.
  - (d) The electric potential difference (voltage drop) between points E and F is equal to the electric potential difference (voltage drop) between points D and I.
  - (e) The electric potential difference (voltage drop) between points J and K is greater than the electric potential difference (voltage drop) between points D and I.

- (f) The electric potential difference between points L and A is equal to the electric potential difference (voltage drop) between points B and K.
3. (a)  $\Delta V = \varepsilon - rI_1 = 18V$   
 (b)  $I_1 = 2A; I_2 = 1.5A$  and  $I_3 = 0.5A$   
 (c)  $P = 40W$   
 (d)  $P_r = 4W; P_1 = 24W; P_2 = 9W$  and  $P_3 = 3W$

Diagram 1

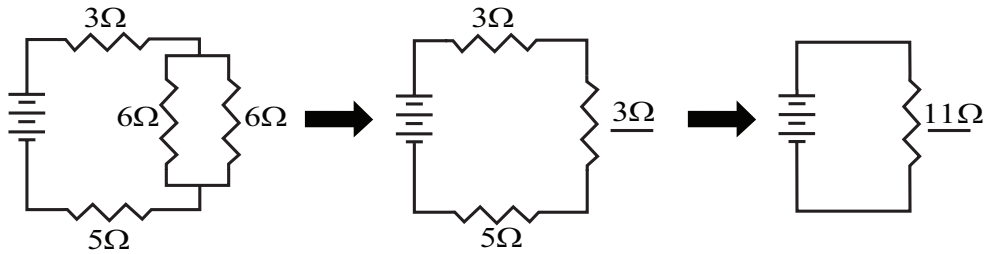


Diagram 2

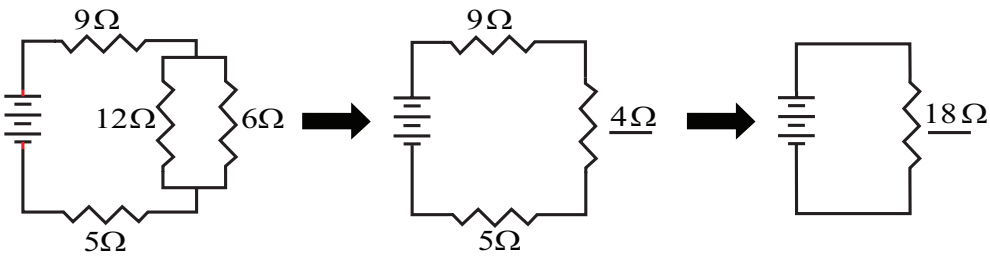


Diagram 3

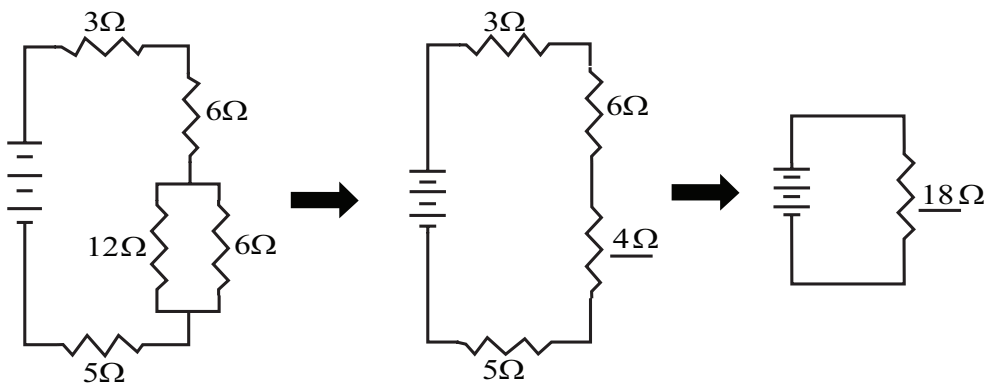


Fig. 13.1

The current in the  $3\Omega$  resistor is  $2A$ , the current in the  $4\Omega$  resistor is  $3A$  and the current in the  $6\Omega$  resistor is  $1A$

4 (a)  $R_p = \frac{10.0 \times 7.00}{7.00 + 10.0} = 4.12\Omega$       $R_{eq} = 4.00 + 4.12 + 9.00 = 17.1\Omega$

b)  $V = IR \Leftrightarrow I = \frac{34.0}{17.1} = 1.99A$  for  $4.00\Omega$  and  $9.00\Omega$

Applying  $V = IR = 1.99 \times 4.12 = 8.18V$

Since  $I = \frac{V}{R}$  then  $I = \frac{8.18}{10.0} = 0.818A$  for  $10.0\Omega$

5. Use the equation for the equivalent resistance of a series circuit:  $R_{eq} = R_1 + R_2 + R_3 + \dots$

(a)  $6\Omega$

(b)  $9\Omega$

(a)  $15\Omega$

(b)  $12\Omega$

(c)  $18\Omega$

(d)  $36\Omega$

6. As the number of resistors in a series circuit increases, the overall resistance increases and the current in the circuit decreases.

7. The conventional current is directed through the external circuit from the positive terminal to the negative terminal. The magnitude of this current ( $I$ ) is everywhere the same - thus the equal sign in the current comparisons.

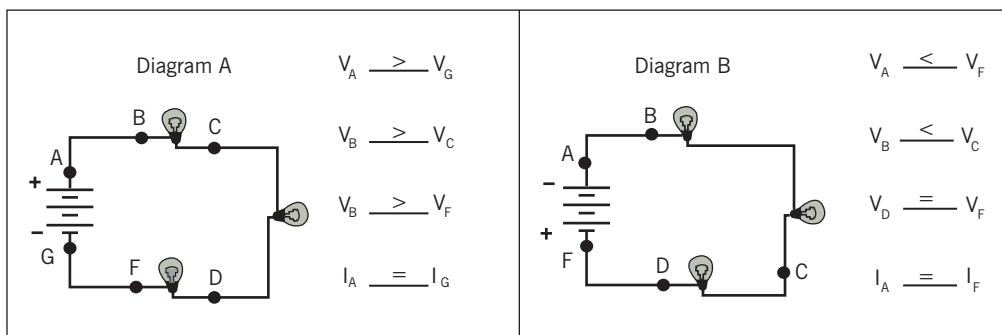


Fig. 13.2

As charge progresses in the direction of the conventional current, there is a drop in electric potential every time it passes through a light bulb. By the time the charge reaches the negative terminal, its electric potential has dropped to zero volts. The closer a position is to the positive terminal, the higher its potential; and conversely, the closer a position is to the negative terminal, the lower its potential.

If two locations are separated by a mere wire (such as location D and F in Diagram B), then their potential is approximately the same since there is relatively little resistance in a wire.

9. The current in a series circuit is the same at each resistor present in the circuit. Since each light bulb has the same resistance (“identical bulbs”) and the same current, they will have the same power output ( $P = I^2R$ ). Thus, they will shine with the same brightness.

Points P and X are outside the branches; they are at locations before (P) and after (X) the nodes. The current at these two locations are the same. The current at these locations are greater than the current at the other three locations since points P and X represent locations through which every charge must flow. Point Q comes after the node and at a location where charge to the middle and the right branch will flow. The current at this location is the greater than the current at locations Y and Z. Locations Y and Z represent locations where charge through a single branch will flow. The current at Y and Z is equal, but less than that at P.

10. As more and more resistors are added in parallel to a circuit, the equivalent resistance of the circuit **decreases** and the total current of the circuit **increases**.

Adding more resistors in parallel is equivalent to providing more branches through which charge can flow. Even though the added branches offer resistance to the flow of charge, the overall resistance decreases due to the fact that there are additional pathways available for charge flow. The fraction of the total charge which encounters a single resistor is now less. The additional branches mean that the circuit can sustain a greater current.

11. **A, C, F, and G**

The current in the battery is dependent upon the electric potential difference across the battery ( $\Delta V$ ) and the total or equivalent resistance of the circuit ( $R_{eq}$ ). A decrease in  $V$  (choice F) and an increase in  $R_{eq}$  would lead to a decrease in the current at the battery location. The overall resistance can be increased by increasing the resistance of any of the light bulbs (choices A and C) or by reducing the number of branches (choice G).

## 13.6 Additional information (content)

### Resistors in Series and in Parallel

Resistors are probably the most commonly occurring components in electronic circuits. Practical circuits often contain very complicated combinations of resistors. It is, therefore, useful to have a set of rules for finding the equivalent resistance of some general arrangement of resistors. It turns out that we can always find the equivalent resistance by repeated application of two simple rules. These rules relate to resistors connected in series and in parallel.

Therefore, from Ohm's Law

$$I_1 = V / R_1$$

$$I_2 = V / R_2$$

But we know the current entering a node (connection point) is equal to the current leaving the node (from Kirchhoff's Current Law)

Therefore

$$I = I_1 + I_2$$

Substituting the values derived for  $I_1$  and  $I_2$  gives us

$$I = V / R_1 + V / R_2$$

$$\text{But } I = V / R_{\text{total}}$$

Therefore

$$1/R_{\text{total}} = 1/R_1 + 1/R_2$$

**Note:**

For N number of resistors all arranged in

- (a) series, the total resistance is given by

$$R_{\text{total}} = R_1 + R_2 + \dots + R_N$$

- (b) Parallel the total resistance is given by

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}$$



## Applications of Electromagnetism

A branch of physics deals with electric current or fields and magnetic fields and their interaction on substance or matter is called Electromagnetism. Electromagnetism has created a great revolution in the field of engineering applications. In addition, this caused a great impact on various fields such as medical, industrial, space, etc.

We can find enormous practical application of electromagnetism in everyday life from domestic appliances to research applications.

If a current carrying conductor wound on a high permeability core (or iron core) creates an electromagnet. If this electromagnet is excited with a source of supply, then the magnetic field is produced. The strength of the magnetic flux depends on the current flowing through the electromagnet and the number of turns wounded on it.

Although all current carrying conductors produce magnetic fields, an electromagnet is specially constructed to maximize the strength of the magnetic field for a specific function.

The magnetic fields produced by electromagnets used for special functioning of the devices. Such devices include transformers, relays, motors, etc. In transformer the magnetic field produced causes the emf to generate in secondary coil such that voltage transfer is carried between two magnetically coupled circuits.

### Household appliances

Electromagnetism serves as a basic principle of working for many of the home appliances in household applications. These applications include lighting, kitchen appliances, air conditioning systems, etc.

- Electric fans, blowers and other cooling systems use electric motors. These motors work on the principle of electromagnetic induction which is the branch of electromagnetism. In any electrical appliance, electric motor is moved by the magnetic field produced by the electric current according to the Lorentz force principle. These motors vary in size, rating and cost based on the application.

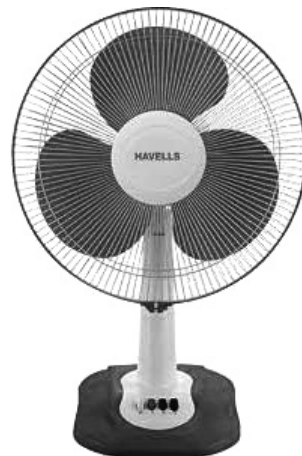


Fig. 13.3. Electric fan

- Kitchen appliances like induction cookers, microwave ovens, electric mixers and grinders, bread toasters, etc. use the electromagnetism for their operation.
- Alarming systems use electrical bells which works based on electromagnetic principle. In these bells, the sound is produced by electromagnetic coils which move the striker against the bell. As long as the coil is energized, iron striker gets attracted by it, hence it strikes the bell.

## Electric Bell

- o Security systems use locking systems for doors which are generally magnetic locking systems. These systems are unlocked either by a magnetic card swiping or having a security code.
  - o Magnetic card reader on the doors reads the number of keys stored in the magnetic tape of the card. When key stored in memory matches with data on the card, then the door opens.
  - o Entertainment system like television, radio or stereo systems use loudspeaker. This device consists of electromagnet which is attached to the membrane or cone surrounded by the magnetic flux produced by the permanent magnet.
- When the current through the electromagnet is varied, electromagnet and membrane of the speaker get moved back and forth. If the current is varied at the same frequencies of the sound waves, results a vibration of the speaker which will further create sound waves.

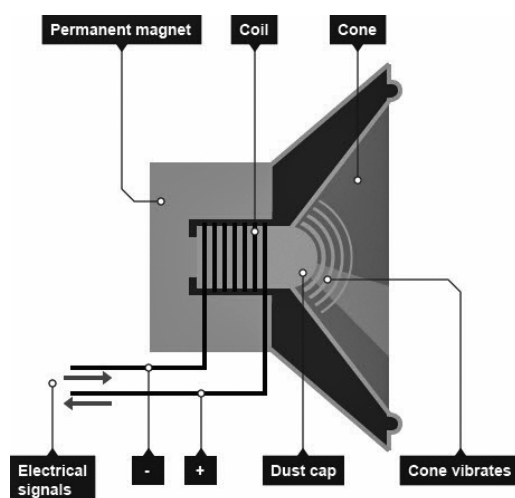


Fig. 13.4. Electric Speaker

## Industrial Applications

Almost all the instruments or devices used in industries are based on the electromagnetism. Materials used in constructing such devices include iron, cobalt, nickel, etc which naturally responds to the magnetic fields.

Starting from small control instruments to the large power equipments, the electromagnetism is used at least at one stage of their working.

- Generators and motors dominate in most of the industries which are the primary power source and driving systems respectively. Generators convert the mechanical to electrical energy whereas the motors convert electrical energy to mechanical energy.
  - o Generators supply the electrical energy in the time of mains power interruption and most of the cases, these are driven by the IC engines. There are different classes of motors which are employed in industries. These are used for cranes, hoists, lifts, conveyor systems, etc.
  - o Medical System: Nowadays electromagnetic fields play a key role in advanced medical equipments such as hyperthermia treatments for cancer, implants and magnetic resonance imaging (MRI).

RF range frequencies are mostly used in medical applications. In MRI scans, sophisticated equipment works based on the electromagnetism can scan minute details of the human body.



Fig. 13.5. Medical system (MRI)

The electromagnetic therapy is an alternate form of medicine which claims to treat disease by applying pulsed electromagnetic fields or electromagnetic radiation to the body. This type of treatments is used for wide range of ailments such as nervous disorders, diabetes, spinal cord injuries, ulcers, asthma, etc.

## 13.7 Remedial extension and consolidation

1. Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right-hand rule to find out the direction of the magnetic field inside and outside the loop.
2. The magnetic field in a given region is uniform. Draw a diagram to represent it.
3. Choose the correct option. The magnetic field inside a long straight solenoid-carrying current
  - (a) is zero.
  - (b) decreases as we move towards its end.
  - (c) increases as we move towards its end.
  - (d) is the same at all points.
4. Which of the following correctly describes the magnetic field near a long straight wire?
  - (a) The field consists of straight lines perpendicular to the wire.
  - (b) The field consists of straight lines parallel to the wire.
  - (c) The field consists of radial lines originating from the wire.
  - (d) The field consists of concentric circles centered on the wire.
5. The phenomenon of electromagnetic induction is;
  - (a) the process of charging a body.
  - (b) the process of generating magnetic field due to a current passing through a coil.
  - (c) producing induced current in a coil due to relative motion between a magnet and the coil.
  - (d) the process of rotating a coil of an electric motor.
6. The device used for producing electric current is called a
  - (a) generator.
  - (b) galvanometer.
  - (c) ammeter.
  - (d) motor.
7. At the time of a short circuit, the current in the circuit
  - (a) reduces substantially.
  - (b) does not change.
  - (c) increases heavily.
  - (d) vary continuously.

8. State whether the following statements are true or false.

- |   | <b>True/False</b> |
|---|-------------------|
| (a) An electric motor converts mechanical energy into electrical energy.                              | True/False        |
| (b) An electric generator works on the principle of electromagnetic induction.                        | True/False        |
| (c) The field at the centre of a long circular coil carrying current will be parallel straight lines. | True/False        |
| (d) A wire with a green insulation is usually the live wire of an electric supply.                    | True/False        |

9. List three sources of magnetic fields.

10. How does a solenoid behave like a magnet? Can you determine the north and south poles of a current-carrying solenoid with the help of a bar magnet? Explain.
11. When is the force experienced by a current-carrying conductor placed in a magnetic field largest?
12. Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from the back wall towards the front wall is deflected by a strong magnetic field to your right side. What is the direction of the magnetic field?
13. A coil of insulated copper wire is connected to a galvanometer. What will happen if a bar magnet is;
- (a) pushed into the coil?
  - (b) withdrawn from inside the coil?
  - (c) held stationary inside the coil?
14. Two circular coils A and B are placed close to each other. If the current in the coil A is changed, will some current be induced in the coil B? Give a reason.

# Unit 14

## Reflection of Light in Curved Mirrors

### Key unit competence:

By the end this unit the learner should be able to analyse applications of reflected light.

### Learning objectives:

By the end this unit, learners should be able to;

- Recall reflection of light in plane mirrors.
- Recall laws of reflection of light in plane mirrors.
- Discuss terms used in curved mirrors.
- Describe the formation of images by spherical mirrors.
- Give the applications of spherical mirrors.
- Appreciate the applications of reflection of light in curved mirrors.
- Adapt scientific and critical thinking in performing experiments of curved mirrors.
- Recognise the applications of plane-curved mirrors.

### Resources:

Curved mirrors, spoon, light source, concave, convex mirror, optical pins and small movable screen. Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

## 14.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. The learners should spend more time demonstrating the activities. Use diagrams and other methods such as questioning and cooperating learning throughout this unit.

## 14.2 Support on assessment strategies and tasks of assessment

Use multiple choice questions and completing the statements for formative assessment during teaching this unit. Graphing and other advanced questions, at the end of the same unit, are used for summative assessment and homework.

## 14.3 Lessons and timing

This unit consists of 10 lessons and each lesson should be covered in 40 minutes.

	Lessons	Periods
1.	Recall on reflection of light on a plane mirror	1
2.	Curved mirrors	3
3.	Use of spherical mirrors	2
4.	Mirrors and magnification and other types of spherical mirrors	2
5.	Summative assessment	2

## 14.4 Solutions of unit activities

### Activity 14.1

Let learners work in groups of four to six and try the activity themselves.

Help learners to use the provided materials as in the learner's book and guide them to do the activity, hence help them to draw a suitable conclusion about the questions provided.

### Activity 14.2

Learners should be working in groups.

- Look at the image in the mirror; it changes in size, in direction.
  - When the image is beyond  $2C$ , the image is real, inverted and smaller than the object.

- ⦿ When the object is between  $2C$  and  $C$ , the image is real, inverted but smaller than object.
  - ⦿ When the object is at  $C$ , the image is real, inverted with the same size as the object.
  - ⦿ When the object is between  $C$  and  $F$ , the image is real, inverted and magnified.
  - ⦿ When the object is between  $F$  and  $P$ , the image is virtual, upright and magnified.
2. Use the reverse process in questions 1.
  3. This process may be produced in different cases such as:
    - ⦿ In side mirrors of cars.
    - ⦿ In supermarkets security mirror.
    - ⦿ Gate keeper mirrors ( for checking cars).

#### Activity 14.2

Do the experiment to find the focal length of the concave mirror as it is assigned in learner's book, and help learners to make real measurement and findings. Then use search internet for further information.

#### Activity 14.3

Take learners in laboratory and close the windows to minimise the light from outside. Hence, Group learners in different groups of four or five and guide them to work on the activity. Tell them to draw a lab report and present their findings.

#### Activity 14.4 and Activity 14.5

Let learners work in groups of four or six and try the activity themselves.

Do the experiment to find the focal length of the convex mirror as it is assigned in the learner's book, and help learners to make real measurement and findings. Then use search engines on the internet to find further information about spherical mirrors.

#### Checking my progress

1. Real/ actual and apparent
2. (a) and (e)
3. (a)
4. (a) TRUE

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{70} + \frac{1}{17.5} \Rightarrow f = +14.0 \text{ cm}$$



## 14.5 Suggested answers for unit 14 Assessment

1. Angle B is the angle of incidence (angle between the incident ray and the normal).

Angle C is the angle of reflection (angle between the reflected ray and the normal).

2. The angle of reflection is  $60^\circ$ . (Note that the angle of incidence is not  $30^\circ$ ; it is  $60^\circ$  since the angle of incidence is measured between the incident ray and the normal.)
3. The light reflects twice before it finally exits the system. Draw a normal at the point of incidence to the first mirror; measure the angle of incidence ( $45^\circ$ ); then draw a reflected ray at  $45^\circ$  from the normal. Repeat the process for the second mirror.
4. In the figure below consider the ray from her foot, AB, which upon reflection becomes BE and enters the E. The light from point A (her foot) enters the eye after reflecting at B; so the mirror needs to extend no lower than B. Because the angle of reflection equals the angle of incidence, the height BD is half of the height AE.

Because  $AE = 1.60\text{m} - 0.10\text{m} = 1.50\text{m}$ , then  $BD = 0.75\text{m}$ .

Similarly, if the woman is to see the top of her head, the top edge of the mirror only needs to reach point F, which is 5cm below the top of her head (half of  $GE = 10\text{cm}$ ). Thus,  $DF = 1.55\text{m}$  above the floor. In general, a mirror need be only half as tall as a person for that person to see all of himself or herself.

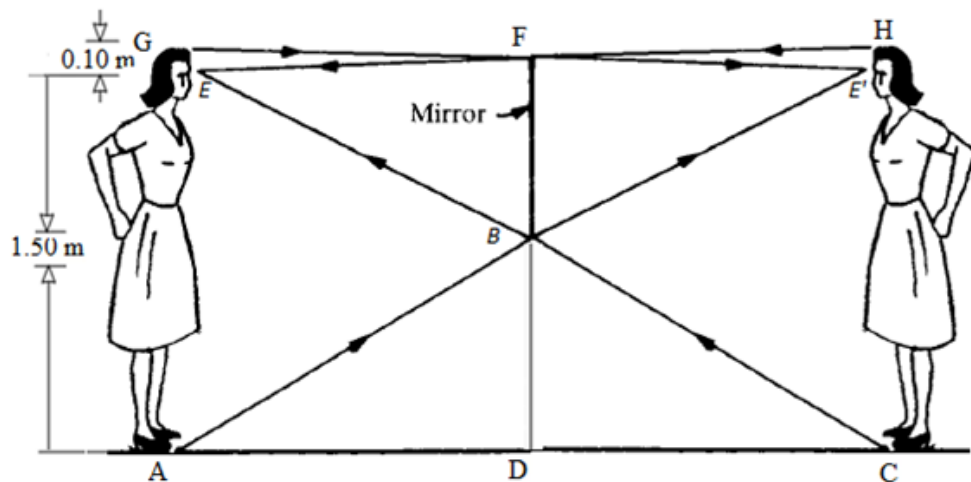


Fig. 14.1

Does this result depend on the person's distance from the mirror? The woman only needs the portion of mirror extending between points F and B in order to view her entire image. All other portions of the mirror are useless to the task of this woman viewing her own image. The distance between the mirror and the woman does not matter

5. Given: The mirror is concave, so  $f$  is positive  $f = +10.0\text{cm}$ . The object is in front of the mirror, so  $p$  is positive  $p = +30.0\text{cm}$ .

Unknown:  $q = ?$   $M = ?$

Use the mirror equation that relates the object and image distances to focal length:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$\frac{1}{d_i} = \frac{1}{10\text{cm}} - \frac{1}{30\text{cm}} \Rightarrow d_i = \frac{30\text{cm}}{2} = 15\text{cm}$$

6. Given: Because the mirror is convex, the focal length is negative  $f = -8.00\text{cm}$ . The object is in front of the mirror, so  $p$  is positive  $p = +10.0\text{cm}$

Unknown:  $d_i = ?$   $M = ?$

Use the mirror equation for focal length and the magnification formula:

$$\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f} \quad M = -\frac{d_i}{d_o} \quad \text{we find } d_i = -4.44\text{cm} \quad m = 0.44$$

The image appears at a distance from the mirror that is shorter than the focal length ( $-8.00\text{cm}$ ). The image is smaller than the object ( $M < 1$ ). The image is virtual as is confirmed by the ray diagram.

7. Given:  $p = 20\text{cm}$   $f = 12\text{cm}$  Unknown:  $q = ?$

Use mirror equation:  $\frac{1}{d_i} = \frac{1}{d_o} + \frac{1}{f}$  we find

- (a)  $q = 30\text{cm}$  real image  
 (b)  $q = -6\text{cm}$  Virtual image

8. Given:  $h = 5\text{cm}$   $h' = 1\text{cm}$   $p = 2.5\text{cm}$  Unknown:  $f = ?$

Use mirror equation and magnification equation:  $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$  and

$$M = \frac{h'}{h} = -\frac{q}{p} = \frac{1}{2.5}$$

We have  $\frac{1}{p} + \frac{1}{Mp} = \frac{1}{f} \Leftrightarrow f = 4\text{cm}$

9.  $q = -6\text{cm}$   $f = -18\text{cm}$  Unknown:  $p$  ?

Use mirror equation and magnification equation:  $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$  and  $M = \frac{h'}{h} = -\frac{q}{p}$ .

We have:  $p = 9\text{cm}$  real object and therefore, 9cm in front of mirror.

10. a) The image is 60.0cm from the mirror on the same side as the object.

The image height is 4.5cm inverted.

b) The mirror equation is symmetric in  $p$  and  $q$ . Thus the new image will be where the old object was. Indeed, we need only reverse the direction of the rays our new situation.

11. a) The image is virtual (since  $q < 0$ ), and is located 60cm behind the mirror. The image is upright (since  $M > 0$ ), and magnified by a factor of 4. It follows that the height  $h'$  of the image is 16cm.

b) The new image is real (since  $q > 0$ ), and is located 100cm in front of the mirror. The new image is inverted (since  $M < 0$ ), and magnified by a factor of 6.67. It follows that the new height of the image is -26.67cm

12. Magnification:  $m = -\frac{q}{p} \Leftrightarrow q = -mp = -4 \times 0.60 = -2.40\text{cm}$

$$\text{Radius: } \frac{1}{p} + \frac{1}{q} = \frac{2}{r} \Rightarrow \frac{1}{0.6} - \frac{1}{2.40} = \frac{2}{r} \Rightarrow r = 1.60\text{ cm}$$

13. Use the mirror equation  $\frac{1}{p} + \frac{1}{q} = \frac{2}{r}$  twice, once for the near end and once for the far end of the meter stick.

Use the magnification equation  $M = \frac{h'}{h} = -\frac{q}{p}$  for each toy figure.

60cm from the mirror surface.

Five-centimeter toy figures stand erect on both the near and far ends of the meter stick.

**a) Near end:**

Sign convention gives  $p = +60\text{cm}$ ,  $r = 2f = -(2 \times 40) = -80\text{cm}$

$$\text{so } \frac{1}{p} + \frac{1}{q} = \frac{2}{r} \Rightarrow \frac{1}{60} + \frac{1}{q} = \frac{2}{-80} \Leftrightarrow q = -24\text{cm}.$$

Negative sign indicates image is virtual, 24 cm to the right of V.

**Far end:**

$$p = +160\text{cm}, r = -80\text{cm} \text{ so } \frac{1}{p} + \frac{1}{q} = \frac{2}{r} \Rightarrow \frac{1}{160} + \frac{1}{q} = \frac{2}{-80} \Leftrightarrow q = -32\text{cm}$$

Far-end image is virtual, 32cm to the right of V.

Meter stick image is  $32\text{cm} - 24\text{cm} = 8\text{cm}$  long.

**b) Near-end toy figure:**

(Image is erect since it is positive).

The toy figure is  $h' = Mh = 0.4 \times 5 = 2\text{cm}$  tall, at near end of the meter stick image.

**Far-end toy figure:**

(Image is erect since it is positive.).

The toy figure is tall, at far end of the meter stick image.

14. From this diagram:

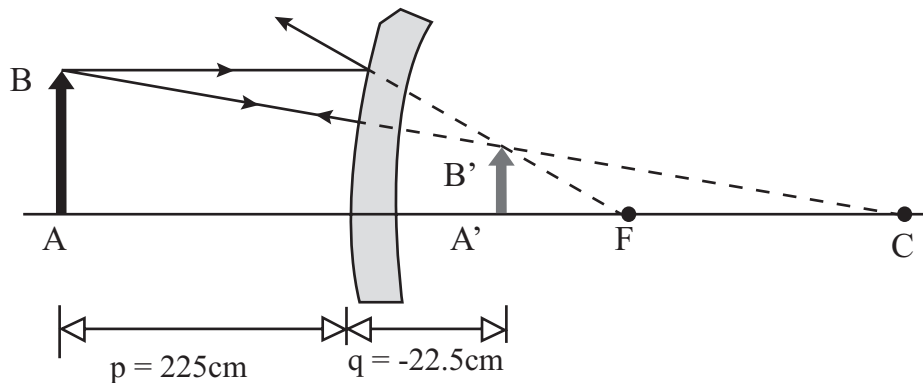


Fig. 14.2

The object must be placed  $p = 225\text{cm}$  in front of the mirror. The image distance is  $q = -22.5\text{cm}$  i.e. the image is located 22.5cm behind the mirror.

We know the major uses of plane mirrors are to see reflections of objects. We use mirrors almost in every place where there is a need to look for what's behind us. Invention of mirrors is the greatest contribution to humankind

**Some applications and uses of mirrors are listed below:**

- Periscopes and kaleidoscopes
- Automobiles
- Torch Lights
- Shaving Mirrors

- In Dentist
- Solar Cooker
- Security

### **Mirrors are used in Periscopes and Kaleidoscopes**

While making periscopes which are used in submarines and kaleidoscopes which are loved by children, these mirrors are used. In submarines, the mirrors used in periscopes reflect the images of any ships present on the surface of the sea. While, mirrors used in kaleidoscopes along with color glass reflects many colorful patterns.

### **Mirrors are used in Automobiles**

Vehicles use mirrors in their head lights for reflecting powerful parallel beams of light. Even we can see major uses of convex mirrors in automobiles as rear view mirrors because they give erect image and due to its curve outwards, it gives a wider field of view.

### **It is used in Torchlights**

It is used in torchlights and flashlights to reflect light beams and even used in overhead projectors for the same reason. These uses of plane mirrors in torchlights indeed can be used for searching purpose at night and dark places.

### **Its main use is Shaving Mirrors**

We wake up every morning and the first thing we use is the mirror to see, to shave, to brush, to do makeup etc. Without it, it would be very difficult to do these activities. Even there are uses of concave mirror as shaving mirrors in order to see larger image of face.

It is also used by Dentist

Dentist use mirrors while performing any examination to see images of teeth. It is also used in microscopes for reflecting the image of the object which is monitored.

### **Mirrors used in Solar Cooker**

In a solar cooker, a plane mirror reflects most of the sunlight which falls on it. Solar cooker is the most efficient way of using renewable energy for cooking purpose.

### **Uses of plane mirrors for Security and Safety**

Mirrors are used while looking for explosives underneath a vehicle. Even these mirrors are used in shops to keep an eye on the customers. Mirrors are also used in blind turns of busy roads to see the vehicles coming from other side.

## 14.6 Additional information (content)

### Spherical aberration in curved mirrors

**Aberration** - a departure from the expected or proper course.

Spherical mirrors have an **aberration**. There is an intrinsic defect with any mirror that takes on the shape of a sphere. This defect prohibits the mirror from focusing all the incident light from the same location on an object to a precise point. The defect is most noticeable for light rays striking the outer edges of the mirror. Rays that strike the outer edges of the mirror fail to focus in the same precise location as light rays that strike the inner portions of the mirror. While light rays originating at the same location on an object reflect off the mirror and focus to a point, any light rays striking the edges of the mirror fail to focus at that same point. The result is that the images of objects as seen in spherical mirrors are often blurry.

The diagram below shows six incident rays travelling parallel to the principal axis and reflecting off a concave mirror. The six corresponding reflected rays are also shown. In the diagram we can observe a departure from the expected or proper course; there is an aberration. The two incident rays that strike the outer edges (top and bottom) of the concave mirror fail to pass through the focal point. This is a departure from the expected or proper course.

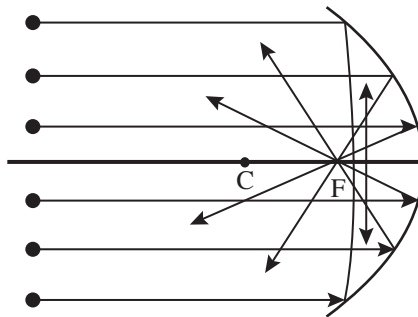


Fig. 14.3

This problem is not limited to light that is incident upon the mirror and travelling parallel to the principal axis. Any incident ray that strikes the outer edges of the mirror is subject to this departure from the expected or proper course. A common Physics demonstration utilises a large demonstration mirror and a candle. The image of the candle is first projected upon a screen and focused as closely as possible. While the image is certainly discernible, it is slightly blurry. Then a cover is placed over the outer edges of the large demonstration mirror. The result is that the image suddenly becomes more clear and focused. When the problematic portion of the mirror is

covered so that it can no longer focus (or mis-focus) light, the image appears more focused.

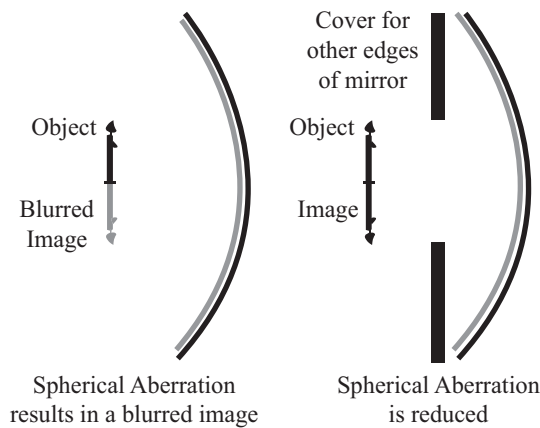


Fig. 14.4

Spherical aberration is most commonly corrected by use of a mirror with a different shape. Usually, a parabolic mirror is substituted for a spherical mirror. The outer edges of a parabolic mirror have a significantly different shape than that of a spherical mirror. Parabolic mirrors create sharp, clear images that lack the blurriness which is common to those images produced by spherical mirrors.

## 14.7 Remedial extension and consolidation

1. Choose the right answer;

I. The colours that you see in objects match the frequencies of light that are ..... by those objects.

- (a) reflected
- (b) selected
- (c) refracted
- (d) transmitted
- (e) absorbed

II. Which of the following describes the images formed by a plane mirror?

- (a) Real, upright images that are the same size as the object.
- (b) Varies depending on whether the object is placed further away from the mirror than the focal point, or inside the focal point.
- (c) Inverted, real, and larger than the object.
- (d) Upright, virtual and smaller than the object.
- (e) Virtual, upright images that are the same size as the object.

2. A converging (concave) mirror is cut from a sphere whose radius is 20cm. What will be the focal length of the mirror?
3. Explain the difference between a real image and a virtual image.
4. What type of image is produced by a plane mirror? Can it ever produce the other type? Defend your answer.
5. Explain when a concave mirror produces a real image and when it produces a virtual image.
6. Will a convex mirror ever produce a real image? Defend your answer.
7. A concave mirror has a radius of curvature of 24cm. An object 3cm. tall is placed in front of the mirror. Use a ray diagram to locate the image of the object and then describe the image (type, size, right-side up or upside down) if the object is located:
  - (a) 48cm from the mirror
  - (b) 30cm. from the mirror
  - (c) 24cm. from the mirror
  - (d) 16cm. from the mirror
  - (e) 6cm. from the mirror
8. Use equations 1 and 2 to locate and describe the images for the previous problem.
9. A convex mirror has a radius of curvature of 24cm. If an object 6cm tall is placed 6cm from the front of the mirror, describe the image using:
  - (a) a ray diagram.
  - (b) Equations 1 and 2.
10. The mirror of the Mount Palomar telescope has a diameter of 5.0m. How many times more light does this telescope gather than a telescope half as big (with a diameter of 2.5m).
11. When you look through an astronomical reflecting telescope, will the image you see be the right-side up or inverted? Why?
12. Can the image produced by a concave mirror ever appear between the focus of the mirror and the mirror? Defend your answer.



# Unit 15

## Basic Electronic Components

### Key unit competence:

By the end of this unit the learner should be able to explain the working principle of basic electronic devices.

### Learning objectives:

By the end of this unit, learners should be able to;

- Define an electronic device.
- Name symbols of electronic components.
- Identify different electronic components.
- Outline the working principle of basic electronic devices.
- Identify electronic components on an electronic motherboard.
- Describe electronic components of a motherboard.
- Suggest possible importances of electronic devices in everyday life.
- Appreciate important roles of electronic devices in life.
- Show the concern of electronics in various technological systems.
- Appreciate the need to use semi-conductor devices in electronics devices.
- Acquire knowledge in analysing and modeling physical processes.

### Resources:

Inductors, Resistors, Capacitors, Ordinary Diodes, Zener diode, Transistors.  
Once materials are not available, you with the learners should improvise the activity in order to make learners more competent.

## 15.1 Specific suggested methods/strategies/approaches of the unit

Use good teaching and learning methods that will keep learners motivated and engaged throughout the lesson. Learners should spend more time demonstrating and presenting the activities.

You may give work to be done in groups and ask learners to find and explain the applications of some electronic components such as diodes and transistors. Question-answer sessions with immediate feedback.

## 15.2 Support on assessment strategies and tasks of assessment

Use question-answer sessions, pair work and group work activities as a means of observing and assessing learners throughout this unit.

Good classroom practices such as direct and immediate feedback will help you get a view of both individual and class performances while learners learn how well they have done.

You may also use multiple choice questions and advanced questions at the end of the unit for summative assessment.

## 15.3 Lessons and timing

This unit consists of 9 lessons and each lesson should be covered in 40 minutes.

	<b>Lessons</b>	<b>Periods</b>
1.	Definition of electronics	1
2.	Illustration of standard symbols of some electronic components.	2
3.	Electronic components on a motherboard	1
4.	Electronic components	1
5	Example of electronic devices and working principle of basic electronic devices	2
6	Summative assessment	1

## 15.4 Solutions of unit activities

### Activity 15.1

Form groups of four or five, and let them discover the difference between electricity and electronics, conductors and semi-conductors, discuss and explain how a TV set, a radio receiver functions, thereafter help them to find proper conclusions as described.

**“Electrical”** as in “electrical engineering” describes everything involving electricity (EE spreads over topics like high voltage and low voltage, high frequency circuits, digital and analog circuits, medical technology, audio/video electronics, measurement and control technology, power generators, electric motors, battery management, communications engineering, to name a few). So basically everything where an electric circuit or an electric field is involved, electrical energy is “generated” (transformed) or transported.



*Fig. 15.1*

“Electronics” is a subset of this: every technology, where you influence and control the behaviour of electrons in a circuit by another current, without mechanical parts (switches, relays) or electromagnetism (coils, oscillation circuit). So this is about Diodes, Transistors and the like, arranged and miniaturised in Integrated Circuits and alike (electron tubes were the start of it). Everything you find in a computer or in the control unit of a car (the electric motors, which led you to adjust your seat or lower your window, would be electrical again). Everything you find in a Smartphone. The voltage is in most cases limited to 5V, with low current. Usually the electronic circuits are soldered on a circuit board:

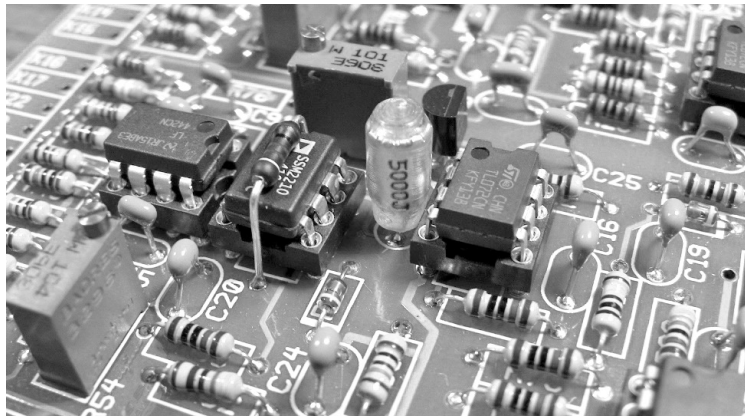


Fig. 15.2

	<b>Electrical Engineering</b>	<b>Electronics Engineering</b>
1	It deals with all aspects of electrical things.	Electronic Engineers deal more at component level, integrated circuits, GPS etc
2	You may say that Electrical Engineering is a superset of Electronics Engineering.	Electronics Engineering is a subset of Electrical Engineering.
3	Electrical Engineers are responsible for research and develop ideas to transit electrical power and find different ways to store the energy and they also work with electrical signals.	Electronic Engineers may develop cell phones through Electronics Engineering.
4	According to market reseach, the statistics show that medium annual salary of an electrical Engineer is around \$84,540.	Medium annual salary of an electronic engineer is around \$90,170.

**Insulator:** These materials through which electricity cannot pass are called insulators. Plastic, glass, wood etc are the examples of insulators. The valence band of those materials remains full of electrons. The conduction band of those materials remains empty. The forbidden energy gap between the conduction band and the valence band is widest. The difference is more than 10eV. Crossing the forbidden energy gap from valence band to conduction band large amount of energy is needed.

↑ **Conductors:** Figure b shows the energy band of a good conductor or metal. The valence band and the conduction band is attached here and overlap each other. There is no forbidden energy gap here so  $E_g = 0$ . At absolute zero temperature large number of electrons remains in the conduction band.

The resistance of conductor is very low, a large number charge carriers are available here. So, the electricity can pass easily through the conductors.

- ↑ **Semi-conductors:** Semi-conductors are those materials whose electrical conductivity is between conductors and insulators. The forbidden energy gap of a semi-conductor is nearly same as insulator. The energy gap is narrower. The value of  $E_g = 1.1$  eV for silicon crystal and  $E_g = 0.7$  eV for germanium at ok. It can easily overcome due to thermal agitation or light. A semi-conductor remains partially full valence band and partially full conduction band at the room temperature. The conduction band remains full empty of a semi-conductor where the valence band remains full of electrons at absolute zero temperature. So, silicon and germanium are insulators at absolute zero temperature. On the other hand with the increasing of temperature the electrical conductivity of semi-conductors increases.

### Activity 15.2

- Is a radio receiver composed by an antenna which receives signal from emitter and inside it has a motherboard which processes the information carried by the antenna. The information carried for the radio receiver are in audio form not video.
- Is an amplifier which transforms the modulated signal (voice) into an electrically amplified signal thus goes out via speakers.
- Is a computer which is composed by the **CPU, the screen, the key board and a mouse**. The computer processes data which are inserted in through input devices and transmit data to be processes out by output devices.
- Is the oscilloscope, which shows the frequency of any periodic signal input to it like, AC electric current, the electromagnetic wave.

### Activity 15.3

Teacher should bring a sample motherboard and guide learners to find out different electronic components of motherboard.

### Activity 15.4

Teacher should bring a sample motherboard of a radio receiver and guide the learners to identify out different electronic components of motherboard.

### Activity 15.5

Teacher should bring a sample motherboard of a desktop computer and guide the learners to identify out different diodes on a motherboard especially different types.

Form groups of three or four learners, let them read instructions provided, then with provided materials perform the activity to show the characteristics of a diode and a resistance. Let them draw a lab report and present their findings.

### Activity 15.6

Teacher should guide the learners to define what a rectifier is, thereafter guide them in discussion to find the answer to the questions provided.

### Activity 15.7

Teacher should bring a sample motherboard of a radio receiver or a computer and guide the learners to identify out different transistors on the motherboards

**Answers to checking my progress 15.1 on page 336 of the Student's book.**

1. (d)
2. (a) TRUE
3. (a) TRUE
4. SCR and Transistor

### Activity 15.8

Take learners to visit an electronic repair workshop and let them ask many questions and tell them to form groups of 4 to 6 to draw a report. Hence, guide them to answer the questions provided in learner's book.

### Activity 15.9

Help learners to perform these activities without damaging the watch and assist them to find out its electronic components.

### Checking my progress

1. (a) to (e) are all types of diodes
2. Current or voltage amplification and switching but resistors are used to reduce or increase current flowing in the circuit.
3. (a) TRUE
4. They contain a circuit where current flows through semi-conductors.

## 15.5 Suggested answer for unit 15 Assessment

- |              |               |
|--------------|---------------|
| 1. Answer: A | 6. Answer: A  |
| 2. Answer: C | 7. Answer: B  |
| 3. Answer: B | 8. Answer: A  |
| 4. Answer: D | 9. Answer: B  |
| 5. Answer: B | 10. Answer: C |
11. Conductors possess high conductivity whereas the characteristic property of insulating materials (or dielectrics) is poor conductivity. Semi-conductors occupy an intermediate position between conductors and insulators though

there is no rigid line separating the conductors from semi-conductors and semi-conductors from insulators.

12. The distinction between conductors, insulators and semi-conductors is largely concerned with the relative width of the forbidden energy gaps in their energy band structures. There is a wide forbidden gap (more than 5eV) for insulators, narrow forbidden gap (about 1eV) in case of semi-conductors and no forbidden gap in case of conductors.
13. Hole is not a fundamental particle in an atom. Holes may be thought of as positive particles, and as such they move through an electric field in a direction opposite to that of electrons.
14. When energy is supplied to a semi-conductor a valence electron is lifted to a higher energy level. The departing electron leaves a vacancy in the valence band. The vacancy is called a hole. Thus, a vacancy left in the valence band because of lifting of an electron from the valence band to conduction band is known as a hole.
15. Because the energy required to release an electron from their valence band (i.e. to break their covalent bonds ) is very small (1.12eV for Si and 0.72eV for Ge).
16. Since energy required in transferring electrons from valence band to conduction band is more in case of Si than that in case of germanium , the conductivity of Ge will be more than that of Si at room temperature.
17. For a pure semi-conductor at a temperature of absolute zero (-273.15°C) the valence band is usually full and there are may be no electron in the conduction band and it is difficult to provide additional energy required for lifting electron the from valence band to conduction band by applying the electric field. Hence the conductivity of a pure semi-conductor at absolute zero temperature is zero and it behaves like an insulator.
18. Temperature, because with the increase in the temperature, concentrations of free electrons and holes increase and the rate of recombination is proportional to the product of concentration of free electrons and holes and also the rate of production of electron-hole pairs (thermal generation) increases with the rise in temperature.
19. Free electrons move in valence band while holes in valence band.
20. Conduction occurs in any given material when an applied electric field causes electrons to move in a desired direction within the material. This may be due to one or both of two processes, electron motion and hole transfer. In case of former process, free electrons in the conduction band move under the influence of the applied electric field. Hole transfer involves electrons which are still attached to the atoms i.e. those in valence band.

## 15.6 Additional information (content)

### Types of Diodes and their Applications

A basic diode consists of two terminals. This terminal is referred to as anode and cathode. It has a property of conducting the flow of current in a single and unified direction. This basic property of the diode makes it as a basic building block in the power supply units because there it is preferred in the process of rectification.

It is used during the modulation of the signals. There exist many uses for the diodes based on the requirements in various fields of electronics as well as electrical. Generally, the diodes are made from the semiconductors such as silicon or germanium based on the necessity the type of semiconductor material is preferred.

### Various Types of Diodes

Firstly, it started with a basic diode that consists of a p-n junction. Further developments and the increase in the needs and the demands for various subsystems paved the way in the formation of various types of diodes. Each diode has its own significance coming to the area of the electronics.

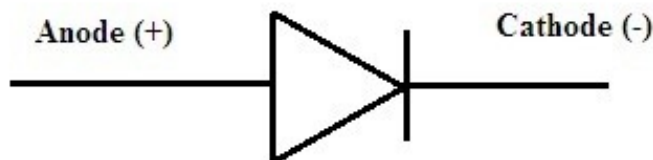
The usage of the diode in the electronic modules is vast. However, the special cases of the diodes have been constructed so that it can operate in reverse bias as well as to satisfy the respective terminologies.

*Let us see the various types of diodes that are used in basic electronics. They are*

#### (a) P-N Junction Diode

This is the basic diode formed with the interaction of p-type and n-type materials. It deals with the concept of biasing. This biasing make it classify into various operating modes.

This diode conducts only during forwarding bias. In reverse bias, there is no evident flow of the current. It indicates that current gets blocked during reverse bias.

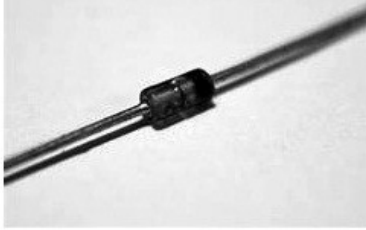


These are utilized where the applications are preferred for low currents such as signal diodes. one of the basic application of this as the rectifiers.



**(b) Zener Diode**

It is the diode designed in such a way that it can operate in the reverse bias mode. For the applied forward bias the operating characteristics will be similar to that of normal diode with the basic p-n junction.

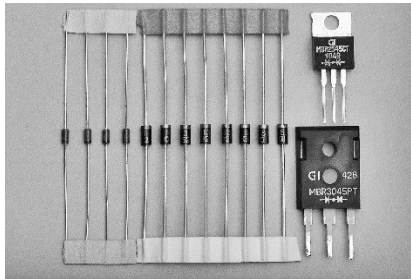


When the diode is in reverse bias mode after it reaches the minimum Zener voltage there we can see the increment in the values of current but the voltage remains constant after that point.

This makes it applicable to making use of it in the regulation of voltages.

**(c) Schottky Diodes**

A diode that can operate with fast switching times in it is referred to as Schottky diode. The voltage drop that is considered to be forward is very low.

**(d) Light - Emitting Diode (LED's)**

This is the types of diodes that operate during forwarding bias operating region. As the diode starts conducting during this region there is a flow of the current. This current is referred to as forwarding current. During this process, the light gets emitted from the diode.

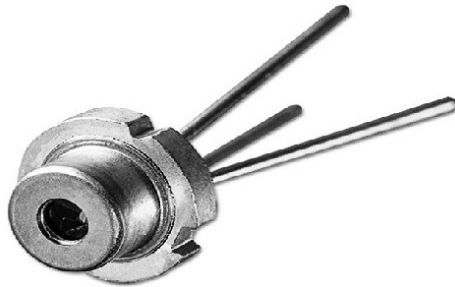


These include various types in LED. Namely blinking one that can act as on and off for a certain amount of time. They can be tricolor leads more than two colors get emitted based on the amount of received a positive amount of voltage.

Further, there are LED's that emits infrared light. The practical application of it can be seen in remote controls. The above discussed are some of the types present in LED.

**(e) LASER Diode**

It cannot be referred to as the same as that normal LED. Because other than normal light is emitted from this type of diode is termed as coherent light. This light is focused as a spot that consists of diameter less than one micrometer.



**(f) Photo Diode**

As the name suggests when the diode gets interacted with the light current gets generated. That means during the stage of darkness there cannot be any flow of the current indicating that it is an open circuit condition.

When the diode meets the light it gets interacted and the amount of current flows in the circuit making the diode bright. The functionality of photodiode resembles more zen diode because it can also conduct during reverse bias.



The current value and the value of the intensity of the light are directly proportional to each other. These also have the response times that are fast enough that is in nanoseconds. This type of diodes can also have the capacity of generating electricity.

## Importance of transistors

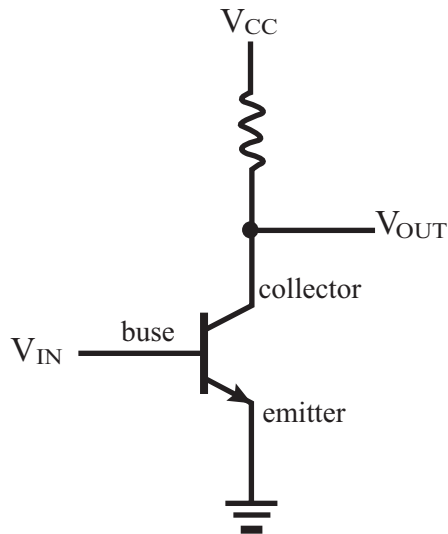


Fig.15.3

The transistor is the key active component in practically all modern electronics. Many consider it to be one of the greatest inventions of the 20<sup>th</sup> century. Its importance in today's society rests on its ability to be mass-produced using a highly automated process (semi-conductor device fabrication) that achieves astonishingly low per-transistor costs. The invention of the first transistor at Bell Labs was named an IEEE Milestone in 2009.

Although several companies each produce over a billion individually packaged (known as discrete) transistors every year, the vast majority of transistors are now produced in integrated circuits (often shortened to IC, microchips or simply chips), along with diodes, resistors, capacitors and other electronic components, to produce complete electronic circuits. A logic gate consists of up to about twenty transistors whereas an advanced microprocessor, as of 2009, can use as many as 3 billion transistors.

## Transistor as a switch

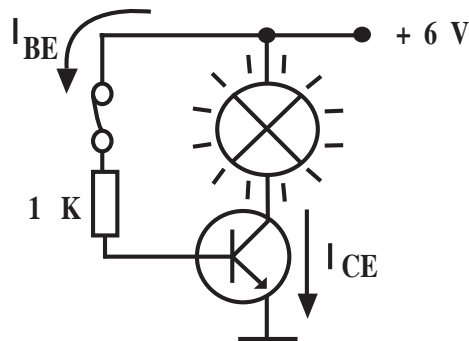


Fig. 15.4

Transistors are commonly used in digital circuits as electronic switches which can be either in an “on” or “off” state, both for high-power applications such as switched-mode power supplies and for low-power applications such as logic gates. Important parameters for this application include the current switched, the voltage handled, and the switching speed, characterised by the rise and fall times.

In a grounded-emitter transistor circuit, such as the light-switch circuit shown, as the base voltage rises, the emitter and collector currents rise exponentially. The collector voltage drops because of reduced resistance from collector to emitter. If the voltage difference between the collector and emitter were zero (or near zero), the collector current would be limited only by the load resistance (light bulb) and the supply voltage. This is called saturation because current is flowing from collector to emitter freely. When saturated, the switch is said to be on.

Providing sufficient base drive current is a key problem in the use of bipolar transistors as switches. The transistor provides current gain, allowing a relatively large current in the collector to be switched by a much smaller current into the base terminal. The ratio of these currents varies depending on the type of transistor, and even for a particular type, varies depending on the collector current. In the example light-switch circuit shown, the resistor is chosen to provide enough base current to ensure the transistor will be saturated.

In a switching circuit, the idea is to simulate, as near as possible, the ideal switch having the properties of open circuit when off, short circuit when on, and an instantaneous transition between the two states. Parameters are chosen such that the “off” output is limited to leakage currents too small to affect connected circuitry; the resistance of the transistor in the “on” state is too small to affect circuitry; and the transition between the two states is fast enough not to have a detrimental effect.

## Types of transistors

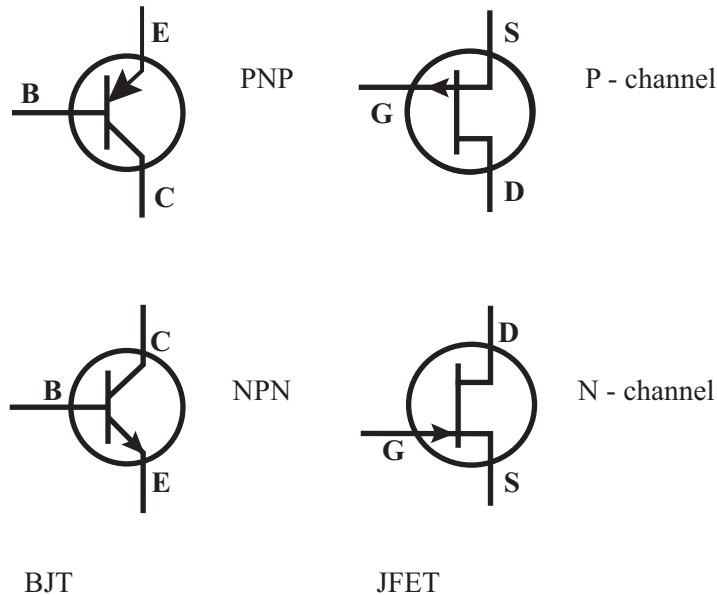


Fig. 15.5

### Transistors are categorised by;

**Semi-conductor material** (date first used): the metalloids germanium (1947) and silicon (1954)—in amorphous, polycrystalline and mono-crystalline form—, the compounds gallium arsenide (1966) and silicon carbide (1997), the alloys silicon-germanium (1989), the allotrope of carbon graphene

**Structure:** BJT, JFET, IGFET (MOSFET), insulated-gate bipolar transistor, “other types”; electrical polarity (positive and negative): n-p-n, p-n-p (BJTs), n-channel, p-channel (FETs); maximum power rating: low, medium, high; maximum operating frequency: low, medium, high, radio (RF), microwave frequency (the maximum effective frequency of a transistor in a common-emitter or common-source circuit is denoted by the term  $f_T$ , an abbreviation for transition frequency—the frequency of transition is the frequency at which the transistor yields unity voltage gain application: switch, general purpose, audio, high voltage, super-beta, matched pair; physical packaging: through-hole metal, through-hole plastic, surface mount, ball grid array, power modules amplification factor  $h_{FE}$ ,  $\beta F$  (transistor beta) or  $g_m$  (transconductance).

Hence, a particular transistor may be described as silicon, surface-mount, BJT, n-p-n, low-power, high-frequency switch.

A popular way to remember which symbol represents which type of transistor is to look at the arrow and how it is arranged. Within an NPN transistor symbol, the arrow will Not Point iN. Conversely, within the PNP symbol you see that the arrow Points iN Proudly.

## 15.7 Remedial extension and consolidation

1. The battery connections required to forward bias a pn junction are .....
  - (a) +ve terminal to p and –ve terminal to n
  - (b) -ve terminal to p and +ve terminal to n
  - (c) -ve terminal to p and –ve terminal to n
  - (d) None of the above

**Answer: A**

2. A reverse bias pn junction has .....
  - (a) Very narrow depletion layer
  - (b) Almost no current
  - (c) Very low resistance
  - (d) Large current flow

**Answer: B**

3. When the temperature of an extrinsic semi-conductor is increased, the pronounced effect is on.....
  - (a) Junction capacitance
  - (b) Minority carriers
  - (c) Majority carriers
  - (d) None of the above

**Answer: B**

4. With forward bias to a pn junction , the width of depletion layer .....
  - (a) Decreases
  - (b) Increases
  - (c) Remains the same
  - (d) None of the above

**Answer: A**

5. In an intrinsic semi-conductor, the number of free electrons .....
  - (a) Equals the number of holes

- (b) Is greater than the number of holes
- (c) Is less than the number of holes
- (d) None of the above

**Answer: A**

6. At absolute temperature, an intrinsic semi-conductor has .....
- (a) A few free electrons
  - (b) Many holes
  - (c) Many free electrons
  - (d) No holes or free electrons

**Answer: D**

7. At room temperature, an intrinsic silicon crystal acts approximately as .....
- (a) A battery
  - (b) A conductor
  - (c) An insulator
  - (d) A piece of copper wire

**Answer: C**

8. What happens to the conductivity of semi-conductor with the rise in temperature? Compare with the conductivity of metals.

With the increase in temperature, the concentration of charge carriers increases resulting in increase in conductivity of semi-conductors. The conductivity of metal decreases with the increase in temperature.

9. Differentiate between intrinsic semi-conductors and extrinsic semi-conductors?

An intrinsic semi-conductor is one which is made of the semi-conductor material in its extremely pure form. When a small amount of impurity is added to a pure semi-conductor crystal during the crystal growth in order to increase its conductivity, the resulting crystal is called extrinsic semi-conductor.

10. Why doping is done in semi-conductors?

Intrinsic (or pure ) semi-conductor by itself is of little significance as it has little current conduction capability at ordinary room temperature. However, if very small amount of impurity (of the order of one atom per million atoms of pure semi-conductor) is added to it in the process of crystallisation, the electrical conductivity is increased many times.

11. Describe the difference between P-type and N-type semi-conductor materials.

When a small amount of trivalent impurity (such as boron, gallium, indium or aluminium) is added to a pure semi-conductor crystal during crystal growth, the resulting crystal is called a P-type semi-conductor. When a small amount of pentavalent impurity (such as arsenic, antimony, bismuth or phosphorus) is added to a pure semi-conductor crystal during crystal growth, the resulting crystal is called the N-type semi-conductor.

12. Explain the term doping and its need.

The electrical conductivity of intrinsic semi-conductor, which has little current conducting capability at room temperature and so is of little use, can be increased many times by adding very small amount of impurity (of the order of one atom per million atoms of pure semi-conductor) to it in the process of crystallisation. This process is called doping.

13. What is a p-n junction?

The contact surface between the layers of p-type and n-type semi-conductor pieces placed together so as to form a p-n junction is called the p-n junction. The forward voltage, at which the current through the p-n junction starts increasing rapidly, is called the cut-in voltage.

14. What do you understand by reverse saturation current of a diode?

Reverse saturation current of a diode is due to minority carriers and is caused when the diode is reverse biased. Only a very small voltage is required to direct all minority carriers across the junction, and when all minority carriers are flowing across, further increase in bias voltage will not cause increase in current. This current is referred to as reverse saturation current.

15. Define breakdown voltage.

Breakdown voltage is defined as the reverse voltage at which p-n junction breaks down.



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