Physics

Teacher Guide

Grade 11

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Physics Teacher Guide Grade 11

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Table of Contents

I Introduction to the Teacher's Guide

Grade 11 physics Textbook and Teachers' Guide in physics are prepared based on the Curriculum Framework and Position Paper prepared by the F. D. R. E. ministry of education (MOE). According to those documents, the main problems in the previous curriculum were the content overload, mismatch between the students' age and the difficulty level of the contents at each grade, irrelevance of the content with indigenous knowledge, and inadequacy in addressing the 21st century skills. Therefore, this curriculum is designed to alleviate the difficulties prevailed in the previous curriculum. There are many elements that make the new curriculum unique.

1. The contents of physics for each grade are carefully selected in line with the students' age level and opportunities for relating physics with the student living environment.
2. 21st century learning skills such as creativity, critical thinking and problem solving, collaboration and communication; literacy skills such as proper use of ICT and media; life skills like flexibility, initiative, social skills and citizenship are incorporated as much as possible. Furthermore, attempts were made to stress the newly included aspects of the subject in the minimum learning competencies and learning strategies as clearly as possible to give guidance to other curricular material developers, school teachers, and teacher educators.
3. The new curriculum mainly encourages hands on approach in the school laboratory as well as students' home and localities.
4. To realize the education philosophy of the country, constructivism, this curriculum was developed with the intension that the student should be directly involved in the learning process through investigation, experimentation, dialogue and argumentation, creative thinking, and community engagement.
5. Throughout the syllabus the learning strategies have been expressed through indigenous knowledge and students' day to day experience. This makes physics enjoyable and relevant subject to the student, not a subject to be feared.
6. Finally, and the most unique feature of this curriculum is the inclusion of Physics and Human Society through grade 9 to 12 with different contents and depth. In these units, the fact that physics is at the heart of everything is addressed so that students will consider the subject not as an alien, abstract, irrelevant, and frustrating science. In general, the goal of this curriculum is to equip high school students with relevant physics knowledge and the developments of useful academic and life skills for their future life.
7. As much as possible we incorporated these unique elements. We hope they are reflected in the STB and TG.

II General Information to the Teacher

This new Student textbook is prepared based on the core principles of constructivism, 21^{st} century skill sets and inclusion of and cognizant of indigenous knowledge and values of society as well as outcome approach to assessment.

Principle of constructivism:

Students have prior knowledge: this entails that every classroom lesson students exposed at is an interaction between the individual student's previous experience and the lesson. This interaction is in the brain of the student. The forms of interaction could result in excellent learning experience and acquisition of more new knowledge or it could result to the contrary. Therefore assessing prior knowledge of students in the form of oral enquiry or brainstorming or written form should be as essential tool to the teaching-learning process.

Students learn faster and deep if the lesson is connected. If the prior knowledge is similar to the new lesson the learning is relatively smooth and effective. If the lesson is entirely new the learning of new knowledge takes time and relatively difficult. What we take from this is: The connection can be made smother and less difficult if we start by revising last lesson, it could be in the form of enquiry or it could be using scaffolding teaching method. If the lesson is new, make a necessary pre-planning for it to take effect. The aforementioned instructional strategies are based on research on cognitive and neurosciences. This is how long term memory is activated and works. Make use of this research based result on how student learn. Bridging and cognitive conflict instructional strategies might be useful tool to use too.

Each individual constructs his own knowledge: every individual has unique knowledge construction. Therefore, you must expect variation between students and prepare your lesson this in mind. Using multiple representations as learning strategy; graphs, tables, diagrams, videos, formulas, writing definition can be utilized to address individual students.

Social learning: most students learn effectively in social setting. This tells us to prepare a classroom setting that is conducive to group discussion, team work on project, laboratory and field trips.

21st Century skills:

We may broadly classify the 21st century skills in to three skill sets: Learning skills, Literacy skills and Life skills.

Learning skills

1. Critical thinking: Akin to problem solving, get solutions.
2. Creativity: Think unthinkable. Bring different view of the challenge or task that no one has thought before.
3. Collaboration: Developing team spirit for focused goal
4. Communication: Talking to others, make it a worthwhile conversation.
5. Literacy skills
6. Information literacy: Understanding facts, figures, statistics, and data
7. Media literacy: Understanding the methods and outlets in which information is published
8. Technology literacy: Understanding the machines that make the Information Age possible

Life skills

1. Flexibility: Deviating from plans as needed
2. Leadership: Motivating a team to accomplish a goal
3. Initiative: Starting projects, strategies, and plans on one's own
4. Productivity: Maintaining efficiency in an age of distractions
5. Social skills: Meeting and networking with others for mutual benefit

Differentiating work for students of varying abilities

As you will, of course, understand, each pupil has different abilities. There can also be a significant difference in age between the oldest and youngest pupil in the class. Some students will learn more effectively by reading a book, some by carrying out a practical activity and some by listening to and absorbing spoken instructions. Some will understand the work very easily, some will take more time. Some will work very quickly through any task you set, some will work slowly. It is impossible for you as a teacher to take all the differences into account all the time, but there are things that you can do to support individuals within a class.

There are two important things that you need to do to be able to effectively cater for everyone in your class:

1. **Know your students:** You need to give them opportunities to work in groups and listen to the conversations; you need to mark their written work; you need to ask questions of individuals in class and you need to encourage them to ask you questions if they don't understand or just want to know more. When you know who understands easily, who finds science difficult, who likes to talk, who likes to write, who likes to draw and who likes doing experiments, you will be in a much better position to help individuals.
2. **Know your subject:** It is unrealistic to expect everyone to remember and understand everything that you do. Students who find science difficult will be overwhelmed if you try and tell them everything. You need to break each topic down into simple steps and make sure that everyone understands the most important ideas.

You can cater for the range of abilities within your group in two main ways:

Differentiating by outcome

This can involve providing a set of questions that get progressively more difficult. Everyone gets as far as they can. Alternatively, you can set open-ended tasks in which students demonstrate what they can do. This also gives you the opportunity to give them a choice about how they present their work, which can be very motivating. You may find that the degree of support that you need to provide to individuals, pairs or small groups within the class varies significantly.

Differentiation by task

This involves giving different tasks to different students, or groups of students. For example, in a practical session some pupils could have instructions provided for them in written form and some could have them in diagram form and some could have a combination of both.

You could provide a set of questions that cover the basic ideas that you judge that everyone needs to understand and a set that are more challenging. The students who you expect to get a grade A could be given the more challenging ones.

Learning style

There is a lot of research that suggests that different students prefer to learn in different ways. The three learning styles that are more commonly referred to are visual, audio and kinaesthetic, i.e. some students prefer diagrams and pictures, some learn best by listening and some prefer to be able to do things.

As a teacher you cannot be expected to cater for all the students all the time, but a good teacher will make sure that their lessons contain activities that cover all three learning styles.

Indigenous Knowledge:

These are cultural artifacts that can be included in the lesson. In physics there are plenty if we want to list them. But to put them as an example in proper physical context needs an exhaustive study. Since physics is the study of measurement, in order to describe the object and put it as an example and activity, we need to know how to measure it. Measuring implies quantifying in this sense. And this is mostly lacking. However, we try our best to include throughout the text, were we are confident the parameters are reasonably accurate and research supported.

We are including here some examples of Indigenous Knowledge that can be used in High-school Physics. The teacher may use them as project work, assignment or field trip to familiarize students. It helps them to understand the physics behind their construction as well as create an attitude change towards appreciating one's own culture.

Experiment/Laboratory

- Experiments or lab works are essential for students:
- They are a place to learn the scientific procedural skills.
    - Identifying problem, hypothesizing, recoding of data, drawing graph, analyzing and interpreting, and conclusion.
- They are a place for providing different opportunities for students, aural, visual and kinesthetic skills.
- They learn how to respect opinions, listen to others, and develop teamwork and communication.
- They also learn how to write a report in science investigation

Learning outcomes

The present curriculum embraces the outcome approach. The outcome approach is essential in several ways.

It clearly identifies the goal at the end of the Unit and sets the focus to everybody concerned: The student, the teacher, the public. For the student and the teacher it is day-to-day experience, a challenge a plan and lens at the same time. For the public, it triggers the question," has our students been treated with the best of the learning experience that leads to accomplish the outcome?"

It clearly sets what must be achieved as MLC: This means every individual student has to fulfill the stated outcomes before declared successful. Even though the formative assessment is imperative to improve learning, the outcome approach requires criterion referenced assessment approach at the end of the day. This avoids the norm-referenced approach, which lacks the base minimum reference standard.

Learning strategies

Brainstorming

This is an activity in which students write everything they know or think about a given topic. The ideas might be right or wrong. This can be done individually, in pairs, small groups or as a whole class with the teacher or a student recording the ideas on the board. This method is used to find out what students already know on a topic before you start teaching.

Multiple representations

This is a strategy to address variation in individual learning style, variability in intelligence dimensions. This can be addressed by preparing the lesson in recognizing students variation in students' learning

- Words or verbal representations
- Graphs
- Evacuations and representation
- Tables and diagrams
- Videos clips and simulations

Concept map

The diagram at the center is the main concept. Any other concepts related to it are branching out from it.

Inquiry

This is also an activity that can be substituted for brainstorming or can be used in conjunction to stimulate and prime students thinking. It is an approach that helps students to connect concepts.

Scaffolding

Sometimes concept in physics may be difficult to internalize. To help students understand the concept, we use students existing knowledge and step by step based on what they can understand we lead them to the desired level.

Problem Solving: A powerful tool of physics learning

Problem-solving skills are essential for the successful accomplishment of physics learning. The ability to apply broad principles of physics, specifically those represented by equations, to specific situations is a very powerful tool of physics learning.

Problem solving is much more powerful than memorizing a list of facts. Analytical skills and problem-solving abilities can be used in applying the laws and principles of physics to new situations. Such analytical skills are useful both for solving textbook problems as well as for applying physics in students' everyday life and even in their future professional careers.

Step 1: Observation and Understanding stage

Examine the situation to determine which physical principles are involved. It often helps to draw a simple sketch at the outset. You will also need to decide which direction is positive and note that on your sketch. Once you have identified the physical principles, it is much easier to find and apply the equations representing those principles. Although finding the correct equation is essential, keep in mind that equations represent physical principles, laws of nature, and relationships among physical quantities. Without a conceptual understanding of a problem, a numerical solution is meaningless.

Step 2: Description stage (Identify the known quantities and the unknowns).

Make a list of what is given or can be inferred from the problem as stated (identify the "knowns"). Many problems are stated very briefly and require some inspection to determine what is known and what is unknown. A sketch can also be very useful at this point. Formally identifying the "knowns" is of particular importance in applying physics to real-world situations.
Essential words/phrases that help beginning students in identifying such quantities are:

How long….?	Time
How far …..?	Distance or displacement,
Where…… ?	Position
How fast…?	Speed or velocity
At the instant…	Incidence of time when some phenomenon takes place
At what rate…?	˜ e change in some quantity per unit of time
From rest ….	Initial velocity is zero
Stopped	˜ e velocity at that moment is zero
How much….	Quantity of energy, force, etc.
At thermal equilibrium,	No heat exchange

After describing the known and unknowns, draw diagrams if the diagram is helpful. It could be free-body diagram, or axis and the zero reference point, the negative/positive directions etc.

Step 3: Formulation Stage (Derive a complete algebraic Solution)

Identify which equation help to find an exact solution for the desired unknown. Find a single equation or set of equations that can help you solve the problem. Your list of known and unknowns can help here. It is easiest if you can find equations that contain only one unknown—that is, all of the other variables are known, so you can easily solve for the unknown. If the equation contains more than one unknown, then an additional equation is needed to solve the problem. Such kinds of equations that are derived for the unknown from the known quantities are said to be complete algebraic solution. Once you reach to a single equation (a complete algebraic solution) you must check for dimensional consistencies of the left hand side and the right hand side terms of the equation. If the two are not dimensionally consistent, there must be some error committed in deriving for the unknown.

Step 4: Ramification stage

Substitute the known's along with their units into the appropriate equation, and obtain numerical solutions complete with units. Make sure that in writing the units all units should be to the same unit equivalence!!! (eg. Km/h to m/s) Converting all units to SI is very important and protects from committing an error. (The chain link unit conversion method stated in the student text can be helpful at this stage. If the units of the answer are incorrect, then an error has been made. However, be ware that correct units and dimensionally consistent solutions do not guarantee for the correctness of the numerical solution of the problem. At this stage, final numerical solutions will be obtained.

Step 5: Validation stage

Check the answer if the solution you got is reasonable and is compatible to the real world scenario. Does it make sense? This stage is very important as the goal of physics is to accurately describe nature in a very appropriate and scientific way. To see if the answer is reasonable, check both its magnitude and its sign, in addition to its units. Students' ability of judgment will improve as they solve more and more physics problems, and it will become possible for them to make finer and finer judgments regarding whether nature is adequately described by the answer to a problem. This stage brings the problem back to its conceptual meaning. If students can judge whether the answer is reasonable, they will have a deeper understanding of physics than just being able to mechanically solve a problem by plug and chug.

Assessment and Evaluation

Evaluation is a continuous process; it forms an integral part of the total system of education, and is intimately related to educational objectives and to the minimum learning Competencies. It exercises a great influence on the students' study habits and teacher's methods of instruction and thus helps not only to measure educational achievement but also improve it. The techniques of evaluation are means of collecting evidence about the students' development in desirable direction.

Evaluation of students' performance is generally done in terms of marks or grades competitively. Sometimes students may be compared with some absolute performance standard instead of making comparison with other students of a given group.

In physics teaching, the evaluation and the assessment that is made by teachers mainly focus on:

- Checking to what extent the objectives are achieved.
- To test how students' behavior in terms of conceptual understanding is changed.
- To test how students skill is improved in terms of handling experiments and solving problems
- To test to what extent students' attitude is changed towards science learning.
- To evaluate student's performance in overall achievement of learning.

In testing students' achievement there are several types of assessment

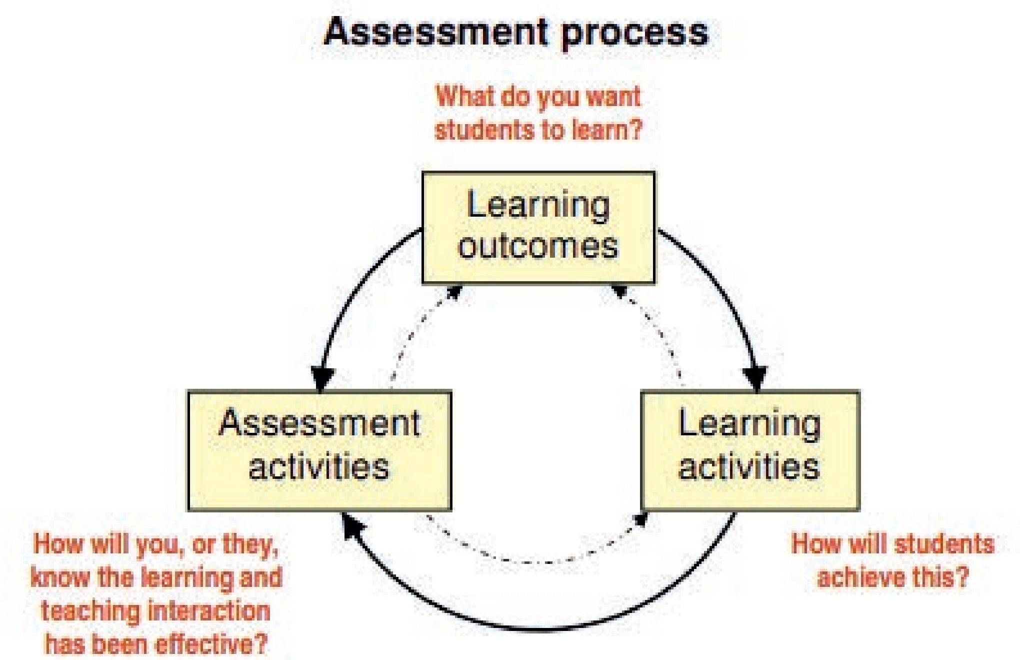
Placement evaluation/ diagnostic test: This type of assessment helps the teacher in identifying students learning background, what previous learning experience they have; the naïve physics they have, the misconceptions and students preconceptions in relation to any scientific concept. (Usually such kind of assessment will not count as the part of the subject matter assessment.)

Continuous assessment: This type of assessment helps teachers to get a continuous feedback on the day-to-day learning and teaching activities. This type of assessment is mainly conducted while the instruction is in progress. (Is usually counted as part of the students subject matter assessment marks)

End of unit or end of semester tests and exams: These types of assessments are the main part of students' achievement tests. I designing such assessment tests special attention need to be taken so as to measure the learning objectives and students' achievement. In doing so, a test blue print should be prepared in advance.

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 students to do and/or learn?' and following from this 'how will the students 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:



Assessment is a continuous process. You should:

- always ask questions that are relevant to the outcomes and content
- use frequent formative tests or quizzes
- check understanding of the previous lesson at the beginning of the next lesson, through questions or a short quiz
- constantly mark or check the students' written exercises, class tests, homework activities and so on
- use appropriate assessment methods to assess the tasks.

Since students prefer different pathways to demonstrate what they have learnt, teachers should use varieties of assessment techniques. (Teachers should assess the same concept or skill for each student at the end of a unit of study; however, they should offer their students a variety of ways to demonstrate their knowledge (e.g., test, written report, projects…)). Authentic assessment should also be used.

Feedback

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

- constructive, so students feel encouraged and motivated to improve
- timely, so students can use it for subsequent learning

Pre-requisites of a good Test

There are certain pre-requisites for preparing a physics test. These are

i. Acquisition of knowledge of various physics concepts and skills.
ii. Development of scientific attitude and interest.
iii. Development of laboratory skills.
iv. High lighting the applications of physics in everyday life and technology.
v. Development of skills of information processing, observation, enquiry and design.
vi. Acquisition to problem solving abilities.

The steps in designing a physics test are:

i. Allocation of marks for the different cognitive levels to be tested.
ii. Allocation of marks for different chapters or units.
iii. Allocation of marks to various types of questions.
iv. Blue print for the question paper.

Example

On the basis of the three allocations of marks prepare a blue-print of the question paper.

Table 1. Allocations of marks for abilities to be tested

Ability	Symbol	Marks
Knowledge	K	45
Comprehension	C	26
Application	A	17
Skills	S	6
Analysis & Synthesis	A/S	6
Total		100

Table 2. Allocation of marks to the type of questions

Question type	Symbol	Questions	Marks
Short answer	SA	17	44
Structured /workout	ST	4	56
Total		21	100

Table 3: Allocations of marks by content area

Content area	Marks
PHS	38
V	11
K	12
D	15
T	24
E	
N	
Total	100

A blue print on the basis of the allocation of marks in the above tables is as follows.

Table 4. Blue print for question paper for the test.

Content area	Abilities									
	K		C		A		S		A/S	Total
Content area	SA	ST	SA	ST	SA	ST	SA	SA	ST	
Physics and Human Society										10
Vectors										12
Kinematics										14
Dynamics										17
Heat and Calorimetry										21
Electrostatics and Electric circuits										14
Nuclear Physics										11
Total										100

After the blue print is ready the actual question paper is set, some of the commonly used tests in physics are fill-ins, true-false, multiple-choice, short answer or essay type etc.

Content area	Marks	Marks alloted	PERIODS ALOT-TED
PHS		10	10
V		12	13
K		14	15
D		17	18
T		21	22
E		14	15
N		11	12
Total		100	105

Annual and Unit Lesson Plan

Teachers are expected to produce Unit Lesson Plan well in advance of time. This will help them organize their duties ahead of time and facilitates record keeping, reflection, feed-back and continuous assessment modalities.

Structure of a Lesson

Lesson often follows a beginning, middle, end structure.

Beginning: Links are made with earlier work, and students are oriented to the lesson's content. The purpose of the lesson is made clear; some teachers advocate reading the objectives out, but most explain them in a less formal ways.

Middle: The student activity is introduced. If teaching is focused on specific skills, then students obtain any necessary explanation and are made aware of the doing-detail. That is, they discover the what, why and how of what they are expected to be able to do. Students then practice with the aim of developing the abilities outlined in the objectives. If the lesson is focused on content rather than skills, the students are given activities requiring them to process or reason with this content. It may be possible to check and correct the students work in some way as they proceed.

End: What has been learned is made clear, summarized and perhaps noted down. A pointer is given to the next lesson.

The format design depends on your individual needs, but should certainly include: unit, title of lesson, specific objectives, teaching aids required, other resources required, evaluation of how the lesson went. It may also include date, day and time of lesson, room, subject, etc.

Activities and timings are then added to this blank format for each new lesson, and the lesson plan kept in a folder along with relevant worksheet etc. for possible future use.

The introduction

As a general rule, the introduction should be about 10% of the overall time available. At the end of this phase students should look forward to what comes next. It needs to be informative about the lesson itself so that students have some idea of what to expect both in terms of the subject matter and how it is planned to be dealt with. Aspects for this first phase of the lesson that might be included:

- Reviewing the previous lesson by asking questions about it, (from the previous lesson's objectives).
- Assessing the entry behavior by asking questions about the topic.
- Describing the importance of the topic and how it might subsequently be used.
- Showing objectives.
- Describing an overview of the session.
- Inform students about the style of the lesson (make your own notes, there will be a test, there will be opportunity to practice for yourself)

Conclusion

It is important to highlight the main points from the lesson. You need to condense the lesson into a few basic points that can be quickly presented to the students to make sure that they have understood the lesson and achieved its objectives. The summary should be brief but sufficient time should be allowed to answer any student questions that may arise. As with the introduction, about 10% of the overall time should be allocated to this part of the lesson.

Physics web Resources

http://tll.mit.edu/help/stem-concept-videos

MIT's Teaching and Learning Laboratory (TLL) has created 47 STEM Concept Videos to help students connect the concepts they learn in introductory STEM

Investigative Science Learning Environment

A very good platform to learn scientific investigation and procedural knowledge.

http://phet.colorado.edu/

- PhET: Physics Education Technology
- An array of physics suits simulation and interactive environment.
- Good for students as well as Teachers

https://blossoms.mit.edu/resources/physics/resources

MIT BLOOSSOMS

Newton’s Laws of Motion and Car Physics

This resource, entitled Newton’s Laws of Motion and Car Physics, provides a large amount of interesting educational material on each of the Three Laws.

Universe and More

Interactive physics games created by an AP physics teacher.

ShareMyLesson

Hosted by ShareMyLesson,this site provides almost 2000 physics resources, including activities, worksheets, games, lesson plans, puzzles, posters, presentations, assessments and other ideas for you to use with your high school students.

PhysLink.com

The PhysLink.com is a comprehensive physics and astronomy online education, research and reference web site. In addition to providing high-quality content, PhysLink.com is a meeting place for professionals, students and other curious minds.

The Physics Classroom

The Physics Classroom Tutorial is an online physics tutorial written for high school physics students. The Tutorial covers basic physics topics using informative graphics and an easy-to-understand language. Each unit is broken up into lessons and sub-lessons.

The Particle Adventure

An award winning interactive tour of quarks, neutrinos, antimatter, extra dimensions, dark matter, accelerators and particle detectors from the Particle Data Group of Lawrence Berkeley National Laboratory.

Einstein Online

Einstein Online is a web portal with information about Albert Einstein’s theories of relativity and their coolest applications, from the smallest particles to black holes and cosmology.

Institute of Physics

Experiments can sharpen students' powers of observation, stimulate questions, and help develop new understanding and vocabulary. This website is for teachers of physics, enabling them to share their skills and experience of making experiments work in the classroom.

PhET Interactive Simulations

PhET Interactive Simulations is an ongoing effort to provide an extensive suite of simulations to improve the way that physics, chemistry, biology, earth science and math are taught and learned. The simulations are interactive tools that enable students to make connections between real life phenomena and the underlying science that explains such phenomena.

ComPADRE Digital Library

The ComPADRE Digital Library is a network of free online resource collections supporting faculty, students, and teachers in Physics and Astronomy Education.

Physics is Phun

Physics is Phun lists websites for teachers that provide a variety of interactive simulations, experiments and ideas—all designed to help students better understand the underlying concepts of physics.

This site is as informative as it is also fun and pleasurable platform to learn High-School physics. We recommend Teachers to select and access it before students.

Unit One

Physics and Human society

[10 periods]

Introduction to the unit

As far back as humans exist the struggle to live and prosper has been the primary motive for doing what human society has been doing. This includes hunting, agriculture, invention, art and war to name a few. The curiosity to know is there all the way back to the ancients. The curiosity to understand, where we came from, from what we came from, why we exist, are among the primary questions we ask ourselves as soon as we started to think independently as a young and as an adult. This is simply human nature. Some questions get answers, some do not. Questions of the type that get answers from observation and experimentation are mainly the domains of science.

Physics primarily deals with energy, matter, and their interactions. Matter and energy are the basic constituents of nature. Therefore, Physics is the basics of all sciences. Physics is important to society in so many different ways. It connects all the major sciences in an important way. It is also lending itself to other science branches the know how or the methodology of gaining knowledge. It is also important to society in providing fundamental (basic) knowledge for understanding nature, in providing applied knowledge for the development of technology. This unit to some extent addresses and discusses the points that physics contributes to society.

Learning outcomes:

After completing this unit, student will be able to:

- *Get acquainted with the impact of physics on society.*
- *Familiarize themselves with physics communities and their roles.*
- *Develop basic understanding of the making of physics knowledge.*
- *Familiarize themselves with basic principles and applications of physics in various disciplines.*
- *Acquire basic knowledge and understandings of nature and appreciate it.*
- *Update themselves with the current status of physics.*

Learning Strategies

In this unit there are opportunities for students to do some activities that help them explore and learn in a meaningful way. Your task as a teacher is helping them accomplish that.

Dear teacher, begin this unit by communicating the lesson objectives or learning outcomes by reflecting the rationale for learning the subject.

Assessments

Assess students' performance carefully before, during and after the lesson delivery. Give them assignments, project work, reading assignments etc. during the lesson presentation.

Suggested field/project work:

In this unit there is an opportunity for students to explore the importance of physics and how physics knowledge is constructed. This can be done through web-search or library. They learn scientific enquiry by acting it out. Even though it is literature search it helps to impart the process of authentic scientific research, such as data gathering, organizing, authenticating the reliability of the data, forming conclusion, communicating, making consensus, summarizing and reporting .

1.1. Importance of physics to society

[2 periods]

At the end of this section the student will be able to:

- *Explain the importance of physics to society*

Physics is highly related with human daily activity and the life of the society. This is manifested by health, transport, technology, agriculture, industry, economy of the country, etc. therefore physics is important for human being to live healthy and to establish a better life.

Methodology

This topic needs to discuss the importance of physic in different fields. Therefore, you should give different titles for the students to search from different sources the contribution of physics for society in different areas. Enable student to present in the class.

Begin by raising questions what science has done or contributed to society? And proceed to invite students to focus and trace if there is any physics deep-down in that contribution.

Accept students answer as they are. The main point is not for them to get the right answer. It is the process and the justification they give, whatever that may be. It does not mean correct answer is unimportant. The fact that we encourage the process more than the correct answer is precisely because the process is what leads them to get the correct answer eventually.

Answer for Activity:1-1

To answer such questions, you should have to know the current status of technology, economic level of the country. Physics have an influence in discovering and improving transport technology of the land and the space. Development of new devise for examine the health status of the patients. To understand the current status of physics you need to find from the internet, the contribution of physics in the development of economic values of the country and development of technologies. i.e.in agriculture, industry, etc. .

Dear Teacher;

- ▷ Put students in groups (select any number of students depending on the size of the class) make sure that they work in harmony. Help them in selecting their group leaders.
- ▷ Recognize learners with special needs in group making. Encourage them to actively participate in their respective groups.
- ▷ Move around the class guiding students as they are performing the activity.
- ▷ Let the students discuss their findings in their groups and finally present to the whole class.
- ▷ Give them appropriate feedback on their presentation and summarize the discussion by raising the major concepts given in the student text under this subsection.

1.2. Physics Communities and Their Roles

[2 Periods]

At the end of this section the student will be able to:

- *Discuss about physics communities and their roles*

Under this topic students need to understand the importance of physics communities for the society. This may be for the benefit of society based on research and invention of new technologies.

Methodology

Make students discuss on different physics communities and why these organizations were established. Give assignments for the student to find different communities of physic, their role and the reason why they established for.

Answer for Activity 1.2

- ▷ Physics community established for the benefit of society.
- ▷ Any one of those organizations that strives to promote the benefits of physics to society. It may include broadening the understanding of natural phenomenon, dissemination of information about the latest technologies, help create responsible and decision-making society based on empirical data. For instance, EPS and similar organizations.
- ▷ Ethiopian Physical Society (EPS) was founded on October 10, 1998 by Ethiopian physics professionals to enhance physics research and education, thereby contributing to the overall development of the country.

Objectives of EPS

- ▷ To promote physics education and research in the country;
- ▷ To organize and coordinate various conferences on physics education and exchange of scientific information;
- ▷ To popularize physics in order to make students develop interest in physics;
- ▷ To promote active participation of Ethiopian physicists and the general public in the design and implementation of the physics curriculum;
- ▷ To create a means for disseminating scientific information; etc.

1.3. Making of physics knowledge

[3 periods]

Learning Strategies

At the end of this section, the student will be able to:

- ◉ *discuss how scientific knowledge is constructed.*
- ◉ *discuss the roles that the learning of physics plays to the individual intellectual satisfaction*

There is a series of steps by which scientific knowledge can be developed. Students should understand those steps and need to be practice in their series of knowledge development in their daily activities.

Methodology

Students should practice those steps by which knowledge can be developed. Therefore, allow students to choose one title and practice the steps by which knowledge can be acquired.

Answer for activity 1.3

Getting the correct answer in the brainstorming is not the main point. The process is more important. Make sure and encourage students to form a group. Let them list and discuss what is in the activity.

What is fundamental knowledge?

- ▷ Fundamental knowledge is knowledge gained by understanding how things work. It may or may not be immediately useful to society. For example, the study of solar system may seem unimportant compared to the societal problems on our planet. It is now clear that Venus' and Mars' environment teach us a lot on green-house effect (climate gone bad!)

Is F = ma, Fundamental knowledge?

- ▷ Yes it is. It is the general understanding of how things move under the influence of a force. Latter it used to describe the motions of planets, satellites, cars, airplanes, rockets etc.

Is the discovery of Electric charge a fundamental knowledge?

- ▷ Yes it is. The nature of electron was unknown before J.J. Thompson discovered it. and no one knows what it is going to be used for. It was discovered for the pure understanding of nature. As we now know it is applied in our daily lives. Such as, mobile phones, electricity, computers, etc.

Is $E = mc^2$ fundamental knowledge?

- ▷ Yes it is. Before its discovery mass and energy were not related in this form. That mass is equal to energy with some multiplying factor. It is now used for electric generation in power plants. It is applied the production of nuclear bombs. It is fundamental in understanding of how stars like our sun produce energy.

What is the contribution of Albert Einstein?

- ▷ Albert Einstein is an American-German scientist who discovered $E = mc^2$ among other important discoveries. He improved the law of gravity after Newton. He discovered that light speed is the maximum speed.

What is the contribution of Isaac Newton?

- Isaac Newton is British scientist who discovered F = ma, among other things. He discovered the law of motion. He has also discovered the law of universal gravitation.

What did J.J. Thompson contribution to physics?

- He is British scientist who is responsible for discovering an electron.

Summarize the answers for students at the end of the section.

- Make a group and let students do some field research by visiting library, a local clinic, shops, offices, hospitals or factories depending where they live and availability to get relevant information.
- Here not only the search for accurate and revenant information is important, but also the process in doing the research.
- It gives students the opportunity to collect, organize, interpret information. They also collaborate, communicate and present the research. It also builds confidence in students.

Starting from students' presentation summarizes their results.

1.4. The mission of physics and career awareness

[2 periods]

At the end of this section the student will be able to:

- *Explain the job opportunities concerning to physics.*

There are a lot of carrier opportunities in different fields of physic. By hopping this encouragement needs students to learn physic in passion to join those different fields.

Methodologies

There are a lot of carrier opportunities listed in students' physics textbook. Allow students to choose one or more fields want to join and allow students why they choose and what physics course help them to join that specific field that they choose.

Begin with some brainstorming questions or activity

1. Some of the mission of high school physics would be:

To equip students with basic working knowledge of physics that is applicable in the job market.

To help students learn to:

- Appreciate the workings of the physical world.
- Cooperate
- Communicate their ideas meaningfully

To help students learn:

- Evidence based decision making.
- Critical thinking.
- Discern facts from fiction especially in web-based information
- IT skills
- To be flexible and appreciate cultural values.

2. Some of the career opportunities at higher level are:

- Researcher at Research institutions
- University Teacher
- Consultant or researcher in manufacturing Industries, etc.

1. **For 12th Grade completes**

At the government level, there are five field based training until completion of grade 12.

They would be employed at:

I. Manufacturing field • Metal Manufacturing • Automotive Technology • Textile and Leather Garment • Wood Working	II. Construction field • Electricity • Plumbing • Carpentry • Finishing Works
III. Information technology and computer science field • Information Technology and Computer Science • Computer Maintenance and Network • Website Design • Computer Graphic Design	IV. Agriculture field • Crop Production and Management • Animal Production and Management • Natural Resources Management • Agricultural Technology

V. Health Science field • Personal, Community Health and Patient Care • Nutrition and Dietetics • Child care and Well-being • Reproductive Health	VI. Possibly self-employed

1.5. Current Status of Physics

[1 period]

At the end of this lesson students will be able to:

- *List at least five recent new developments or discoveries in the fields of physics.*

This content may help students to understand the current status of physic; the level by which physics can attain in this century. There may be new invention. Allow students to find different new inventions.

Methodology

This section is more of informative than it is to be understood by the students. The teacher role is to present it as simple and as lively as possible. Perhaps, if resources are available some video clips, picture might facilitate this sections lesson. It is just to excite students than really to be understood in depth as the topics are at the forefront of physics.

Answer for the equation of end of this content

Dear teacher please facilitate the student search for information as much as your school and circumstances allow.

You have to give this activity a day or two in advance so that it is timely for the lesson. Make students present their result of the research for half of the period. Discuss and summarize and proceed to the next topic.

Fundamental knowledge discoveries. The following website might help:

- https://en.wikipedia.org/wiki/Timeline_of_fundamental_physics_discoveries#21st_century.

Applied knowledge discoveries. The following website might help.

- https://www.bbc.com/news/science-environment-30415007
- https://physicsworld.com/a/physics-world-announces-its-breakthrough-of-the-year-ÿnalists-for-2020/

Answer to Activity 1-16

- Listen and facilitate their presentation. Summarize and conclude

Summarize this section by pointing out:

- In this section we have learned the status of physics from international and national point of view.
- Also we have learned the future prospects of physics and major discoveries in recent years.

Questions

1. What is the current status of physics looks like
2. What do you think the future of physics looks like. Your opinions in one paragraph or two with justification.
3. What is the significances of the two discoveries- gravitational wave, and Higgs boson

Review questions

Dear teacher, take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

1. What is the current status of physics looks like
2. What do you think the future of physics looks like? Your opinions in one paragraph or two with justification.
3. What is the significances of the two discoveries- gravitational wave, and Higgs boson

Answer to questions

1. Physics as a research field is getting bigger and larger in size and collaboration. It is also becoming very expensive looking for fundamental knowledge. It is now a Billion-Dollar enterprise.
2. It is also becoming more integrated with fields such as Biology, Medicine and Chemistry.
3. The most important element of the two discoveries is the strength of the human spirit (perseverance). It took hundred and sixty years respectively to discover what was hypothesized that long ago.

In the case of Higgs boson, it has completed the standard model. The standard model is the complete, up to date understanding of the world we are living.

In the case of gravity wave, it has opened a new field of observational astronomy. In the coming decades gravitational waves could be used as detecting the evolution of early universe as additional instrument to radio telescopes and other ground-based telescopes.

It is also that, physics is a predictive science, only accepted what is proved right. It doesn't accept your dream; your friends dream or anyone else's dream. What is acceptable as science is what is proved experimentally. That and only that!

End of Unit questions

1. What is the importance of learning physics in your opinion?
2. What did you benefit from knowing physics at this level?
3. List at least ten technological benefits that physics has contributed.
    a. List them.
4. Is there a physics community in your high school? If the answer is yes. List it. What is it helpful for?
5. What process skills should you use investigating a phenomenon?
6. What are the process skills you are using in your in investigating a phenomenon?
7. What are the choices at career level that a physicist might take?
8. What are the job markets for 12^{th} grade completes related to physics?
9. At the forefront in physics research, there are many countries collaborating. Why is that?
10. What recent discoveries, technologies you have heard that are directly related to physics.

Dear Teacher check that the learners do the self-test exercise and that their answers are correct.

Answer to End of unit questions

1. Learning physics is important:

- ▷ For intellectual satisfaction, to know how things work.
- ▷ To be self-employed/employed in several fields of industry and teaching institutions

To solve societal problems in: Communication, Energy, Information technology, Hazard prevention, Health and medicine, Remote sensing and exploration

2. This is an individual answer from students

3. (a) Lighting system, such as: house lighting and road lights.
   (b) Health and medical, such as: x-ray, MRI and Ultrasound
   (c) Communication system, such as: cell-phone and radio, satellite
   (d) Transportation system, such as: Airplanes, cars and ships.
   (e) Information technology, such as: computers and internet
   (f) Remote sensing, such as: weather prediction and environmental protection
   (g) Mineral exploration, such as: Gold, Aluminum and Diamond
   (h) Petroleum exploration, such as: Oil and Gas
   (i) Ground water exploration, such as: Drinking water resource exploration
   (j) Geothermal exploration, such as: looking for geothermal energy source
   (k) Nuclear energy
   (l) Wind energy.
   (m) Entertainment industry, such as: Television, films, videos.

4. Student answer.
5. The answers to question number 5, 6, 7, 8 and 10 are given at activities above.
6. At the highest level of physics research, the questions are very fundamental, such as "why is the electron has such mass?" Why does it have a mass in the first place? Why the Universe as big as it is now? The answers to these questions require a collaboration of experts and scientists from different fields of physics and engineering and technology. It is also very expensive. Therefore, to share the burden in financing and intellectuals' contribution it has to be multinational enterprise.

Also, the answer to these questions is so profound that it touches the very existence of life and non-life, therefore it has to be shared among human society.

1. The answers to question number 5, 6, 7, 8 and 10 are given at activities above.

Unit Two

Vectors

[13 periods]

Introduction to the unit

Many familiar physical quantities can be specified completely by giving a single number and the appropriate unit. For example, "the lecture lasts 45 min" or "the water tank holds 200 L" or "the distance between two points is 100 m." A physical quantity that can be specified completely in this manner is called a scalar quantity. Time, mass, distance, length, volume, temperature, and energy are examples of scalar quantities.

Scalar quantities that have the same physical units can be added or subtracted according to the usual rules of algebra for numbers.

Many physical quantities, however, cannot be described completely by just a single number of physical units. For example, a pilot flying from one airport to another must know not only the distance between the cities but also the direction from one city to the other so she can get to her destination as quickly as possible. Physical quantities specified completely by giving a number of units (magnitude) and a direction are called vector quantities. Examples of vector quantities include displacement, velocity, position, force, and torque.

We can add or subtract two vectors, and we can multiply a vector by a scalar or by another vector, but we cannot divide by a vector. The operation of division by a vector is not defined.

Unit outcomes

At the end of this unit, students will be able to:

- *Familiarize themselves with basic principles of vector operations*
- *Interpret physical phenomena using the concept of vector*
- *Develop skills of using the concept of vector in solving various problems*

Learning Strategies

Since students have already developed the concept of vectors in their grade 10 physics lesson, you may start the lesson by brainstorming questions on what vectors are and how they can be represented. The students should then use their previous knowledge and try to investigate vector addition. They should also relate this concept to what they observe or do in their day to day activities.

Activity: Make group discussion so that students can explain some practical examples of vectors and vector addition from what they observe/practice in their day to day activities and present it using chart. As an example: Student must use their creativity to construct "force table" and use it for reinforcing the concept of force as a vector.

Walking from point A to point B, in different paths, the student should identify the shortest path. The need for vector, rather than scalar, addition of forces is best displayed by means of a demonstration.

- ▷ Use arrows, drawn to scale, "heads to tail" to show triangle law (i.e. the resultant of two vectors completes the triangle formed by the two).
- ▷ Commutative law of vector addition can be demonstrated by producing same resultant when varying order of vector addition.

Help students to show how three non-zero vectors can be added up to be zero. Draw an example.

Activity: Consider a farmer who ploughs his land. What forces are involved and how they are added together so that the plow can easily dig into, break up, and turn over the soil?

Assessment

In order to check whether the student has acquired the minimum competency required, each students should be assessed continuously over the whole unit and compare it with the following description.

To achieve the minimum required competency, the student should be able to: give the definitions of the terms: vectors, unit vectors, collinear, coplanar, non-coplanar vectors, zero vector, orthogonal vector; add and subtract vectors by using graphical and analytical methods, use the triangle and parallelogram law of addition of vectors, define the scalar product of vectors, resolve vectors into their rectangular components, explain some of the applications of vectors, determine graphically a resultant of two vectors, add or subtract two or more vectors by the vector addition rule, solve problems related to scalar products of two vectors in a plane, explain properties of vector operations.

Assisting low achievers (students achieving below the minimum competence level) and praising the high achievers (students achieving above the minimum competence level) is very important in the assessment process. In this way, the low achievers attain the minimum competency level and the high achievers will be motivated for further high level achievements.

2.1. Vectors and types of vectors

[3 periods]

At the end of this topic, students will be able to:

- *Describe the difference between vector and scalar quantities.*
- *List down the common vector quantities in our everyday life.*
- *Discuss geometric representation of vectors.*
- *Give the definitions of the different types of vectors.*

Introduction to the topic

Vectors are very important in the study of physics. The importance of the study of vectors is clearly observed when dealing with complex mathematics involving quantities such as force, velocity momentum, that need to be represented by their magnitude and direction.

Students used variables and graphs to represent vector quantities. They know how to represent vector quantities using vector diagrams. In a diagram, a line segment with an arrowhead represents a vector quantity. Its point of origin is called the tail, and its terminal point (arrowhead) is the tip. If the magnitude of a vector is given, the vector can be drawn to scale. The length of the line segment depends on the vector's magnitude. The arrowhead indicates direction. Drawing vector diagrams to represent motion helps you to visualize the motion of an object. Properly drawn, vector diagrams enable you to accurately add/subtract vectors and to determine an object's position and velocity.

Teaching method

In their Grade 10 physics lesson, the students have already been introduced to the concepts of vectors in one dimension. They also know how to represent vectors by using symbols and graphs. In this section plane vectors, vectors of two dimensions are discussed.

Start by asking students about what is meant by vectors and scalars, how vectors are represented graphically, what is the need for using scale diagrams, and name examples of vector quantities based on their previous knowledge as well as their daily practices.

Answers to Exercises, Activities, Review questions and End of unit questions.

Activity 2.2

Assign four or five groups each of 5 or 6 students (as convenient). Make sure that each group has a graph paper, measuring tape, pencil and marker. Assist the students in doing the activity and discuss the results in groups.

Answers to Review questions 2.1

1. Vectors are represented graphically by an arrow drawn to scale. The length of the arrow drawn to scale represents the magnitude of the vector and the head of the arrow points in the direction of the vector.
2. A scale diagram is used to represent vectors with large magnitudes that are not convenient to show on paper with a 1:1 scale.
3. Vector $\overrightarrow{AA}$ and vector $-\overrightarrow{AA}$ are opposite in direction.

2.2. Graphical Method of Vector Addition of in 2-D

[3 periods]

At the end of this topic, students will be able to:

- *Define the term resultant vector.*
- *Explain the geometric method for addition and subtraction of vectors in a plane.*
- *Apply geometric method of addition of vectors to find resultant of vectors in two dimensions.*

A single vector that can represent a number of vectors is known as a resultant vector. A resultant is the sum/difference of two or more vectors.

Unlike scalar quantities, vector addition/subtraction involves both the magnitude and direction of the vectors. Vector addition may be done by geometric method or algebraic method. In this section we will discuss graphical method of addition of vectors in 2 D.

Teaching method

Start by asking students about geometric method of addition of vectors in one dimension and how to represent a point on the xy plane in terms of its coordinates (Cartesian coordinate system).

Discuss the triangle law, parallelogram law and polygon laws of addition/ subtraction of vectors using scale diagrams on graph paper.

Answers to Exercises, Activities, Review questions and End of unit questions

Activity 2.3

Students should have their own pencils, scale paper, protractor and ruler (cm scale). Use a scale 1 cm: 1 unit. With angle between the vectors 60°, the approximate length of the resultant $\vec{A}+\vec{B}$ and $\vec{B}+\vec{A}$ should be about 12.3 units.

Activity 2.4

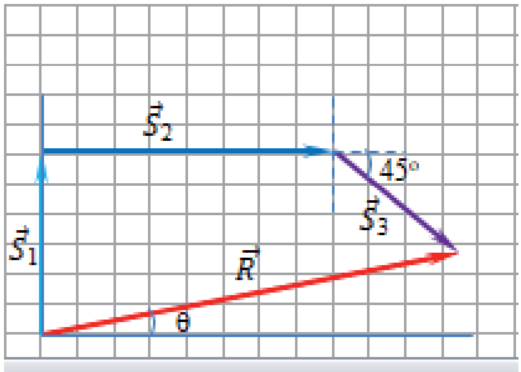
Focus on the fact that vector addition involves not only the magnitudes of the vectors but also their direction.

Activity 2.5

To find the resultant vector of a system of non-collinear vectors using graphical method, follow the following steps:

1. Create an appropriate scale.
2. Choose a set of reference coordinates.
3. Draw vector 1 to scale. Measure its direction from the tail.
4. Draw vector 2 to scale. Draw its tail at the tip (arrowhead) of vector 1. And continue on doing the same with each of the remaining vectors.
5. Draw the resultant vector by connecting the tail of vector 1(the first vector) to the tip of last vector.
6. Measure the magnitude (length) of the resultant. Measure the direction (angle) of the resultant from its tail.
7. Use your scale to convert the magnitude of the resultant to its original units.
8. State the resultant vector. Remember to include both magnitude and direction.

This method also works for more than two vectors. You can add the vectors in any order. Following polygon law of addition of vectors make sure that the displacements vectors are placed on the xy plane as shown. The resultant will be 23.59 m, $\theta = \tan^{-1}(0.21) = 12^{o}$

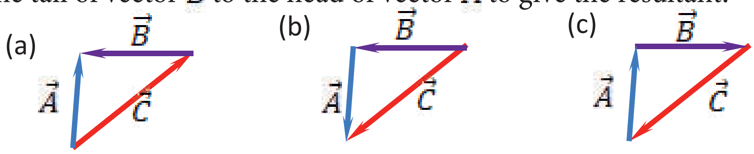


Answer to Exercise 2.1

Adding vector $-\overrightarrow{AA}$ to vector $\overrightarrow{AA}$ gives a resultant of zero vector.

Answers to Review questions 2.2

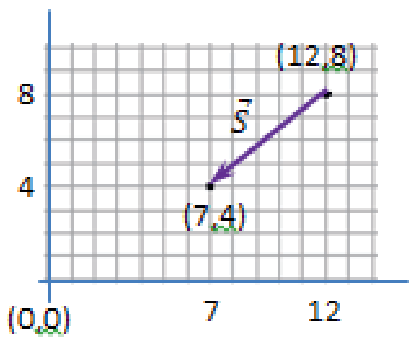
1. (b), Vector $\vec{B}$ and vector $\vec{A}$ are connected head-to tail and vector $\vec{C}$ is drawn from the tail of vector $\vec{B}$ to the head of vector $\vec{A}$ to give the resultant.



2.
3. When the head of the last vector falls on the tail of the first vector the resultant vector is a zero vector.
4. No, $\vec{A} - \vec{B} = \vec{A} + (-\vec{B}) = (-\vec{B}) + \vec{A}$ while $\vec{B} - \vec{A} = \vec{B} + (-\vec{A})$
5. Yes, $\vec{A} + (\vec{B} + \vec{C}) = (\vec{A} + \vec{B}) + \vec{C}$
6. a) C = A + B when $\vec{A}$ and $\vec{B}$ are along the same direction.

   b) C = |A − B ||A − B | when $\vec{A}$ and $\vec{B}$ are in opposite directions.

7. The initial coordinate is A (12, 8) and the final coordinate is B (7, 4). The vector starting at A and ending at B represents the displacement $\vec{S}$.



8. Two. Two equal and opposite vectors can be added to give a zero resultant.

2.3. Algebraic Method of addition of vectors in 2-D

[4 periods]

After completing this section, the students will be able to:

- *Apply algebraic method to find the resultant of two collinear vectors, and perpendicular vectors.*
- *Apply trigonometry to determine the direction of a resultant vector in terms of the angle it forms with a reference direction.*
- *Compare the resultant of two given vectors as determined by way of geometric construction and by analytic method.*
- *Resolve a vector into its components.*
- *Find the resultant of two or more vectors applying component method.*
- *Define unit vector and determine a unit vector in the direction of a given vector.*
- *Apply the unit representation of vectors to determine the resultant of two or more vectors.*

In this section students will be introduced to algebraic method of addition of vectors in 2D. The algebraic method involves mathematical formulas and the process of breaking a given vector into its components. Component of a vector is simply the shadow of the vector on the coordinate axes. The x and y components of a 2 D vector $\vec{A}\vec{A}$ have scalar components of A_x along the x axis, and A_y along the y axis.

$\vec{A}x$ and $\vec{A}y$ are the vector components of vector $\vec{A}$.

$$\vec{A} = \vec{A}_x + \vec{A}_y$$

In order to determine components of a vector requires the application of trigonometric relations such as sine, cosine or tangent.

A 2 D vector can also be represented in terms of unit vectors $\hat{\imath}\hat{\imath}$ 'read as i hat', $\hat{\jmath}\hat{\jmath}$ 'read as j hat'.

$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath}$$

Note that x and y components are perpendicular.

The magnitude of vector $\vec{A}$ is $A = \sqrt{A_x^2 + A_y^2}\sqrt{A_x^2 + A_y^2}$

The angle between the vector and the x axis is $\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)\left(\frac{A_y}{A_x}\right)$

Teaching method

Remember that by now the students are able to define vectors, represent vectors graphically and add or subtract vectors in one and two dimensions employing graphical method of addition of vectors.

Start by asking students about the difference between adding scalars and adding vectors. Review trigonometric relations which you are going to apply to calculate the components of 2D vectors. It is worth getting students practice the application of trigonometric relations. Solve examples that will enable students to apply trigonometry to find the x and y components of a given vector.

Introduce the concepts of unit vectors which are very important to specify the direction of a given vector.

Answers to Exercises, Discussion of Activities, Review questions and End of unit questions

Exercise 2.2

The largest resultant is obtained when the vectors are in the same direction and the smallest is obtained when the vectors are in opposite directions.

Largest resultant = 13 units + 9 units = 22 units

Smallest resultant = 13 units – 9 units = 4 units

Exercise 2.3

The vectors are in opposite directions and the magnitude of the resultant will be

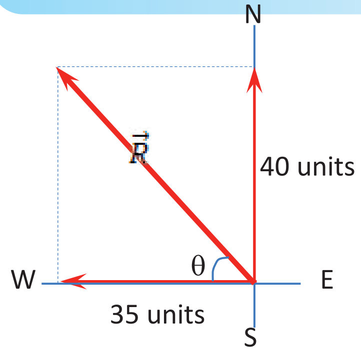
$$R = 0.5\ m/s - 0.3\ m/s = 0.2\ m/s$$

The direction of the resultant velocity will be upstream..

Exercise 2.4

A vector will have its x and y components of equal values when it is directed at an angle of 45^o with either of the axes. (Sin 45^o = cos 45^o)

Exercise 2.5



Draw the vector diagram

The magnitude of the vector is

R = $\sqrt{(-35\ \text{units})^2 + (40\ \text{units})^2}\sqrt{(-35\ \text{units})^2 + (40\ \text{units})^2}$ = 53.1 units

The direction of the vector is

$\tan^{-1}(\frac{40}{35}\frac{40}{35}) = \tan^{-1}(1.14) = 48.8^\circ$ N of W

Exercise 2.6

Vector $\vec{A}$ has $A_x = 0$ and $A_y = 30$ units

The resultant vector $R = \vec{A} + \vec{B}$ has $R_x = 0$ and $R_y = -10$ units

Required is vector $\vec{B}$

Knowing that $R_x = A_x + B_x$ and $R_y = A_y + B_y$,

we have $0 = 0 + B_x$, $B_x = 0$ unit

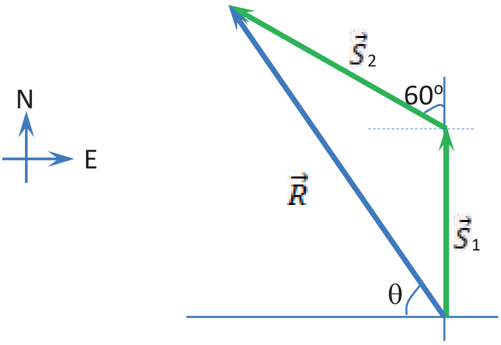
and -10 units $= 30$ units $+ B_y$, $B_y = -40$ units

$$B = \sqrt{(B_x)^2 + (B_y)^2}\sqrt{(B_x)^2 + (B_y)^2}$$

B = $\sqrt{(0\ \text{unit})^2 + (-40\ \text{units})^2}\sqrt{(0\ \text{unit})^2 + (-40\ \text{units})^2}$ = 40 units

$\vec{B}$= 40 units along the negative y-direction

Exercise 2.7



	x component	y component
$\vec{S}_1$	0	20 km
$\vec{S}_2$	- (25 km) sin 60° = - 21.65 km	(25 km) cos 60° = 12.50 km
$\vec{R}$	- 21.65 km	32.50 km

$$R = \sqrt{(R_x)^2 + (R_y)^2}\sqrt{(R_x)^2 + (R_y)^2} = \sqrt{(-21.65\text{ km})^2 + (32.50\text{ km})^2}$$

$$\sqrt{(-21.65\text{ km})^2 + (32.50\text{ km})^2} = 39\text{ km}$$

$$\theta = \tan\text{-}1\left(\frac{32.50}{21.65}\right)\left(\frac{32.50}{21.65}\right) = 56.3^\circ$$

$\vec{R}\vec{R}$ = 39 km, 56.3° N of W

Exercise 2.8

Let $\vec{Q} = Q_x\hat{i} + Q_y\hat{j}$

$$\vec{P}\vec{P} + \vec{Q}\vec{Q} = (P_x+Q_x)\hat{i} + (P_y+Q_y)\hat{j}$$

$$= (1+Q_x)\hat{i} + (-1+Q_y)\hat{j}$$

$$= \hat{i} + 0\,\hat{j}$$

$$1 + Q_x = 1,\ Q_x = 0$$

$$-1 + Q_y = 0,\ Q_y = 1$$

Therefore, $\vec{Q} = \hat{j}$

Exercise 2.9

A unit vector has magnitude of 1. Therefore,

$$U = \sqrt{(0.4)^2 + b^2}\sqrt{(0.4)^2 + b^2} = 1$$

$0.16 + b^2 = 1$, $b^2 = 0.84$, $b = 0.92$

Answer to Review Questions 2.3

1. Let the vectors be $\vec{A}\vec{A}$ and $\vec{B}\vec{B}$. When they are parallel A + B = 8 and when they are antiparallel, $|A - B||A - B| = 2$
   Solving the simultaneous equation we obtain A = 5units and B = 3 units or A = 3units and B = 5 units
2. The vector sum of two vectors having the same magnitude but opposite direction is a zero (a null) vector.
3. A. Distance S = 50 m + 10 m + 10 m + 10 m + 20 + 10 m + 40 m + 10 m = 160 m
   B. Taking forward as positive, and backward as negative we have Displacement S = + 50 m −− 10 m + 10 m −− 10 m + 20 −− 10 m + 40 m −− 10 m = + 80 m

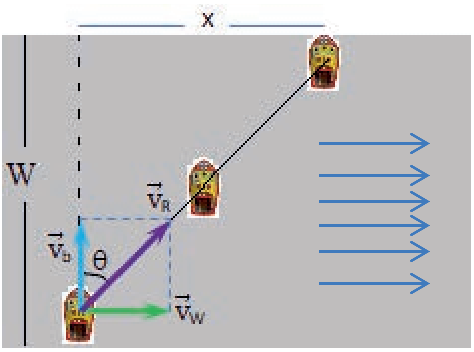
   $\vec{S}$ = 80 m [forward]

4. A. Let $\vec{R} = \vec{C} + \vec{B}$,

   15 km, East = 10 km, East + $\vec{B}$
   $\vec{B}$ = 15 km, East −− 10 km, East
   = 15 km, East ++ 10 km, West = 5 km, East

   B. Let $\vec{R} = \vec{C} + \vec{B}$,
   15 km, west = 10 km, east + $\vec{B}\vec{B}$
   $\vec{B}$ = 15 km, West −− 10 km, East
   = 15 km, West ++ 10 km, West = 25 km, West

5. A) The actual path along which the boat will travel is shown below.



$\vec{V}_b$ = velocity of boat

$\vec{V}_w$ = velocity of water

$\vec{V}_R$ = Resultant velocity

$v_R = \sqrt{(v_b)^2 + (v_w)^2}\sqrt{(v_b)^2 + (v_w)^2}$

$= \sqrt{(1\ m/s)^2 + (0.5\ m/s)^2}\sqrt{(1\ m/s)^2 + (0.5\ m/s)^2}$

$= 1.11$ m/s, $\theta = \tan\text{-}1\left(\frac{0.5}{1}\right)\left(\frac{0.5}{1}\right)$

$= 26.5^\circ$, relative to the straight-across direction.

B. Let the width of the river be W.

$\tan\theta = \frac{x\ x}{WW}$, $x = W\tan\theta = W\tan(26.5^\circ) = 0.5\ W$

6. $\vec{B} = (-\hat{i} + 2\hat{j})$ m, $3\vec{B} = 3(-\hat{i} + 2\hat{j})$ m $= (-3\hat{i} + 6\hat{j})$ m

$\vec{C} = (3\hat{i}\hat{i} -- 2\hat{j})$ m,

$-\vec{C} = -(3\hat{i}\hat{i} - 2\hat{j})$ m

$= (-3\hat{i}\hat{i} ++ 2\hat{j}\hat{j})$ m

$\vec{D} = (D_x\hat{i} + D_y\hat{j})$ m

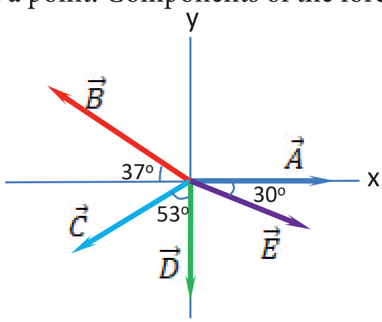
$3\vec{B} - \vec{C} + \vec{D} = 0$

$(-3 -3 + D_x)\hat{i}\hat{i} + (6 + 2 + D_x)\hat{j}\hat{j} = 0$, $D_x = 6$ m, $D_y = -8$ m

7. $\vec{S}_1 + \vec{S}_2 = [(3 - 2)\hat{i} + (6 - 4)\hat{j}]$ m $= (\hat{i} + 2j)$ m

$\vec{U} = \frac{\vec{S}1 + \vec{S}2\ \ \vec{S}1 + \vec{S}2}{|\vec{S}1 + \vec{S}2||\vec{S}1 + \vec{S}2|} = \frac{\hat{i} + 2j\ \ \hat{i} + 2j}{\sqrt{1^2+2^2}\sqrt{1^2+2^2}} = \frac{1\ \ 1}{\sqrt{5}\sqrt{5}}(\hat{i} + 2j)$ m

8. The forces acting at a point. Components of the forces are shown in the table.



	X component	Y component
$\vec{A}$	A	0
$\vec{B}$	- B cos 37° = - 0.8 B	B sin 37° = 0.6 B
$\vec{C}$	- C sin 53° = - 0.8 C	- C cos 53° = - 0.6 C
$\vec{D}$	0	- D
$\vec{E}$	E cos 30° = 0.866 E	- E sin30° = - 0.5 E

2.4. Product of Vectors [3 periods]

After completing this section, students will be able to:

- *Define dot product of a vector*
- *Apply the technique of dot product to solve practical problems*

A vector can be multiplied by another vector but may not be divided by another vector. There are two kinds of products of vectors used broadly in physics and engineering. One kind of multiplication is a scalar multiplication of two vectors. Taking a scalar product of two vectors results in a number (a scalar), as its name indicates. Scalar products are used to define work and energy relations. For example, the work that a force (a vector) performs on an object while causing displacement (a vector) is defined as a scalar product of the force vector with the displacement vector. A quite different kind of multiplication is a vector multiplication of vectors. Taking a vector product of two vectors returns as a result a vector, as its name suggests. Vector products are used to define other derived vector quantities. For example, in describing rotation, a vector quantity called torque is defined as a vector product of an applied force (a vector) and its distance from the pivot to the force (a vector). It is important to distinguish between these two kinds of vector multiplications because the scalar product is a scalar quantity and a vector product is a vector quantity. Multiplying a vector by scalar n results in a new vector whose magnitude is n times the given vector. The direction of the new vector is along the direction of the given vector if n is a positive scalar and opposite in direction to the given vector if n is a negative scalar.

Dot product

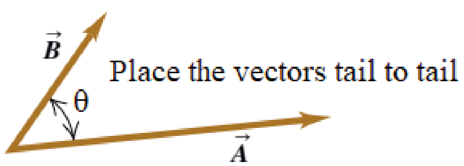
The scalar product of two vectors is denoted by $\vec{A} . \vec{B}$. Because of this notation, the scalar product is also called the Dot product. Although $\vec{A}$ and $\vec{B}$ are vectors, the quantity $\vec{A}\vec{A} . \vec{B}$ is a scalar.

The dot product of vectors $\vec{A}$ and $\vec{B}$ is defined as

$$\vec{A} . \vec{B} = AB \cos \theta,$$

where θ is the angle between the vectors.

Vectors are placed tail to tail to form angle θ.



If $\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath}$, $\vec{B} = B_x\hat{\imath} + B_y\hat{\jmath}$, then

$$\vec{A}\cdot\vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath}).(B_x\hat{\imath} + B_y\hat{\jmath})$$

$$= A_xB_x(\hat{\imath}.\hat{\imath}) + A_xB_y(\hat{\imath}.\hat{\jmath}\hat{\imath}.\hat{\jmath}) + A_yB_x(\hat{\jmath}.\hat{\imath}) + A_yB_y(\hat{\jmath}.\hat{\jmath}.\hat{\jmath})$$

But $\hat{\imath}.\hat{\imath} = |\hat{\imath}||\hat{\imath}|\cos 0^o = (1)(1)(1) = 1$, $\hat{\jmath}.\hat{\jmath}. = |\hat{\jmath}||\hat{\jmath}|\cos 0^o = (1)(1)(1) = 1$

$\hat{\imath}.\hat{\jmath}\hat{\imath}.\hat{\jmath} = |\hat{\imath}||\hat{\jmath}|\cos 90^o = (1)(1)(0) = 0$, $\hat{\jmath}.\hat{\imath}\hat{\jmath}.\hat{\imath} = |\hat{\jmath}||\hat{\imath}|\cos 90^o = (1)(1)(0) = 0$

Using these results we get

$$\vec{A}\cdot\vec{B} = A_xB_x(11) + A_xB_y(00) + A_yB_x(0)0) + A_yB_y(11) = A_xB_x + A_yB_y$$

The definition of dot product of vectors can be used to determine

- the angle between the vectors, $\cos\theta = \frac{\vec{A}.\vec{B}}{AB}$
- the components of a given vectors along the coordinate axes,
  $A_x = \vec{A}.\hat{\imath}$, and $A_y = \vec{A}.\hat{\jmath}$
- The scalar projection of a given vector along the direction of a given vector
  The scalar projection of $\vec{A}$ onto $\vec{B}$ $= \frac{\vec{A}.\vec{B}}{B}$

  The scalar projection of $\vec{B}$ onto $\vec{A} = \frac{\vec{A}.\vec{B}}{A}$

Examples of application of scalar product of two vectors are the definition of work as a scalar product of Force and displacement, and the definition of power as the scalar product of force and average velocity.

Teaching method

Start with brainstorming questions such as:

- What is the resultant (sum) of two identical vectors?
  If the x and y components of vector $\vec{P}$ are 3 and 4 units, respectively, what are the respective components of $\vec{P} + \vec{P}$?
- What are the similarities and differences of $\vec{P} + \vec{P}$ and $2\vec{P}$?
- What is the difference between $\vec{P}$ and -$\vec{P}$?

Answers to Exercises, Discussion of Activities, Review questions and End of unit questions

Exercise 2.10

The angle between two vectors can be obtained from the scalar product of the vectors as

$$\vec{A}.\vec{B} = A\,B\cos\theta,\ \cos\theta = \frac{\vec{A}.\vec{B}}{AB}$$

$$\vec{A}.\vec{B} = A_xB_x + A_yB_y$$

$$A = \sqrt{A_x^{\ 2} + A_y^{\ 2}}\sqrt{A_x^{\ 2} + A_y^{\ 2}} \text{ and } B = \sqrt{B_x^{\ 2} + B_y^{\ 2}}\sqrt{B_x^{\ 2} + B_y^{\ 2}}$$

(a) $\theta = \cos^{-1}(0.707)(0.707) = 45^{o}$

(b) $\theta = \cos^{-1}(1)(1) = 0^{o}$

(c) $\theta = \cos^{-1}(0)(0) = 90^{o}$

Exercise 2.11

(a) The angle between P and the x axis is $\cos\theta = \frac{\vec{P}.\vec{i}\quad \vec{P}.\vec{i}}{\cdots} = \frac{-4 \qquad -4}{\cdots} = -0.51$

(b) The angle between P and the y axis is $\cos\theta = \frac{\vec{P}.\vec{j}\quad \vec{P}.\vec{j}}{(P)(j)(P)(j)} = \frac{6 \qquad 6}{(\sqrt{60})(1)(\sqrt{60})(1)} = 0.77$

Answer to Review Questions 2.4

1. The dot product of a vector by itself is

$$\vec{A}.\vec{A} = A.A\cos 0^{o} = A^{2}$$

3. No, $\vec{A}.\vec{B} = |A||B|\cos\theta$, $-\vec{B}.\vec{A} = |-B||A|\cos(180 - \theta)$

$= -|B||A||B||A|\cos\theta$

4. $\theta = 90^{o}$

5. Given $\vec{F} = (25\hat{i} - 30\hat{j})$ N and $\vec{S} = (-2\hat{i} - 3\hat{j})$ m.

$W = F.S = F_xS_x + F_yS_y = 40$ J

7. Given $\vec{D} = 5\hat{i} -- 3\hat{j}$ and $\vec{E} = 2\hat{i} + \hat{j}$

Let $\vec{R}\vec{R} = \vec{D}\vec{D} + \vec{E}\vec{E}$,

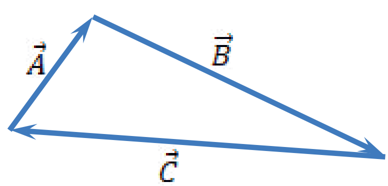
$\vec{R}\vec{R} = (D_x + E_x)\,\hat{i}\hat{i} + (D_y + E_y)\,\hat{j}\hat{j} = 7\,\hat{i}\hat{i} - 2\,\hat{j}$

The angle between $\vec{R}\vec{R}$ and the x axis is

$$\cos\theta = \frac{\vec{R}.\vec{i}}{(R)(i)} = \frac{7}{(\sqrt{53})(1)} = 0.96 \quad \text{Thus, } \theta = 15.9^{o}$$

Answers for the End of unit 2 Questions

1. The three vectors are connected head to tail to form a triangle.



2. The tail of the first vector and the head of the last vector meet at a point. Therefore, the resultant of the vectors is zero.

$\vec{A} + \vec{B} + \vec{C} = 0$. Choice 'd' is not correct.

3. The maximum possible resultant is obtained when the force are applied in the same direction.
4. Three. When three unequal vectors join head-to-tail to form a triangle, they give a zero resultant.
5. The resultant of two vectors is minimum when the vectors are in opposite directions.
6. As the angle between the vectors increases, the magnitude of the resultant decreases.
7. Both the x and y components of a vector are negative when the vector lies in the third quadrant. Its components will be opposite in sign when the vector is either in the second or in the fourth quadrant.
8. No, the least number of unequal vectors that give a zero resultant is three.
9. The dot product of a vector with a unit vector along the x, or y direction gives the component of the vector along the respective axis.

$$\vec{P} \cdot \hat{i} = P_x \,,\ \vec{P} \cdot \hat{j} = P_y$$

10. If $\vec{C}\vec{C}$ is perpendicular to $\vec{D}\vec{D}$, then $\vec{C}\vec{C}$ has no component along $\vec{D}\vec{D}$.

11. $\vec{S}\vec{S} = [(-2 + 1 + 3)\,\hat{i}\hat{i} + (3 + 2 - 2)\,\hat{j}\hat{j}]$ m $= (2\,\hat{i}\hat{i} + 3\,\hat{j}\hat{j})$ m

$S = \sqrt{13}\sqrt{13}$ m, $\theta = \tan^{-1}(1.5)(1.5) = 56.3^{o}$, above the positive x axis

12. $\vec{A}\vec{A} + B - \vec{C}\vec{C} = 0$,

Writing this component wise we have,

$A_x + B_x - C_x = 0,\ 4 + 2 - C_x = 0\ ,\ C_x = 6$

$A_y + B_y - C_y = 0,\ -3 + 1 - C_y = 0,\ C_y = -2$

(A) $\vec{C}\vec{C} = 6\hat{i} - 2\hat{j}$, $C = 2\sqrt{10}$, $\theta = \tan^{-1}\left(\frac{1}{3}\right) = 18.4^{o}$,

below the positive x axis

(B) $\vec{U}\vec{U}_C = \frac{1}{2\sqrt{10}}(6\hat{i}\hat{i} - - 2\hat{j}\hat{j})$

13. $\vec{v}\vec{v} = |v|\,\vec{U}_D$, $\vec{U}_D = \frac{\vec{D}\vec{D}}{DD} = 0.6\hat{i} + 0.8\hat{j} = (5\text{ m/s})\,(0.6\hat{i}\hat{i} + 0.8\hat{j}\hat{j}) = (3\,\hat{i} + 4\hat{i})$ m/s

14. The dot product of vector $\vec{A}$ and a unit vector along the direction of $\vec{B}$ gives the component of vector $\vec{A}$ along $\vec{B}$.

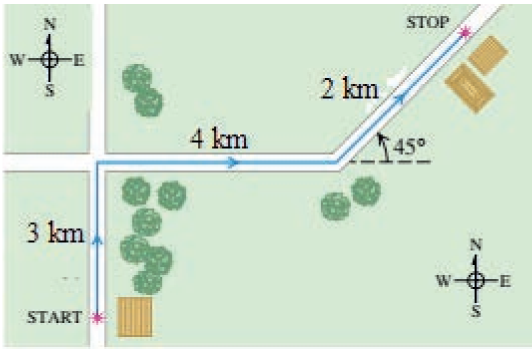
Component of $\vec{A}$ along $\vec{B}\vec{B} = \frac{\vec{A}.\vec{B}}{B} = \frac{AB\cos\theta}{B} = 5.63$

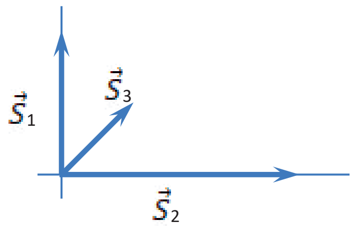
15. $\vec{S}_1 = (5\hat{i} + 2\hat{j})$ cm, $\vec{S}_2 = (-2\hat{i} - 3\hat{j})$ cm,

(a) $\Delta\vec{S}\vec{S} = (-7\hat{i}\hat{i} - - 5\hat{j}\hat{j})$ cm

(b) $\Delta S = 8.6$ cm, $\theta = \tan^{-1}\left(\frac{5}{7}\right)\left(\frac{5}{7}\right) = 35.5^{o}$, below the negative x axis.

16. The displacement vectors of the delivery truck can be shown on the coordinate axis as





The results obtained from the scale diagram will approximately show the following:

$\vec{S}_1$ = 3 km N, $\vec{S}_2$ = 4 km, E, $\vec{S}_3$ = 2 km NE

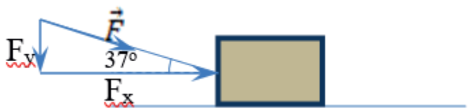
$\vec{R} = \vec{S}_1 + \vec{S}_2 + \vec{S}_3$

$\vec{R}_x = \vec{S}_{1x} + \vec{S}_{2x} + \vec{S}_{3x}$ = 0 km + 4 km + (2) cos 45°) = 5.41 km

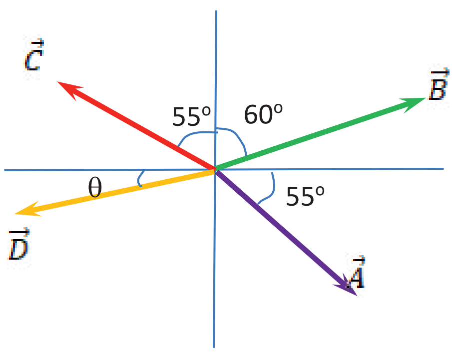
$\vec{R}_y = \vec{S}_{1y} + \vec{S}_{2y} + \vec{S}_{3y}$ = 2 km + 0 km + (2) cos 45°) = 3.41 km

$\vec{R} = \sqrt{(5.41\text{km})^2 + (3.41\text{km})^2}$ = 6.39 km ,

$\theta = \tan^{-1}(0.63) = 32.2^\circ$



17. A girl pushes the box along the floor

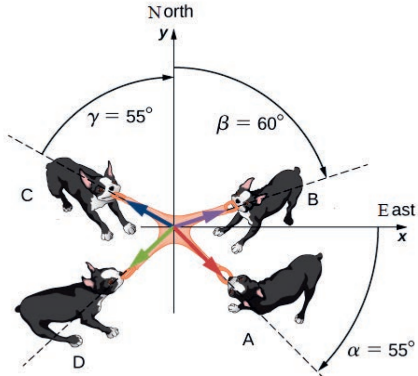


$F_x = F \cos 37^\circ = 50\text{ N} \times 0.8 = 40\text{ N}$, $F_y = -F \sin 37^\circ = -50\text{ N} \times 0.6 = -30\text{ N}$

$\vec{S}\vec{S}_2$

18. Dogs enjoying a Tug-of-war game

	x comp.	y comp
$\vec{A}$	91.77 N	-131.06 N
$\vec{B}$	173.20 N	100.00 N
$\vec{C}$	-114.68 N	80.30 N
$\vec{D}$	D_x	D_y
$\vec{R}$	0 N	0 N



D_x = -150.29 N, D_y = - 41.24 N, $\vec{D}$ = 155.84 N,
θ = 15.3° below the negative x direction

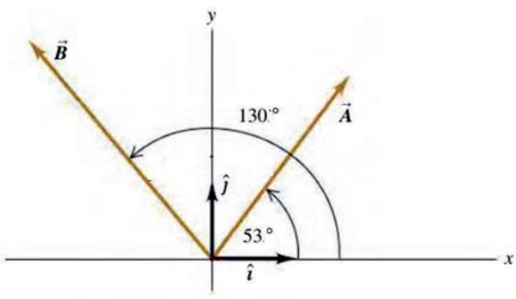
19. Given $\vec{X} = 4\hat{i} + \hat{j}$ and $\vec{Y} = 6\hat{i} + 3\hat{j}$,
$\vec{X}.\vec{Y} = 27$

$X = \sqrt{17}$, $Y = \sqrt{45}$

Answer: (a) $\theta = \cos^{-1}\left(\frac{\vec{X}.\vec{Y}}{X\,Y}\right) = \cos^{-1}\left(\frac{27}{27.66}\right) = 12.5^o$

(b) Component $= \frac{\vec{X}.\vec{Y}}{Y} = \frac{27}{\sqrt{45}} = 4.03$,

$A_y = A\cos\theta = \sqrt{17}\cos(12.5^o) = 4.03$ units



Writing the given vectors on in terms of their components we have

$\vec{A} = (A\cos 53^o)\,\hat{i} + (A\sin 53^o)\,\hat{j} = (0.6\,A)\,\hat{i} + (0.8\,A)\,\hat{j}$

$\vec{B} = -(B\cos 50^o)\,\hat{i} + (B\sin 50^o)\,\hat{j} = -(0.64\,B)\,\hat{i} + (0.76\,B)\,\hat{j}$

$\vec{A}\,.\,\vec{B} = -0.384\,AB + 0.608\,AB = 0.224\,AB$

Unit Three

Motion in One and Two Dimensions

[15 periods]

Introduction to the unit

The unit comprises five sub units and each sub unit is started by brain storming questions. These questions help students to recall knowledge from previous grades that are related to the topics followed. Activities, examples, and exercises are included in each sub unit. At the end of each sub unit there is a review questions and finally the unit will end by a unit summary and the usual end-of-unit questions.

Learning outcomes

Students will be able to:

- *Gain an understanding of the fundamental principles of kinematics in one and two dimensions.*
- *Develop skills in applying equations of motions to solve practical problems.*
- *Recognize the effect of air resistance and force of gravity on motion of a body.*
- *Describe technological advances related to motion; and identify the effects of societal influences on transportation and safety issues.*

Learning and teaching strategies

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 and a kinesthetic learner prefers to do hands on activities. Therefore, a teacher needs to design a teaching/ learning strategy that could address all students or that makes all students to be actively involved.

So, you need to design appropriate practical activities or experiments, promote classroom discussions, encourage individual and group activities using resources that can be found in your school or location. 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
- ▷ Field work
- ▷ Research
- ▷ Use of analogies, and examples
- ▷ Group work
- ▷ Cooperative learning
- ▷ Use of Charts
- ▷ Mind Maps or Concept Maps
- ▷ Models

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.

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

Role of the learner

The learning activities are organized 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.

- ▷ In practical lessons, (experiments), learners will work in groups depending on the availability of the apparatus, however if the apparatus numbers permit, then they better work individually.
- ▷ 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.

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 competence-based curriculum is all 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 organize learners in or outside the classroom, engaging them through participatory and interactive methods.

As a teacher, you will:

- model democratic values of fairness, justice and equal respect.
- 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.
- encourage your learners to adopt a reflecting and questioning characteristic on their learning.

Learning has to be effective in enhancing students' knowledge, skill and attitude. Thus, students have to use all possible ways to acquire these learning outcomes. The knowledge part should be developed through discussion, doing the activities and exercises. The skill part should be developed by doing hands on activities. The attitude part could be improved by appreciating the work of scientists like Galileo Galilei.

Assessment

Assessment is an integral part of the teaching and learning process. It 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 doesn't only come after teaching, but it is an integral part of teaching and learning process. Its primary purpose is not to evaluate and classify learner performance, but to inform teaching and improve learning.

Assisting low achievers (students achieving below the minimum competence level) and praising the high achievers (students achieving above the minimum competence level) is very important in the assessment process. In this way, the low achievers attain the minimum competency level and the high achievers will be motivated for further high level achievements.

3.1. Uniformly Accelerated Motion in 1 D

[2 periods]

By the end of this section, you will be able to:

- *Explain a uniformly accelerated motion in 1D*
- *Explain the difference between average velocity and instantaneous velocity*
- *Solve problems involving average velocity, instantaneous velocity and acceleration*

Suggested methodology

- Discussion and group work
- Explanation (lecture)
- Practical work: demonstration and experiment, and
- Question and answer

Teaching Aids:

Teachers use a variety of tools to make the process of teaching and learning simple, interesting, and effective. They help students to make their learning unforgettable. It also makes sense and saves time as students learn very quickly by watching rather than reading. Therefore, teachers need to use teaching aids.

Functions of Teaching Aids:

- It provides inspiration and curiosity among the students about the subject.
- It provides the opportunity to the students to take part indifferent activities.
- It makes the subject interesting, simple and entertaining.
- It makes difficult part of chapter easier to understand.
- It develops interest of students in the subject.
- It makes lessons influential and teaching-learning impressive.
- There are many students with a tendency to forget easily. Such students can get benefits with teaching aids.
- Teaching aids make the subject interesting and encourage students to learn it in depth.
- Teaching aids help to understand the concept easily and grasp it completely.
- With teaching aids, students can understand the concept by making the proper image of the topic.
- Teaching aids enhance the conceptual thinking of students.
- Teaching aids do not make the concept boring instead it creates the environment of interest and makes it interesting to learn.
- With the help of teaching aids, students can learn with accuracy and even faster.
- It is proved that learning with visual representation stays in memory for a longer time than textual representation. It impacts better with direct experience.

The following teaching aids are suggested to be used.

- Ball/wooden block/trolley/tin can
- Ramp,
- meter stick.
- electronic stopwatch
- Ticker-timer with power supply unit
- Ticker-tape
- Sellotape

Teaching aids could be, audio (radio, tape recorder, and teleconferencing), visual (maps, models, charts, bulletin board, museum and projectors), audiovisual (films, television, and computer) and activity aids (in which students learn by engaging in some useful activities).

With the help of different types of teaching aids, the teacher makes teaching and learning interesting and attractive. It helps students in their mental development. With its help, the teacher saves time in explaining any topic. So, teaching aids are important tools in the education system.

Start your lesson by introducing the brainstorming questions. These questions are introduced to recall basic concepts and terms used in motion along a straight line. You can also take as a diagnosis test. The diagnostic questions will help you to know the prior knowledge of students. Then you can prepare your lessons accordingly.

- The examples are prepared to help learners to fulfil educational objectives in the teaching-learning process.
- The activities are designed in such a way that students develop a skill in learning collaboratively. Hands on activities (experiments) are also included in the activities. So, try to guide students so that the expected result is achieved. The constructivist view of knowledge acquisition holds that learning is a process of connecting new knowledge to existing knowledge, involving active engagement of the learner's mind.
- The exercises are prepared for the students to practice problem solving and check themselves whether they understood that topic or not and their problem-solving abilities.

After defining and discussing the concept of acceleration and deceleration directly go to activity 3.1. Learners can carry out this activity on an individual basis.

Answer to Activity 3.1:

1. Does negative acceleration necessarily mean slowing down?

   Answer: Not necessarily. An object can have a negative acceleration when the object is slowing down while moving in a positive direction. An object can also have a negative acceleration if it is speeding up while moving in a negative direction.

2. Does positive acceleration necessarily mean speeding up?

   Answer: Not necessarily. An object with negative acceleration could be speeding up, and an object with positive acceleration could be slowing down. There are two types of situations where an object can have a positive acceleration. If an object is speeding up and moving in a positive direction, it has a positive acceleration. An object can also have a positive acceleration if it is slowing down while moving in a negative direction.

Answer to Activity 3.2:

This activity is an experiment. Physics is both experimental and theoretical and the presentation of it has always been multimodal. Thus, physics textbooks should demonstrations and experiments in order to be effective in achieving the competencies of the subject.

Beforehand think about how students could get the materials required to do the experiment. Arrange your students in groups. This activity shall be done in groups. In this activity, the different groups should determine acceleration. Ensure that they taka as of the given table. Make the calculations and finally report their findings.

Based on their data, students should be able to conclude by themselves that the motion of an object down an inclined plane is an accelerated motion. You give time to see their reports.

Laboratory experiments enable learners to:

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

Answers to Review Questions 3.1

1. The average acceleration is the rate of change in velocity over a measurable time interval. The instantaneous acceleration is the rate of change in velocity at an instant in time.
2. If acceleration points in the same direction as the velocity, the object will be speeding up. And if the acceleration points in the opposite direction of the velocity,

the object will be slowing down.

3. Whenever a car increases its velocity, it is said to be accelerating and whenever it is slowing down, it is said to be decelerating. Acceleration means the rate at which an object speeds up, and deceleration means the rate at which an object slows down. Note that, negative acceleration may or may not be deceleration, and deceleration may or may not be considered negative acceleration.

4. $a = 1.4 m/s^2, v_i = 0$

(a) $v_f = 2 m/s, t = ?$

$$t = \frac{v_f - v_i}{a} = \frac{2m/s - 0}{1.4 m/s^2} = 1.43\,s$$

(a) $v_f = 0,\ t = 0.8\,s,\ a = ?$

$$a = \frac{v_f - v_i}{t} = \frac{0 - 2m/s}{0.8\,s} = -2.5 m/s^2$$

5. A particle is in motion and is accelerating. The velocity of the motion as a function of time is given by: $\vec{v}(t) = 20t - 5t^2$ m/s. Find (a) the functional form of the acceleration, (b) the instantaneous velocity at t = 3s, and (c) the instantaneous acceleration at t = 3 s.

(a)
$$\mathrm{a}(t) = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \lim_{\Delta t \to 0}\left(\frac{\mathrm{v(t+\Delta t)} - v(\mathrm{t})}{\Delta \mathrm{t}}\right)$$

$$\text{Since}, v(t) = 20t - 5t^2$$

$$\Rightarrow v(t + \Delta t) = 20(t + \Delta t) - 5t^2 - 5(\Delta t)^2 - 10t\Delta t$$

$$\mathrm{a}(t) = \lim_{\Delta t \to 0}\left(\frac{\mathrm{v(t+\Delta t)} - v(\mathrm{t})}{\Delta \mathrm{t}}\right)$$

$$= \lim_{\Delta t \to 0}\left(\frac{(20t + 20\Delta t - 5t^2 - 5(\Delta t)^2 - 10t\Delta t - 20t + 5t^2}{\Delta \mathrm{t}}\right)$$

$$= \lim_{\Delta t \to 0}\left(\frac{20\Delta t - 5\Delta t - 10t\Delta t}{\Delta \mathrm{t}}\right)$$

$$= \lim_{\Delta t \to 0}\left(20 - 5\Delta t - 10t\right), \mathit{Since}\,\Delta t \approx 0$$

$$= 20 - 10t$$

(b)

$$v(t) = 20t - 5t^2$$

$$v(3) = 20(3) - 5(3)^2$$

$$v(3) = 15 m/s$$

(c)

$a(t) = 20 - 10t$

$a(3) = 20 - 10(3)$

$a(3) = -10m/s^2$

3.2. Equations of Uniformly Accelerated Motion in 1 D

[4 periods]

By the end of this section, you will be able to:

- *Derive and apply the equations of uniformly accelerated motion in 1D.*
- *Solve various problems of uniformly accelerated motion in 1D.*

This section deals about the equations of motion with constant acceleration. Students are expected to derive these equations and use them in solving problems.

- Ask them to use their algebraic knowledge to make v_f the subject of the formula in the given equation. Ensure that they master the first equation of motion by answering some questions.
- Let them use the expression given to derive the second equation of motion. Guide them through and offer individual assistance to others in need.
- Ask them to use the first and the second equations of motion to derive the third equation of motion. Are they able to derive this equation in the right format?
- Emphasize to them that they should master these equations as they are important in mechanics and will need to remember them to solve equations of motion.
- Ask volunteers to write the equations on board in turns after which you clarify where necessary.
- Guide them through examples 3.3 and 3.4. Ensure that they are able to substitute in the equations.
- Observe as the learners derive the six equations of motion basing on their knowledge of algebra and substitution. How well can they do the substitution to get the equations in the right format?
- Give them an opportunity to discuss and use the equations they have derived to
- discuss examples 3.3 and 3.4. How well are they able to apply the equations? Can they do the correct substitutions in the right equation?
- Ensure that they have mastered them.

Teaching Aids

- Flash Cards, Slides, Charts, Pictures, Maps, Bulletin Boards, Library, Internet

Answer to Exercise 3.2:

Before you go to the solution of this exercise you need to know your reaction time. That will be done on section 3.4, vertical motion. Then assist students the step-by-step way of doing it. Pay attention to the discussion on the potential damage that could be caused by the automobile running with 80 km/h compared to that moving with 20 km/h.

Speedometer reading (km/h)	Speedometer reading (m/s)	reaction distance $s_r = vt$ $t = your\ reaction\ time$	**braking distance** $s_b = \frac{v^2}{2\mu g}$	**Stopping distance** $s_r + s_b$
80 km/h	22.22 m/s	$22.22t$	$s_b = \frac{(22.22)^2}{2(0.7)(9.8)} = 36m$	
60 km/h	16.67 m/s	$16.67t$	$s_b = \frac{(16.67)^2}{2(0.7)(9.8)} = 20.25m$	
30 km/h	8.33 m/s	$8.33t$	$s_b = \frac{(8.33)^2}{2(0.7)(9.8)} = 5.06m$	
20 km/h	5.56 m/s	$5.56t$	$s_b = \frac{(5.56)^2}{2(0.7)(9.8)} = 2.25m$	

Answers to Review Questions 3.2

1. Derive the equations for a uniformly accelerated rectilinear motion in 1D.

2. $v = 60\ km/h = 16.67 m/s$

$$s = \frac{v_f^2 - v_i^2}{2a} = \frac{0-(16.67)^2}{2(-4.57)} = \frac{277.8889}{9.14} = 30.4m$$

3. $v_i = 30\, m/s, v_f = 0, s = 100m,\ a = ?$

$$a = \frac{v_f^2 - v_i^2}{2s} = \frac{0-(30)^2}{2(100)} = -\frac{900}{200} = -4.5m/s^2$$

4. $v_i = 18\, m/s, reaction time t = 0.7s$

$$Re\,action\ \,dis\tan ce = vt = 18\,m/s \times 0.7s = 12.6m$$

$$v_i = 18\,m/s,\ v_f = 0,\ a = 4.6m/s^2$$

$$Braking\ dis\tan ce(s_b)$$

$$s_b = \frac{v_f^2 - v_i^2}{2a} = \frac{0-(18)^2}{2(-4.6)} = \frac{324}{9.2} = 35.2m$$

Total distance covered= 12.6 m + 35.2 m= 47.8 m

This means, the motorist passes the stop line by a distance of 47.8 m – 30.0 m= 17.8 m

5. $v_i = 40\,m/s, v_f = 0, a = -2m/s^2, s = ?$

$$s = \frac{v_f^2 - v_i^2}{2a} = \frac{0-(40)^2}{2(-2.0)} = \frac{1600}{4.0} = 400m$$

Since the platform is 400m, it will just stop in time.

6. Distance travelled during nth second = Distance travelled in 'n' sec – Distance travelled in (n-1) sec

$$s_n = un + \frac{1}{2}an^2 - [u(n-1) + \frac{1}{2}a(n-1)^2]$$

$$= un + \frac{1}{2}an^2 - [un - u + \frac{1}{2}a(n^2 - 2n + 1)]$$

$$= un + \frac{1}{2}an^2 - \left[un - u + \frac{1}{2}an^2 - an + \frac{1}{2}a\right]$$

$$= un + \frac{1}{2}an^2 - un + u - \frac{1}{2}an^2 + an - \frac{1}{2}a$$

$$= u + an - \frac{1}{2}a = u + a\left(n - \frac{1}{2}\right) = u + \frac{1}{2}a(2n-1)$$

3.3. Graphical Representation of Uniformly accelerated Motion in 1 D

[3 periods]

By the end of this section, you will be able to:

- *Graphically, represent position versus time graph, displacement time graph, velocity time graph, and acceleration time graph of a uniformly accelerated motion in 1D.*
- *Interpret a graph of velocity vs. time, displacement vs. time and acceleration vs. time.*
- *Draw graphs from the kinematic equations.*
- *Determine the velocity of a motion from the slope of displacement-time graph, and acceleration from the slope of velocity – time graph.*
- *Determine the displacement covered from the area under velocity – time graph.*

This section deals about the representation of uniformly accelerated motion in 1 D using three types of graphs.

1. Distance/displacement vs time graph.
2. Speed/velocity vs time graph, ad
3. Acceleration vs time graphs.

Prerequisites of this unit

Knowledge on distance, displacement, speed, velocity, acceleration and free fall of a body and the skills of plotting and interpreting a distance-time, displacement-time, speed-time and velocity-time graphs learnt in grades 9 and 10 are taken as a prerequisite to this section. Students should be able to:

- draw theses graphs and interpret uniform and non-uniform motion.
- Use question and answer to review the sketching graphs of motion. Graphs of distance-time, velocity-time and acceleration-time.
- Review the important aspects of drawing a graph e.g., proper scale (depending on the data) labeling axis, stating the units of the quantities presented, which quantity should be on x or y -co-ordinates.
- Guide them to remember that the quantities, distance, velocity and acceleration are usually represented on the y-axis and time on the x-axis.
- Ask the students to volunteer to sketch some graphs on the chalk/white board as others evaluate how accurate they are.
- Let a few students to present their work to class.
- Let the student differentiate between distance-time and displacement-time graph, speed-time and velocity-time graph. This will help the students to realize that the analysis of the motion is the same only in one the direction is not specified.
- The learners should have gained skills on graph drawing in mathematics.

- The learners should have prior the knowledge and skills on finding areas of different shapes.
- Ensure that they participate in the discussion by asking questions at random.
- Observe them work in groups. Look at their graphs and guide them where necessary.

Teaching Aids

- Charts, Pictures, Maps, Bulletin Boards, Models

Suggested methodology

- Group discussion,
- Question and answer,
- Role play model and presentation.

You may guide those who may be having difficulties and then advise them to review the example later so that they may be able to follow. Ensure that the learners can draw and interpret the graphs accordingly.

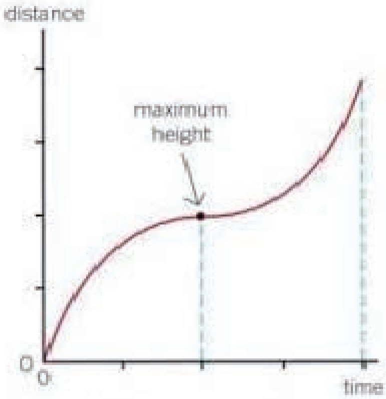
Answer to Exercise 3.2:

To accomplish this activity, remind the learners on the requirements of drawing a graph. Labeling of axes is key when drawing a graph and so are the points to be plotted among others.

Let them present the graphs they have drawn to the class and interpret them. Are they able to interpret the graphs?

This activity will concentrate on distance – time graphs. It is important to review the previous example on displacement – time graphs. This will form a basis on which advanced concepts will be built.

- Organize the learners in convenient groups of mixed abilities. Ask them to sketch and analyze the three graphs for bodies under different circumstances. Let them describe the motion of the objects under motion.
- Observe the learners as they are discussing. Are they able to explain the graphs correctly? Can they differentiate the different graphs?
- Observe them draw the graphs as you move around guiding them where possible.
- Observe as they do their presentation on the blackboard.
- Let the groups present their findings to the class. Are they able to explain the shape of the graphs? Ask them to compare their graphs.
- Ask learners to do Exercise 3.2 in the student's book, that is, to plot a distance-time graph of an object with non-uniform speed.



Distance-time graph of an object thrown vertically upward

Answers to Activity 3.4:

By now, the learners have familiarized themselves with graph drawing. This activity is about velocity- time graphs. Let them brainstorm about velocity – time graphs.

Can the learners be able to analyze graphs of bodies whose speed is increasing or decreasing with time? Are they able to explain what the gradient in each case represents?

Mention to them that the graphs for a body moving with a constant velocity are a straight line in the positive quadrant. However, the same body moving with the same velocity but in an opposite direction will exhibit a straight-line graph but in the negative quadrant. Figure 3.8.

Let the learners work in groups of three. Review the previous lessons.
Ask the learners to draw and interpret speed – time graphs for a body at rest.
Let the learners discuss example 6.9 as you guide them through. Ensure that they label the axes and plot as required. Ask them to do the same for a body moving with uniform and non-uniform speed. Let them do the same for another body whose speed is increasing.

Ask them to compare and analyze the graphs in class.

1. The displacement-time graph of an accelerated motion a parabola, because from the equation ($s = \frac{1}{2}at^2$), the magnitude of displacement is directly proportional to the square of the time elapsed ($s \propto t^2$)
2. The slope of the tangent line to a point in a displacement-time graph gives the instantaneous velocity at that time.

Answer to Exercise 3.4:

The principle is that the slope of the line on a velocity-time graph gives useful information about the acceleration of the object.

1. If the acceleration is zero, then the slope is zero (i.e., a horizontal line).
2. If the acceleration is positive, then the slope is positive (i.e., an upward sloping line).
3. If the acceleration is negative, then the slope is negative (i.e., a downward sloping line).

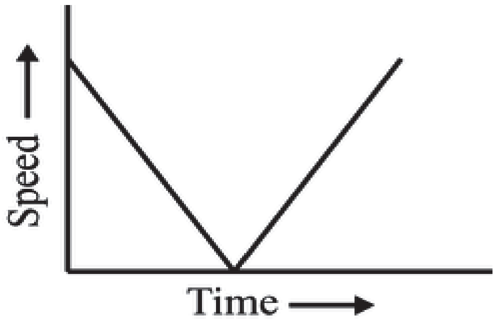
Answer to Exercise 3.4

You have already grouped the learners before when they were doing activity 1.1, you may decide to maintain the groups for this activity or form new groups. Forming new group sometimes is important because it help learners to interact and share new ideas from different learners. It also promotes **teamwork**, **cooperation** among other competences in learners.

- ▷ Provide the learners with the graph papers and ensure they have personal mathematical geometrical set prior to the lesson.
- ▷ Ask learners to do activity 1.2 provided in the student's book pages 4-5,that is, to plot a distance-time graph of an object moving with a uniform speed.
- ▷ Go around the class to check whether the learners are doing the right thing. Visit as many groups as possible. Help those who may have challenges of choosing a good scale for drawing the graph, especially, the slow learners.
- ▷ Let them suggest suitable scales.
- ▷ Allow them to draw the graph and describe the motion as a group on their own.
- ▷ Let them display their graph on the board.
- ▷ Call them in front and discuss their graphs. Develop a marking scheme together.
- ▷ Hold a brief discussion on their graphs drawn and description given. Give the learners opportunity to point out errors and omission from other groups' findings. Allow them to exchange their graphs and mark their colleagues' graphs using the marking scheme. At this point remind learners that people can disagree over an issue but always let it be a constructively.

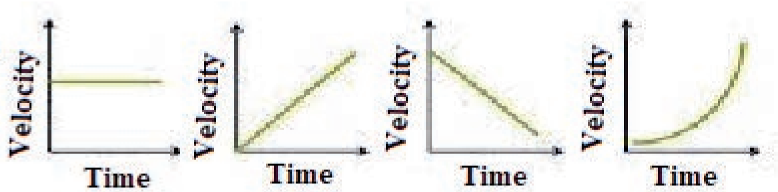
(a) The distance vs. time graph of a ball thrown vertically upward and returns back to the throwers hand, is shown in Exercise 3.2.

(b) The speed vs. time graph of a ball thrown vertically upward and returns back to the throwers hand is shown below.



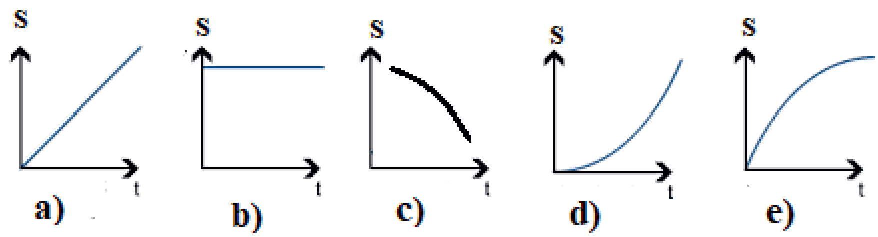
Answer to review Questions 3.3

1.



(a) Uniform motion
(b) Uniformly accelerated motion.
(c) Uniformly decelerated motion.
(d) Non-uniformly accelerated motion.

2.



(a) Uniform motion
(b) No motion, at rest.
(c) Uniformly acceleration but in the opposite direction.
(d) Uniformly accelerated motion.
(e) Uniformly decelerated motion.

3.The area of the top triangle is:

$$A_1 = s_1 = \frac{1}{2}(v_f - v_i)t$$

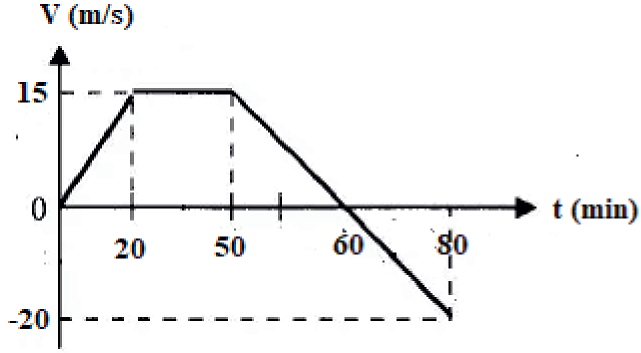
The area of the bottom rectangle is:

$$A_2 = s_2 = v_i t$$

The magnitude of total displacement is the sum of the above two displacements.

$$S = s_1 + s_2 = \frac{1}{2}(v_f - v_i)t + v_i t = \frac{1}{2}v_f t - \frac{1}{2}v_i t + v_i t = \frac{1}{2}v_f t + \frac{1}{2}v_i t = \left(\frac{v_i + v_f}{2}\right)t$$

4.



Answer to activity 3.4:

In order to perform this activity students' need your assistance.

Copy the link https://phet.colorado.edu/en/legacy/moving-man., paste it on the address bar and run it. The simulations are animated, interactive, and game-like environments where students learn through exploration. They emphasize the connections between real-life phenomena and the underlying science, and help make the visual and conceptual models of expert scientists accessible to students.

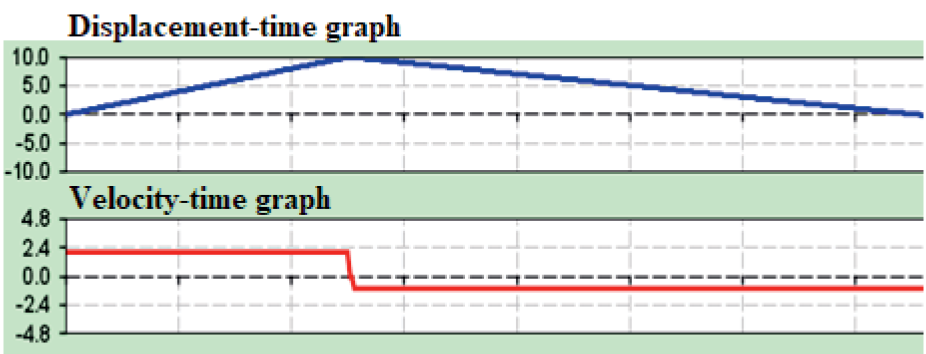
By just following the instructions step by step students will get all what they need.

(a) Compute the distance covered in each motion using the formula the area of the region in the graph and compare them.

(b) Determine the time required to go east, $t_1 = \frac{s_1}{v_1}$, the time necessary to go west, $t_2 = \frac{s_2}{v_2}$, and compute the total duration?

(c) Why is the acceleration 0 in the motion?

(d) What are your thoughts on the computed and simulated st values?



3.4. Vertical motion

By the end of this section, you will be able to:

- *Describe what vertical motion is.*
- *Solve various problems of vertical motion*
- *Describe the motion of objects that are in free fall.*
- *Calculate the time, position and velocity of an object given the initial velocity of an object under vertical motion*
- *Solve problems related to an object thrown vertically upwards, downwards, and a freely falling body.*

This section deals about vertical motions which are affected by gravity. It is assumed that the only force acting on bodies under vertical motion if gravity. Hence, the acceleration of such motion is acceleration due to gravity, g. As a result, the equations of motion with a constant acceleration cab be easily modified to these motions.

Teaching Aids:

- Flash Cards, Slides, Charts, Pictures, Maps , Bulletin Boards, Models, Audio tape , Computer set , Projectors , Printed materials, Laboratory

Suggested methodology

- Group discussion,
- Question and answer,
- Lecture

Answer to Exercise 3.6:

A ball is thrown vertically upwards with a velocity of 10m/s from the balcony of a tall building. The balcony is 15m above the ground and gravitational acceleration is 10m/s2. Find (a) the time required for the ball to hit the ground, and (b) the velocity with which it hits the ground.

$$v_0 = 10m/s, h = 15m, g = 10m/s^2$$

(a) $$t = \frac{2v_0}{g} = \frac{2\times 10m/s}{10m/s^2} = 2s$$

(b) $$v = v_0 - gt = 10m/s - 10m/s^2 \times 2s = -10m/s$$

Answer to activity 3.5:

Experiment

Measurement of acceleration due to gravity (g) using the freefall method.

This activity measuring acceleration due to gravity can be done in different ways. In this unit you are allowed to use the concept of free fall. If you can't get the free apparatus, you can let your students to do it by releasing a small and denser object from the top of anything with some height from the ground.

Answer to activity 3.6:

This experiment showing acceleration due to gravity is constant.

Drop two balls of different mass (basketball, and tennis ball) from the same height. Which will hit the ground first?

This is a very simple but interesting experiment. Let students to do it by themselves and assign them to bring to the class what they have observed. Finally, they will prove that, the acceleration of a freely falling body is independent of the mass and size of objects.

Answer to activity 3.7:

Assume a drop of rain is falling from a height of 450m. If the drag force were not there, what would be it velocity on reaching the surface of the Earth. Discuss the effect of this velocity on living things on Earth.

Answer:

Using the equation of a free fall, the velocity of the rain drops on reaching the surface f the Earth would be:

$$v = \sqrt{2gh} = \sqrt{2 \times 10m/s^2 \times 450m} = 94.9m/s = 341.5km/h$$

This is a very huge velocity which can cause damage to any living thing on Earth. This tells us we are living on Earth because of terminal velocity the velocity of falling objects would not increase unlimited.

Activity 3.8: Experiment

Calculating Reaction time.

Knowing your reaction time is very helpful. If you have a big reaction time you need to minimize it by doing practices. Tell students to do this activity in the classroom as a fun.

Activity 3.9: Project work

Make a group containing 4 to 5 members in your class. Search internet or books and came up comparing the difference between Aristotle's, Galileo's and Newtons view of motion.

Answer to Review Questions 3.4

1. A freely falling body moves under the acceleration due to gravity and therefore, its acceleration is constant. So, it is a uniformly accelerated rectilinear motion.
2. $v_0 = 20m/s, h = 25m, g = 10m/s^2$

$$(a)\ h = \frac{v_0^2}{2g} = \frac{(20m/s)^2}{2\times 10m/s^2} = 20m$$

$$(b)\ h = v_0 t - \frac{1}{2}gt^2$$

$$-25 = 20t - 5t^2$$

$$t^2 - 4t - 5 = 0$$

Solving the above equation using the general quadratic formula and taking positive time, gives t = 5seconds.

3. A ball is dropped on the floor from a height of 10 m. It rebounds to a height of 2.5 m. If the ball is in contact with the floor for 0.01 *sec*, what is the average acceleration during contact?

$$h_1 = 10m, h_2 = 2.5m, t = 0.01s$$

$$v_i = \sqrt{2gh_1} = \sqrt{2\times 10m/s^2 \times 10m} = \sqrt{200}m/s = 14.14m/s$$

$$v_f = \sqrt{2gh_1} = \sqrt{2\times 10m/s^2 \times 2.5m} = \sqrt{50}m/s = 7.07m/s$$

$$a = \frac{\Delta v}{\Delta t} = \frac{14.14m/s - 7.07m/s}{0.01s} = 707m/s^2$$

4. $v_0 = 10m/s,\ h = 60m,\ t = ?$

$$h = v_0 t + \frac{1}{2}gt^2$$

$$60 = 10t + 5t^2$$

$$t^2 + 2t - 12 = 0$$

Solving the above quadratic equation using the general formula:

$$Quadratic\ formuula: t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} =$$ Gives t = 2.6 seconds

3.5. Uniform Circular Motion

By the end of this section, you will be able to:

- *Define a uniform circular motion*
- *Calculate for angular and tangential displacement, angular and tangential velocity, and centripetal acceleration,*
- *Explain uniform circular motion in the horizontal plane,*
- *Identify the force required for circular motion to take place*
- *Define the term relative velocity*

In this section a uniform circular motion is discussed. Note that a uniform circular motion is a motion with constant speed but direction of motion continuously changes. Because the direction changes, it is an accelerated motion.

Teaching Aids

- Slides, Charts, Pictures, Maps, Bulletin Boards, Models, Projectors, Printed materials, Physics laboratory , Models

Suggested methodology

- Discussion
- Field trip
- Question and answer

Answer to activity 3.11:

1. The following are some real-life examples of circular motion.
    1. Ceiling fan
    2. Satellites orbiting around planets.
    3. Stone tied to a String.
    4. Running on a Circular track.
    5. merry-go-rounds in parks,
    6. a car going around a roundabout,
    7. the moon orbiting around the Earth or
    8. the Earth revolving around the Sun.
    9. Movement of electrons around the Nucleus of an atom.
    10. Centripetal acceleration could be made to be larger, either by increasing the speed of the motion or by decreasing the radius of the circle.

Answer to Exercise 3.6:

When the speed of a car changes from 30 km/h to 90 km/h, it increases 3 times. Hence, centripetal acceleration increases by $3^2 = 9$ times.

Answer to Exercise 3.7:

Suppose the diameter of the merry go round in Figure 3.20 is 4.0 m. (a) What will be the radial acceleration of the kid if she rotates one rotation every 3 seconds? (b) Draw schematic circular path that shows the direction of the centripetal acceleration of the circular motion by applying vector subtraction method.

Uniform Circular Motion in a Horizontal Plane

As usual start the section by presenting the given brain storming questions. You can arrange students in groups of each 5 to 7 members. The brainstorming question:

‘’Mention, from daily life experiences, an object that undergoes uniform circular motion in a horizontal plane.’’

So this question allows students to relate their learning with their real life phenomenas.

Answer to Activity 3.12:

It is a common experience to see cars skidding out of a roundabout and collide with anything in the nearby the road. Discuss in group about the causes of such accidents and suggest the remedy. Present your group’s opinion to the class and make class level discussion.

Exercise 3.8:

Calculate the maximum speed with which a car can be driven safely along a curved road of a radius of 30m and banked at an angle of 30° with the horizontal. (take $g = 9.8 m/s^2$)

Answers to review questions 3.5

1. A uniform circular motion a motion along a circular path with constant speed, but direction of motion continuously changes.
2. Centripetal or radial acceleration is the acceleration that causes an object to move along a circular path, and centripetal force is a force that causes centripetal acceleration.
3. The direction of centripetal acceleration and centripetal force radially toward the center of the circle.
4. A body could accelerate by changing the direction of its velocity even though its magnitude (speed) is not changing.
5. What is (a) the tangential velocity? (b) the angular velocity? and (c) the centripetal acceleration, due to the Earth’s rotation, of a body on the equator? Radius of Earth = 6,400 km.

Given Data: The radius of earth is: $R = 6400km = 6.48\times10^6$m

(a) the tangential velocity =

$$v = \frac{2\pi r}{T} = \frac{2\times3.14\times6.4\times10^6 m}{24\times60\times60s} = \frac{4.0192\times10^7}{8.64\times10^4} m/s = 465.185m/s$$

$$(b)\ the\ angular\ velocity\,(\omega) = 1rev/day = 2\pi rad/8.64\times10^4 = 7.27\times10^{-5} rad/s$$

$$(c)\ \text{centripetal acceleration}\,(a_c) = \omega^2 r = (7.27\times10^{-5})^2\times6.4\times10^6 m = 1.26\times10^{-3} m/s$$

6. $r = 40cm = 0.4m,\ v = 20km/h = 5.56m/s$

$$T = \frac{2\pi r}{v} = \frac{2\times3.14\times0.4m}{5.56m/s} = \frac{2.512m}{5.56m/s} = 0.45s$$

$$\omega = v/r = 0.45m/s/0.4m = 1.125/s$$

7. Find the banking angle of the railway track with a radius of curvature of 1500m. If the train's maximum speed is 15m/s. If the distance between the two tracks is 1.8m, calculate the elevation of the outer track over the inner track.

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = \tan^{-1}\left(\frac{15^2}{1500\times10}\right) = \tan^{-1}(0.015) =$$

Answer to end of Unit Questions

1. Choice d is the correct answer.
2. No, because the magnitude of the velocity (speed) changes velocity cannot be constant.
3. Yes, when the direction of velocity changes without a change in magnitude, speed is constant but velocity changes.
4. Motion on one dimension is motion in a straight line. Example: the motion of a train on a straight rail. Motion in two dimensions is a motion which two rectangular coordinates specify the position of object changes with time. It is a curved path in a plane Example: Motion of a ball kicked up from the ground.
5. No, the magnitude of displacement is always less than or equal to the distance travelled by an object.
6. Yes, the direction of velocity of an object can change when it's acceleration is constant. For example: When we throw a ball upward, it's acceleration is the acceleration due to gravity. Its direction is always downward and with a value of 9.8 m/s^2.
7. Yes, an object can be accelerated without speeding up or slowing down. A body can accelerate by changing the direction of its velocity without speeding up or slowing down. For example, in a uniform circular motion, the speed is constant but it accelerates because of change of direction.

8. The magnitude of the average velocity is 0.833 m/s
9. The final velocity of the bullet is 502.2m/s.
10. (c) s = 17.2 m (d) v = 28.8 m/s
11. (a) the acceleration (a) -2m/s^2,

    (b) the final velocity (v_f) = 5m/s, and
    (c) the distance moved (s) = 150 m.
12. (a) The automobile overtakes the truck after moving for 40m.

    (b) At that time the automobile is moving at 20 m/s.

13.

- ▷ 0 to 10 minutes: Uniform acceleration.
- ▷ 10 to 15 minutes: Uniform motion.
- ▷ 15 to 30 minutes: Uniform deceleration.
- ▷ 30 to 40 minutes: Uniform acceleration in the opposite direction.
- ▷ 40 to 55 minutes: Uniform deceleration in the opposite direction.

14. The time taken for the entire motion is 65 seconds? The distance traveled is 875 m.
15. v_f = 100 km/h = 27.78 m/s, Vi = 27.78 m/s - 0

    A) what can you say about the maximum average acceleration of the bike? B) How far does it travel in this time?
16. (a) t = 6.3 s, (b) v = 62.9m/s
17. (a) h = 31.25 m, (b) t = 2.5 s, (c) v_f = 26.9 m/s
18. h = 48 m
19. (a) v = 7.1 m/s, (b) t = $2\sqrt{5}$ sec
20. 200 m/s^2.
21. T = 105 N
22. Fc = 3.03N, and v = 2.7 m/s.

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Unit Four

Dynamics

[18 periods]

Introduction to the unit

Classical mechanics describes the relationship between the motion of objects found in our everyday world and the forces acting on them. As long as the system under study doesn't involve objects comparable in size to an atom or traveling close to the speed of light, classical mechanics provides an excellent description of nature. In Unit 3, students have learnt kinematics which describes the motion of an object without considering the cause. In order to predict how and explain why an object moves, one has to understand dynamics. Dynamics is the study of how forces affect the motion of objects and systems. It considers the causes of motion of objects and systems of interest, where a system is anything being analyzed. The foundations of dynamics are the laws of motion stated by Isaac Newton (1642–1727). These laws provide an example of the breadth and simplicity of principles under which nature functions.

This unit also deals with a force that we encounter in our day to day activities, friction. Friction is a force that is present in almost all real-life situations. In some cases, friction is desirable while in other cases, friction reduces the effectiveness of mechanical systems. Its magnitude depends on the nature of the surfaces in contact and the force that presses the surfaces against each other.

The concept of work energy and power is also treated in this unit. Energy is the most fundamental concept in physics. Everything that occurs in nature can be traced back to energy. The complicating factor is that there are so many forms of energy and that it is often very difficult to keep track of what happens to the energy when it is transferred. Energy is a scalar quantity. This chapter focuses on gravitational potential energy, kinetic energy, and mechanical energy.

The other important phenomenon in physics that is covered in this unit is Collision. Collision is one of the interactions between objects. Collisions may be categorized as elastic or inelastic depending on what happens to the kinetic energy of the system before and after collision.

What happens when two vehicles collide? How does the impact affect the motion of each vehicle, and what basic physical principles determine the likelihood of serious injury? What makes a rocket move in empty space? How is it possible for a spaceship to safely land on Mars? Why does a gun recoil backward as it shoots a bullet?

Our understanding of the phenomenon of momentum will help us to answer questions involving interaction between objects. Intuitively, anyone or anything that has a lot of momentum is going to be hard to stop. Physically, the more momentum an object has, the more force has to be applied to stop it in a given time. This concept leads to one of the most powerful principles in physics: conservation of momentum. Using this law, complex collision problems can be solved without knowing much about the forces involved during contact.

Unit outcomes

At the end of this unit students will be able to:

- *Demonstrate an understanding of the relationship between net force and the acceleration of an object in linear motion*
- *Analyze the effect of a net force in quantitative terms, using graphs, free-body diagrams, and vector diagrams*
- *Describe the first condition of equilibrium quantitatively.*
- *Demonstrate an understanding, in qualitative and quantitative terms, of the concepts of work, energy, energy transformations and power*
- *Design and carry out experiments and solve problems involving energy transformations and the law of conservation of energy.*
- *Realize that momentum is an inherent property of moving objects*
- *Express the relationship between impulse and momentum.*

Teaching strategies

- Organize a lesson to make sure that the students understand the effects of a force on a body and that Newton's laws govern all motion. Emphasize that the result of a net force is the acceleration of a body, and if no net force exists, the body will remain in equilibrium. Equilibrium includes moving with constant velocity having no acceleration.
- Momentum and energy conservation are concepts that are equivalent to Newton's laws, but are more powerful and at the same time, more abstract. Forces can be felt and acceleration can be measured; momentum and energy must be calculated. Use Billiard balls to qualitatively observe collision between balls of equal or different masses.
- Activity: Let students discuss Newton's laws of motion by giving practical examples and simulated animations, Activity 4.4.

- Activity: Determine static and kinetic friction by method of sliding block along an inclined surface, Activity 4.7.
- Project Work(s) classify in the form of table which of Newton's laws are involved and what type of force is there: friction, normal, gravitational, on the following situations (seat belts, rocket travel, sports, all ball games, importance of friction in everyday experience, e.g. walking, etc.)
- Encourage group discussion and presentation of the result to the class.
- Organize your own demonstration to explain the transformation of energy from one form to another. Hang a pendulum from a support bar. Mount a meter stick vertically behind the pendulum. Demonstrate that a pendulum starting its swing from a given height on one side of its rest position will swing the same height on the other-side. Measure this with the meter stick. Discuss transformation of energy from kinetic to potential and back.
- Use a spring-powered toy to demonstrate that work is done on a spring, stored in the form of potential energy and converted to kinetic energy.
- Select two students of nearly equal masses and let them run upstairs or lift equal masses to the same height. Record the time taken by each student to do the activity. Estimation of average power developed (by person running upstairs; person repeatedly lifting weights to a height, etc.)
- Use the concept of kinetic and potential energy of a water fall or a dam to explain the power delivered by a power plant.

Assessment

In order to check whether the student has acquired the minimum competency required, each students should be assessed continuously over the whole unit and compare it with the following description.

To achieve the minimum required competency,

- the student should be able to: define the terms; linear momentum, elastic and inelastic collision and center of mass, the law of conservation of momentum;
- solve problems involving the basic laws of dynamics and momentum conservation.
- Use Newton's laws, state Newton's second law in terms of momentum,
- apply Newton's laws of motion to explain and predict the behavior of bodies acted by external forces,
- use the principle of momentum conservation, explain qualitatively how frictional forces depend on the nature of surfaces and normal contact force,
- use free body diagram representing forces on a point mass;
- define the terms work , energy, power ,kinetic energy, potential energy, conservative and dissipative forces;
- identify work as a scalar product of force and displacement,
- calculate the work done by constant force, derive work-energy theorem,
- state the law of conservation of energy, apply work-energy theorem and the law of

conservation of energy to solve practical problems,

- distinguish between elastic and inelastic collisions and solve problems involving such collisions.

Assisting low achievers (students achieving below the minimum competence level) and praising the high achievers (students achieving above the minimum competence level) is very important in the assessment process. In this way, the low achievers attain the minimum competency level and the high achievers will be motivated for further high level achievements.

4.1. The concept of Force and Newton's Laws of motion

[3 periods]

At the end of this topic, students will be able to:

- *Discuss what the concept of force means in physics, and why forces are vectors.*
- *Define force and discuss its effects on a body.*
- *Distinguish between contact forces and field forces.*
- *Discuss the four fundamental forces in nature and their real life application.*
- *State Newton's laws of motion*
- *Demonstrate the cause effect relationship of force and acceleration.*
- *Apply Newton's second law to determine the weight of an object.*
- *Demonstrate the relationship between weight and normal force.*

A force is commonly imagined as a push or a pull on some object, perhaps rapidly, as when we hit a tennis ball with a racket or as when we stand on the floor. We can hit the ball at different speeds and direct it into different parts of the opponent's court. That means we can control the magnitude of the applied force and also its direction, so force is a vector quantity, just like velocity and acceleration.

If you pull on a spring, the spring stretches. If you pull hard enough on a wagon, the wagon moves. When you kick a football, it deforms briefly and is set in motion. These are all examples of contact forces, so named because they result from physical contact between two objects.

Force can also be considered non-contact type. These forces operate even when objects are far apart from one another. The Sun, affects the motion of a distant object such as Earth despite no evident physical connection between the two objects.

The known fundamental forces in nature can be categorized as: the strong nuclear force, electromagnetic forces, weak nuclear force, and gravitational force between objects.

Screeching tires on the road and the sound of metal and fiberglass being crushed are familiar sounds of a vehicle collision. Depending on the presence of airbags and the correct use of seat belts and headrests, a motorist may suffer serious injury. In order to design these safety devices, engineers must understand what forces are and how forces affect the motion of an object.

In this chapter, you will investigate how forces affect motion and how to explain and predict the motion of an object using Newton's three laws.

Newton's laws of motion

Newton's first law is general and can be applied to anything from an object sliding on a table to a satellite in orbit. Experiments have verified that any change in velocity (speed or direction) must be caused by an external force.

Newton's first law is stated as "A body at rest remains at rest or, if in motion, remains in motion at constant velocity unless acted on by a net external force." It can also be stated as "Every body remains in its state of uniform motion in a straight line unless it is compelled to change that state by forces acting on it." To Newton, "uniform motion in a straight line" meant constant velocity, which includes the case of zero velocity, or rest. Therefore, the first law says that the velocity of an object remains constant if the net force on it is zero.

Newton's first law is usually considered to be a statement about reference frames. It provides a method for identifying a special type of reference frame: the inertial reference frame. In principle, we can make the net force on a body zero. If its velocity relative to a given frame is constant, then that frame is said to be inertial. So by definition, an inertial reference frame is a reference frame in which Newton's first law is valid. Newton's first law applies to objects with constant velocity. From this fact, we can infer the following statement.

Newton's second law is closely related to his first law. It mathematically gives the cause-and-effect relationship between force and changes in motion. Newton's second law is quantitative and is used extensively to calculate what happens in situations involving a force.

First, what do we mean by a change in motion? The answer is that a change in motion is equivalent to a change in velocity. A change in velocity means, by definition, that there is acceleration. Newton's first law says that a net external force causes a change in motion; thus, we see that a net external force causes nonzero acceleration.

According to the discussion followed by what is demonstrated in Figure 4.9, it seems reasonable that acceleration would be directly proportional to and in the same direction as the net external force acting on a system and inversely proportional to mass.

We have thus far considered force as a push or a pull; however, if you think about it, you realize that no push or pull ever occurs by itself. When you push on a wall, the wall pushes back on you. This brings us to Newton's third law.

Newton's third law represents certain symmetry in nature: Forces always occur in pairs, and one body cannot exert a force on another without experiencing a force itself. We sometimes refer to this law loosely as "action-reaction," where the force exerted is the action and the force experienced as a consequence is the reaction. Newton's third law has practical uses in analyzing the origin of forces and understanding which forces are external to a system.

There are two important features of Newton's third law. First, the forces exerted (the action and reaction) are always equal in magnitude but opposite in direction. Second, these forces are acting on different bodies or systems: A's force acts on B and B's force acts on A. In other words, the two forces are distinct forces that do not act on the same body. Thus, they do not cancel each other.

Teaching method

Start by asking students to define the term force in their own words and mention some of the natural phenomena that show the action of a force on or between objects in their surroundings.

Revise what the students have learnt about force in lower grade levels. Check that they understand force as a vector and that it can be represented graphically by an arrow.

Form a group of 5 or 6 students to discuss how understanding of forces helps humans interact with their environment?

Review important steps of resolving a vector into its horizontal and vertical components.

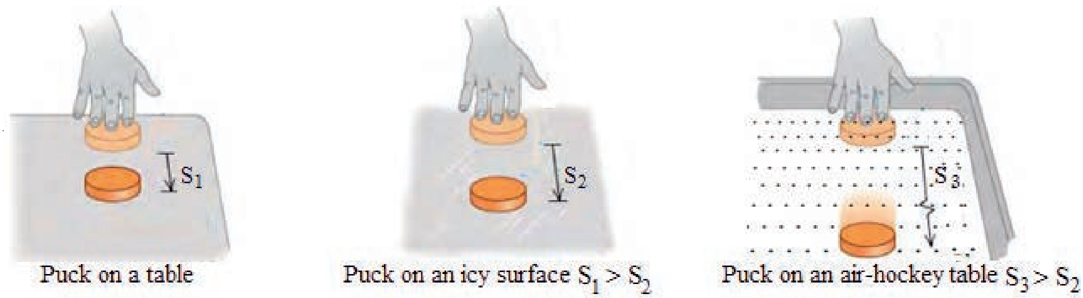
Newton's laws of motion

Set up apparatus to demonstrate what is shown in Activity 4.1. Guide students to use materials available in their surroundings. You can set the demonstration by using three tables: a smooth and lubricated table, smooth table but not lubricated and a slightly rougher table. Give the puck a slight push in each case and see how far the puck moves before stopping? Ask students what causes the difference in stopping distances?

Ask students about their understanding of the relationship between Force, mass and acceleration based on the inquiry approach shown in Figure 4.9.

Form a group of 5 or 6 students and ask them to explain the action-reaction pairs given below based on Newton's third law:

- ▷ As a man walks on the floor, he exerts a force backward on the floor. The floor exerts a reaction force forward on the man that causes him to accelerate forward.
- ▷ A car accelerates forward because the ground pushes forward on the drive wheels, in reaction to the drive wheels pushing backward on the ground.
- ▷ Rockets move forward by expelling gas backward at high velocity.
- ▷ Helicopters create lift by pushing air down, thereby experiencing an upward reaction force.
- ▷ An octopus propels itself in the water by ejecting water through a funnel from its body, similar to a jet ski.



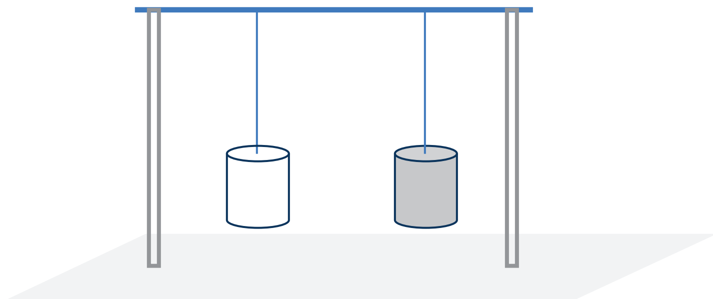
Answer: The puck is pushed horizontally on three surfaces of different nature. The opposing force that arises between the puck and the surface is greatest in case a and the least in case c. The puck travels the longest distance where opposition is the least.

Activity 4.2

Suspend the cans from a horizontal beam. Fill one of the cans with sand and leave the other empty.

(a) a) Give a slight push to each of the cans one after the other to set them in motion.

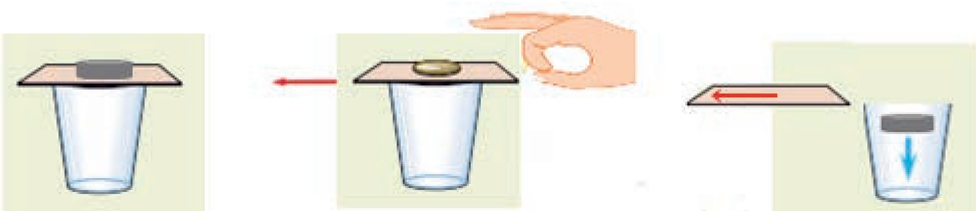
(b) Try to stop the already swinging cans.
Compare the resistance you experience in case (a) and (b).



The can filled with the sand has the larger mass ant hence the larger inertia. The heavier can is difficult to set it into motion (from rest) as well as to stop it once it is set in motion.

Activity 4.3

For a better result choose a smooth card in order to minimize the possible friction between the card and the glass as well as between the glass and the coin.

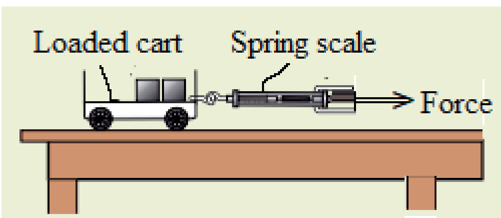


(a)

When the card on which the coin is placed is given a sharp flick, the card will fly out while the coin falls into the glass. This is due to inertia of the coin.

Activity 4.4

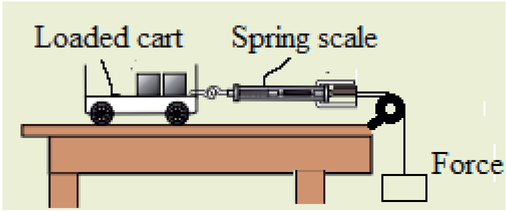
Group work



Set up of the materials

Your observation in steps B and C, and also D and E are expected to be:

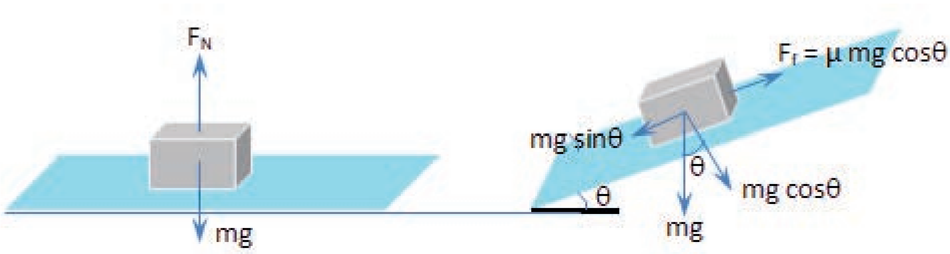
1. When the mass is increased from 200 g to 1 kg, (step c) while keeping the force constant, the acceleration of the mass is found to decrease.
2. When the force is reduced while mass is constant, the acceleration is found to decrease.
3. Keeping the force constant poses difficulty. One way to simplify the effort to keep the force constant is suspending a mass from the string whose one end is attached to the spring balance and passing over an essentially frictionless pulley.



Activity 4.5

When a fat person and a thin person that are running in opposite directions accidentally collide with each other, the forces that they exert on one another are equal in magnitude but opposite in direction. The thin person falls backward while the fat person stands still because the effects of the forces depend on the masses of the bodies.

Activity 4.6



(a) The normal force in Figure 4.15a is FN = mg

(b) In Figure 4.15b, the force that tends to move the object down the plane if mg sinθ.

(c) In Figure 4.15b, the force that keeps the object on the surface of the plane if mg cosθ.

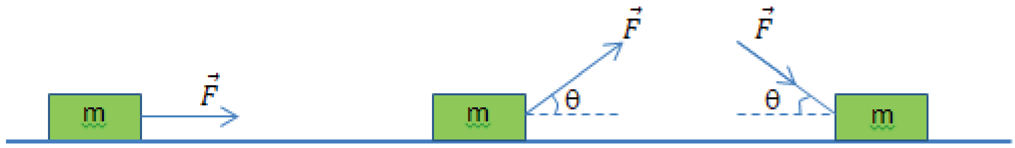
(d) No, the friction force kept the book from sliding.

(e) For the book to start moving the force down the plane has to be just enough to overcome static friction between the book and the plane.

$$\text{mg sinq} = \mu_s \text{ mg cosq}$$
$$\tan q = \mu_s$$

Review Questions 4.1

10. A block of mass m is placed on a horizontal surface as shown in Figure 4.16. What is the normal force in each of the following cases?



For the first arrangement, $F_N = mg$,
for the second one $F_N = mg - F\sin\theta$,
for the third one $F_N = mg + F\sin\theta$,

11. Answer:

(a) The weight of a body depends on the value of acceleration due to gravity. The same amount of gold weighs less in Alaska than in Addis Ababa. The cost of buying the gold per unit mass is less (cheaper) in Alaska than in Addis.

(b) Mass is independent of location and the cost will be the same everywhere.

4.2. Frictional Force

[3 periods]

At the end of this section students will be able to:

- *Describe the general characteristics of friction*
- *List the various types of friction*
- *Calculate the magnitude of static and kinetic friction, and use these in problems involving Newton's laws of motion*
- *Solve more complex acceleration problems involving Newton's laws of motion.*
- *Use free-body diagrams to solve problems on Newton's Laws of motion.*

When a body is in motion, it has resistance because the body interacts with its surroundings. This resistance is a force of friction. Friction opposes relative motion between systems in contact but also allows us to move, a concept that becomes obvious if you try to walk on ice. Friction is a common yet complex force, and its behavior still not completely understood. However, it is possible to understand the circumstances in which it behaves.

Friction is a force that opposes relative motion between systems in contact.

There are several forms of friction. One of the simpler characteristics of sliding friction is that it is parallel to the contact surfaces between systems and is always in a direction that opposes motion or attempted motion of the systems relative to each other. If two systems are in contact and moving relative to one another, then the friction between them is called kinetic friction. When objects are stationary, static friction can act between them; the static friction is usually greater than the kinetic friction between two objects.

Newton's three laws of motion contain all the basic principles we need to solve a wide variety of problems in mechanics. These laws are very simple in form, but the process of applying them to specific situations can pose real challenges. In this section we'll point out three key ideas and techniques to use in any problems involving Newton's laws.

1. Newton's first and second laws apply to a specific body. Whenever you use Newton's first law, $\sum \vec{F} = 0$, for an equilibrium situation or Newton's second law, $\sum \vec{F} = m\vec{a}$, where there is acceleration, you must decide at the beginning to which body you are referring.
2. Only forces acting on the body matter. The sum $\sum \vec{F} = 0$ includes all the forces that act on the body in question. Hence, once you've chosen the body to analyze, you have to identify all the forces acting on it.
3. Free-body diagrams are essential to help identify the relevant forces. A free-body diagram shows the chosen body by itself, "free" of its surroundings, with vectors drawn to show the magnitudes and directions of all the forces that act on the body. Be careful to include all the forces acting on the body. When a problem involves more than one body, you have to take the problem apart and draw a separate free-body diagram for each body.

Teaching Method

Start by asking the brainstorming questions such as:

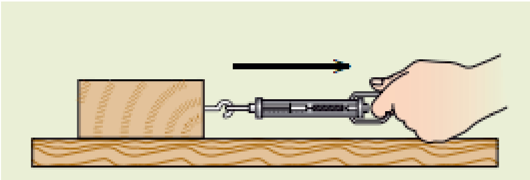
What is the role of friction in our daily life?
Can you get rid of friction?

Mention pros and cons of frictional force? Let the students write their own responses on their notebook and read it to their classmates.

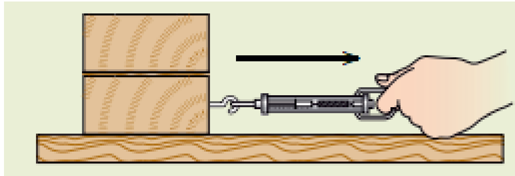
Ask the students about the cause of the difference in stopping distance of the pack in the three different cases suggested in Activity 4.1 of the previous section in terms of frictional force.

Activity 4.7

Arrange the block, the spring balance and the horizontal surface as shown. Keep the spring balance horizontal by exerting a horizontal force on it.



(a)



(b)

The force that is just enough to start moving the block is maximum static friction. It depends on the nature of surfaces in contact and the normal force. As the number of blocks increases, the normal force and hence the static frictional force between the contacting surfaces increases and we say that the applied force that is just enough to set the blocks in motion is directly proportional to the number of blocks places on the board.

Answers to Exercises, Discussion of Activities, Review questions and End of unit questions

Activity 4.8

Group work

Apparatus: A ramp, a block wood, and sandpaper.

(a) First place the block on the ramp and set the angle of inclination of the ramp so that the block slides down the ramp.

(b) Then remove the block and now rub the surface of the ramp with the sandpaper (to reduce friction between the ramp and the block) and place the block on the ramp.
Compare the acceleration of the block down the ramp in cases a and b?

Activity 4.9

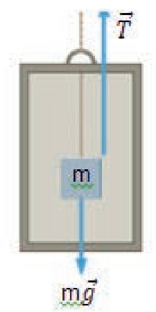
During rainy seasons the rod becomes slippery (with low friction) and speeding vehicles may skid out of the road.

Activity 4.10

Interleaving the pages increases the frictional force between the papers when the papers tend to slide over one another. It turns out that when you try to pull the two books apart, the interleaved pages in the middle get squished together harder—this increases the normal force between them, thereby increasing overall friction. The friction being on the two faces of each of the papers it is difficult to pull the books apart.

Exercise 4.2

Mass m hangs from a string attached to the ceiling of an elevator. The tension in the string acts upward while the weight of the body acts downward.



(a) When the elevator is at rest, a = 0 and T = mg
(b) when the elevator accelerates upward, T – mg = ma, T = m(g + a)
(c) When the elevator accelerates downward, mg – T = ma, T = m (g – a)
(d) When the elevator is decelerating downward, T = m (g – (- a)) = m (g +

Answers for Review Questions 4.2

2. Think of the static frictional force between your foot and the ground while walking and the static frictional force between tires of a moving car and the ground.
3. Static friction just before the box starts to slide is greater than the kinetic friction while the box is in motion.
4. Static frictional force F_s = 70 N, Fs = $\mu_s mg$,
$70\ N = \mu_s (25\ kg)(10\ m/s^2)$, $\mu_s = 0.28$
Kinetic frictional force F_k = 60 N, $F_k = \mu_k mg$,
$60\ N = \mu_s (25\ kg)(10\ m/s^2)$, $\mu_s = 0.24$
5. As the car is moving at a constant speed in a fixed direction (constant velocity), there is no unbalanced force acting on it.
6. When the cable that supports the elevator breaks, the elevator and its contents will fall with acceleration equal to acceleration due to gravity. The elevator and

everything inside it will experience apparent weightlessness.

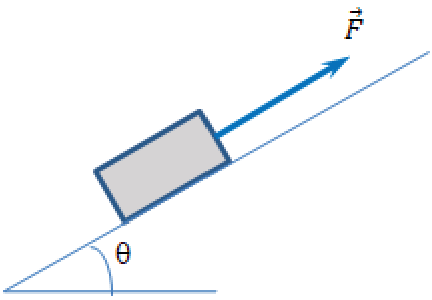
7.

(a) If the reading is equal to mg, then the elevator is at rest or moves with a constant speed.

(b) If the reading is greater than mg, then the elevator is either accelerating upward or decelerating downward.

(c) If the reading is less than mg, then the elevator is accelerating downward or this may also happen if the elevator falls freely (a = g downward), where the reading is zero (condition of apparent weightlessness).

8. The block is pulled up the inclined surface by force $\vec{F}\vec{F}$.



$F_{net} = ma$

$F - mg \sin\theta = ma$

(a) For a constant speed a = 0,

$F = mg \sin\theta$

(b) When the mass accelerates up the plane $\quad F = mg \sin\theta + ma$

9. $F_{net} = ma$

$F - (mg \sin q + \mu_k mg \cos q) = ma$, where

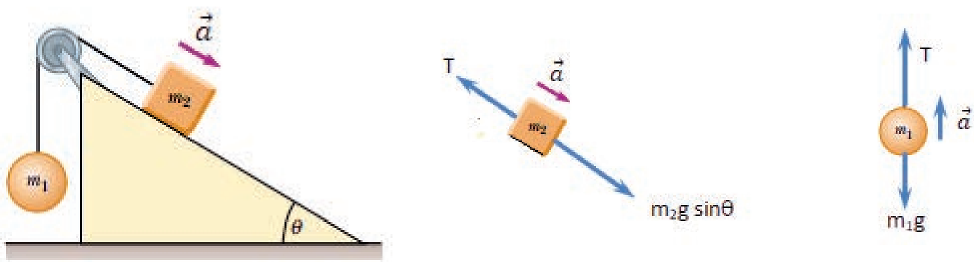
(a) For a constant speed a = 0, μ_k = coefficient of kinetic friction

$F = mg \sin q + \mu_k mg \cos q = mg (\sin q + \mu_k \cos q)$

(b) When the mass accelerates up the plane,

$F = mg (\sin q + \mu_k \cos q) + ma$

10. Connected mass system



Applying Newton's second law for m1 and m2 we have

$T - m_1 g = m_1 a$

$m_2 g\sin\theta - T = m_2 a$

Rearranging these equations we get $m_2 g\sin\theta - m_1 g = (m_1 + m_2)\, a$

$$a = g\,(m_2\sin\theta - m_1)/\,(m_1 + m_2)$$

11. The deceleration is caused by frictional force.

$$F_{net} = F_f$$
$$\mu mg = -\,ma$$
$$a = -\mu g$$

Using $v^2 - u^2 = 2as$, we write, $0 - u^2 = 2ad$,

$$d = \frac{-u^2}{2a}\frac{-u^2}{2a} = \frac{-u^2}{2(-\mu g)}\frac{-u^2}{2(-\mu g)} = \frac{u^2}{2\mu g}\frac{u^2}{2\mu g}$$

(a) The stopping distance does not depend on the mass.

(b) If the initial velocity is doubled, the stopping distance will be 4 times as large.

4.3. The First Condition of Equilibrium

[2 periods]

At the end of this topic, students will be able to:

- *Define the term equilibrium*
- *Explain the first condition of equilibrium*
- *Apply the first condition of equilibrium to solve practical problems.*

Objects that are either at rest or moving with constant velocity are said to be in equilibrium. The net force acting on a body in equilibrium is zero and the acceleration of the body is zero. Because a = 0, Newton's second law applied to an object in equilibrium gives

$$\sum \vec{F}\sum \vec{F} = 0 \qquad \text{(The first condition of equilibrium)}$$

Writing this component wise, we have

$$\sum F_x = 0 \text{ and } \sum F_y = 0$$

When using the equation $\sum \vec{F}\sum \vec{F} = 0$, only forces acting on the body in question must be taken into account. Hence, once you've chosen the body to analyze, you have to identify all the forces acting on it.

Free-body diagrams discussed in the previous section are essential to help identify the relevant forces. Pay attention in identifying all the forces acting on the body and in a problem that involves more than one body, you have to draw a separate free-body diagram for each body.

Teaching method

Check students' understanding of resultant forces and the steps used to determine the magnitude and direction of the resultant of a number of forces acting at a point (concurrent forces).

Ask students to define acceleration and to discuss the cause of acceleration and how these cause and the effects are related by Newton's second law of motion.

Review the use and application of a free-body diagram which is essential to help identify and solve complex problems involving the action of forces at a point.

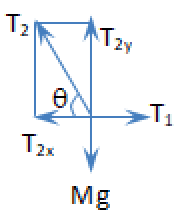
Answers to Exercises, Discussion of Activities, Review questions and End of unit questions

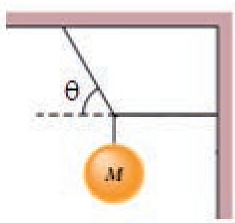
Activity 4.11

No, for an object to be in equilibrium the net force acting on it must be zero. An object at rest can still have net force acting on it. A body projected vertically upward stops momentarily as it reaches its maximum height while it is still under the pull of gravity.

Answers to Review Questions 4.3

1. No, for an object to be in equilibrium, the net force acting on it must be zero. The least number of forces that can give a zero resultant is two.
2. 2. Answer: d, if a body moves at a constant velocity it is said to be in equilibrium.
3. Applying the first condition of equilibrium





$T_1 + T_2 + W = 0$

$T_{1x} - T_{2x} = 0$, $T_1 - T_2 \cos 53^o = 0$, $T_1 - 0.6\, T_2 = 0$, $T_1 = 0.6\, T_2$

$T_{ly} - W = 0$, $T_1 \sin 53^o = Mg$, $0.8\, T_1 = Mg$,
$T_1 = Mg/0.8 = 1.25\, Mg = 1.25 \times 10\ kg \times 10\ m/s^2 = 125\ N$

4.4. Work, Energy and Power

[3 periods]

By the end of this section, students will be able to:

- *Define work in terms of the applied force and the displacement.*
- *Calculate the work done by a constant force, by a varying force.*
- *Demonstrate by examples that maximum work is done when the applied force is parallel to the displacement vector.*
- *Apply work-energy theorem to solve problems.*
- *Calculate kinetic energy and potential energy of a body.*
- *Differentiate between conservative and non-conservative forces.*
- *Explain the law of the conservation of energy.*
- *Solve problems by applying the law of conservation of energy.*
- *Define power and solve problems involving power.*

The concept of energy is one of the most important topics in science and engineering. In everyday life, we think of energy in terms of fuel for vehicles and heating, electricity for lighting and appliances, and foods for consumption. However these ideas do not really define energy. They merely tell us that fuels are needed to do the job and those fuels provide us with something we call energy.

Energy is present in the universe in various forms such as heat energy solar energy, mechanical energy, etc. The other important feature of energy is that it transfers from one body to another or transforms from one form into another. Every physical process that occurs in the Universe involves energy and energy transfers or transformations. Consider an archer is pulling back her bowstring. She does work on the bow transforming chemical energy in her muscles into elastic potential energy in the bow. When she releases the string, the bow does work on the arrow. The elastic potential energy of the bow is transformed into the energy of motion of the arrow, called kinetic energy.

Work is a measure of the amount of energy transferred when a force acts over a given displacement. It is calculated as the product of the magnitude of applied force and the displacement of the object in the direction of that force.

The concept of energy can be applied to the dynamics of a mechanical system without resorting to Newton's laws. This "energy approach" to describing motion is especially useful when the force acting on a particle is not constant; in such a case, the acceleration is not constant, and we cannot apply the constant acceleration equations discussed that were developed in the previous unit in this textbook.

In physics, the study of mechanics includes kinematics (the study of motion), statics (the study of forces in equilibrium), and dynamics (the study of non-zero forces and the motion that results from them). Gravitational potential energy, elastic potential energy, and kinetic energy form what is called mechanical energy. When work is done on a system, there may be changes in the potential and kinetic energies of the system. This relationship is expressed as the work-energy theorem.

Consider a particle with mass m moving along the x-axis under the action of a constant net force of magnitude F pointing in the positive x-direction. The body accelerates and the change of velocity results in a change in kinetic energy of the particle.

Work–energy theorem: Work done by the net force on a particle equals the change in the particle's kinetic energy.

Particles in nature are often subject to forces that vary with the particles' positions. These forces include gravitational forces and the force exerted on an object attached to a spring. We shall describe techniques for treating such situations with the help of an important concept called conservation of energy. It turns out there are two general kinds of forces. The first is called a conservative force. Gravity is probably the best example of a conservative force.

A non-conservative force is generally dissipative, which means that it tends to randomly disperse the energy of bodies on which it acts. This dispersal of energy often takes the form of heat or sound. Kinetic friction and air drag are good examples.
In this unit we shall focus on mechanical energy and its conservation. Mechanical energy is the sum of kinetic energy and potential energy.

$$\mathbf{ME = KE + PE}$$

Power, the rate at which energy is transferred, is important in the design and use of practical devices, such as electrical appliances and engines of all kinds. The concept of power, however, is essential whenever a transfer of any kind of energy takes place. Power is defined as the rate of energy transfer with time:

Teaching method

Discuss the term work with the students. Check that they understand work has a different meaning in physics to its meaning in everyday language? Ask students to name various types of energy and sources of energy that are common in their localities?

Go through worked examples and activities so as to make sure that the students have understanding of work done and energy transfer and apply the formulas to solve practical problems.

Motivate students to design their own experiments to demonstrate the mechanisms by which energy transforms from one form to another or transfers from one body to another.

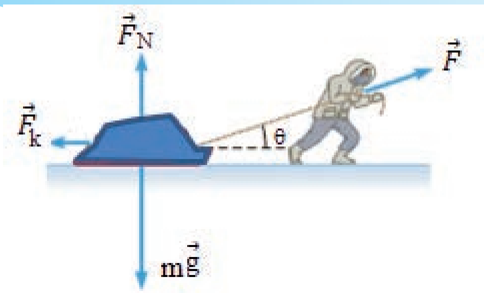
Revise what the students know about power. Discuss with them the meaning of the word in everyday life and its meaning in physics.

Answers to Exercises, Discussion of Activities, Review questions and End of unit questions

Exercise 4.3

$W = \vec{F} \cdot \vec{S} = \vec{F} \cdot \vec{r} = (150\,\hat{\imath} - 40\,\hat{\jmath}) \cdot (14\,\hat{\imath} + 11\,\hat{\jmath})$ Nm $= (150)(14) + (-40)(11) = 1660$ J

Activity 4.13



$W_{tot} = F_{net}\,S$

The net force in the direction of the displacement is

$$F_{net} = F_x - F_k = F\cos30^{o} - F_k = (400\text{ N})(0.866) - 100\text{ N} = 246.4\text{ N}$$

$$W = F_{net}\,S = (246.4\text{ N})(10\text{ m}) = 2464\text{ J}$$

Activity 4.14

The area of F vs S graph gives the work done.

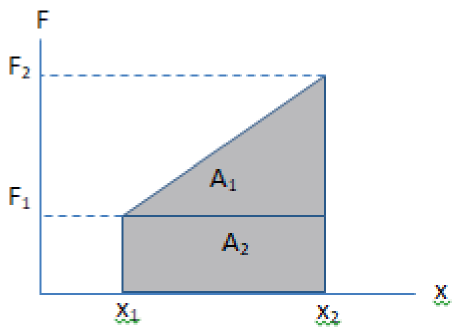
Activity 4.15

The force required to stretch a spring of force constant k through displacement x is F = kx. When an initially upstretched spring is stretched to have elongation of x, the force

applied changes from $F_1 = 0$ N to $F_2 = kx$.
Since the force varies linearly with x, the work done is calculated by taking the product of the average of the fore and the elongation.

$W = F_{av} . x = ½ (F_1 + F_2) . x = ½ kx^2$ = Elastic potential energy of a spring

As the extension of the spring changes from x_1 to x_2, the elastic potential energy of the spring changes from $PE_1 = ½ kx_1^2$ to $PE_2 = ½ kx_2^2$ The work required to change the extension of the spring from x_1 to x_2 is $W = \Delta PE = ½ k (x_2^2 - x_1^2)$



Area $A_1 = ½ (F_2 - F_1) (x_2 - x_1)$
$= ½ (kx_2 - kx_1) (x_2 - x_1)$
$= ½ k(x_2 - x_1) (x_2 - x_1)$
$= ½ k(x_2^2 - 2 x_1x_2 + x_1^2)$

Area $A_2 = (F_1) (x_2 - x_1) = kx_1(x_2 - x_1) = k(x_1x_2 - x_1^2) = kx_1x_2 - k x_1^2$

Work = area A_1 + area$_2$ $= ½k x_2^2 - k x_1x_2 + ½ k x_1^2) + (kx_1x_2 - k x_1^2) = ½k (x_2^2 - x_1^2)$

Activity 4.16

Answers

(2) The slop of the F vs x graph gives the force constant of the spring.

(3) The area of F vs x graph gives the work done

Exercise 4.4

(a) For they have equal mass and moved through the same height h, the work done by the boy is equal to the work done by the girl = mgh
(b) The girl developed more power than the boy, for she did the same work in a shorter period of time than the boy.

Activity 4.17

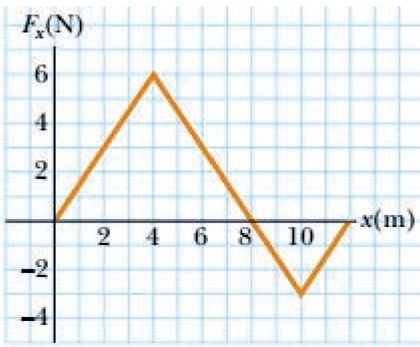
The work done depends on the height through which the object is lifted while the power developed depends on both the height and the tine taken to do the work.

Answers to Review questions 4.4

2. Having the same speed, the one with the larger mass has the larger kinetic energy. The kinetic energy of the second bullet is two times that of the first bullet.
3. (a) Kinetic energy is directly proportional to the square of the speed. Doubling the speed makes an object's kinetic energy four times larger.

   (b) If the total work on an object is zero in some process, its speed at the initial point must be the same as the speed at the final point.

5. Force versus displacement graph



Work done is equal to the area under F vs x graph.

(c) from x = 0 to x = 8 m, W = 24 J

(d) from x = 8 m to x = 10 m, W = -3 J

(e) from x = 0 to x =10 m. W= 21 J

6. (a) PE = ½ kx^2, if x is doubled, PE will be four times as large (quadrupled).

   (b) if x is doubled, then PE becomes nine times as large.

7. (a) PE = ½ kx^2 = 1.125 x 10^{-2} J

   (b) PE = ½ kx^2 = 1.125 x 10^{-2} J

8. (a) The total mechanical energy at the top (point A) = The total mechanical energy at the top (point B)

$PE_A = KE_B + PE_B$

$mgh_A = \frac{1}{2} mv^2 + mgh_B$

$\frac{1}{2} mv^2 = mg(h_A - h_B)$, $v = \sqrt{2g(h_A - h_B)} = 10\sqrt{2}$ m/s

(b) The total mechanical energy at the top (point A) = The total mechanical energy at the bottom (point C)

$$PE_A = KE_C$$
$$mgh_A = ½\, mv^2$$
$$v = \sqrt{2gh_A} = 10\sqrt{3}\text{ m/s}$$

9. The force required to accelerate the block is

$$F - F_f = ma$$
$$F - \mu mg = ma, \text{ where } a = \frac{v-u}{t} = \frac{20\text{ m/s} - 0\text{ m/s}}{5\text{ s}} = 4\text{ m/s}^2$$
$$F = 60\text{ N}$$
$$P = F \cdot v_{av} = F\left(\frac{v+u}{2}\right) = 600\text{ W}$$

10. The work done by the motor = ΔKE = ½ m $(v^2 - u^2)$ = 375000 J

The power developed = $\frac{\text{work done}}{\text{time taken}} = \frac{375000\text{ J}}{8\text{ s}} = 46875\text{ W}$

4.5. Conservation of mechanical energy

[3 periods]

At the end of this unit, students will be able to:

- *Define mechanical energy.*
- *State the law of conservation of mechanical energy.*
- *Apply the law of conservation of mechanical energy to solve problems*

In the last section the students have defined mechanical energy as the sum of kinetic energy and potential energy.

$$ME = KE + PE$$

The law of conservation of energy states that in the absence of dissipative forces such as air resistance and friction, the total mechanical energy of an object or system objects remains constant.

$$\Delta ME = 0$$
$$\Delta KE + \Delta PE = 0$$

The mechanical energy of a particle stays constant unless forces outside the system or non-conservative forces do work on it, in which case, the change in the mechanical energy is equal to the work done by the non-conservative forces:

$W_{nc} = \Delta KE + \Delta PE$, where W_{nc} is work done by non-conservative forces

As work done by non-conservative forces is denoted by f is $W_{nc} = -f.S$, we write

$$-f.S = ½\,(mv_2^2 - ½\, mv_1^2) + mg\,(h_2 - h_1) + ½\, k(x_2^2 - x_1^2)$$

Answers to Review Questions 4.5

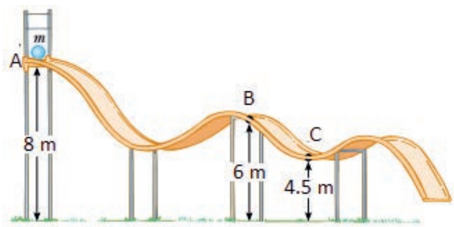
1. It possesses its maximum kinetic energy at the instant it is thrown and as it just hits the ground (the lowest point of its trajectory) and the ball-Earth system will have the maximum potential energy as the ball reaches the highest point of its trajectory.

2. PE at point A (top) = KE at point B + PE at point B

Using KE at B = 2PE at B, we have
PE at point A (top) = 3 PE at point B

$$mgh_A = 3mgh_B$$
$$h_B = \frac{1}{3} h_A = 6 \text{ m}$$

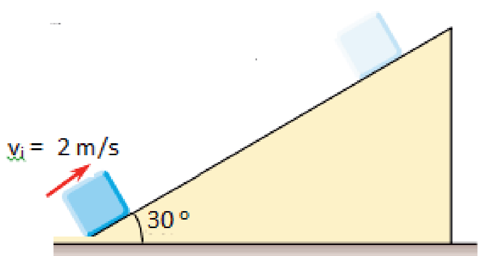
3. A particle of mass m = 8 kg is released from point A and slides on the frictionless track shown.



(a) The particle's speed at points B, $mg_A = mgh_B + ½ mv_B^2$, $v_B = 6.32$ m/s
The particle's speed at points C $mgh_A = mgh_C + ½ mv_C^2$, $v_C = 8.36$ m/s
(b) The net work done by the gravitational force in moving the particle from A to C

$$W_G = F_G h = -\Delta PE$$
$$= -mg(h_C - h_A) - (8 \text{ kg}) (10 \text{ m/s}^2) (4.5 \text{ m} - 8\text{m})$$
$$= 280 \text{ J}$$

4. A block is kicked up the plane with initial velocity = 2 m/s



(a) $W_d = \Delta ME$

$$-f_k d = (KE_f - KE_i) + (PE_f - PE_i)$$

Assuming no friction, $W_d = 0$

$$0 = (0 - KE_i) + (PE_f - 0)$$
$$KE_i = PE_f$$

$$\tfrac{1}{2} mu^2 = mgh,\ h = S \sin\theta$$
$$= mgS \sin\theta$$

$$u^2 = 2gS\sin\theta,$$

$$4\ \mathrm{m/s^2} = (2)\ (10\ \mathrm{m/s^2})\ (S)\ (\sin 30^\circ),\ S = 0.4\ \mathrm{m}$$

(b) With friction between block and the surface,

$$W_d = DME$$
$$-f_k d = (KE_f - KE_i) + (PE_f - PE_i)$$
$$-(\mu mg\cos q)\, S = (0 - KE_i) + (PE_f - 0)$$
$$KE_i = PE_f + (\mu mg\cos q)\, S$$
$$\tfrac{1}{2} mu^2 = mgS \sin q + (\mu_k mg\cos q)\, S$$
$$u^2 = 2gS[\sin q + \mu_k \cos q]$$
$$S = 0.28\ \mathrm{m}$$

5. In the presence of friction we write

$$W_d = \Delta ME$$
$$-f_k d = (KE_f - KE_i) + (PE_f - PE_i)$$
$$-f_k S = (0 - KE_i) + (0 - 0)$$
$$f_k S = KE_i$$
$$f_k (S) = \tfrac{1}{2} m u^2,\ f_k = 0.02\ \mathrm{m}$$

6. As in the solution for problem 5, the skidding distance is directly proportional to the initial speed of the car. Doubling the initial speed will increase the skidding distance by a factor of four.

4.6. Impulse and Linear Momentum

[4 periods]

At the end of this unit, students will be able to:

- *Discuss impulse and linear momentum*
- *Relate impulses to collisions*
- *Apply the impulse-momentum theorem to solve problems*
- *Differentiate the difference between Elastic and inelastic collisions*
- *State the law of conservation of linear momentum*
- *Explain the meaning and usefulness of the concept of center of mass*
- *Calculate the center of mass of a given system*
- *Calculate the velocity of the center of mass*
- *Apply the law of conservation of linear momentum to solve problems involving collision in one dimension.*

In this section we shall discuss one of the interactions between objects, collision, and the phenomena associated with it. The physical quantity momentum describes an effort required to set an object in motion or to stop an object that was already in motion. It is defined as the product of mass and velocity. It is a vector quantity with its direction along the direction of the velocity.

In this study of momentum and impulse, students will investigate the motion of objects that interact, how the velocity of a system of objects is related before and after collision, and how safety devices incorporate the concepts of momentum and impulse. Many situations and activities in the real world, such as skating, involve an object gaining speed and momentum as it moves. Sometimes two or more objects collide, such as a bat hitting a ball, and a player kicking a ball. What physics principles apply to the motion of colliding objects? How does the combination of the net force during impact and the interaction time affect an object during a collision?

When objects interact during a short period of time, they may experience very large forces. Evidence of these forces is the distortion in shape of an object at the moment of impact.

In this chapter, you will examine how the net force on an object and the time interval during which the force acts affect the motion of the object.

Designers of safety equipment for sports and vehicles use this type of analysis when developing new safety devices. In a system of objects, you will also investigate how their respective velocities change when the objects interact with each other.

Teaching method

Start by asking the brainstorming question given in the student's text. Let the students discuss factors that determine the magnitude of momentum of a body.

Drive the impulse-momentum equation to help students recognize how force and momentum are related.

Bring a balloon to your class, blow it and release it. Ask students to tell what they saw and why this happened. Make a brief association of what they saw with the motion of a spaceship traveling to the moon.

Mention the following thought experiment and ask students to respond to the questions that follow. Suppose you place a cubical block each of sides 50 cm on a horizontal floor and that you stand on it. Suppose you jump off the box and land on the floor. What would you do if you want to land without experiencing pressure (pain) on your feet?

Answers to Exercises, Discussion of Activities, Review questions and End of unit questions

Exercise 4.5

1. How would the momentum of an object change if
   (a) the mass is doubled but the velocity remains the same?
   (b) the velocity is reduced to one-third of its original magnitude?
   (c) the direction of the velocity changes from South to East?

$\vec{P} = m\vec{v}$, momentum is directly proportional to both mass and speed.

(c) When the direction of the velocity changes from South to East,

$$\Delta\vec{P} = \vec{P}_f - \vec{P}_i = m(\vec{v}_f - \vec{v}_i)$$

Assume initial and final velocities of the same magnitude, each of u. We take $\vec{v}_f = -\vec{u}$ and $\vec{v}_i = \vec{u}$

$$\Delta\vec{P} = -2m\vec{u}$$

Exercise 4.6

(a) Impulse = $\Delta\vec{P} = m\Delta\vec{v} = (1500\ kg)\ (0\frac{m}{s} - 10\frac{m}{s}, \text{E})$

$(1500\ kg)\ (0\frac{m}{s} - 10\frac{m}{s}, \text{E})$ = - 15000 kg m/s, E

(b) $\Delta\vec{P} = \vec{F}\,\Delta t$, $\vec{F} = \frac{\Delta\vec{P}}{\Delta t} = \frac{-15000\ \text{kgm/s,E}}{0.25\ \text{s}}$ = - 60 kN, E = 60 kN, W

(c) $\vec{F} = \frac{\Delta\vec{P}}{\Delta t} = \frac{-15000\ \text{kgm/s},E}{0.04\ \text{s}} =$ - 375 kN, E = 375 kN, W

Activity 4.19

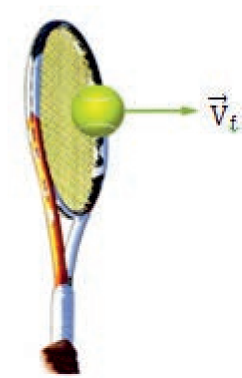
Bend your knee slightly so as to increase the time of interaction with the ground.

Exercise 4.7

What is the acceleration of the ball in the above example while it was in contact with the striker's foot? How long does it take for the ball to pass the goal line? (Assume the ball obtained a slight air clearance on its path to the goal line so that friction can be neglected.)

Exercise 4.8

Calculating Force: Venus Williams' Tennis Serve



The tennis ball acquires a final velocity of 209 km/h (58 m/s).

Answer

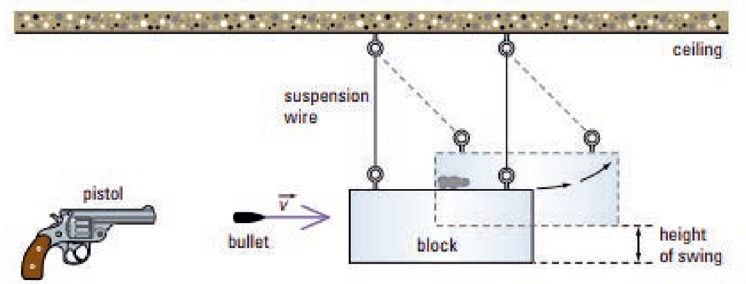
Initial velocity of the ball u = 0
Final velocity of the ball v = 58 m/s
Time of contact t = 5 ms = 0.005 s
Impulse = change of momentum
$F\Delta t = m\Delta v$

$$F = \frac{m\Delta v}{\Delta t} = \frac{m(v-u)}{\Delta t} = \frac{(0.057\ \text{kg})(58\ \text{m/s} - 0\ \text{m/s})}{(0.005\ \text{s})} = 661.2\ \text{N}$$

Activity 4.22

Throw the book to one direction (side) say forward so that he gains a recoil velocity in opposite direction (backward).

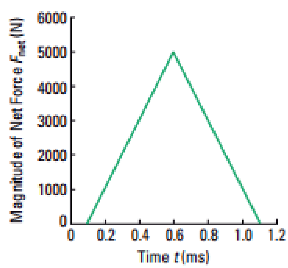
Activity 4.23



The bullet is embedded in the block and some of the kinetic energy of the bullet is lost Converted into heat energy) in the process. The collision was a perfectly elastic collision.

Answers to Review Questions 4.6

1. No, Momentum directed toward south is different from momentum directed toward northwest
2. The interaction time is shorter with the concrete floor than with the wood. The shorter the time the larger will be the force if interaction.
3. Answer: b, the speed of the apple increases on its way down so the momentum and kinetic energy increase with time. But in the absence of air resistance, the sum of the kinetic and potential energies remains the same.
4. (a) The impulse provided to the ball is Area of F vs t graph, Impulse = 2.5 Ns
   (b) Impulse = ΔP, 2.5 Ns = (0.05 kg) (v – u), v = 50 m/s



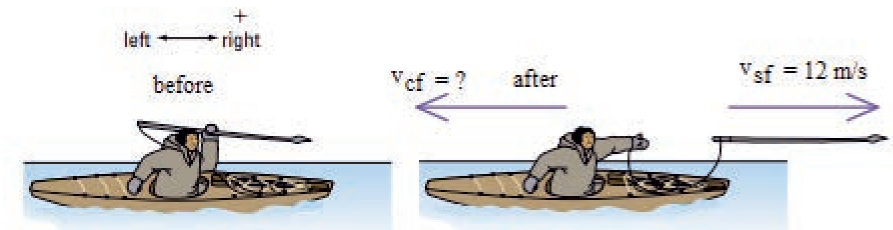
Magnitude of Net force vs. Interaction time for a golf ball being hit by the golf club.

5. When two identical balls make elastic collision, the will exchange velocities aftrer interaction.
6. A 0.16 kg billiard ball traveling at 0.5 m/s, due North strikes a stationary 0.18 kg snooker ball and rebounds at 0.23 m/s due South. The snooker ball moves off at 0.463 m/s due North. Ignoring the possible rotational effect, determine if the collision is elastic?

Mass m_1 = 0.16 m/s
u_1 = 0.5 m/s, north
= + 0.5 m/s
v_1 = 0.23 m/s, south

mass m_2 = 0.18 m/s
u_2 = 0 m/s
v_2 = 0.463 m/s, north
= + 0.463 m/s

Compare the kinetic energy of the system before collision and that after collision to decide whether or not the collision is elastic. The collision is not elastic.



8. $(m_m + m_c + m_s)\ u = (m_m + m_c)\ v_{cf} + m_s v_{sf}$

(75 kg + 10 kg + 0.72 kg) (0 m/s) = (75 kg + 10 kg) (vcf) + (0.72 kg) (12 m/s)

v_{cf} = - 0.1 m/s

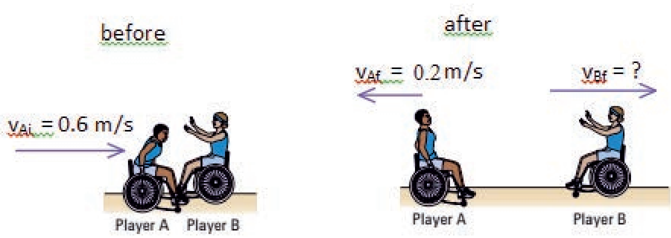
Velocity of the man and the canoe after interaction is 0.1 m/s toward left (backward).

9. m_A = 58 kg,

v_{Ai} = + 0.6 m/s,

v_{Af} = -0.2 m/s

m_B = 85 kg, v_{Bi} = 0 m/s $\qquad v_{Bf}$ = ?



$$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$$

$$(58\ kg)\ (0.6\ m/s) + (85\ kg)\ (0\ m/s) = (58\ kg)\ (-0.2\ m/s) + (85\ kg)\ (v_{Bf})$$

$$v_{Bf} = 0.55\ m/s$$

Answers to End of Unit 4 Questions:

1. Answer: c, the ball pulling upward on the earth with a force of magnitude equal to the weight of the ball.
2. Answer: b, the vertical component of the force acts in opposite direction to the weight, thereby weight of the roller is decreased and friction decreased.

6. Answer: d, action reaction pairs of force do not cancelled to each other.

7. Answer: No, for two equal and opposite forces to constitute action and reaction pair, they must act on two different bodies (the force of one body on the other one and vice versa)

8. A player running to kick the ball.

Answer: a) $a = \frac{\Delta v}{\Delta t} = \frac{8\ m/s}{2.5\ s} = 3.2\ m/s^2$ b) The player experiences a force of F = ma = 224 N

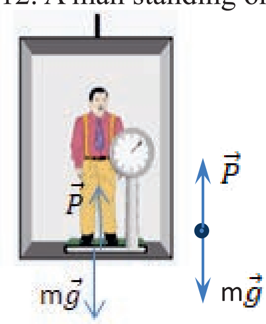
10. Dust is removed from a carpet by shaking is explained by Newton's first law.

According to Newton's first law of motion, the dust particles stay in a state of rest, while the carpet moves. Hence, the dust particle comes out of the carpet due to inertia.

11. Why is it advised to tie a rope on the luggage to a luggage rack while you travel by the bus?

Due to inertia, the luggage may fall off the bus depending on its mass and the magnitude of the force (the acceleration of the bus and the friction force between the luggage and the surface on which it is placed). The luggage will be secured and will not fall off the bus if it is tied up.

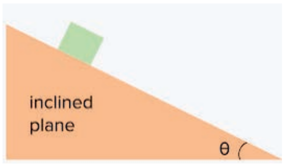
12. A man standing on a scale in an elevator

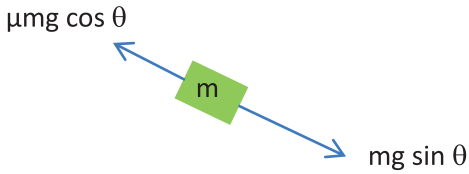


Answer: a) For acceleration upward $P = m(g + a) = 840$ N

b) For motion ata constant speed, $P = mg = 750$ N

14. A block on a an inclined plane





Answer: a) when the mass is at rest,

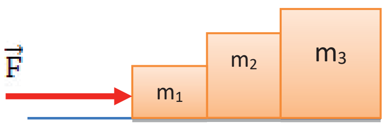
$mg\sin\theta = \mu_s mg\cos\theta$, $\tan\theta = \mu_s$, $\theta = \tan^{-1}(\mu_s)$

b) when the mass accelerates down the plane,

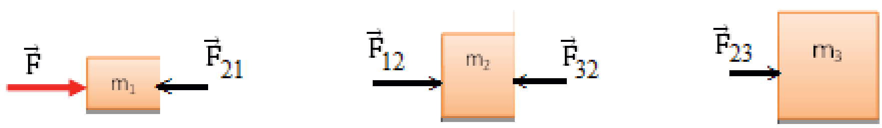
$a = g(\sin\theta - \mu_k \cos\theta)$,

The acceleration does not depend on the mass placed on the inclined plane. If the surface is frictionless, the block starts to accelerate for any angle θ of inclination.

15. Three blocks are in contact with each other on a frictionless horizontal surface.



$\vec{F}_{12}$ = force exerted on m_2 by m_1, $\vec{F}_{21}$ = force exerted on m_1 by m_2, $\vec{F}_{12} = -\vec{F}_{21}$
$\vec{F}_{23}$ = force exerted on m_3 by m_2, $\vec{F}_{32}$ = force exerted on m_2 by m_3, $\vec{F}_{23} = -\vec{F}_{32}$



(a) The acceleration of each of the blocks (moving together) is calculated as

$F_{net} = ma$

$F = (m_1 + m_2 + m_3)\,a$, $a = 3\ m/s^2$

(b) The net force on $m_1 = m_1a = (1\ kg)(3\ m/s^2) = 3N$,

The net force on $m_2 = m_2a = (2\ kg)(3\ m/s^2) = 6N$.

The net force on $m_3 = m_3a = (3\ kg)(3\ m/s^2) = 9N$

(c) The contact force between m_1 and m_2, F_{21} is

$F - F_{21} = m_1a$, $F_{21} = F - m_1a = 18\ N - 3\ N = 15\ N$

The contact force between m_2 and m_3

$F_{12} - F_{32} = m_2a$, $F_{32} = F_{12} - m_2a = 15\ N - 6\ N = 9\ N$

18. No. Impulse depends on the force and the time for which it is applied.

19. The momentum doubles since it is proportional to the speed.

The kinetic energy increases by a factor of 4 (quadruples), since it is proportional to the square of the speed.

20. $KE = \frac{1}{2} mv^2 = \frac{p^2}{2m}$,
$P^2 = 2m\ KE$,

$$\left(\frac{P_1}{P_2}\right)^2 = \frac{m_1 KE_1}{m_2 KE_2}$$, for $KE_1 = KE_2$, we have $\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$

Their momenta are equal if both mass and direction of motion are the same

21. Answer: $KE = \frac{1}{2} mv^2$, $1600\ J = \frac{1}{2}\ (200\ kg)\ v^2$, $v = 4\ m/s$,
$P = mv = (200\ kg)\ (4\ m/s) = 800\ kg\ m/s$

22. Answer: $KE \sim v^2$

To double the KE, the speed must change by a factor of $\sqrt{2}$.

23. A 120 N force applied on a 30 kg block.

Answer: (a) The net force = 120 N – 5 N = 115 N

The net work done = (115 N) (0.8 m) = 92 J

(b) Work done by the applied force = (120 N) (0.8 m) = 96 J

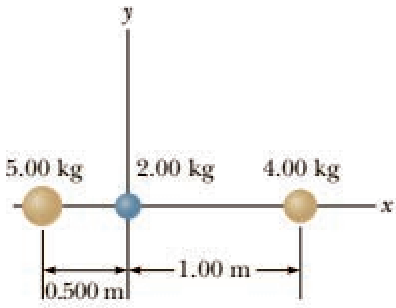
Work done by the frictional force = (5 N) (0.8 m) = 4 J

The net work done = 96 J – 4 J = 92 J

(c) The net work done = $\Delta KE = \frac{1}{2}\ m(v_2 - u_2)$

$\frac{1}{2}\ (30\ kg)\ (v^2 - 0^2) = 92\ J$, $v = 2.5\ m/s$

24. Answer: Raising a mass straight upward requires more force than doing the same along an inclined path. The same PE will be gained by the mass.
25. Three objects are located in a coordinate system as shown.



Answer: 5 kg at (-0.5, 0) m

2 kg at (0, 0) m

4 kg at (1, 0) m

Center of mass is x = $\frac{(5\text{ kg})(-0.5\text{ m})+(2\text{ kg})(0\text{ m})+(4\text{ kg})(1\text{ m})}{5\text{ kg}+2\text{ kg}+4\text{ kg}} = \frac{1.5\text{ kg m}}{11\text{ kg}} = \frac{1.5}{11}$ m, and

y = 0

Center of mass is at ($\frac{1.51.5}{11\ 11}$, 0) m

Unit Five

Heat Conduction and Calorimetry

[22 periods]

Introduction to the unit

This unit is about heat transfer mechanisms, thermal properties of matter, phase changes and calorimetry, which are highly related to students' day to day activities. Some topics, namely, heat capacity, specific heat capacity, and thermal expansions will be treated quantitatively. Experiments mixed with calorimetry problems will be employed at the end of this unit.

Unit outcomes

At the end of this unit, students will be able to:

- *Gain comprehensive knowledge on basic properties of fluids, thermal properties of matter, phase changes, calorimetry*
- *Quantitatively and qualitatively describe about heat capacity, specific heat capacity, and thermal expansions.*
- *Solve calorimetry problems.*
- *Use specific heat and heat of transformations in the practical application of calorimetry.*

Learning Strategies

Dear physics teacher, activate the learners' prior knowledge of the concepts of heat conduction by using thought provoking questions.

Ask the learners what they notice when they put a cold metal teaspoon into a hot cup of tea, or why they feel warm when cooking or when one sits or stands near a fire or in the sunshine. From their response, introduce the concept of heat transfer.

Problems that deal with thermal expansion of solids are interesting. Qualitative properties are best understood if students can see demonstrations of these properties

- ▷ Activities: Determination of the amount of heat necessary to convert a known quantity of ice at 0°C to water at 0°C.
- ▷ Measurement of specific heat capacity, e.g. of water. Measurement of the specific latent heat of fusion of ice Measurement of the specific latent heat of vaporization of water
- ▷ Discuss p-T (phase diagram) and three states separated by curves for boiling, freezing, and sublimation, meeting at triple point. Boiling curve terminates at critical point. For water, mention uniqueness of freezing curve resulting in lowering of freezing point with increase of applied pressure.
- ▷ Project: let the learners investigate in groups why water is added in the radiator of a car? Why different additives are added in the radiator water. This can be done through literature search, asking knowledgeable person.
- ▷ Help students solve thermal expansion problems.
- ▷ Project: Let the students discuss and present the applications of thermal expansion in their locality.

You need to list down teaching-learning materials and inform your students to access them in advance. They also need to identify the materials that can be used in the class for observation, experimentation and demonstration purposes. Some types of apparatus important in this unit are Gravesend's ring -and -ball apparatus, balloons, thermometers, calorimeter/s, metal rods, candles.

Assessment

You should undertake continuous assessment in order to check whether every student has acquired the minimum learning competencies over the whole unit. For the student to achieve the minimum required competencies, he/she should be able to: explain heat transfer, define the terms: calorimeter, change of phase, latent heat, heat capacity, specific heat capacity; distinguish between the concepts: heat, temperature, internal energy, work; identify the units for heat, heat capacity, specific heat capacity; Solve problems involving thermal expansion, change of state, explain the methods used for the measurement of specific heat capacities.

Assisting low achievers (students achieving below the minimum competence level) and praising the high achievers (students achieving above the minimum competence level) is very important in the assessment process. In this way, the low achievers attain the minimum competency level and the high achievers will be motivated for further high level achievements.

5.1. The concept of heat

[3 periods]

At the end of this topic, you should be able to:

- *Explain the concept of heat*

Students have learnt about temperature and its measurement methods in their grade 10 physics lessons. They have also learnt about energy and heat. Concepts of temperature, energy and its transformation are the primary prerequisite knowledge for this unit.

Answers to Thinking on brainstorming questions

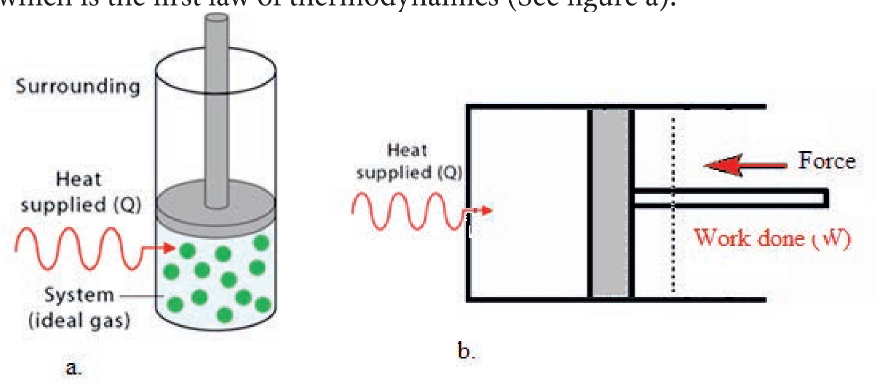
Let students try to answer all these questions. They have learnt that Temperature is defined as the measure of the average kinetic energy of particles of the substance. Let them try the second question, but you should not give the detail answer. Simply tell them that they will learn the concept of heat step by step as they go down this topic.

Teaching method

Start this lesson by asking the above brainstorming questions. Explain definition of heat, difference and relationships between heat and temperature. Describe the concept of heat elaborating with practical examples and its relationships and differences with internal energy and thermodynamic work.

Heat, internal energy and thermodynamic work

When heat is supplied to a gas, closed by a piston, as shown in the figure below, some of the energy stores in the system in the form of internal energy and some will do work on lifting the piston upwards. The change in internal energy is then, the heat supplied to the system minus the work done by the system on the surrounding ($\Delta U = Q - W$), which is the first law of thermodynamics (See figure a).



If heat is supplied and work is done simultaneously on the system as shown in figure b, the change in internal energy is the sum of the two ($\Delta U = Q + W$).

Answers to Review Questions 5.1:

1. The concept of heat is there in student's textbook. Tell effects of heat and introduce them that most of these effects will be the concern of this unit. Effects of heating are:

- ▷ Raises temperature.
- ▷ Increases volume.
- ▷ Changes state.
- ▷ Brings about chemical action.
- ▷ Changes physical properties.

2. The temperature difference between two systems causes heat transfer. Spontaneously heat flows from hotter to colder region. By other external factors, heat may flow from colder region to hotter region as is observed in refrigerators. A pressure difference between two regions can also cause heat transfer.
3. Objects, in thermal equilibrium, exchange heat but there is no net heat flow between them.
4. It is possible to reduce net heat flow to zero. Internal energy can be reduced to zero at absolute temperature. Internal energy of a system is the sum of all the microscopic energies such as:

- ▷ translational kinetic energy.
- ▷ vibrational and rotational kinetic energy.
- ▷ potential energy from intermolecular forces.

Temperature is the measure of the sum of the average translational and rotational kinetic energies only, but not potential energy from intermolecular forces. Therefore, internal energy highly depends on temperature. However, it is not only change in temperature that affects the internal energy but the potential energy from intermolecular forces also affects it.

5. The two systems are different only in temperature.

   (a) We cannot say A or B has stored heat. It is meaningless to say A or B has higher heat.
   (b) Since they are identical except different in temperature, so A has higher internal energy than B.
   (c) A loses and B gains energy. The direction of heat flow is from A to B. The average kinetic energy of particles in B increase since it is gaining energy.

6. Assuming that the system is isolated.

   (a) The heat stores as internal energy of the gas.

(b) In this case, the internal energy is changing to work by then decreasing the internal energy of the system.
(c) In this case, the heat supplied into the system is equal to the internal energy converted to thermodynamic work.

7. Heat and work are two different ways of transferring energy from one system to another. Heat is the transfer of thermal energy between systems, while work is the transfer of mechanical energy between two systems.

5.2. Heat transfer mechanisms

[3 periods]

At the end of this topic, you should be able to:

- *Explain the concept of heat conduction*

This section is about heat transmission in different media. The concept of energy transformation is important for this section. It will be helpful to start by revising the concept of heat discussed above. Every time the issue of heat transmission is always there with us. Plan or organize different phenomena related to heat transmission in students' environment. You can start by organizing a discussion among students.

Answers to Thinking about brainstorming questions

1. If one end of a metal rod is heated, the other end also gets heated up. This is due to conduction.
2. Heat is carried upwards from its source by convection. When the steam touches your skin, it transfers heat into your skin.
3. In this case, heat is carried from the sun to you in the form of electromagnetic wave.
4. Students may give different appropriate answers. Generally metals will feel colder, and insulators such as plastic and wood, and especially cloths or fur, will feel warmer.

Teaching method

From section 5.1, students have learnt that heat is energy transferring from hotter object to a cooler object by virtue of temperature differences. Based on their previous knowledge, let students try to think and suggest some ideas on questions given in the above activity. However, you should not tell them all of the answers immediately. Tell them that they will learn each of these step by step as they go down this section.

Carry on your lesson by raising different phenomena of heat transfer by giving examples occurring in kitchens, in sunny days, and so on.

- ▷ To teach heat transfer by conduction, ask students and allow them to predict. When you touch one end of a metal rod whose other end is on a fire, you feel warm. How is that happened? They will find the answer of this question from the discussion on heat transfer by conduction.
- ▷ Do the same for the remaining three questions. The fourth question is related to the heat conductivity of different materials.

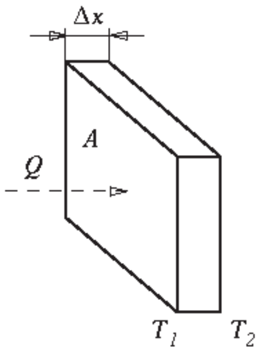
Answers to Activity 5.1: Demonstrations

1. Let students try this demonstration. The reason why a piece of metal and a piece of wood are at the same temperature yet the metal feels colder than the wood is that the metal has higher conductivity and it extracts more heat from your hand than wood in a given time. Therefore, you perceive the metal as being colder than the wood.
2. In this activity, ask students whether cross-sectional area has impact on the rate of heat flow or not. After asking this question, encourage them to be engaged in the demonstration. You need a source of heat and two rods of equal length but having appreciable thickness difference. Put one end of each on the same heat source. They should not be arranged as shown in the figure, instead let the two rods lay on the opposite sides so that they will not share heat by radiation. Use thermometers to measure temperatures of the colder ends at the same time. Repeat the activity until visible difference is observed.

   Expected result: Conduction depends on the cross-sectional area of the material. The larger the area, the faster the heat transfer will happen since more collisions between the molecules will also occur.
3. The rate of heat transfer through an object depends on different factors. If you consider the slab of thickness Δx, with opposite faces of area A at temperature differences, $\Delta T = T_2 - T_1$, where $T_2 < T_1$ the speed of heat flow across the slab:

- ▷ depends on the property of the material – for example large for metals and small for water.
- ▷ directly proportional to the change in temperature (ΔT).
- ▷ directly proportional to the area (A) of the slab which is perpendicular the direction of heat flow.
- ▷ inversely proportional to the thickness (Δx) of the slab.

Therefore, to build good insulating material for a given temperature difference, decrease the area, use insulating materials such as wood, and increase the thickness. In the figure shown, heat reaches faster in the thicker rod, i.e., wider cross-sectional area.



Answers to Activity 5.2: Project:

1. Let students list different materials in the homes and classify them as good and bad conductors of heat. Give opportunities for group leaders to report their results.
2. Let students come with practical model projects by construction or by drawing, houses to be built in hot areas, or cloths to be dressed in hot areas. This project may not end with some pre-determined answers. Different options may be mentioned. Some are wear light-colored, loose-fitting clothing. Shower, bathe or sponge off with cool water. Cover windows with shades, blinds or curtains during the hottest part of the day, drink as much fluid as possible.

Answers to Review Questions 5.2:

1. The water molecules move faster and faster. Steam pressure builds up. Eventually the lid can't hold it any more. Heat is transferred by conduction from the heat source to the water. The water molecules at the bottom will transfer heat by conduction. Within the water heat is also transferred by convection as the denser cold water is displaced downward and the less dense hot water at the bottom move upward.
2. Conduction involves molecules transferring kinetic energy to one another through collisions. Convection occurs when hot fluid rises, allowing cooler fluid to come in and be heated.
3. Rate of heat flow is high for large cross-sectional area of the medium.
4. In solids, heat passes from one point to another through conduction. In Liquids and gases, heat transfer takes place by convection. Heat transfer takes place by the process of radiation when there are no particles of any kind which can move and transfer heat.
5. By radiation
6. If air were a better conductor than it is at nighttime the earth would be considerably colder than it is. This is because the air would quickly conduct away any heat radiated from the ground and there would be no additional heating from the sun resulting in lower temperatures.

7. Yes! Heat transmits through the handle by conduction as the handle is in solid form; by convection in the liquid and primarily by radiation in air.

5.3. Heat capacity and specific heat capacity

[4 periods]

After completing this section, you should be able to:

- *Differentiate between heat capacity and specific heat capacity*
- *List the specific heat capacity of various materials*

Students know from their day to day life that some object get hotter faster than others while they are exposed to the same heat supply. Why water is used as a coolant, why steel exposed to sun light burns us and so on are important issues to start the lesson with.

Teaching method

Start your presentation from brainstorming questions. Let students suggest their assumptions. Then do not tell them the answer immediately, rather let them ask other knowledgeable persons in their environment so that they attain more knowledge and develop additional skills. Ask them again whether their prediction matches with the actual answer or not. Discuss about heat capacity and specific heat capacity. These topics involve calculations.

Before rushing to use the formula, students should understand the concept as clearly as possible. Students should be aware that heat added or removed from an object does not always result in change in temperature. During phase change, the temperature stays constant while the object is absorbing or releasing heat. Tell them that let them think over that and tell them that they are going to learn about that in the next sections.

Answers to Brainstoming Questions

Water is used as a coolant for machinery because it has the highest specific heat capacity and thus can be able to absorb large quantities of heat. Coolant additives are added to increase cooling efficiency. To use these additives, the water must be distilled water. Coolant additives work by reducing the surface temperature of the distilled water they are added to, allowing more surface area of the water to contact the motor. Additionally these coolant additives will help lubricate, protect, and reduce corrosion in your internal motor components.

Heat capacity and specific heat capacity

Heat capacity, C, is extensive physical quantity as its value depends on mass and Specific heat capacity, c, is an intensive property. When heat, Q, causes change in temperature, ΔT,

- ▷ heat capacity: $C = Q/\Delta T$
- ▷ specific heat capacity: $c = C/m = Q/m\Delta T$, where m is mass of object.

Answers to Review Questions 5.3:

1. A good insulator has a higher Specific Heat Capacity because it takes time to absorb more heat before it actually heats up (temperature rising) to transfer the heat.
2. Concrete absorbs more heat than soil in the day time. Similarly, the concrete releases more heat during the night than the day time, by then making cities warmer than country sides during the night other factors kept the same.
3. Given: m =100g = 0.1 kg, T_0= 20°C, T = 100°C, c = 129 J/kg.°C

   The heat supplied is

   $Q = mc\Delta T = 0.1\text{ kg} \times 129\text{ J/kg.°C} \times (100°C - 20°C) = 1032\text{J}$
4. Water has a higher heat capacity than soil and rock, so the ocean takes much longer to heat and to cool than the land. Coastal areas will generally have more moderate temperatures than inland areas because of the heat capacity of the ocean.
5. Given: $T_0 = 10$ °C, C = 2580 J/K, $T_{Au} = 50$°C, $c_{Cu} = 385$ J/kg.K, $c_{Au} = 129$ J/kg.K

   The heat absorbed by gold or copper is

   $$Q = C\Delta T = 2580\text{ J/K} \times (50\text{ °C} - 10\text{ °C}) = 103200\text{ J}$$

   The mass, m, of gold/copper is

   $$m = \frac{C_{Au}}{c_{Au}} = \frac{2580\text{ J/K}}{129\text{J/kg.K}} = 20\text{kg}$$

   $$Q = mc_{Cu}\left(T_{Cu} - T_0\right)$$

Solving this for T_{Au} and T_{Cu} from $Q = mc\left(T - T_0\right)$, for gold and copper, respectively, yield

$$T_{Au} = \frac{Q}{mc_{Au}} + T_0 = \frac{103200\text{J}}{20\text{kg} \times 129\text{J/kg.°C}} + 10\text{°C} = 50\text{°C}$$

$$T_{Cu} = \frac{Q}{mc_{Cu}} + T_0 = \frac{103200\text{J}}{20\text{kg} \times 385\text{J/kg.°C}} + 10\text{°C} = 23.4\text{°C}$$

6. Given: $m_{Al} = 0.80$ kg, $m_w = 0.20$ kg, $T_0 = 25.0$ °C, T = 85.0 °C

   a) Heat required to bring about this temperature,

   $Q = m_{Al}c_{Al}\Delta T + m_w c_w \Delta T$

$$Q = (0.80kg \times 900J/kg.K + 0.20\ kg \times 4200J/kg.K) \times (85.0\ °C - 25.0\ °C)$$

$$Q = 93600J$$

b) Heat absorbed by the pan is

$$Q_{pan} = (0.80kg \times 900J/kg.K) \times (85.0\ °C - 25.0\ °C) = 43200J$$

$$Q_{pan}\% = \frac{Q_{pan}}{Q} \times 100\% = \frac{43200J}{93600J} \times 100\% = 46.15\%$$

7. Half of the gravitational energy of the steel (U = mgh) is converted to heat.

Q = ½ U, implies mcΔT =½mgh.

Simplifying this, yields

$$\Delta T = \frac{gh}{2c} = \frac{10m/s^2 \times 50m}{2 \times 448J/kg.°C} = \frac{1000J/kg}{896J/kg.°C} = 0.56°C$$

5.4. Thermal expansion

[4 periods]

After completing this section, you should be able to:

- *Solve problems associated with thermal expansion*

This section focuses on one of the primary effects of heating; namely, thermal expansion. Students learned about thermal expansion in their grade nine physics. The commonly observed phenomenon of heating is objects expand when heating and contract when cooling. The peculiarity of water around 4°C is that water expands when it loses heat and contracts when heat is added to it. Some applications of heating are discussed in this section as well. Reading through the minimum learning objectives with students is very crucial.

Teaching method

Let students try to answer brainstorming questions on Activity 5.7. Since these questions are not new to students, you may expect complete answers from them. Focus on concepts which are new to them.

Answers to Brainstorming Questions

Ask students but do not tell them answers immediately

1. To insert ball bearings into the outer metal ring, there are two options: heat up the

outer ring to expand until the ball is inserted in and cool down it or cool the ball bearings to contract until it is accommodated by the outer ring.

2. Gaps are made between metal slabs in rail ways. These gaps which are of the order of a few millimeters are provided to allow room for the rails to expand the rise in temperature due to the atmospheric temperature as well as the friction caused by running of train. When temperatures rise, steel tracks will expand, meaning they get longer. Heat-related expansion places a lot of stress on the ties, ballasts, and rail anchors that keep the tracks fixed to the ground.

Thermal expansion of materials with anisotropic structures

Students should aware beforehand that any object of any size undergoes volume/cubic thermal expansion for a given temperature change. However, since the change in size in thermal expansion is directly proportional to the original size, we can ignore changes on negligibly smaller dimensions and consider the dimension with significant initial size.

If a cube of original side length L_0, experiences a temperature change ΔT , the fractional change in:

- length, $\Delta L / L_0 = \alpha\Delta T$, α is the coefficient of linear expansion
- area, $\Delta A / A_0 = \Delta L^2 / L_0^2 = \beta\Delta T$, β is the coefficient of area expansion
- volume, $V / V_0 = \Delta L^3 / L_0^3 = \gamma\Delta T$, γ is the coefficient of volume xpansion.

Real and apparent expansion coefficients of liquids

The value we may find in direct measurement for the coefficient of volume expansion of a liquid is the apparent coefficient of volume expansion, γ_a . The real/actual coefficient of volume expansion, $_r$, of the liquid can be calculated by

$$\gamma_r = \gamma_a + \gamma_c$$

where γ_c is the coefficient of cubic expansion of the container.

The generalized approaches of thermal expansion

▷ All formula of thermal expansion discussed above, cannot be applied for gases since expansion of gases is also affected by pressure. Tell your students that there are other methods used for gases but do not go into the details.

▷ Consider also the following generalized rules.

  ▷ For isotropic materials, the cubic thermal expansion coefficient is twice the area coefficient and three times the linear coefficient of thermal expansion. $\gamma = 2\beta = 3\alpha$

  ▷ Materials with anisotropic structures, such as crystals and many composites, will generally have different linear expansion coefficients in different directions. As a result, the total volumetric expansion is distributed unequally among the three axes.

- ▷ Thermal expansion coefficients of solids usually show little dependence on temperature (except at very low temperatures) whereas liquids can expand at different rates at different temperatures.

Answers to Activity 5.7:

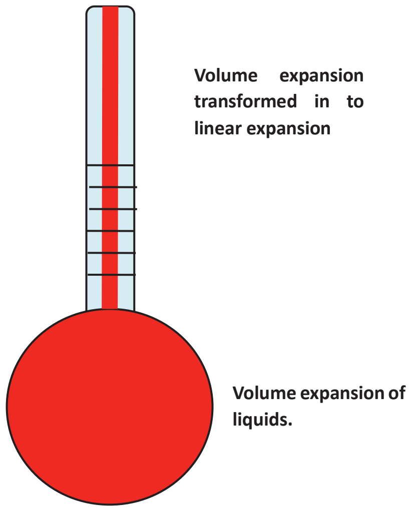
This activity is for Brainstorming before proceeding to applications of thermal expansion.

1. Encourage and help your students to discuss and present applications of thermal expansion in their locality. Let each group present its observations to the whole class. Note what they have provided, but do not go through the details at the instant the groups' presentations. Tell them that this is what you are going to deal next.

Students may mention the following examples. If not, discuss these with them.

- ▷ If you are unscrewing a stuck lid from a glass jar and found it difficult to open, pour some hot water on the lid of the glass jar. The heat will cause the lead of the pot to expand slightly, allowing it to open easily.
- ▷ When air is heated, it expands and becomes less dense than the surrounding air, which employs an upward force on the hot air, causing steam and smoke to rise and hot air balloons to float. Liquid in a container closed with lid, expands when heated and pushes the lid upwards.
- ▷ Liquid expands on heating and can be made to rise into a tube. The expansion of a liquid, for instance, mercury, is used by thermometers to measure temperature using a calibrated scale.
- ▷ Railroad tracks and bridges have expansion joints that allow them to expand and contract freely in response to temperature changes. Gaps get narrowed during hot days and get wider during cold days.
- ▷ Doors resist opening during cold seasons; and so on.

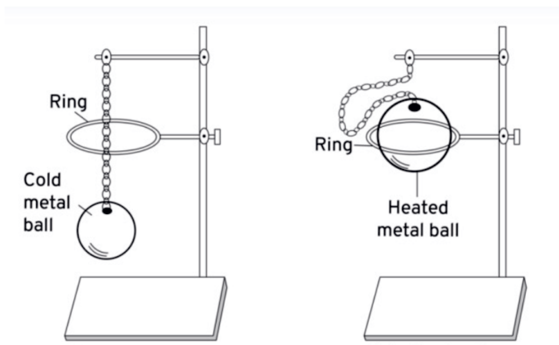
2. Most substances expand linearly of volume wise when heat is supplied to them. This property of the material can be skillfully utilized to measure the temperature of the substance. If a liquid substance such as mercury or alcohol expands in volume, we can transform the volume expansion of the alcohol to linear expansion, as shown in the figure, since only one dimensional expansion is enough to measure temperature.



3. The third question deals with two demonstrations.

   (a) In the first activity,

- ▷ Take an iron ball and an iron ring such that the ball can just pass through the ring.
- ▷ Take a metal stand with a hook and a burner. Suspend the ball by a chain from the hook. Heat the ball and try to pass through the ring. Now cool it and try again.



(a) Before heating at room temperature
(b) after heating

Observation and conclusion:

- ▷ When the ball is heated it doesn't pass through the ring due to the thermal expansion of the ball. But when it is cooled, it regains its original size and easily passes through it. This shows solids expand on heating and contract in cooling.

   (b) If a balloon is tied at its neck at normal temperature and is placed on hot water, it will certainly expand and when it is cooled, it will be as it was before showing that gases expand on heating and contract on cooling.

Answers to Review Questions/5.4:

1. When you heat around the steel cork, it expands faster than glass since its coefficient of thermal expansion exceeds that of glass. Heating helps to open it easily.
2. Heating a thin, circular ring make it wider.
3. **Given:** $\alpha_{st} = 11\times10^{-6}{}^\circ C^{-1}$, $L_0 = 60$ m, $T_0 = 0.0°C$, $T = 40.0°C$

   The final length is

   $$L = L_0(1+\alpha_{st}\Delta T) = 60\text{m}\times(1+11\times10^{-6}{}^\circ C^{-1}\times 40°C)$$
   $$L = 60.0264\,\text{m}$$
4. If glass were to expand more than the liquid, the liquid level would fall relative to the tube wall as the thermometer is warmed. If the liquid and the tube material were to expand by equal amounts, the thermometer could not be used because the liquid level would not change with temperature.
5. Mercury is used in thermometers because it has a high coefficient of expansion compared to that of the glass so that even a small rise in temperature brings about sufficient expansion which can be detected in the capillary of the calibrated part of the thermometer.
6. Since rings get wider on heating, the ring gets wider on heating and allows the ball to pass through. When cooled, the ring gets contracted and does not allow the ball to pass through.
7. **Given:** $d_p = 10$ cm, $d_s = 9.9$ cm, $\alpha = 11\times10^{-6}\ {}^\circ C^{-1}$

Change in temperature, ΔT, to increase the diameter of the steel cylinder to d_p is derived from $d_p = d_s(1+\alpha_s\Delta T)$ to be

$$\Delta T = \frac{d_p - d_s}{\alpha_s d_s} = \frac{10\text{ cm} - 9.9\text{ cm}}{11\times10^{-6}{}^\circ C^{-1}\times 9.9\text{ cm}} = 91.83\,°C$$

Therefore, the desired change in temperature should be

$$\Delta T \geq 91.83°C$$

8. **Given:** $V_0 = 300$ L, $\gamma_a = \gamma_{r,ethyl} - \gamma_{steel} = 107.8\times10^{-5}\,{}^O C$, $T_0 = 10°C$, $T = 100$ °C.

The Ethyl alcohol that over flows if the system is heated to 100 °C, is

$$\Delta V = V_0\gamma_a\Delta T = 300L\times107.8\times\ 10^{-5}\,°C^{-1}\times\left(100°C^{-1} - 10°C^{-1}\right) = 29.106L$$

The ethyl alcohol overflown is 29.106L.

9. **Given**: $L_0 = 40.0cm$, $T_0 = 0°C$, $T = 100\ °C$, $\Delta L_1 = 0.08cm$, $\Delta L_2 = 0.05cm$, $\Delta L_3 = 0.06cm$

The change in length of the composite bar is

$$\Delta L_3 = \left[\alpha_1 x + \alpha_2\left(L_0 - x\right)\right]\Delta T$$

Solving this for x, we obtain

$$x = \frac{\Delta L_3 - \alpha_2 L_0\Delta T}{\left(\alpha_1 - \alpha_2\right)\Delta T}$$

But $\alpha_1 = \frac{\Delta L_1}{L_0\Delta T}$ and $\alpha_2 = \frac{\Delta L_2}{L_0\Delta T}$. Substituting these into the above and simplifying yields

$$x = \left(\frac{\Delta L_3 - \Delta L_2}{\Delta L_1 - \Delta L_2}\right)L_0 = \left(\frac{0.06cm - 0.05cm}{0.08cm - 0.05cm}\right)\times 40.0cm = 13.3cm$$

And the length of the second bar is $L_0 - x = 40.0cm - 13.3cm = 26.7cm$

10. **Given**: $\Delta T = 5\ °C$, $d_0 = 12{,}742\ km$, $\alpha = 1.2\times10^{-5}\,°C^{-1}$

The change in diameter is

$$\Delta d = \alpha d_0\,\Delta T = 1.2\times10^{-5}\,°C^{-1}\times12{,}742km\times5°C = 0.76452km$$

The all round clearance between the hoop and the earth's surface becomes

$$\Delta r = \frac{1}{2}\Delta d = 0.38226km = 38.226cm$$

11. The new length, L, is

$$L = 3L_0 + (2\alpha_b + \alpha_s)(L_0\Delta T)$$
$$L = [3 + (2\alpha_b + \alpha_s)T]\,L_0$$

12. $L_{0s} - L_{0Cu} = 0.05\ cm$, $T_0 = 0°C$

The temperature, T, at which $L_s = L_{Cu}$, is obtained as follows.

$$L_{0Cu}\left[1 + \alpha_{Cu}\left(T - T_0\right)\right] = L_{0s}\left[1 + \alpha_s\left(T - T_0\right)\right]$$

But $L_{0s} = L_{0Cu} + 0.05cm$, then

$$L_{0Cu}\left[1 + \alpha_{Cu}\left(T - T_0\right)\right] = \left(L_{0Cu} + 0.05cm\right)\left[1 + \alpha_s\left(T - T_0\right)\right]$$

$$L_{0Cu}\left(1+\alpha_{Cu}T\right)=\left(L_{0Cu}+0.05cm\right)\left(1+\alpha_{s}T\right)$$

$$T=\frac{0.05cm}{100cm\times\left(17\times10^{-6}{}^{\circ}C^{-1}-11\times10^{-6}{}^{\circ}C^{-1}\right)-11\times10^{-6}{}^{\circ}C^{-1}\times0.05cm}$$

$$T=83.41^{\circ}C$$

13. **Given:** $A_0 = 0.05\ m^2$, $\alpha = 9 \times 10^{-6}\ {}^{\circ}C^{-1}$, $\Delta T = 96\ {}^{\circ}C$

$$\Delta A=\beta\ A_0\ \Delta T=2\alpha\ A_0\Delta T$$

$$\Delta A=2\times9\ x\ 10^{-6}{}^{\circ}C^{-1}\times0.05\ m^2\times96^{\circ}C=0.864cm^2$$

14. $\Delta V = \gamma V_0 \Delta T = 2.1 \times 10^{-4}\ {}^{\circ}C^{-1} \times 1.0\ m^3 \times 80^{\circ}C$

$\Delta V = 0.0168 m^3$

5.5. Change of phase

[4 periods]

After completing this section, you should be able to:

- *Discuss the phenomena of change of phase*

Students have learnt about heat, internal energy, and thermodynamic work. They have also learnt about effects of heating on objects. All these are prerequisite knowledge for this lesson. Peculiarity of thermal expansion of water is treated slightly under the topic thermal expansion. It is very basic concept to start your lesson in this section.

Teaching method

Here the brainstorming questions, in Activity 5.8, are related to the subject matter of this topic. You will start this topic by asking these questions but you will not give the answers immediately. Tell them that they will learn the details of these step by step as you go down this section. This will help them to have clues what they are going to learn and it will also help you to know their prior knowledge on the topic.

Answers to Brainstorming Questions

When heat is removed or supplied to a substance, it may cause either of two things: change in temperature or change in internal energy. When internal energy is changed as heat is supplied the substance undergoes phase change. At phase change the heat supplied is used to change the molecular structure to break the bonds between molecules keeping the temperature constant. There is no change in temperature during phase transitions; namely, melting/solidifying, and evaporation/condensation.

Latent heat

The energy, Q, absorbed or released by a substance of mass m, during a change in its physical state (phase) that occurs without changing its temperature is called latent heat, L, and is given mathematically by

$$Q = mL$$

Use $L = L_f$ for heat of fusion and $L = L_v$ for heat of vaporization. Its SI unit is joule per kilogram (J/kg). Latent heat depends on the nature of the phase change as well as on the properties of the substance.

The phase diagram

Phase diagram is a graphical representation of the physical states of a substance under different conditions of temperature and pressure. The commonly known phase diagram has pressure on the y-axis and temperature on the x-axis, as shown in the student's textbook.

The two important points on the phase diagram to be given emphasis in this section are the triple point and the critical point.

The triple point: The triple point is a point at which the three lines on the pressure-temperature graph converge, offering an equilibrium state where all the three phases of solid, liquid and gas exist simultaneously. For example, the single combination of pressure and temperature at which liquid water, solid ice, and water vapor can coexist in a stable equilibrium occurs at exactly 273.1600 K and a partial vapor pressure of 611.657 Pa.

Critical point (or, critical state): The critical point occurs where the critical temperature and critical pressure of a substance meet. Above this point clear phase boundaries cease to exist. For water the critical point is around 647 K and 22 MPa. The properties of the gas and liquid phases merge together giving only one phase at the critical point. Beyond the temperature of the critical point, the merged single phase is known as a supercritical fluid. Above the critical temperature it is not possible to form a liquid, regardless of any increase in pressure.

Uniqueness of the phase diagram for water

In the phase diagram of water, the slope of the line between the solid and liquid states is negative rather than positive as is in the case of the general phase diagram. The reason is related to the unusual thermal expansion of water around 4°C. Therefore, a pressure change has the opposite effect on those two phases.

Answers to Review Questions/5.5:

1. The melting point of ice decreases when pressure increases because when pressure is increased volume is decreased and the volume of water is less than ice. So it will be easier to change the state from solid to liquid, and therefore, the melting point decreases.
2. The critical temperature of a substance is the temperature at and above which vapor of the substance cannot be liquefied, no matter how much pressure is applied. Each substance has a single critical temperature. Critical temperature is different from boiling point. Unlike critical temperature, boiling point changes with changing pressure.
3. The boiling point increases with increased pressure up to the critical point, where the gas and liquid properties become identical. The boiling point cannot be increased beyond the critical point.
4. Boiling point is different from temperature at triple point.

Substance	Triple point temperature (°C)	P (kPa)	Boiling point at SP (°C)
Mercury	−39.0	1.65×10^{-7}	356.7
Water	0.01	0.6117	0.0
Zinc	419.50	0.065	907
CO_2	−56.60	517	−70

5. The critical temperature of water is 373.85 °C which is less than 374°C. Therefore, water cannot liquefy at and above 374°C.
6. **Given**: m = 10 g = 0.01kg, $L_{f,\,Cu}$ = 209000 J/kg

   $Q = mL_f = 0.01\text{kg}\times 209000\text{ J/kg} = 2090\text{ J}$
7. **Given**: m = 0.1kg, $L_{f,Al}$ = 376000 J/kg, $L_{v,Al}$ = 11,370 J/kg, c_{Al} =900 J/kg.°C , ΔT = 660.3 °C - 2,470 °C = -1809.7°C

   $Q = m\,L_{v,Al} + m\,c_{Al}\,\Delta T + m\,L_{f,Al}$
   Q =0.1kg×[-11,370 J/kg + 900 J/kg.°C ×(-1809.7°C) - 376000 J/kg]
   Q = -201610 J, the negative sign indicates heat released not added.
8. The diagram showing the phase diagram of CO_2 is given in students textbook.

   (a) The solid, liquid and vapor phases of CO_2 coexist in equilibrium at -56.7°C temperature and 5.1 atm pressure, which is the triple point.
   (b) The triple point of CO_2 is (5.1 atm, 56.7° C) means that liquid CO_2 cannot exist at pressures lower than 5.11 atm. Therefore, at 1 atm, solid CO_2 sublimes directly to the vapor while maintaining a temperature of −78.5°C, the normal sublimation temperature.
   (c) Carbon dioxide is a popular supercritical fluid and has a critical temperature

of 31.1° C and a critical pressure of 73.8 bars.

9. The freezing point of water at 1 atm is 0 °C. The phase of water at 1 atm and 0.01 °C is then solid. At 611.657 Pa pressure and 0.01°C temperature, water exists as solid (ice), liquid (water), and gas (water vapour). This is the triple point of water.

5.6. Calorimetry

[4 periods]

After completing this section, you should be able to:

- *Solve problems associated with Calorimetry*
- *Investigate a phenomena related with heat capacity from every day experience.*

Up to now, students have learnt the different quantities that are related to the different thermal properties of matter such as specific heat capacity and specific latent heat. Now this is time to deal with measurement techniques of these quantities.

Teaching method

Start this lesson by asking students about heat capacity, specific heat capacity and latent heats of substances since these are prerequisite knowledge for this topic. Give some time for students to discus on measurement techniques of these quantities, based on Activity 5.10. Then proceed the lesson by defining calorimetry as Calorimetry is the measurement of the quantity of heat exchanged between substances. Or, calorimetry is the experimental approach of measuring heat capacities and the heat changes during chemical and physical processes. A calorimeter is a device used to measure specific heat capacity and specific latent heat of solids or liquids.

Measuring specific heat capacity

Although there are different methods to determine specific heat capacity, all these methods involve values of mass of the substance, amount of heat supplied, starting temperature, and final temperature. The principle applied involve the principle of calorimetry

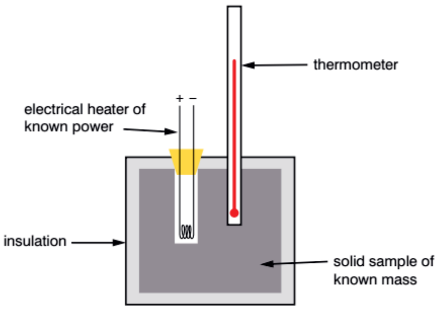
Heat gained by cold object = Heat lost by hot object, or $Q_{gain} = -Q_{lost}$

- To measure specific heat capacity, c_s, of a solid by electrical heating method (See figure a), record the rate of heat supplied, P, the time, t, the current is supplied, the mass of the solid, m_s, and the change in temperature, ΔT. Then, c_s, is calculated by

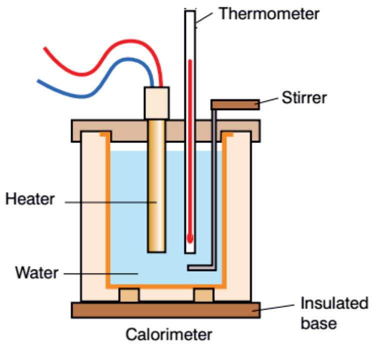
$$c_s = \frac{Pt}{m_s \Delta T}$$

▷ To measure specific heat capacity, c_L, of a liquid by electrical heating method (See figure b), record specific heat capacity, c_c, and mass m_c of the calorimeter, mass of the liquid, m_L. Then, c_L is calculated by

$$c_L = \frac{1}{m_L}\left(\frac{Pt}{\Delta T} - m_c c_c\right)$$



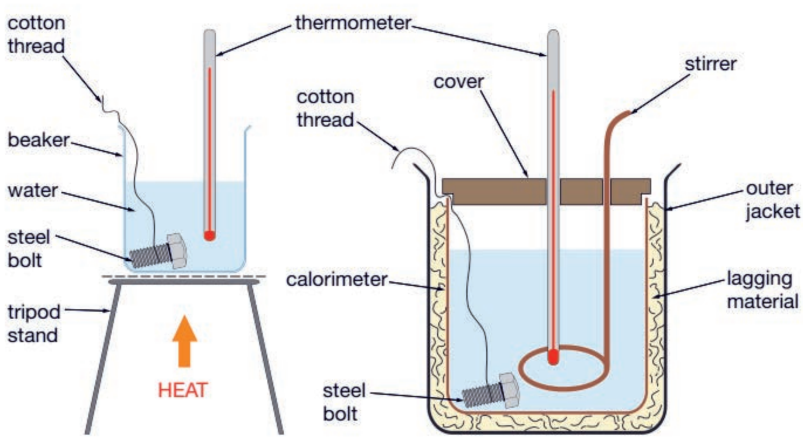
(a) Electrical heating method to measure specific heat capacity of a solid



(b) Electrical heating to measure specific heat capacity of a liquid

▷ To measure the specific heat capacity of a solid and a liquid by mixture method (See the figure below for c of solid), the solid of known mass, m_s, is heated in a water bath to a temperature of T_h. It is then quickly transferred to the cold water of known mass, m_w, in the calorimeter. If temperature at thermal equilibrium is T_f, then c_s is

$$c_s = \left(\frac{m_w c_w + m_c c_c}{m_s}\right)\left(\frac{T_f - T_c}{T_h - T_f}\right)$$



Answer to Activity 5.3:

Students are asked to discuss uses of specific heat in their daily life in groups and share to the class. In this activity, ask them whether they have encountered uses of specific heat mentioned in their physics textbook. Then, help them to share others which are not mentioned there.

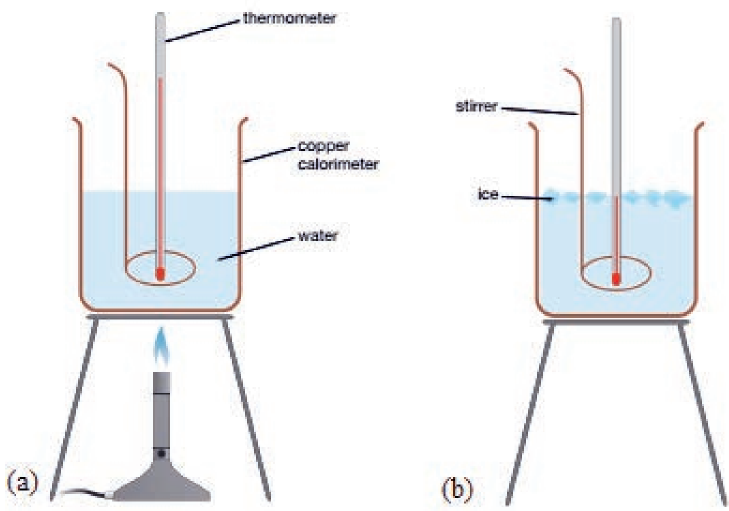
Measuring specific latent heat

Devices used in determining the specific heat can also be used to measure the specific latent heats.

Answer to Activity 5.4: Experiments

Demonstrate an experiment using any device you have in your school. Determine the amount of heat required to convert a 1kg of ice at 0°C to water at 0°C.

You can use the apparatus in the figure below if there is in your school. This method is in use to determine the specific latent heat of fusion, L_f , of ice by mixture method. The copper calorimeter and stirrer is weighed before being half filled with water. The mass of the water present in the calorimeter is then determined before the water is heated to at least 10 °C above room temperature. Small quantities of ice are then added to the water, while stirring, until the temperature is below room temperature and all the ice has melted. The mass of the calorimeter, stirrer and water is then determined to find out the mass of ice added.



We will use the principle here that the heat energy lost from the water and the calorimeter will go to warming and melting the ice and then warming the cold water produced when the ice melts.

Heat absorbed by ice and cold water = Heat liberated from calorimeter/stirrer and water

$$m_i L_i + m_i c_i (T_f - T_{0i}) = m_{hw} c_w (T_{0w} - T_f) + m_c c_c (T_{0w} - T_f)$$

After some rearrangements, we have

$$L_i = \frac{(m_{hw} c_w + m_c c_c)(T_{0w} - T_f)}{m_i} - c_i (T_f - T_{0i})$$

Answer to Review Questions 5.6:

The heat required to convert 1kg of water from ice to water is its latent heat of fusion, Lf.

1. **Given**: $m_m = 1.0$ kg, $T_m = 400.0°C$, $m_w = 2.0$ kg, $T_w = 15.0°C$, $T = 20.8°C$

   From the calorimetry principle,

   $$-Q_{lost} = Q_{gain}$$

   $$-m_m c_m (T - T_m) = m_w c_w (T - T_w)$$

   $$c_m = \frac{m_w c_w (T - T_w)}{m_m (T_m - T)}$$

   $$c_m = \frac{2kg \times 4186J/kg.°C \times (20.8°C - 15°C)}{1kg \times (400°C - 20.8°C)} = 128.05J/kg.°C$$

   From the table of specific heat capacity, we can see that the type of the metal is lead.

2. **Given**: $m_c = 250\text{ g} = 0.25kg$, $m_w = 200\text{ g} = 0.2kg$, P = 1000 W, t = 5 min=300s, T = 80°C, $T_w = 20$ °C

   We use the principle of calorimetry,

   $$Pt = m_c c_c (T - T_w) + m_w c_w (T - T_m)$$

   $$c_c = \frac{1}{m_c}\left(\frac{Pt}{T - T_w} - m_w c_w\right)$$

   $$c_s = 0.25kg \times \left(\frac{1000w \times 300s}{80°C - 20°C} - 0.2kg \times 4186J/kg.°C\right)$$

   $$c_s = 16651.2J/kg.°C$$

3. Given: $m_m = 0.25\text{ kg}$, $T_m = 200°C$, $m_c = 0.02\text{ kg}$, $V_w = 150\text{ cm}^3$, $T_w = 25°C$, $T = 40°C$

$$-m_m c_m (T - T_m) = m_c c_c (T - T_w) + m_w c_w (T - T_w)$$

Mass of water, $m_w = \rho_w V_w = 1g/cm^3 \times 150cm^3 = 150g = 0.15kg$, then

$$c_m = \frac{(m_c c_c + m_w c_w)(T - T_w)}{m_m (T_m - T)}$$

$$c_m = \frac{(0.02kg \times 385J/kg.°C + 0.15kg \times 4186J/kg.°C)(40°C - 25°C)}{0.25kg \times (200°C - 40°C)}$$

$$c_m = 238.35J/kg.°C$$

If some heat is lost to the surroundings, then the value of specific heat capacity will be less than the actual value.

4. **Given:** $m_{Cu} = 20\text{ kg}$, $T_{Cu} = 500°C$, $L_{f,w} = 3.33 \times 10^5 J/kg$

$$m_i L_i = m_{Cu} c_{Cu} (T_{Cu} - T)$$

$$m_i = \frac{m_{Cu} c_{Cu} (T_{Cu} - T)}{L_i} = \frac{20kg \times 385J/kg.°C \times (500°C - 0°C)}{3.33 \times 10^5 J/kg}$$

$$m_i = 115.62kg$$

Unit summary

- Heat is energy in transit due to temperature differences.
- Two objects are said to be in thermal equilibrium if they are equal in temperature. Two or more objects, which are in thermal equilibrium, do not exchange heat energy.
- Internal energy of a system or a body with well defined boundaries is the total of the kinetic energy due to the motion of molecules and the potential energy associated with the vibrational motion and electric energy of atoms within molecules. It includes the energy in all the chemical bonds. Internal energy increases with rising temperature and with changes of state or phase from solid to liquid and liquid to gas.
- Heat and work are two different ways of transferring energy from one system to another. Heat is the transfer of thermal energy between systems, while work is the transfer of mechanical energy between two systems. Heat can be transformed into work and vice verse, but they aren't the same thing. Heat and work both contribute to the total internal energy of a system.
- Conduction is the process by which heat energy is transmitted through collisions between neighboring atoms or molecules.
- Convection (or convective heat transfer) is the transfer of heat from one place to another due to the movement of fluid.

- Radiation heat transfer occurs via electromagnetic waves. Unlike conduction and convection, radiation does not need a medium for transmission.
- Heat capacity , C, is the amount of heat, Q, required to raise the temperature of an object by 1 °C . The SI unit of C is joule per kelvin (J/K); you know that 1 J/K=1J/°C).

$$C = Q / \Delta T$$

- Specific heat capacity, c, is energy required to change the temperature of a unit mass of a substance by 1° C. The SI unit of specific heat capacity is J/kg.°C, or J/kg.K.

$$c = \frac{C}{m} = \frac{Q}{m\Delta T}$$

- When an object experiences a change in temperature ΔT ,
  - the fractional change in length, $\Delta L / L_0 = \alpha\Delta T$, where α is the coefficient of linear expansion of the material, and L_0 is original length.
  - the fractional change in area, $\Delta A / A_0 = \beta\Delta T$, where β is the coefficient of area expansion and A_0 is original area.
  - the fractional change in volume, $\Delta V / V_0 = \gamma\Delta T$, where γ is the coefficient of volume/cubic expansion and V_0 is original volume.

where $\gamma = 2\beta = 3\alpha$ is the volume coefficient of thermal expansion, with a unit of $^0C^{-1}$.

- The real value of coefficient of volume expansion, γ_r , of a liquid is given by

$$\tilde{a}_r = \tilde{a}_a + \tilde{a}_c$$

where γ_a is the apparent value and γ_c is cubic expansion coefficient of container.

- Latent heat of an object of mass, m, is given mathematically by

$$Q = mL$$

where L is called the latent heat of the substance; i.e., $L = L_f$ for heat of fusion and $L = L_v$ for heat of vaporization. Its SI unit is joule per kilogram (J/kg).

- Latent heat depends on the nature of the phase change as well as on the properties of the substance.
- Latent heat of fusion is the amount of heat absorbed to convert a unit mass of a substance from solid to liquid - leaving the temperature of the system unaltered.
- Latent heat of vaporization is the amount of heat absorbed to change a unit mass of liquid to gas.
- The triple point represents the combination of pressure and temperature that facilitates all phases of matter at equilibrium.
- Critical Point is the point in temperature and pressure on a phase diagram where the liquid and gaseous phases of a substance merge together into a single phase.
- The law of calorimetry states that for an isolated system, the heat energy lost from the hot body will equal the heat gained by the cold body.

Heat gained by cold object = Heat lost by hot object

Answers to End of unit questions 5

1. For net heat flow, there must be a temperature difference between two places or between the two ends of the material. It is not necessary to have a heat-conducting material for heat transfer.
2. Net heat flow from one object to another object stops when the two objects attain thermal equilibrium. At thermal equilibrium, two objects may exchange energy, but net heat flow is zero.
3. Spontaneously heat flows towards the cooler region.
4. Whenever a body absorbs heat, it becomes hotter, and when it releases heat, it becomes colder provided that no phase change takes place. When a body absorbs heat, the average kinetic energy of its particles rises, by then causing the body's temperature to rise. If no phase shift occurs, the heat provided to a body is exactly proportional to its temperature change. That is, heat (Q) = mass (m) × specific heat capacity (c) × change in temperature (ΔT). If the potential energy in the gas is neglected (the gas is assumed to be ideal gas), its internal energy depends only on temperature.
5. Temperature is proportional to the average kinetic energy of atoms and molecules in a substance. Internal energy of a system or a body with well defined boundaries is the sum of the total kinetic energy of its molecules and the total intermolecular potential energy. Therefore, increasing temperature or average molecular kinetic energy keeping intermolecular potential energy constant increases the internal energy of the system.
6. Heat is the energy in transit whenever temperature differences exist. The internal energy is equal to the sum of internal kinetic energy due to molecular motion and internal potential energy due to molecular attractive forces. A hot body has more internal energy than an identical cold body. When heat is supplied to an inflated balloon, the balloon expands by then doing work on the surrounding and the gas in the balloon gets hotter by then increasing the internal energy.
7. The three heat transfer mechanisms:

- ▷ Conduction heat transfer is the transfer of heat through matter (i.e., solids, liquids, or gases) by collisions between particles of the medium but without molecular drift or without bulk motion of the medium. On the other hand, heat transfer in solids is due to the combination of lattice vibrations of the molecules and the energy transport by free electrons.
- ▷ Convection heat transfer occurs partly due to molecular movement and partly as a result of mass transfer.
- ▷ Radiation is the method of transferring heat from one body to another without engaging the medium's molecules. Radiation heat transfer does not rely on the medium.

The general mode of heat transfer in solids, in liquids and gases:

- ▷ The general mode of heat transfer in solids is conduction.
- ▷ The general mode of heat transfer in liquids and gases is convection.

8. The ambient temperature is uniform on the cylinder's periphery, and the temperature is uniform. As a result, it only happens in the radial direction.
9. The boiling point of water can be changed in several ways such as by adding solutes such as sugar, salt and other non-volatile solutes. The important factor which changes the boiling point of water, and is the primary focus of this topic is that the boiling point of water or any fluid can be changed by changing the pressure.

10. Given: $T_0 = 20.0^oC$, $A_0 = 100.0cm \times 50.0cm = 5000.0cm^2$, $\alpha = 11\times10^{-6}\,{}^oC^{-1}$, $T = 100.0^oC$

Change in area

$$\Delta A = A_0\alpha\Delta T = 5000.0cm^2 \times 11\times10^{-6}\,{}^oC^{-1} \times \left(100.0^oC - 20.0^oC\right) = 4.4cm^2$$

Area at $T = 100.0^oC$,

$$A = A_0 + A_0\alpha\Delta T = 5000.0cm^2 + 4.4cm^2 = 5004.4cm^2$$

11. Given: $\Delta T = 10.0°C$, $Q = 9000$ J, $m = 1000$ g=1kg

The specific heat capacity of the metal, c, can be calculated from $Q = mc\Delta T$, as

$$c = \frac{Q}{m\Delta T} = \frac{9000J}{1kg\times10.0°C} = 900J/kg.°C;$$

The metal is Aluminium.

12. Thermal energy is part of internal energy, but not internal energy. The thermal energy of a system is the average kinetic energy of the system's constituent particles due to their motion.
13. A phase diagram is a graphical representation of the phases present in the system of materials at various temperatures, and pressures. It can be used to determine the melting temperature of various phases, the range of solidification, and so on.
14. At 374°C, particles of water in the gas phase are moving very, very rapidly. At any temperature higher than that, the gas phase cannot be made to liquefy, no matter how much pressure is applied to the gas. The critical pressure (P_c) is the pressure that must be applied to the gas at the critical temperature in order to turn it into a liquid. For water, the critical pressure is very high, 217.7 atm. The critical point is the intersection point of the critical temperature and the critical pressure.

15. Given: $m_m = 200\ g = 0.2kg$, $T_0 = 20°C$, T = 105 °C, P= 20W, t = 100s

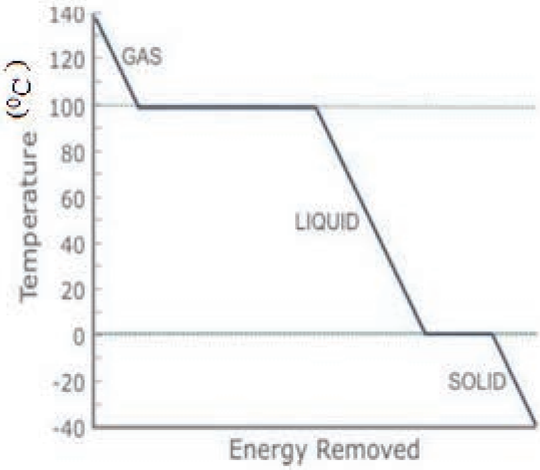
Use the principle of calorimetry,

$$Pt = m_m c_m \left(T - T_0\right)$$

After some rearrangements, we obtain

$$c_m = \frac{Pt}{m_m\left(T - T_0\right)} = \frac{20W\times100s}{0.2kg\times\left(105°C - 20°C\right)} = 11.76\ J/kg.°C$$

16. The cooling curve for water is given below.



17. Given: $m_s = 0.5kg$, $T_s = 100.0°C$, $m_c = 0.2kg$, $T_w = 30.0°C$, $T = 80.0°C$,
$c_w = 4200.0J/kg.K$, $c_{Cu} = c_c = 420.0\,J/kg.K$, $L_{v,w} = 2.26 \times 10^6 J/kg$

- ▷ Fall in temperature of steam: $T_s - T = -\Delta T_s = 100.0°C - 80.0°C = 20.0°C$
- ▷ Rise in temperature of water + calorimetry: $T - T_w = 80.0°C - 30.0°C = 50.0°C$
- ▷ Heat lost by steam:

$$Q_s = m_s L_{v,w} + m_s c_w (T_s - T)$$
$$Q_s = 0.5kg \times 2.26 \times 10^6 J/kg + 0.5kg \times 4200.0J/kg.°C \times 20°C$$
$$Q_s = 1.172 \times 10^6 \ J$$

- ▷ Heat gained by water + calorimeter:

$$Q_{w+c} = m_c c_c \Delta T_w + m_w c_w \Delta T_w$$
$$Q_{w+c} = 0.2kg \times 420.0J/kg.°C \times 50.0°C + m_w \times 4200.0J/kg.°C \times 50.0°C$$
$$Q_{w+c} = 4200.0J + 210000.0J/kg \times m_w$$

- ▷ We know heat lost by steam is equal to heat gained by water and calorimetry. Substituting values in to $Q_s = Q_{w+c}$ and solving for m_w, we obtain

$$m_w = 5.56kg$$

Unit Six

Electric Current and Circuits

This unit should be completed approximately in 15 periods.

Introduction to the unit

This unit comprises of six sub units. Like the previous units, each sub unit is started by brain storming questions. These questions help students to recall knowledges from previous grades that are related to the topics followed. Activities, examples, and exercises are included in each sub unit. At the end of each sub unit there is a review questions and finally the unit will end by a unit summary and the usual end-of-unit exercises.

Learning outcomes

Students will be able to:

- *Calculate the electric field resulting from a point charge.*
- *Determine the magnitude and direction of the electric force among any point charges.*
- *Acquire knowledge and understanding in electrostatic phenomenon*
- *Demonstrate an understanding of the components and functions of electrical circuits that are commonly found at home and in the workplace*
- *Construct, analyze, simple electrical circuits, using schematic diagrams, working with electrical tools and components, and examining small everyday electrical devices and appliances*
- *Define a capacitor and explain some of its applications in life.*
- *Apply Kirchhoff's rules to solve circuit problems.*

Learning and teaching strategies

As usual start the lesson by introducing the brainstorming questions. These questions help students to recall previous knowledge related to the topics that are going to be discussed. It can be done in group or individually. Brainstorming allows students to think critically about ideas and solutions, and share ideas with peers. It is a means to gather as many ideas as possible and expand on them at a later time.

Examples, activities, exercises and notes are included in this topic.

- ▷ The examples are prepared to help learners to fulfil educational objectives in the teaching-learning process.
- ▷ The activities are designed in such a way that students develop a skill in learning collaboratively. Hands on activities (experiments) are also included in the activities. So, try to guide students so that the expected result is achieved. The constructivist view of knowledge acquisition holds that learning is a process of connecting new knowledge to existing knowledge, involving active engagement of the learner's mind.
- ▷ The exercises are prepared for the students to practice problem solving and check themselves whether they understood that topic or not and their problem-solving ability of students.

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
- ▷ Field work
- ▷ Research
- ▷ Use of analogies, and examples
- ▷ Group work
- ▷ Cooperative learning
- ▷ Use of charts
- ▷ Mind Maps or Concept Maps
- ▷ Models

The role of the teacher should be to guide learners in constructing their own knowledge. The teacher must select and develop appropriate teaching materials like models, charts, ICT, and 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. Attention should also be paid to developing learner's affective and psychomotor skills.

- ▷ Electrostatics is fundamental to any study of electrical phenomena. Experiments and demonstrations are extremely important due to the abstract nature of the discussions.
- ▷ Let the students investigate the nature of electric field lines between two similar and opposite charges.
- ▷ To explain the nature of electric fields, first review the fundamentals of the electrostatic force and state- Coulomb's law. Explain how charges establish electric fields around themselves.

- ▷ Experiments recommended in this unit can be performed by the students themselves.
    - ▷ I-V characteristics (Ohm's law) for a given unknown resistance (e.g. 100cm constant wire), plotting a graph of potential difference versus current. From the slope of the graph and the length of the wire, calculate the resistance per cm of the wire.
    - ▷ Verification of the laws of combination of resistance
    - ▷ Determination of internal resistance of a cell using potentiometer
    - ▷ Finding an unknown resistance by the use of Wheatstone's bridge.
- ▷ Demonstrations
    - ▷ Compare the emf of two cells using a potentiometer.
    - ▷ Variation in potential drop with length of wire for constant current.
- ▷ Explain Kirchhoff's two powerful rules that aid in the analysis of circuits. First discuss his loop rule. Show how to apply Kirchhoff's loop rule to some more complicated circuits. Clarify Kirchhoff's junction rule by stating it in simple words as current in equals current out. Highlight that Kirchhoff's rule is an implication of the principle of conservation of charge, which states that charge is neither created nor destroyed. The amount of charge flowing in equals the amount of charge flowing out. With the help of the teacher, let students practice using Galvanometer, Ammeter, and voltmeter. Conversion of galvanometer to Ammeter and Voltmeter can also be practiced by the students.
- ▷ Demonstration; 1. Solve simple circuit, and then show by measuring currents and voltages with digital meters that theoretical values are confirmed. Discuss errors in measurement and meter errors and their propagation through calculation
- ▷ Given circuit diagram, let students rank the bulbs in the circuit according to brightness when the switch is open, when the switch is closed. They should also explain their reasoning. 3. Let students state whether the bulbs in the given circuits are arranged in series, parallel, or neither, for each possible combination of switch positions.
- ▷ Take apart a commercial capacitor (can be obtained from thrown away electronic gadgets like radio receiver) to show its metal and plastic foils
- ▷ Project work: Determination of the resistance of a given resistor using color coding.

Assessment

Since our curriculum is competence-based, our 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 (it comprises of knowledge, skills, competences and attitudes).

In order to check whether the student has acquired the minimum competency required, each student should be assessed continuously over the whole unit and compare it with the competencies.

The teacher must devise remedial strategies in and outside the classroom to assist low achievers and those with learning difficulties, in order to ensure they keep pace with other learners in acquiring the required competences. Assisting the low achievers (students achieving below the minimum competence level) and praising the high achievers (students achieving above the minimum competence level) is very important. In this way, the low achievers are assisted to attain the minimum competency level and the high achievers will be motivated for further high-level achievement.

6.1. Coulomb's Law

(2 periods)

By the end of this section, you will be able to:

- *State Coulomb's law.*
- *Calculate the magnitude and direction of electric force between any two charges.*
- *Solve problems involving Coulomb's law.*
- *Explain Coulomb's law using the idea of vectors.*
- *Explain the meaning of a coulomb.*

In this section Coulomb's law is first defined and discussed. Then, using the concept of vector addition, the net electric force on a charged particle due to two or more charges will be discussed (the superposition principle). For this reason, examples, exercises, and activities are widely used.

Teaching Aids

The following teaching aids are required in this section:

- Flash Cards, Slides, Charts, Pictures, Maps, Bulletin Boards, Models, Computer set, Projectors, Printed materials , Internet , Electroscopes, Van de Graff generator, ebonite rods, glass rods, treads, and silk.

Suggested methodology

Use good teaching methods that will keep learners motivated and engaged throughout the lesson. We suggest the following as a teaching/learning methodology.

▷ Experiments,
▷ Demonstration activities.
▷ Group discussion and presentation,
▷ Question and answer with immediate feedback,
▷ Solving problems in pairs or in groups,

- ▷ Field trip
- ▷ Group works.

Answer to activity 6.1:

Discuss in pair about the following questions. Present what you have agreed in your group to the class.

1. Nothing will happen if electrons were positively charged and protons negatively charged. Opposite charges would still attract, and like charges would repel. The naming of positive and negative charge is merely a convention.
2. Earth is electrically neutral but the crust is negatively charged and interior of Earth is positively charged. Since the charges are exactly equal and opposite, according to the charge-neutrality principle, the electric charge of the whole Earth is zero.
3. Any charged object - whether positively charged or negatively charged - will have an attractive interaction with a neutral object. Positively charged objects and neutral objects attract each other; and negatively charged objects and neutral objects attract each other.
4. Can positive charges move and create electric current electrostatically? Only the negative charges (electrons) move through a wire. But you can have a buildup of either negative charges or positive charges in an object, and then that object is electrically charged.

Answer to Exercise 6.1

(a) (a) $n=\frac{q}{e}=\frac{2.0\times10^{-9}C}{1.6\times10^{-19}C}=1.25\times10^{10}\,electrons$

(b) (b) $n=\frac{q}{e}=\frac{0.5\times10^{-6}C}{1.6\times10^{-19}C}=3.125\times10^{12}\,electrons$

Answer to Exercise 6.2:

1. Comparison of Newton's law of gravitation and coulomb's law

Comparison of electrostatic force and gravitational force:

Similarities:

1. Both the forces obey the inverse square law.
2. These two forces operates in vacuum.
3. These are conservative forces.
4. Both having central forces.

Dissimilarities:

1. Electrostatic force can be either attractive or repulsive but gravitational force is always attractive in nature.
2. The presence of dielectric medium effect the electrostatic force but the medium has no effect on gravitational force.
3. Electrostatic force is more stronger than gravitational force.

2. 2. $$\frac{F_e}{F_g}=\frac{kq_1q_2/r^2}{Gm_1m_2/r^2}=\frac{kq_1q_2}{Gm_1m_2}=\frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{6.67\times10^{-11}\times9.1\times10^{-31}\times1.67\times10^{-27}}=2.27\times10^{39}$$

This means the electrostatics force is 2.27×10^{35} larger than the gravitational force between an electron and a proton. The electrostatic force between two subatomic particles is far greater than the gravitational force between the same two particles.

Answer to Activity 6.2:

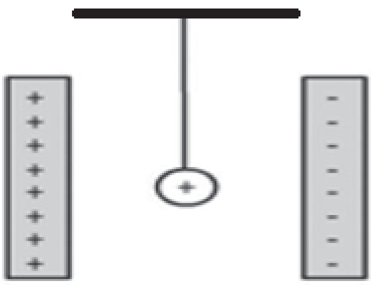
Group learners into different groups and make sure you balance gender and learners with disability. Hence, guide them through the activity and help them to draw a suitable conclusion of their findings.

When you rub a balloon against your sleeve, your sleeve loses some electrons. The balloon is thus negatively charged after you rub with your head. The water is made of positive and negative charged particles. When you bring the balloon towards the water, the positive charged particles in the water will move the water towards the negatively charged balloon since positive and negative charges are attracted to each other. When a negatively charged rod is brought near an unbroken stream of water coming from a tap then a positive charge can be induced on the part of the stream near the charged rod. The force of attraction between the two will deflect the stream. This cannot happen if the stream is broken into separate drops.

Figure 6.4: A charged body (balloon) attracts a neutral body (stream of water)

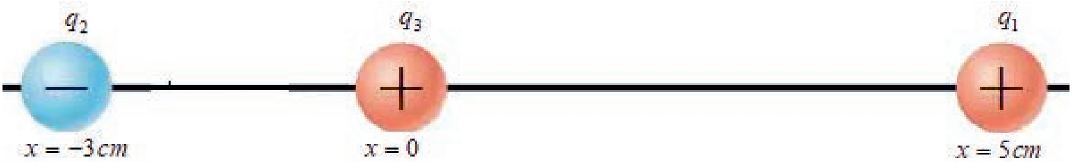
Answer to Activity 6.3:

The ball will be attracted to the negatively charged plate. It'll touch and pick up some electrons from the plate so that the ball becomes negatively charged. Immediately the ball is repelled by the negative plate and is attracted to the positive plate. The ball gives up electrons to the positive plate so that it is positively charged and suddenly attracts to the negative plate again, flies over to it and picks up enough electrons to be repulsed by negative plate and again to the positive plate and that continues. The positively charged ball moves between both charged plates till the plates and the ball all become neutral.



Answer to Exercise 6.3:

Referring to the question on the above example 6.3, determine the magnitude and direction of the total electrostatic force acting (a) on q_1, and (b) on q_2.



Solution:

(a) **The force charge q_3 exerts on charge q_1 is given by:**

$$F_{31} = k\frac{q_1q_3}{r_{13}^2} = 9.0\times10^9\left(\frac{6\times10^{-6}\times2\times10^{-6}}{(5\times10^{-2})^2}\right) = 43.2N$$

Similarly, the magnitude of the force charge q_2 exerts on charge q_1, F_{21} is given by

$$F_{21} = k\frac{q_2q_1}{r_{21}^2} = 9.0\times10^9\left(\frac{5\times10^{-6}\times6\times10^{-6}}{(8\times10^{-2})^2}\right) = 42.1875N$$

Charge q_3 (positive) repels charge q_1 (positive) to the right: $\overrightarrow{F_{31}} = 43.2N\hat{i}$

Charge q_2 (negative) attracts charge q_1 (positive) to the left: $\overrightarrow{F_{21}} = 42.1875N -\hat{i}$

Therefore, since these forces act in opposite directions, the resultant force, F_R acting on charge q_1, will be their sum.

$$\overrightarrow{F_R} = \overrightarrow{F_{31}} + \overrightarrow{F_{21}} = 43.2N\hat{i} + (-42.1875N\hat{i}) = 1.0125N\hat{i}$$

Thus, the magnitude of the resultant force acting on charge q_1 is $1.0125N$, and the force is directed along the positive x-axis.

(b) The force charge q_1 exerts on charge q_2 is given by:

$$F_{12} = k\frac{q_1 q_2}{r_{21}^2} = 9.0\times10^9\left(\frac{5\times10^{-6}\times6\times10^{-6}}{(8\times10^{-2})^2}\right) = 42.1875N$$

Similarly, the magnitude of the force charge q_3 exerts on charge q_2, F_{32} is given by

$$F_{32} = k\frac{q_2 q_3}{r_{23}^2} = 9.0\times10^9\left(\frac{5\times10^{-6}\times2\times10^{-6}}{(3\times10^{-2})^2}\right) = 100.0N$$

Charge q_1 (positive) attracts charge q_2 (negative) to the right: $\overrightarrow{F_{12}} = 43.2N\hat{i}$
Charge q_3 (positive) attracts charge q_2 (negative) to the right: $\overrightarrow{F_{31}} = 100.0N\hat{i}$
Therefore, since these forces act in the same direction (both to the right), the resultant force, F_R acting on charge q_3, will be their sum.

$$\overrightarrow{F_R} = \overrightarrow{F_{13}} + \overrightarrow{F_{13}} = 43.2N\hat{i} + 100.0N\hat{i} = 143.2N\hat{i}$$

Thus, the magnitude of the resultant force acting on charge q_3 is $143.2N$, and the force is directed along the positive x-axis.

Answers to review questions 6.1

1. State Coulomb's law in your own words.

   Coulomb's law states that the magnitude of the electrical force between two point charges is directly proportional to the product of the quantity of charge on the objects and inversely proportional to the square of the separation distance between them.

2. Mathematically:

   $F = k\dfrac{q_2 q_1}{r^2}$ in scalar form

   $\overrightarrow{F_{12}} = k\dfrac{q_1 q_2}{r^2}\widehat{r_{21}}$ in vector form

3. A coulomb (abbreviation: C) is the standard unit of electric charge in the International System of Units (SI). It was named after the French physicist Charles A. de Coulomb, who formulated the law of electrical force that now carries his name. A coulomb (C) is the amount of electricity that a 1-ampere (A) current carries in one second (s).

4. $Let\, q_1 = 3\mu C, q_2 = 12\mu C, and\; q_3 = -2\mu C$

Since q_3 is found mid-way between q_1 *and* q_2, thus $r_{13} = r_{23} = 0.5m$

$$F_{13} = k\frac{q_1 q_3}{r_{13}^2} = 9\times10^9\frac{3\mu C\times2\mu C}{(0.5m)^2} = 0.216N(-\hat{i})$$

$$F_{23} = k\frac{q_2 q_3}{r_{23}^2} = 9\times10^9\frac{12\mu C\times2\mu C}{(0.5m)^2} = 0.864N(\hat{i})$$

The net force on $q_3 = -2\mu C$, will therefore be:

$$F_{net} = \overrightarrow{F_{13}} + \overrightarrow{F_{23}} = 0.216N(-\hat{i}) + 0.864N(\hat{i}) = 0.648N(\hat{i})$$

$$F_1 = 0.05N, r_1 = 0.25m$$

Then, applying Coulomb's law:

$$F = k\frac{q_2 q_1}{r^2} \Rightarrow 0.05 = 9\times10^9\frac{q_2 q_1}{(0.25)^2}$$

$$\Rightarrow q_2 q_1 = 0.35\times10^{\;12}C^2$$

On the second scenario, each sphere will acquire equal charges of:

$$q_1^{'} = q_2^{'} = \frac{q_1 + q_2}{2}$$

Then, applying Coulomb's law

$$F = k\frac{q_1^{'}q_2^{'}}{r^2} = k\frac{\left(\frac{q_1+q_2}{2}\right)^2}{r^2}$$

$$\Rightarrow 0.06 = 9\times10^9\frac{\left(\frac{q_1+q_2}{2}\right)^2}{(0.25)^2}$$

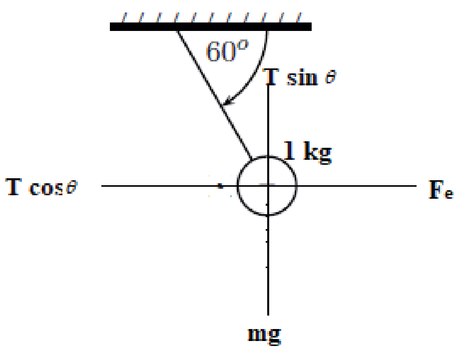
$$\Rightarrow q_1 + q_2 = 1.3\times10^{-6}$$

Finally combining the above two equation, $q_2q_1 = 0.35\times10^{-12}C^2$, with

$q_1 + q_2 = 1.3\times10^{-6}$ simultaneously gives:

$q_1 = 0.92\mu C \ \ or \ \ q_1 = 0.38\mu C$ and $q_2 = 0.38\mu C \ \ or \ \ q_2 = 0.92\mu C$

1. The free body diagram of the problem will be:



Since the system is at equilibrium:

$$T\sin\theta = mg$$

$$\Rightarrow T = \frac{mg}{\sin\theta} = \frac{1kg(10kg/m^2)}{\sin 60^0} = 11.55N$$

$$T\cos\theta = k\frac{q^2}{r^2}$$

$$\Rightarrow q^2 = \frac{T\cos\theta r^2}{k} = \frac{11.55(0.5)(0.5)^2}{9\times10^9} = 0.16\times10^{-9}$$

$$\Rightarrow q = 0.013mC$$

6.2. Electric Fields

(2 periods)

By the end of this section, you will be able to:

- *Define the terms, electric field, and electric flux.*
- *Sketch electric field lines.*
- *Solve problems involving electric field.*
- *Map an electric field lines pattern using electric lines of force.*
- *Calculate the magnitude and direction of electric field due to a point charge and two-point charges.*

In this section the concept of electric field and electric field strength is discussed. Then the equation for the electric field strength of a point charge will be derived from Coulomb's law. Since, electric field is a vector quantity, using vector addition (the superposition principle), how to determine the net electric field at a point due to two or more charges will be discussed.

Teaching Aids

The following teaching aids are recommended to be used in this section.

- Flash Cards, Slides, Charts, Pictures, Maps , Library , Internet

Suggested methodology

- ▷ Experiments,
- ▷ Demonstration activities.
- ▷ Group discussion and presentation,
- ▷ Question and answer with immediate feedback,
- ▷ Solving problems in pairs or in groups,
- ▷ Field trip
- ▷ Group works.

Answer to activity 6.4:

1. Properties of electric field lines

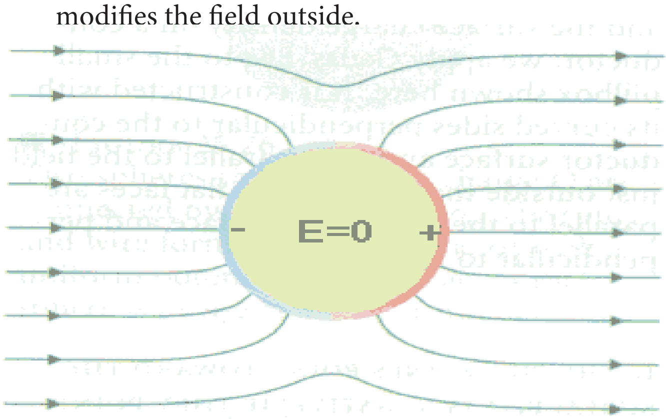
   Here are the various properties of electric field lines:

- ▷ They start from a positive charge.
- ▷ These lines end on a negative charge.
- ▷ The movement of electric field lines is away from the positive electric charge.
- ▷ The movement of electric field lines is towards the negative electric charge.
- ▷ A tangent can be drawn at any point on an electric field line, thereby providing the

direction of the field at that point.

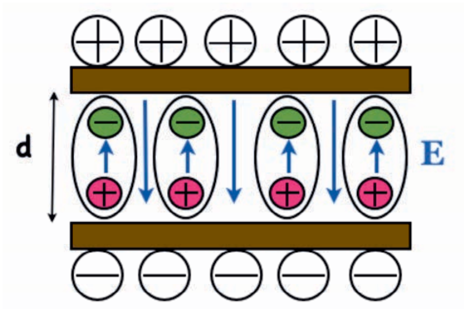
- ▷ The electric field can never have two directions at a particular point. Consequently, the field lines never intersect each other.
- ▷ The magnitude of charge and the number of field lines are proportional to each other.
- ▷ Electric field lines enter or exit a charged surface in a normal manner.
- ▷ The field lines are uniformly spaced, parallel, and straight in a uniform electric field.
- ▷ The field lines are perpendicular to the surface of the charge.
- ▷ It is not possible for electric field lines to go through a conductor. As such, inside a conductor, the electric field is always equal to zero.
- ▷ Electric field lines can be affected by the force of attraction between two objects that are oppositely charged. Due to this, they tend to contract in length.
- ▷ The electric field lines are continuous curves in a region that is charge-free.
- ▷ The expansion of the electric lines of force tends to happen laterally. This means that these lines tend to separate from each other in a direction that is perpendicular to their lengths. The reason for this is the presence of a force of repulsion between charges.

2. (a) In a conductor electrons are free to move. If they are acted on by a force, they will accelerate in the direction of the force. If a conductor is placed into an external electric field, a force **F** = -e**E** acts on each free electron. Electrons accelerate and gain velocity in a direction opposite to the field. Soon electrons will pile up on the surface on one side of the conductor, while the surface on the other side will be depleted of electrons and have a net positive charge. These separated negative and positive charges on opposing sides of the conductor produce their own electric field, which opposes the external field inside the conductor and modifies the field outside.



When enough electrons have piled up on one side and enough positive charge has been left on the other side, then the field produced by these separated charges exactly cancels the external field inside the conductor, and electrons inside the conductor no longer experience a force. This is the case in the picture shown above. **Electrostatic field is zero inside a conductor.**

(a) An **electrical insulator** is a material in which electric current does not flow freely. The atoms of the insulator have tightly bound electrons which cannot readily move. **The electric field must be zero inside a conductor in electrostatic equilibrium, but not inside an insulator.** When dielectrics are placed in an electric field, practically no current flows in them because, unlike metals, they have no loosely bound, or free, electrons that may drift through the material. Instead, electric polarization occurs. The positive charges within the dielectric are displaced minutely in the direction of the electric field, and the negative charges are displaced minutely in the direction opposite to the electric field. This slight separation of charge, or polarization, reduces the electric field within the dielectric. Hence, an insulator placed in a static electric field will make the field weaker.



Answer to Exercise 6.4:

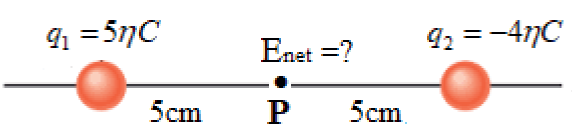
We need to assume the −0.25 μC charge is placed at a point where the electric field is $7.2\times10^5\,N/m^2$. This is because the electric field of a point charge is not uniform. Which means placing a charge at points faces a different electric force. Then, using the equation:

$$\vec{F} = q\vec{E} = -0.25\,\mu C \times 7.2\times10^5\,N/m^2$$
$$= -0.25\times10^{-6}\times7.2\times10^5\,N$$
$$= -0.18N$$

The negative sign indicates that the force that acted on the charge is opposite in direction to the electric field.

Answer to Exercise 6.5:

Repeat example 6.5, if (a) both q_1 and q_2 are positively charged, and (b) they are both negatively charged.



The magnitude of the electric field at point P due to both charges q_1 and q_2 is the same as in the example. That is:

$$E_1 = k\frac{q_1}{r_1^2} = 9\times10^9\, N.m^2/C^2\left(\frac{5\times10^{-9}C}{(0.05m)^2}\right) = 1.8\times10^4\, N/m$$
$$E_2 = k\frac{q_2}{r_2^2} = 9\times10^9\, N.m^2/C^2\left(\frac{4\times10^{-9}C}{(0.05m)^2}\right) = 1.44\times10^4\, N/m$$

(a) In this case since both q_1 and q_2 are positively charged, the direction of $\vec{E}_1$ is to the right, but that of $\vec{E}_2$ is to the left.

Thus,
$\overrightarrow{E_{net}} = \vec{E}_1 + \vec{E}_2 = 1.8\times10^4\, N/m(\hat{i}) + 1.44\times10^4\, N/m(-\hat{i}) = 3.6\times10^3\, N/m(\hat{i})$

(b) In this case since both q_1 and q_2 are negatively charged, the direction of $\vec{E}_1$ is to the left, but that of $\vec{E}_2$ is to the right.

Thus,
$\overrightarrow{E_{net}} = \vec{E}_1 + \vec{E}_2 = 1.8\times10^4\, N/m(-\hat{i}) + 1.44\times10^4\, N/m\,\hat{i} = 3.6\times10^3\, N/m(-\hat{i})$

Answer to Review Questions 6.2

1.
   (a) Electric field is a region around a charged particle within which an electric force would be exerted on other charged particles.
   (b) Electric field strength (E) is defined as the force per unit charge experienced by a small positive test charge (q) placed at the point in the field.
   (c) An electric field line is an imaginary line or curve drawn through a region by considering the direction of the force the field would exert on an isolated test charge placed at that point.
   (d) electric flux, is a measure of the number of electric lines of force (or electric field lines) that intersect a given area.

2. See, Figure 6.8 on the textbook.
3. The similarities and differences between gravitational and electrostatic forces

The key similarities are:

- ▷ The magnitude of the gravitational and electrostatic force between two point masses or charges follow inverse square law relationships
- ▷ The field lines around a spherical masses and spherical charges are radial
- ▷ The field lines in a uniform gravitational and electric field are identical (they are parallel and equally spaced)

- ▷ The gravitational field strength and electric field strength both have a $\frac{1}{r^2}$ relationship in a radial field.
- ▷ The gravitational potential and electric potential both have a $\frac{1}{r}$ relationship

The key differences are:

- ▷ The gravitational force acts on particles with mass whilst the electrostatic force acts on particles with charge
- ▷ The gravitational force is always attractive whilst the electrostatic force can be attractive or repulsive
- ▷ The gravitational potential is always negative whilst the electric potential can be either negative or positive

4. (a) Region II, (b) No where.
5. Where they are close to each other the field is strong and where they are far apart the field is weak.
6. What is the net electric field strength at point *P* in the system shown below.

The field due to the $1.0\mu C$ charge is:

$$E_1 = k\frac{q_1}{r_1^2} = 9\times10^9\,N.m^2/C^2\left(\frac{1.0\times10^{-6}C}{(3.0m)^2}\right) = 1.0\times10^3\,N/m$$

The direction of E_1 is to the right. Hence

$$\overrightarrow{E_1} = 1.0\times10^3\,N/m(\hat{i})$$

The field due to the $-3.0\mu C$ charge is:

$$E_1 = k\frac{q_1}{r_1^2} = 9\times10^9\,N.m^2/C^2\left(\frac{3.0\times10^{-6}C}{(3.0m)^2}\right) = 3.0\times10^3\,N/m$$

The direction of E_2 is to the left. Hence

$$\overrightarrow{E_2} = 3.0\times10^3\,N/m(-\hat{i})$$

$$E_{net} = \overrightarrow{E_1} + \overrightarrow{E_2} = 1.0\times10^3\,N/m(\hat{i}) + 3.0\times10^3\,N/m(-\hat{i})$$

$$= 2.0\times10^3\,N/m(-\hat{i})$$

7. (a) $E = \frac{F}{q} = \frac{4\times10^{-6}N}{2\times10^{-8}C} = 2\times10^2\,N/C$

   (b) $F = qE = -1\times10^{-8}C\times2\times10^2\,N/C = -2\times10^{-6}\,N$

6.3. Electric Potential

(2 periods)

By the end of this section, you will be able to:

- *Define the terms electric potential, equipotential surface.*
- *Solve problems involving electric potential.*
- *Explain the meaning of a volt, potential difference, and emf.*

In this section the concept of electric potential with analogy to gravitational potential is discussed. Then the equation for the potential of a point charge (absolute potential) is derived. Since potential is a scalar quantity, finding the total potential at a point due to two or more charges would be the algebraic sum of the potential of each charge at that point. The concept of potential difference is also discussed and with analogy to gravitational potential difference.

Teaching Aids

The following teaching aids are recommended to be used in this section.

- Flash Cards, Slides, Charts, Pictures, Maps, Bulletin Boards

Suggested methodology

- ▷ Experiments,
- ▷ Demonstration activities.
- ▷ Group discussion and presentation,
- ▷ Question and answer with immediate feedback,
- ▷ Solving problems in pairs or in groups,
- ▷ Field trip
- ▷ Group works.

Answer to Activity 6.5:

Potential difference between the ends of the wire makes electric current to flow in the wire.

Answer to Exercise 6.6:

(a)

$$V = V_1 + V_2 = k\frac{Q_1}{r_1} + k\frac{Q_2}{r_2}$$

$$V = k\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right) = 9\times10^9\left(\frac{2\times10^{-6}}{1.5} + \frac{-5\times10^{-6}}{0.5}\right)$$

$$V = -7.8\times10^4 V$$

(b) $V = V_1 + V_2 = k\frac{Q_1}{x} + k\frac{Q_2}{1-x} = 0$

$$\Rightarrow \frac{Q_1}{x} = -\frac{Q_2}{1-x}$$

$$\Rightarrow \frac{2\times10^{-6}}{x} = -\frac{-5\times10^{-6}}{1-x}$$

$$\Rightarrow 2(1-x) = 5x$$

$$\Rightarrow x = 2/7 = 0.29m$$

Answer to Review Questions 6.3

1.

(a) electric potential, is defined as the amount of work needed to move a unit charge from a reference point to a specific point against an electric field.

(b) The electric potential difference between points A and B, $V_B - V_A$ is defined to be the change in potential energy of a charge q moved from A to B, divided by the charge.

$$V_B - V_A = \frac{W}{q} = \frac{\Delta U}{q}$$

(c) The volt (symbol: V) is the unit of electric potential, or potential difference, and electromotive force in the International System of Units. It is named after the Italian physicist Alessandro Volta (1745–1827).

(d) The equipotential surface is the surface that consists of points having equal potentials. Points in an electric field that are at the same potential are known as equipotential points and if they are connected by a curve, then it is called an equipotential line.

2. The two units of electric field are:

$newton\ per\ coulomb\,(N/C,\ from\,E = F/q, and\ volt\ per\ meter\,(V/m,\ from\,E = V/d).$

3. If the electric potential is constant in the given region, the electric field will be zero everywhere in the region.
4. (a) when an electron is released in a uniform electric field, its electrical potential energy increases, and (b) when a proton is released in a uniform electric field its electrical potential energy decrease.

5. Electric field lines and equipotential lines are always drawn perpendicular to each other.

6. $E=\frac{V}{d}=\frac{1.5V}{1.0\times10^{-2}m}=1.5\times10^{2}V/m=150V/m$

7. (a) $V=V_1+V_2=k\frac{Q_1}{r_1}+k\frac{Q_2}{r_2}$

$$V=k\left(\frac{Q_1}{r_1}+\frac{Q_2}{r_2}\right)$$

$$=9\times10^{9}\left(\frac{-5\times10^{-6}}{0.15}+\frac{2\times10^{-6}}{0.05}\right)$$

$$=9\times10^{9}\times10^{-6}\left(\frac{-5}{0.15}+\frac{2}{0.05}\right)$$

$$=9\times10^{3}\left(-33.33+40\right)$$

$$=6.0\times10^{4}V$$

(b) The potential at the lower left corner is:

$$V=k\left(\frac{Q_1}{r_1}+\frac{Q_2}{r_2}\right)$$

$$=9\times10^{9}\left(\frac{-5\times10^{-6}}{0.05}+\frac{2\times10^{-6}}{0.15}\right)$$

$$=9\times10^{9}\times10^{-6}\left(\frac{-5}{0.05}+\frac{2}{0.15}\right)$$

$$=9\times10^{3}\left(-100+13.33\right)$$

$$=-7.8\times10^{5}V$$

The potential difference between the potential at the lower left corner and right top corner is:

$$V_R-V_L=6.0\times10^{4}V-(-7.8\times10^{6}V)$$

$$=8.4\times10^{5}V$$

8. $V=V_1+V_2=k\frac{Q_1}{x}+k\frac{Q_2}{1-x}=0$

$$\Rightarrow\frac{Q_1}{x}=\frac{Q_2}{1-x}$$

$$\Rightarrow\frac{3\times10^{-8}}{x}=\frac{2\times10^{-8}}{15-x}$$

$$\Rightarrow 3(15-x)=2x$$

$$\Rightarrow x=45/5=9.0\,cm$$

9. $V = k\dfrac{Q}{r}$

$$Q = \frac{Vr}{k} = \frac{-2.0V \times 1.0 \times 10^{-3}m}{9.0 \times 10^{9}V.m/C} = -\frac{2}{9} \times 10^{-12}C$$

$$= 0.22 \times 10^{-12}C = 0.22\,pC$$

10. $V = V_1 + V_2 = k\left(\dfrac{Q_1}{r_1} + \dfrac{Q_2}{r_2}\right).$

$$V = 9 \times 10^{9}\left(\frac{10 \times 10^{-12}C}{0.5m} + \frac{-2.0 \times 10^{-12}C}{0.5m}\right)$$

$$= 9 \times 10^{9} \times 10^{-12}\left(\frac{10}{0.5} + \frac{-2.0}{0.5}\right)$$

$$= 9 \times 10^{-3}(20 - 4)$$

$$= 144\,mV$$

6.4. Electric Current, Resistance and ohm's law

(5 periods)

By the end of this section, you will be able to:

- *Define the terms electric current, current density, resistance, conductivity, resistivity and drift velocity.*
- *Explain the effect on the current (brightness) and potential difference of connecting light bulbs in series.*
- *Explain the effect on the current (brightness) and potential difference of connecting light bulbs in parallel.*
- *Draw electric circuits consisting of three resistors connected in series and parallel.*
- *Determine equivalent resistance of resistors connected in series and parallel.*
- *Describe the principles of potentiometer and Wheatstone bridge.*
- *Describe how to convert galvanometer to a voltmeter and ammeter.*
- *Explain the meaning of an ohm, resistance.*
- *Explain the SI units of electric current, current density, resistance, resistivity, conductivity.*
- *State and apply Kirchhoff's laws.*
- *Solve problems involving network of resistors.*

This section contains four sub sections: Basic principles, Kirchhoff's rules, measuring

Instruments, and the Wheatstone bridge and the potentiometer.

Under basic principles learners should investigate the conditions for current flow using appropriate electric equipment to measure current, electromotive force, resistance, resistivity and also the units of electric current the ampere, quantity of electricity (coulomb), volt, Ohms and ohm- meter and solve problems. They should verify Ohm's law experimentally and write the relationship between the resistance, length of a conductor and its diameter, derive the equation and apply it in calculations.

The next section considers Kirchhoff's rules, which are important tools for analysis of circuits. Learners should investigate series and parallel circuits and apply it to the domestic electricity supply. They should solve problems in series and parallel circuits and apply the **Kirchhoff 's rules.**

Then the properties of electrical measuring instruments such as ammeter, voltmeter and galvanometer are discussed. Finally, the different functions of a Wheatstone bridge and potentiometer will be discussed.

Teaching Aids

The following teaching aids are suggested to be used in this section.

- Charts , Computer set , Projectors , Video, Library, Internet , Resistors , Rheostat , Rectangular block , Galvanometer , Ammeter & voltmeter

Suggested methodology

- ▷ Experiments,
- ▷ Demonstration activities.
- ▷ Group discussion and presentation,
- ▷ Question and answer with immediate feedback,
- ▷ Solving problems in pairs or in groups,
- ▷ Field trip
- ▷ Group works.

Answer to Activity 6.6:

A water pump pushes the water up to be stored in the tank. Then, a difference in height (to provide a difference in pressure) is needed between the tanker and the ground. Similarly in electricity a difference in potential is needed for current to flow in the circuit. This potential difference is provided by the cell or battery.

Answer to Exercise 6.7:

The direction of current density is opposite to the direction of flow of electrons. When the electrons are flowing from left to right, the direction of current density is from right to left.

Answer to Exercise 6.8:

1. $J = \frac{I}{A} = env_d$

$$v_d = \frac{I}{enA} = \frac{1.0A}{1.6\times10^{-19}C(8.5\times10^{28}m^{-3})(5\times10^{-6}m^2)}$$

$$v_d = 0.015mm/s$$

2. In an electric circuit the direction of:
   (a) Electrons is from the negative to the positive terminal of the source,
   (b) Electric current is opposite to the direction of flow of electrons. That is from the positive to the negative terminal of the source,
   (c) Current density is the same as the direction of the current.
   (d) The electric field is from the positive terminal of battery to the negative terminal of battery.
   (e) The drift velocity is opposite to the direction of the applied electric field..

Answer to Activity 6.7:

The drift speed of electrons through a wire is around 0.1- 0.4 millimeters per second. But if electrons move so slowly, how can a switch turn on a lamp instantaneously. To explain this think of a tube filled with marbles: if you add a marble at one end, a marble will come out the other end at almost the same instant, even though each marble didn't move that far on its own. Likewise, a copper wire contains lots of electrons ($8.5\text{x}10^{28}$ per cubic meter. Those electrons are packed in so tightly that even a small movement will travel down the wire from electron to electron at an impressive speed, letting you turn on the lights without having to wait for electrons to travel the whole way there.

Answer to Exercise 6.9:

Since resistance is unchanged:

$$\frac{V_1}{I_1} = \frac{V_2}{I_2}$$

$$\Rightarrow V_2 = \frac{V_1 I_2}{I_1} = \frac{12V \times 2 \times 10^{-6} A}{2 \times 10^{-3} A}$$

$$\Rightarrow V_2 = 0.012V$$

Answer to Activity 6.8:

1. There is no change in current as it passes through a resistor. This is because, for constant resistance, current depends on applied voltage (Ohm's law). So, when current passes through a resistor, no change in current is seen unless we change the resistance.
2. The resistance to electric current introduced by a resistor is remarkably similar to the resistance to fluid flow introduced by a pipe constriction. The battery in an electric circuit is similar to the pump in a water circuit. The battery absorbs charge at low voltage, performs some work on it, and ejects it at high voltage. In contrast, the pump takes a fluid at low pressure, performs some work on it, and ejects it at high pressure.

Answer to Activity 6.9:

For resistors connected in series, the total resistance is larger than the resistance of the resistor with the largest resistance. The equation for total resistance for resistors connected in series is:

$$R_T = R_1 + R_2 + R_3 + ...R_n.$$

This tell us that as more resistors are connected in series the total resistance increases.

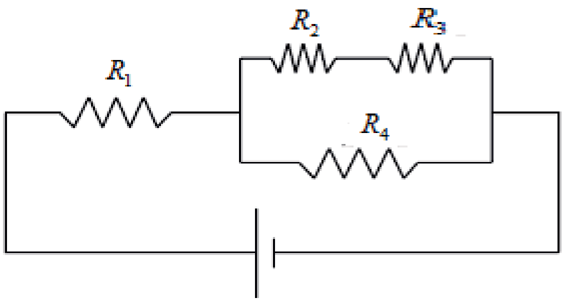
But for resistors connected in parallel, the equation for total resistance is:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

This tell us that as more resistors are connected in parallel the total resistance decreases. Hence, the total resistance is smaller than the resistance of the resistor with the smallest resistance.

Answer to Exercise 6.10:

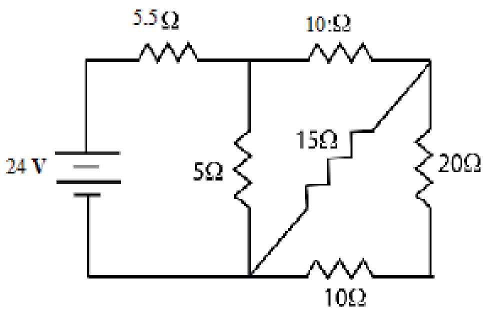
For the circuit shown below, list resistors that are connected (a) in series, and (b) in parallel.



R_2 *and* R_3 are connected in series. No other single resistors are connected either in series or in parallel, but the equivalent resistance of R_2 *and* R_3 is in parallel with R_4 and the equivalent resistance of R_2, R_3 *and* R_4 is in series with R_1.

Answer to Exercise 6.11:

(a) What is the equivalent resistance of the circuit shown in the figure? (b) What current flows through the 5Ω resistor?



First combining the 10Ω and 20Ω resistors in series gives 30Ω. This is in parallel with the 15Ω resistor giving an equivalent resistance of 10Ω. This in turn is in series with another 10Ω at the top, giving an equivalent resistance of 20Ω. This is in parallel with the 5Ω resistor, giving an equivalent resistance of 4Ω. Finally, this is in series with the 5.5Ω resistor giving the total or equivalent resistance of the circuit to be 9.5Ω.

Activity 6.10:

Use the links below to perform virtual experiment on DC Circuits. You may need your teacher's guidance on how to use it.

- *https://phet.colorado.edu/en/simulations/circuit-construction-kit-dc*

- *http://phet.colorado.edu/sims/html/circuit-construction-kit-dc-virtual-lab/latest/circuit-construction-kit-dc-virtual-lab- en.html*

Activity 6.11: Experiment

This activity is an experiment to Verify the laws of combination of resistance in series and in parallel. Inform and assist students to strictly follow the procedures given in the textbook. By making real measurements and doing calculations students themselves should be able to verify the laws of resistors connected in series and in parallel.

Answer to Exercise 6.12:

(a) Before the ammeter is introduced, the current in the circuit is:

$$I = \frac{V}{R} = \frac{6V}{4\Omega} = 1.5A$$

(b) After the ammeter is introduced the current in the circuit became:

$$I = \frac{V}{R} = \frac{6V}{4\Omega + 0.5\Omega} = 1.33A$$

(c) These results show that, the insertion of an ammeter in the circuit decreases the flow of current, that is why it should have a very small internal resistance.

Answer to Exercise 6.13:

(a) When the voltmeter is not in place, using the voltage divider formula, the potential difference across the 20 kΩ, resistor is:

$$V_1 = \frac{R_1}{R_1 + R_2} V = \frac{20\,k\Omega}{10\,k\Omega + 20\,k\Omega} \times 6V = 4V$$

(b) When the 50 kΩ, voltmeter is connected in parallel, the equivalent resistance in that branch became:

$$R = \frac{20\,k\Omega \times 50\,k\Omega}{20\,k\Omega + 50\,k\Omega} = 14.29\,k\Omega$$

The total resistance of the circuit then became:

$$R_T = 10\,k\Omega + 14.29\,k\Omega = 24.29\,k\Omega$$

The current from the source will then be:

$$I = \frac{V}{R} = \frac{6V}{24.29\,k\Omega} = 0.247mA$$

With this, the potential difference across the 10 $k\Omega$, will be:

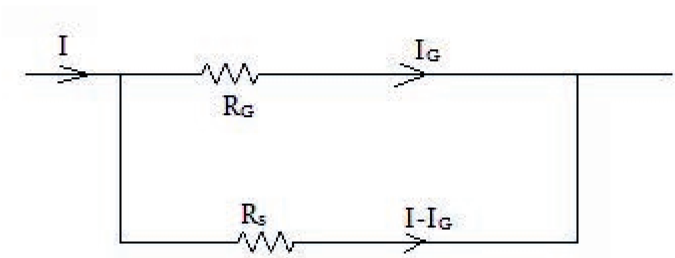
$$V = IR = 0.247mA \times 10k\Omega = 2.47V$$

The remining potential difference = $6V - 2.47V = 3.53\ V$

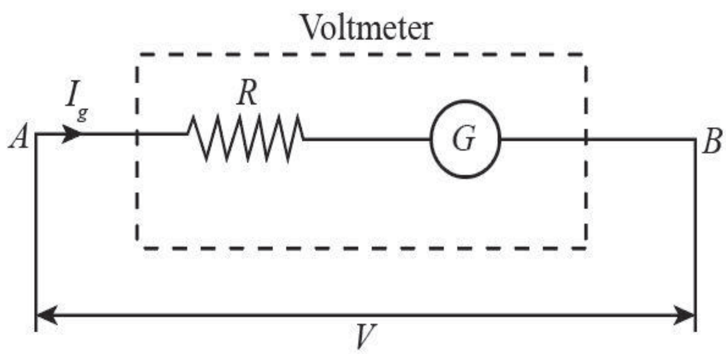
(c) This result shows that introducing voltmeters in parallel decreases the potential difference across that resistor. But if the internal resistance of the voltmeter is made to be very large the effect could be reduced.

Answer to Exercise 6.13:

(a) Since, an ammeter must have very low resistance, a galvanometer can be converted into an ammeter by connecting a very small shunt resistance in parallel with the galvanometer.



(b) A galvanometer can be converted into a voltmeter by inserting a multiply resistor of infinite (very large) resistance in parallel to the galvanometer.



Answer to Activity 6.12:

A balanced Wheatstone Bridge have the many applications. To mention some of them:

- The Wheatstone bridge is used for the precise measurement of low resistance.
- Wheatstone bridge is used to measure physical parameters such as temperature, light, and strain.

- Quantities such as impedance, inductance, and capacitance can be measured using variations on the Wheatstone bridge.
- Can be used to measure the light intensity, pressure, strain.
- Are used as positional sensors, photo-resistive sensors, and temperature sensors.

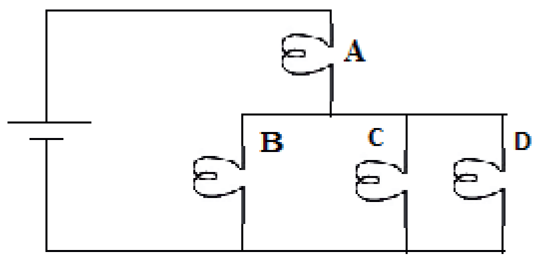
Activity 6.13: Experiment, WHEATSTONE BRIDGE

Answer to Activity 6.14:

Usually we refer the wattage of an electric bulb to choose for better brightness, but instream we should refer the Lumen.

Answer to Exercise 6.14:

When another bulb is connected in parallel as shown in the Figure the brightness of the bulbs increases, because Inserting Bulb D in parallel with bulbs B and C decreases the total resistance of the circuit increasing the current and hence the brightness.



Answer to Activity 6.15:

This activity is designed to give an idea of the advantages of CFL and LED lamps over the Incandescent lamps. After making a discussion with their group mates give then an advice to use CFL and LED lamps in order to save energy and money.

Answer to Exercise 6.15:

Applying Kirchhoff's junction rule:

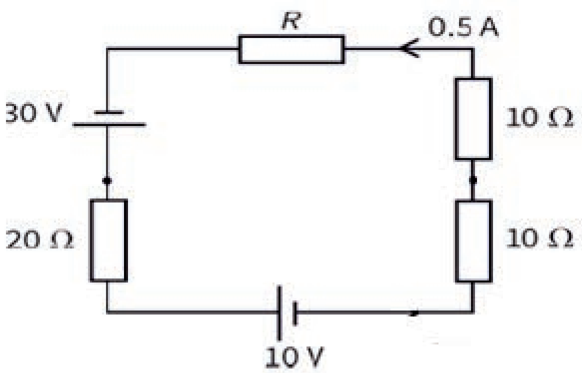
$$\sum I_{in} = \sum I_{out}$$

$$3A + 2.5A + I_x = 7A$$

$$I_x = 7A - 5.5A = 1.5A$$

Answer to Exercise 6.16:

Applying Kirchhoff's second law for the circuit below gives:



$$-0.5R - 0.5(10) - 0.5(10) + 10 - 0.5(20) - 30 = 0$$
$$\Rightarrow R = 50\Omega$$

Answer to Review Questions 6.4

1.
   (a) Current is a flow of electrons through a conductor. Mathematically the amount of charge travelled divided by the time taken.
   (b) Current density the amount of electric current flowing per unit cross-sectional area of a material.
   (c) Resistance is a measure of the opposition to current flow in an electrical circuit. It is measured in ohms, symbolized by the Greek letter omega (Ω).
   (d) Electrical conductivity is a measure of at which an electric charge can pass through a material. It is measured in
   (e) Resistivity is a property that describes the extent to which a material opposes the flow of electric current through it. It is the reciprocal of conductivity.
   (f) Drift velocity is the average velocity acquired by a charge carriers travelling through the conductor due to an electric field.

2. The SI unit of electric current is ampere (A), current density is A/m2, resistance is ohm (Ω), resistivity is ohm-meter (Ω-m), and that of conductivity is Siemens per meter or (Ω^{-1}).
3. One ohm is a resistance in a conductor, when a current of 1A flows through a potential difference of 1V.
4. The basic principle of the potentiometer is that the potential drop across any section of the wire will be directly proportional to the length of the wire, provided the wire is of a uniform cross-sectional area and a uniform current flow through the wire.

5. See, activity 6.10.
6. See exercise 6.13.
7. Kirchhoff's first law states that the sum of current entering a junction is equal to the sum of current leaving a junction. It is based on the law of conservation of charge. Kirchhoff's second law states that the algebraic sum of potential drops in a closed circuit is zero. It is based on the law of conservation of energy.
8. Applying Kirchhoff's junction law, $I_x = 0.1A$.
9. Applying Kirchhoff's loop law:

$$-10(I) - 20(I) + 6 - 40(I) - 20(I) + 12 = 0$$

$$\Rightarrow I = \frac{18}{90} A = 0.2A$$

10. Resistance of galvanometric coil = 36 Ω, shunt resistance = 4 Ω

From the formulae,

$$R_{sh} = \left(\frac{I_g}{I - I_g}\right) R_g$$

$$R_{sh}(I - I_g) = R_g I_g$$

$$R_{sh} I - R_{sh} I_g = R_g I_g$$

$$R_{sh} I = I_g (R_{sh} + R_g)$$

$$\Rightarrow \frac{I_g}{I} = \frac{R_{sh}}{R_{sh} + R_g} = \frac{4\Omega}{36\Omega + 4\Omega} = \frac{4\Omega}{40\Omega} = \frac{1}{10}$$

11. First combining the 4Ω and 2Ω resistors in series gives 6Ω. This is in parallel with the 6Ω resistor giving an equivalent resistance of 3Ω. This in turn is in series with the 2Ω at the top, giving an equivalent resistance of 5Ω. Finally, this is in parallel with the 1Ω resistor, giving an equivalent resistance of 0.83Ω.

6.5. Capacitors and Capacitance

(3 periods)

By the end of this section, you will be able to:

- *Define the terms capacitors, capacitances, dielectric.*
- *Explain the effect of inserting dielectric in the gap between the plates of a capacitor.*
- *Solve problems related to capacitance of parallel plate capacitor.*
- *Calculate the equivalent capacitance of capacitors connected in series and parallel.*

In this section students will investigate the properties of capacitors in groups and individually. how make it, factors affecting it, when to charge and discharge it and how to connect them in series and parallel. Finally, solve problems on series and parallel connection of capacitor.

Teaching Aids

The following teaching aids are suggested to be used in this section.

- Bulletin Boards, Computer set , Projectors , Video, Library , Internet , Galvanometer , Ammeter & voltmeter , Capacitors

Suggested methodology

- ▷ Experiments,
- ▷ Demonstration activities.
- ▷ Group discussion and presentation,
- ▷ Question and answer with immediate feedback,
- ▷ Solving problems in pairs or in groups,
- ▷ Field trip

Answer to Exercise 6.17:

$$A = 0.05m \times 10m = 0.5m^2, d = 2mm = 2\times10^{-3}m, V = 24V, and\ k = 5$$

$$C = k\varepsilon_0 \frac{A}{d} = 5\times8.85\times10^{-12}m^{-3}\,kg^{-1}\,s^4\,A^2\,\frac{0.5m^2}{2\times10^{-3}m}$$

$$C = 11.0625\times10^{-9}C$$

$$Q = CV = 11.0625\times10^{-9}F\times24V$$

$$Q = 2.655\times10^{-7}C$$

Answer to Activity 6.16:

The factors important in designing capacitance are area, dielectric constant and separation.

$$C = k\varepsilon_0 \frac{A}{d}$$

Thus, to get larger capacitance;

- ▷ Increase the area of the plates,
- ▷ Decrease the distance between the plates, and
- ▷ Insert a dielectric of larger dielectric constant in the region between the plates of the capacitor.

Answer to Activity 6.17:

1. (a) When a capacitor is inserted in the region between the plates of the capacitor which is still connected to the source:

- ▷ The capacitance increases,
- ▷ The potential difference between the plates remains unchanged (keeping the voltage of the source),
- ▷ The charge stored increases (due to polarization),
- ▷ The electric field between the plates remains unchanged (directly proportional to the electric field).

(b) When a capacitor is inserted in the region between the plates of the an isolated capacitor (disconnected from the source):

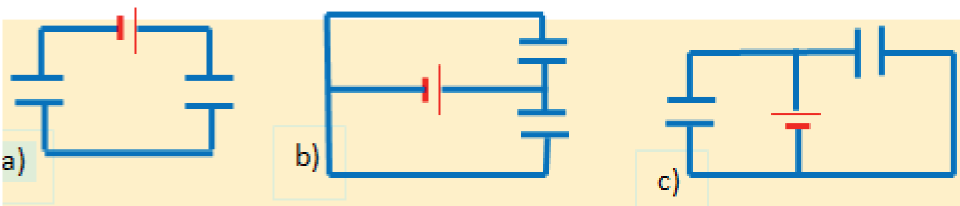
- ▷ The capacitance increases,
- ▷ The potential difference between the plates decreases,
- ▷ The charge stored increases,
- ▷ The electric field between the plates decreases.

2. When a dielectric is withdrawn the opposite of what happen during insertion will take place

Activity 6.18: Project

Search an internet or read books on how to make a capacitor, and construct it using locally available materials. Demonstrate your capacitor to your class by showing a practical work, like charging your cell phone.

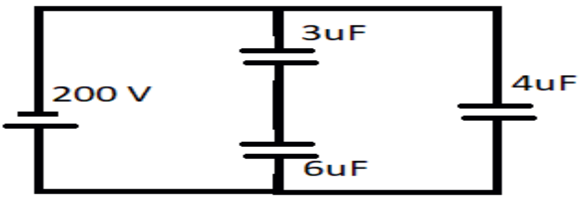
Answer to Exercise 6.18:



(a) They are connected in series.
(b) They are connected in parallel.
(c) They are connected in parallel.

Answer to Exercise 6.19:

For the network of capacitors shown in the figure below, determine (a) the equivalent capacitance, (b) the charge stored on each capacitor, and (v) the voltage across each capacitor.



First combining the $3\mu F$ and $6\mu F$ capacitances in series gives $2\mu F$. This is in parallel with the $3\mu F$ capacitor, giving an equivalent capacitance of $6\mu F$.

$$C_T = 6\mu F, V_T = 200V$$
$$\Rightarrow Q_T = C_T V_T == 6\mu F \times 200V = 1.2\, mC$$

Since the $6\mu F$ capacitor is in parallel with the source:

$$C = 6\mu F, V = 200V$$

The charge stored on this capacitor is:

$$Q_4 = C_4 V_4 == 4\mu F \times 200V = 0.8\, mC$$

The remaining charge ($1.2\, mC - 0.8\, mC = 0.4\, mC$) is then stored in the $3\mu F$ and $6\mu F$ capacitors. The voltage in these capacitors will then be:

$$V = \frac{Q}{C} = \frac{0.4mC}{3.0\mu F} = 133.33V \text{ and } V = \frac{Q}{C} = \frac{0.4mC}{6.0\mu F} = 66.67V$$

Answer to Activity 6.19:

The common applications of capacitors are:

- energy storage,
- power conditioning,
- electronic noise filtering,
- tuning,
- remote sensing and
- coupling/decoupling.
- A capacitor can also use as a temporary battery.

Answer to Review Questions 6.5

1.

- ▷ A capacitor is a device used to store an electric charge. It consists of one or more pairs of conductors separated by an insulator.
- ▷ Capacitance is a measure of the capacity of the capacitor to store charge. It is measured in Farad (1F = 1C/1V)
- ▷ A dielectric is an insulator to be inserted between the plates of the capacitor.

2. The factors that affect the capacitance of a capacitor are

- ▷ The area of the plates,
- ▷ The distance between the plates, and
- ▷ The nature of the dielectric inserted between the plates.

3. Refer activity 6.15.
4. A pair of parallel flat metal plates are placed a distance of 10 mm apart. The plates are circular, with a radius of 10 cm. How much charge must be placed on each plate to produce an electric field of 500 V/m between them?

$$d = 10mm = 1\times10^{-2}m, r = 10cm = 0.1m$$

$$A = \pi r^2 = 3.14(0.1m)^2 = 0.0314m^2, E = 500V/m$$

$$C = \varepsilon_0 \frac{A}{d} = 8.85\times10^{-12} m^{-3}\, kg^{-1}\, s^4\, A^2 \frac{0.314m^2}{1\times10^{-2}m}$$

$$C = 2.78\times10^{-10}F$$

$$Q = CV = CEd = 2.78\times10^{-10}F\times500V/m\times10^{-2}m$$

$$Q = 1.39\times10^{-9}C$$

5. For the network of capacitors shown in the figure below, determine (a) the equivalent capacitance, (b) the charge stored on each capacitor, and (v) the voltage across each capacitor.

(a) First combining the $2\mu F$ and $4\mu F$ capacitances in parallel gives $6\mu F$. This is in series with the $6\mu F$ capacitor, giving an equivalent capacitance of $3\mu F$.

$C_T = 3\mu F, V_T = 9V$

$\Rightarrow Q_T = C_T V_T = 3\mu F\times9V = 27\,\mu C$

Since the $6\mu F$ capacitor is in series with the source:

$C = 6\mu F, Q = 27\mu C$

The potential difference on this capacitor is:

$$V_6 = \frac{Q_6}{C_6} = \frac{27\mu C}{6\mu F} = 4.5V$$

The remaining voltage ($9V - 4.5V = 4.5V$) is then the potential difference across the $2\mu F$ and $4\mu F$ capacitors connected in parallel, $V_2 = V_4 = 4.5V$.

The charge stored on in these capacitors will then be:

$$Q_2 = C_2V_2 = 2\mu F \times 4.5V = 9.0\,\mu C \text{ and}$$

$$Q_4 = C_4V_4 = 4\mu F \times 4.5V = 18\,\mu C$$

6. First combining the $8\mu F$, $12\mu F$ and $24\mu F$ capacitances in series gives $4\mu F$. This is in parallel with the $4\mu F$ capacitor, giving an equivalent capacitance of $2\mu F$ .Finally, this $2\mu F$ capacitor, the $2\mu F$ capacitor and the $2\mu F$ capacitors are connected in series. The total capacitance will then be: $C_T = 1.15\mu F$

6.6. Electric Circuits in Our Surroundings

(1 period)

By the end of this section, you will be able to:

- *Apply the knowledge about electric circuits to explain household electric installation.*

This section is all about electric circuits in our homes and surroundings. It needs to be related to our daily life. How to read the color code of capacitors and resistors are given attention. If capacitors and resistors are not available in your school physics laboratory, students can easily get them from radio and television repair houses.

Teaching Aids

- Slides
- Charts
- Pictures
- Maps
- Bulletin Boards
- Color coded resistors
- Color coded capacitors

Suggested methodology

- Discussion
- Field trip
- Question and answer

Answer to Activity 6.20:

If possible, arrange an educational trip to visit the new national Science Museum located Addis Ababa? If you succeed inform students to prepare a report about the smart house they visited.

Answer to Activity 6.21:

Green = 5, the first digit
blue = 6, the second digit
yellow = 4 multiplier, (number of zeros)
the last band (the tolerance) is silver $\pm 10\%$.
The numerical value of this resistor will therefore be:
R = $570000 \pm 10\%\ \Omega$

Activity 6.22: Project

This is an interesting project. Arrange students in group and let to demonstrate what they have from electronic repair houses.

Answer to End of Unit Questions

1. The electric force between two charged particles is inversely proportional to the square of the distance between them. Hence, in this case since the distance between the is doubled, the electric force will decreases by one fourth ($F/4$).
2. Potential difference is the source of electric field.
3. Choice c is correct: newton-coulomb is not the unit of electric field.
4. Choice a is correct: When resistors are connected in series, we are connecting one next to the other. Hence its length is changing.
5. Choice b is correct: When resistors are connected in parallel, we place them side by side and connect their ends to a common point. Hence, we are increasing the thickness of the wire.
6. Applying Coulomb's law the electrostatic force between these charges will be:

$$F = k\frac{q_1 q_2}{r^2} = 9\times10^9\,\frac{5\times10^{-6}\times2\times10^{-6}}{(4\times10^{-2})^2}$$

$$F = 56.52N$$

Since the charges are opposite in sign the force s attractive.

7. Using the equation for the electric field of a point charge, the electric field due to Q_2. At the position of Q_1 is:

$$E_2 = k\frac{q_2}{r^2} = 9\times10^9\,\frac{2\times10^{-6}}{(4\times10^{-2})^2}$$

$$E_2 = 1.125\times10^6\,N/C$$

Similarly, the electric field produced by Q_1 at a point where Q_2 is placed is:

$$E_1 = k\frac{q_1}{r^2} = 9\times10^9 \frac{5\times10^{-6}}{(4\times10^{-2})^2}$$

$$E_1 = 2.8125\times10^6 N/C$$

The direction of the electric field is the direction of the electrostatic force the source charge exerted on the positive test charge placed at that point.?

8. The largest resistance is obtained when they are connected in series:

$R = R_1 + R_2 + R_3 = 36.0\ \Omega + 50.0\ \Omega + 700\ \Omega = 786\ \Omega$.

Smallest resistance is obtained when they are connected in parallel:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R} = \frac{1}{36} + \frac{1}{50} + \frac{1}{700}$$

$$\frac{1}{R} = \frac{50\times700 + 36\times700 + 36\times50}{36\times50\times700} = \frac{35,000 + 25,200 + 1,800}{1,260,000}$$

$$\frac{1}{R} = \frac{62,000}{1,260,000}$$

$$\Rightarrow R = \frac{1,260,000}{62,000} = 20.32\Omega$$

9. (a) When connected in series:

$$R_{series} = 10R_1 = 10\times75\Omega = 750\Omega$$

(b) When connected in parallel:

$$R_{parallel} = \frac{R_1}{10} = \frac{75\Omega}{10} = 7.5\Omega$$

10. Bulbs connected in parallel circuit are brighter than the same bulbs connected in series. This is because, when in parallel the all equally use the voltage of the source.
11. To produce heat, the heating element must have enough electrical resistance.
12. In a conductor resistance is measured by the amount of collision the conduction electros made with atoms of the conductor. When a metallic conductor is heated, the atoms in the metal vibrate with greater amplitude and frequency. Due to increase in temperature, the thermal velocities of free electrons also increase.

Therefore, the number of collisions between free electrons and atoms increases. This increases the resistance of the conductor.

For semiconductors, resistance decreases with increase of temperature. This is because the number of charge carriers increases when the temperature is increased. Such materials have a negative temperature coefficient.

13. For superconductors, that has zero resistance at and below a certain temperature, above the critical temperature, the resistivity follows the trend of a normal metal. A superconductor loses its superconductivity if its temperature is raised above its critical temperature.
14. Electromotive force (emf) is the voltage difference that exists across a battery when electric current does not flow through the battery while the terminal voltage is the actual voltage difference that exists within a battery when electric current does flow through the electric circuit.
15. The internal resistance of a cell or battery is the resistance offered within the voltage source. This occurs due to the presence of ions which opposes the flow of electrons. This opposition results in a decrease in voltage, and the energy lost due to the opposition is converted to heat.
16. To get larger resistance we connect resistors in series, and to get smaller resistance we connect them in parallel.
17. Since, resistance and current are inversely related, to get larger current, total resistance should be small. That will be when connecting resistors in parallel.
18. Equating the emf in the two cases:

$$I_1(r+R_1)=I_2(r+R_2)$$
$$2(r+4)=1.5(r+6)$$
$$2r+8=1.5r+9$$
$$0.5r=1$$
$$\varepsilon_1=I_1(r+R_1)=2(2+4)=12V,\ or$$
$$\varepsilon_2=I_2(r+R_2)=1.5(2+6)=12V$$

19. A 12 V battery causes a current of 3.0 A to flow into the circuit shown in the figure below. Find (a) the value of the unknow resistor $R_{2,}$ and (b) the voltage drop across the 3Ω resistor.

(a)

$$\left(\frac{3R_2}{3+R_2}+2\right)3=12$$
$$\frac{9R_2}{3+R_2}+6=12$$
$$6(3+R_2)=9R_2$$
$$18+6R_2=9R_2$$
$$18=3R_2$$
$$R_2=18/3=6\Omega$$

(b) The potential difference across the 2Ω resistor is:

$$V = IR = 3A \times 2.\Omega = 6V$$

The remaining 6V, then goes to R_2 and the $2.\Omega$, resistors, which are connected in parallel.

$$V_{R2} = V_3 = 6V$$

$$I_3 = \frac{V_3}{R_3} = \frac{6V}{3\Omega} = 2A$$

Since, the source provides a current of 3.0 A, a current of 2.0A flows through the 3Ω, the current through R_2 will be (Kirchhoff's junction rule), 1A.

$$R_2 = \frac{V_2}{I_2} = \frac{6V}{1A} = 6\Omega$$

20. Applying Kirchhoff's junction rule: $A_1 = 100mA, A_2 = 50mA, and\ A_3 = 20mA$

21. Applying both Kirchhoff's junction and loop rules:

$$I_1 = 0.6A, I_2 = 0.2A, and\ I_3 = 0.8A$$

22. The equivalent capacitance of the circuit grows as the number of capacitors in parallel increases, and thus the energy stored in the circuit increases. Therefore, the capacitors should be connected in parallel.

23. $C_T = \frac{12}{23}C = 0.52C$

Unit Seven

Nuclear Physics

[12 periods]

Introduction to the unit

Nuclear forces are produced from the interaction of mesons which are independent of charges. Different discoveries of atomic theories including the Rutherford model, Bohr model are described as a foundation for nuclear physics in the early chapter of the student's text book. Then, fundamentals of the Binding energy of the nucleons for the atoms were discussed. The discussion of the isotopes and radioactivity were discussed in the student's textbook. The concept of a different kind of emissions like α, β, and γ, were also addressed. Furthers, the fission and fusion processes in atomic nuclei were discussed in the framework of reactivity of different elements and isotopes. Finally, the safety processes set by the standards of the International Atomic Energy Institute (IAEA) were addressed.

Unit outcomes

At the end of this unit, students should be able to:

- *Appreciate the basic concept of the atomic nucleus.*
- *Describe qualitatively the basic nuclear processes (concepts of radioactivity, and nuclear reaction).*
- *Discuss the types of nuclear forces.*
- *Explain application of radioactivity and nuclear reaction to society.*
- *Describe the application of radioactivity and nuclear reaction to explain the energy source of stars.*
- *Define terms like nuclear fission, nuclear fusion, and isotope.*
- *Gain the basic knowledge of nuclear medicine.*
- *Demonstrate high level of awareness to protect themselves and their community from radiation hazard.*

Learning Strategies

Before you begin the lesson, ask students general brainstorming question on what of atomic and nuclear physics. Then let the student name important physicists who contributed to the discovery of the nucleus and its constituent particles, illustrations of experiments related to the nucleus.

After giving a short lecture about the historical discovery of the nucleus and its constituents, let the students discuss in small groups why the electron could be or could not be constituent particle of the nucleus.

- Put learners in groups (select any number of learners depending on the size of the class) make sure that they work in harmony.
- Help them in selecting their group leaders. Recognize learners with special needs in group making.
- Encourage them actively participate in their respective groups. Move around the class guiding learners as they are discussing.
- Let one of the group member from each group presents its points of discussion to the whole class.
- Finally, consolidate the lesson by developing and giving your ideas basing on learners' ideas.
- Let students collect pictures and diagrams showing particles of the nucleus, important physicists who contributed to the discovery of the nucleus and its constituent particles, illustrations of experiments related to the nucleus. In class time, give a short lecture about the historical discovery of the nucleus and its constituents. Let students discuss in small groups and by polling of the whole class why the electron could be or could not be constituent particle of the nucleus.
- **Sit-work exercise:** Give students a table of isotopes and nuclear mass (A table containing few elements is enough). May be different groups may deal with different elements and their isotopes. Let individual students do the calculations for the binding energy of different isotopes and a group come-up with a set of biding energy. In whole class discussion, let individual groups contribute the result they arrived at about the least and highest binding energy and ask the class to comment on the result to give explanation about how the binding energy varies from isotope to isotope and from element to element.
- It is highly risky for the students to experiment by themselves in the area of nuclear physics. Moreover, demonstrations also depend primarily on the availability of the equipment and radioactive sources. It might be possible to contact a local hospital regarding the use of nuclear medicine for analysis or treatment. If a tour cannot be arranged, perhaps a specialist can speak to the class.
- Experiments on Half-life simulation can be performed using free applets available from the internet
- Dear physics teacher, download experiments on Half-life and Nuclear Collisions from the free applets available in the internet and show students with brief explanation
- Demonstrations:
    - Use either a prism or diffraction grating spectrometer to show the difference between continuous or line spectra. A simple absorption spectrum can be shown by crushing leaves in alcohol. The chlorophyll

solution will absorb at both ends of the spectrum

- ▷ If Geiger counter is available decay of radioactive materials can be detected. Some counters can separate betas from gammas by absorbing the betas in a metallic cover. Few have windows thin enough to detect alphas. If you can detect betas and gammas, use aluminium sheets and lead sheets to show that betas are stopped by aluminium, but lead is required to stop gammas.

- ▷ Ask students to explain why some atoms are stable and others are not, it helps to consider a diagram of stable and unstable nuclides.
- ▷ If it is an Experiment,
    - ▷ Indicate the resources needed
    - ▷ Indicate the procedure (guideline) to follow
- ▷ Provide the following materials to the learners in groups: Candle, Marbles…. Lead the learners through the procedures of the activity.
- ▷ After the activity, select some students and explain a candle flame near a charged electroscope and it discharges leaves. Flame produces ionization of nearby air. Repeat demonstration with opposite charge on electroscope. Holding weak radioactive source near electroscope may also cause discharge. Simulate nuclear reactions produced by high speed particles by using marbles accelerated down sloping aluminium channel into saucer. Those in saucer are analogous to target nuclei. Include several ball bearings of differing sizes. Show effect of speed by launching from different height and angles and effect of mass and increased momentum of projectiles by using different ball bearings. Ball with sufficient momentum can cause ejection of one or more marbles from saucer. Discuss analogy to bombarding nuclei with particles of ever increasing mass-proton, deuteron, and alpha.
- ▷ Project Works: assign learners in groups
    - ▷ Let the discus (ask experts) about the fraction of energy generated from nuclear power in Africa and the rest of the world; Peaceful uses of Nuclear Radiation in Ethiopia and Africa
    - ▷ Nuclear Facilities in Africa.

Then report their finding to the class.

- ▷ Demonstrate nuclear reactions using virtual laboratory simulation soft-wares like PhET.
- ▷ Small group work: Let students gather information about the possible sources of nuclear radiation from the internet. Let them also enquire about radiation hazards in their locality by having a meeting with the nearby Radiation Protection Authority and what could be done to protect themselves and others from radiation hazards. If there is no nearby authority, let them send their questions to an accessible body of authority by email. Let students organize a report about what measures they need to take as school community and present it to the whole class.

Assessment

Students' use of experimental and theoretical facts to accept or reject theoretical models of the nucleus is credited. To achieve the minimum required competency, the student should be able to: define the terms atomic mass, isotopes, radioactivity, mass defect, nuclear fission and fusion; describe the composition and size of a nucleus, radioactive decay law; State the nature ,charge, and properties of alpha, beta, and gamma radiation; explain the meaning of a half-life; Write equations to illustrate alpha and beta decay; Interpret equations representing nuclear reactions indicating the nature of energy released; Identify the relationship between mass and energy, work through simple problems on half-life; associate the release of energy in a nuclear reaction with a change in mass; Represent nuclear reactions in the form of equations; Distinguish between fission and fission.

Ask students to discuss about safety rules. The depth of students reasoning in discussing such societal issues as nuclear energy generation, contraband nuclear medicine, or radiation damages, must be highly credited.

7.1. The nucleus

[2 periods]

Students have learnt about an atom and its constituting fundamental particles in their chemistry and other science lessons. You can also focus on other concepts which are prerequisite for this unit, such as the concept of energy and its different forms; electrostatic forces and other fundamental universal forces.

Answers to Activity 5.1: Thinking on brainstorming questions

Most probably, students may not be that much familiar with the question "What force keeps protons and neutrons at the center of the atom?". Let them try it but you should not give the detail answer immediately. Simply tell them that they will learn the detail of this step by step as they go down this topic.

Read through the minimum learning objectives with students.

Teaching method

Let you give time to your students to discuss on brainstorming questions in Activity 5.1. Then, start your presentation by asking them these brainstorming questions. They have learnt most of these concepts at different levels primarily in their chemistry course.

Then, explain the modern atomic model under the scope of this lesson. Let you make your students appreciate how small the volume and how big the mass of the nucleus is compared to the atom as a whole. Explain why the mass number excludes the mass of the electron; what isotopes of an element are; who discovered the nucleus and how? Who discovered proton and how? Who discovered the neutron and how? More emphasis should be given on the experimental methods applied or used for each. Explain about strong and weak nuclear forces; binding energy and binding energy per nucleon including calculations; about nuclear stability and unstability.

Sizes and representations of the atom

- ▷ The mass of the nucleus is more than 99.9% of the mass of the atom and electrons have negligible mass. That is why the mass number, A, excludes that of the electron. When Z is the atomic number, then element X is designated by ${}^{A}_{Z}X$.
- ▷ The nucleus of an atom occupies only less than 0.01% of the volume of the atom. The radius of the nucleus is $R_0 = 1.2\text{fm} = 1.2 \times 10^{-15}\,\text{m}$. Radius of the atom is estimated by:

$$R = R_0 A^{1/3} = \left(1.2 \times 10^{-15}\,\text{m}\right) A^{1/3}$$

- ▷ Atoms with the same number of protons but different numbers of neutrons are called isotopes of an element. They share almost the same chemical properties, but differ in mass and therefore differ in physical properties.

Answers to Activity 7.2

- ▷ Let students collect pictures and diagrams showing particles of the nucleus, important physicists who contributed to the discovery of the nucleus and its constituent particles; illustrations of experiments related to the nucleus. Assess and appreciate their works and give other suggestions if any.
- ▷ Electrons obey the rules of quantum mechanics, according to which they can only have very specific energies and therefore cannot fall into the nucleus. However, the configuration of the atom, even when described by quantum mechanics, depends on the ratio of the masses of the components. So the mass factor is essential.

1.1.1. Historical origins of the nucleus and its constituting particles

Discovery of the nucleus: Rutherford discovered the nucleus experimentally. In his experiment, he bombarded an extremely thin piece of gold foil (100 nm thickness) with $\alpha-$ radiation emitted from radioactive source. The result was observed on a fluorescent zinc sulfide screen around the thin gold foil (The apparatus used is sketched in student's textbook). Based on his observations, Rutherford proposed a new atomic model in 1911, called the solar system model as all the positive charge and most of the mass is concentrated in a tiny central nucleus.

Discovery of the proton: Later in 1920, Rutherford postulated the hydrogen nucleus to be a new particle, which he called proton.

Discovery of the neutron: The British physicist James Chadwick discovered the neutron in 1932. A polonium source was used to irradiate beryllium with alpha particles. The resulting collisions produced a new kind of particle with a mass nearly equal to that of the proton, but with higher penetration through lead than the proton can do as neutrons are electrically neutral. Finally, he determined the mass of the neutron to be slightly greater than that of proton using conservation laws of energy and momentum.

1.1.2. What keeps the nucleus together?

Strong nuclear force: The strong nuclear force is a very short-range attractive force that acts between nucleons: protons and neutrons. This force is strong enough to withstand the electric repulsion force within a distance of slightly more than the radius of a nucleon, 10^{-15} m. Both nucleons are affected by the nuclear force almost identically.

Weak nuclear force: The weak nuclear force acts inside of individual nucleons, which means that it is even shorter ranged than the strong nuclear force. This force is the cause of decay of atoms by beta-emission which is the concern of the next section.

Nuclear binding energy

Nuclear binding energy is the energy that holds nucleons together. Another equivalent definition of binding energy is the minimum energy that is required to disassemble the nucleus of an atom into its constituent nucleons. It is mathematically given by

$$BE = \Delta mc^2$$

where c is the speed of light in vacuum, and Äm is the mass defect.

Nuclear energy is measured in "atomic energy unit (aeu)"; or "megaelectron volt (MeV)"; $1\text{aeu} = c^2 \times 1\text{ amu} = 1.44\times10^{-10}\text{J}$, and $1\text{MeV} = 1.602\times10^{-13}$ J, so $1\text{aeu} = 931.1\text{MeV}$.

The mass defect of an atom can be calculated by $\ddot{A}m = Zm_p + (A - Z)m_n - M$, where Zm_p is the total mass of the protons; $(A - Z)m_n$ is the total mass of the neutrons, and M is the mass of the nucleus. Using this into the former equation, we obtain:

$$BE = \Delta mc^2 = [Zm_p + (A-Z)\,m_n - M]\,c^2 = [Zm_p + (A-Z)\,m_n - M \times 931.1MeV$$

where $m_p = 1.0072766$u, $m_n = 1.0086654$ u, and $m_e = \dfrac{m_p}{1836} = 0.00054858$ u.

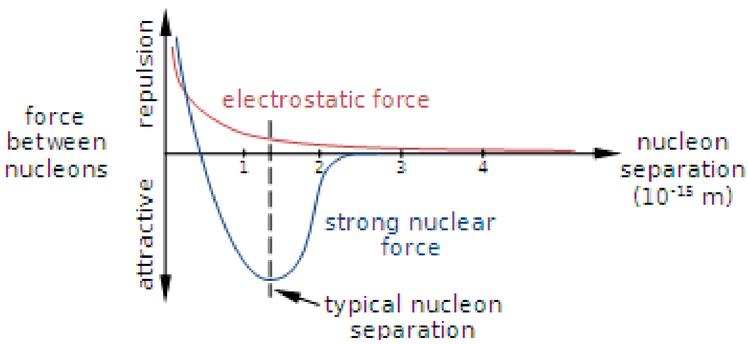
Binding energy per nucleon: Binding energy per nucleon (BEN) is the average energy required to remove an individual nucleon from a nucleus and is given by

$$\text{BEN} = \frac{\text{BE}}{\text{A}}$$

Answers to Activity 7.3:

Let students select few isotopes of some elements in the periodic table. Let individual students of each group do the calculations for the binding energy of different isotopes and the rest members of the group come up with a set of biding energy from different sources such as internet. Let each group contribute its result in a whole class discussion about the least and highest binding energies. Allow some students to explain about how the binding energy varies from isotope to isotope and from element to element. This variation is shown graphically in student's textbook, which is the next topic to consider.

Nuclear stability: Nuclear stability is determined by the binding energy per nucleon. The net binding energy of a nucleus is that of nuclear attraction, minus the disruptive energy of the electrostatic force. The figure below shows nuclear force, and disruptive Coulomb force. You can add the net force to the drawing. Details are discussed in student's text book.



Answers to Review Questions/7.1

1. The ratio of the radii of the two atoms of radius R_1 and R_2, are

$$\frac{R_1}{R_2} = \frac{R_0 A_1^{1/3}}{R_0 A_2^{1/3}} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

But $A_1 : A_2 = 27 : 125$, then the ratio of their nuclear radii is

$$\frac{R_1}{R_2} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$$

2. Given isotopes ^{16}O, ^{18}O, ^{18}F, ^{18}Ne and ^{20}Ne.

(a) ^{16}O, and ^{18}O are isotopes of oxygen. ^{18}Ne and ^{20}Ne are isotopes of neon.

(b) ^{18}O, and ^{18}F have equal number of neutrons.

3. $^{58}_{28}X$ and $^{58}_{30}Y$, then the neutron number of Y is $N_Y = 58 - 30 = 28$. X and Y cannot

be isotopes of the same element, because they have different number of protons.

4. (a) The electrostatic force is responsible for the deflection of alpha particles. (b) Most of the space in the atom is empty.
5. Rutherford's model of the atom failed to explain the stability of atoms. The arrangement of electrons in a circular path was not defined. Any particle that is moving in a circular path would undergo acceleration and radiates energy. Thus, the revolving electron would lose energy and finally fall into the nucleus.
6. In 1932, the physicist James Chadwick conducted an experiment in which he bombarded Beryllium with alpha particles from the natural radioactive decay of Polonium. The resulting radiation showed high penetration through a lead shield, which could not be explained via the particles known at that time. With the postulate of an uncharged (neutral) particle, of about the same weight as a proton, however, Chadwick's interpretation problems disappeared quite naturally. Thus, his results could be explained within the known laws of nature, in particular with regard to energy and momentum conservation.
7. The strong nuclear force is a very short range (about 1 to 3 fm) force, which acts to hold neutrons and protons together in nuclei. In nuclei, this force acts against the enormous repulsive electromagnetic force of the protons. The weak nuclear force is one of the four fundamental forces. The weak nuclear force (or just the weak force, or weak interaction) acts inside of individual nucleons, which means that it is even shorter ranged than the strong force.
8. Electrostatic force is a long range force. A proton can interact with all the protons within the nucleus through electrostatic force. Electrostatic force is a weak force. Nuclear force acts between the nucleons and it is independent of the charge. Nuclear force is short range force.
9. **Given**: m(H-1) = 1.007900 u, m(neutron) = 1.008665 u, m(Fe-56) = 55.934939u, m(Bi-209) = 208.980388u.

Binding energy of iron,

$$BE_{Fe} = [Zm_p + (A-Z)m_n - M] \times 931.1\text{MeV}$$

$$BE_{Fe} = [26 \times 1.007900\text{u} + (56-26) \times 1.008665\text{u} - 55.934939\text{u}] \times 931.1\text{MeV}$$

$$BE_{Fe} = 493.8656821\text{MeV}$$

The energy per nucleon of an iron atom, is then

$$BEN_{Fe} = \frac{BE_{Fe}}{A} = \frac{493.8656821\text{Me}V}{56} = 8.81\text{MeV/nucleon}$$

Binding energy of bismuth,

$$BE_{Bi} = [Zm_p + (A-Z)m_n - M] \times 931.1\text{MeV}$$

$$BE_{Bi} = [83 \times 1.007900u + (209-83) \times 1.008665u - 208.980388u] \times 931.1\text{MeV}$$

$$BE_{Bi} = 1645.3486722\text{MeV}$$

The energy per nucleon of a bismuth atom, is then

$$\frac{BE_{Bi}}{A} = \frac{1645.3486722\text{MeV}}{209} = 7.87\text{MeV/nucleon}$$

10. Why is it that certain combinations of nucleons are stable in a nucleus while others are not? A complete answer to this question cannot yet be given, largely because the exact nature of the forces holding the nucleons together is still only partially understood. We can, however, point to several factors which affect nuclear stability. The most obvious is the neutron/proton ratio. If this is too high or too low, it makes for an unstable nucleus.
11. If we plot the number of neutrons against the number of protons for all known stable (i.e., nonradioactive) nuclei, we obtain the result shown in the Figure given in the student's textbook. All the stable nuclei lie within a definite area called the zone of stability. For low atomic numbers most stable nuclei have a neutron/proton ratio which is very close to 1. As the atomic number increases, the zone of stability corresponds to a gradually increasing neutron/proton ratio. In the case of the heaviest stable isotope, $^{209}_{83}Bi$ for instance, the neutron/proton ratio is 1.518. If an unstable isotope lies to the left of the zone of stability, it is neutron rich and decays by ˜ emission. If it lies to the right of the zone, it is proton rich and decays by positron emission or electron capture.
12. The weak nuclear force is the force that allows protons to turn into neutrons and vice versa through beta decay. This keeps the right balance of protons and neutrons in a nucleus.

7.2. Radioactivity

[3 periods]

At the end of this section, students will be able to:

- *Define the terms radio-activity, and distinguish between the three types of emissions, alpha radiation, beta- radiation and gamma- radiation*
- *Recognize and discuss dangers of ionizing radiation;*
- *Discuss radioactive dating and radiation detectors;*
- *Identify radioactive sources in the school, home, and workplace and recommend protective measures to the school community.*

You can start this lesson by asking your students on concepts they have learnt above, which can be used as prerequisite knowledge for this section. For example, they have learnt about dependence of nuclear stability on binding energy per nucleon. They have learnt about the roles of weak and strong nuclear forces; and so on.

Teaching method

Start your lesson by revising nuclear unstability. Then explain types of the three radiations observed during spontaneous nuclear decay. Explain the important properties such as charge, penetration and ionization powers; their biological effects; and protection of risks on human's health. Explain the concept of half-life in depth and help them to calculate half-lives of some radioisotopes. Discuss different radiation detectors and the science used in such devices behind detection and measurement of radiation.

Types of nuclear radiations

Unstable nuclides decay spontaneously by any of the three radiations: alpha (˜), beta (°) and gamma (¸) emissions.

Beta emission

Beta radioactivity requires the weak nuclear force. Beta decay is a radioactive decay in which a beta ray is emitted from an atomic nucleus. There are two beta decay types: beta minus (° ⁻) and beta plus (° ⁺).

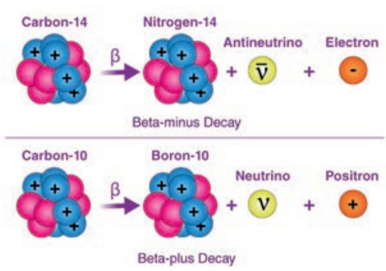
In beta minus, a neutron is transformed to yield a proton, causing an increase in the atom's atomic number. To maintain the conservation of charge, the nucleus in the process also produces an electron (beta-minus) and an antineutrino. Antineutrino is the antimatter counterpart of neutrino. Both of these are neutral particles with negligible mass- you can read more. In beta minus decay, the change in atomic configuration is:

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta + \overline{\upsilon} $$

In beta plus decay, the proton disintegrates to yield a neutron causing a decrease in the atomic number of the radioactive sample. The nucleus experiences a loss of proton but gains a neutron. Again, conservation of charge is important. The beta plus decay in order to obey the conservation law also yields a positron and a neutrino. A positron is the antimatter equivalent of an electron; the same in all aspects except that a positron has a positive charge. A neutrino's behavior is the same as the antineutrinos. As expressed in the equation, it is:

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}\beta $$

You can use examples sketched below.



Alpha and gamma emissions

Alpha and gamma radioactivity result from a nucleus having too much energy which it needs to expel to go into its lowest energy state. Alpha radiation is when a nucleus expels an alpha particle which is a helium 4 nucleus consisting of two protons and two neutrons. This normally occurs in heavier elements. It involves both the strong nuclear force and the electromagnetic force. The strong nuclear force liberates binding energy which allows the alpha particle to form and be ejects by electromagnetic repulsion of the positively charged nucleus and alpha particle. Equation of decay by alpha emission,

$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

Gamma radiation occurs when a nucleus has too much energy. It normally happens after alpha or beta decay to minimize the energy of the remaining nucleus. Gamma radiation consists of photons which are the carriers of the electromagnetic force.

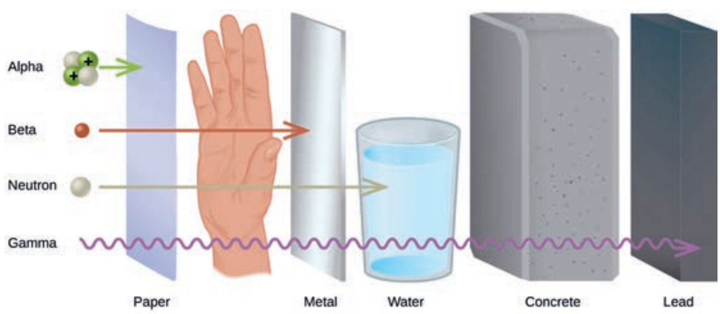
Answers to Activity 7.4:

- To discharge the electroscope, you will need to blow gently over the flame so that the ions pass over the top of the disc. The electroscope should discharge quickly to earth when the air above its disc is ionized.
- Similarly, holding weak radioactive source near the electroscope also ionizes the air around the electroscope which causes the discharge.

Ionization and penetration powers of nuclear radiations

When alpha, beta and gamma radiations penetrate matter, they produce ions and molecular fragments by knocking electrons from them. The greater mass presents the greater the ionizing power. Thus, alpha-radiation has the highest and gamma radiation has the least ionization powers.

The figure below compares penetrating powers of these radiations. Neutron is added to show impact of charge on penetration power.



Dangers of ionizing radiation, effective dose and safety precautions

When radiation passes through cellular tissue, it ionizes water molecules which change into free radicals. These radicals are highly reactive and can interact with the important genetic material in the cell, the DNA. In addition, the DNA may also be ionized directly.

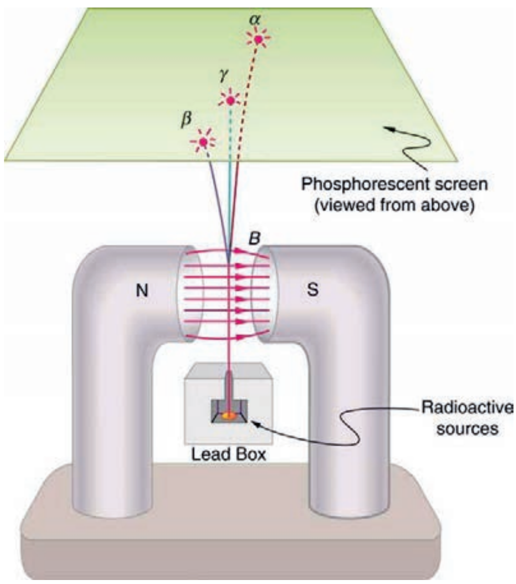
Because the radiations ionize to different extents, the hazard level is also different for each one. The extent of the potential damage depends on several factors, including: the type of radiation, the sensitivity of the affected tissues and organs, the manner and length of time exposed, the radioactive isotopes involved and characteristics of the exposed person (such as age, gender and underlying condition). Details of these and units used to measure effective dose are given in student's textbook.

Radiation Detectors

A particle detector, also known as a radiation detector, is a device used to detect, track, and/or identify ionizing particles, such as beta radiation, gamma radiation, and alpha radiation. There are different types of radiation detectors, most widely used one which is discussed in the student's textbook is Geiger counter, also known as the Geiger-Muller tube.

Answers to Activity 7.5: Demonstrations

▷ If there is Geiger counter in your school, exercise the demonstration type that your device can support. If there is no any detector in your school, it might be possible to contact a local hospital regarding the use of nuclear medicine for analysis or treatment. If a tour cannot be arranged, try to invite a specialist and let him/her speak to the class.



Use either a prism or diffraction grating spectrometer to show the difference between continuous or line spectra. A simple absorption spectrum can be shown by crushing leaves in alcohol. The chlorophyll solution will absorb at both ends of the spectrum.

Note that ˜ ray spectrum is continuous but ° and ¸ rays spectra do not.

- ▷ Here the detection of Geiger Muller counters of different radiations (°, ˜ a nd ¸ particle) emitted from radioactive isotopes, is shown in the figure below.

When °, ˜ and ¸ radiations pass through magnetic fields, alpha- and beta- radiations deflect in opposite directions while gamma radiation passes undeflected. .

Answer to Activity

Research common detectors for ° -particle, ˜ -particle and ¸ -rays

Organize your students to do in small group: Let them research the various forms of detectors for nuclear radiation. Let them prepare a summary of their research to present to the rest of the class. Help them to choose an appropriate format for their presentation.

The half life

The number of any radioactive parent nuclei decreases with time since it emits radiation in the form of ° , or ˜ emissions. The decay of a particular nucleus cannot be predicted and is not affected by physical influences like temperature. The decay rate, called the activity, A, is given by

$$A = \frac{\Delta N}{\Delta t} = -\lambda N$$

where the negative sign shows the decrease in the number of the radioactive nuclei with time; N is the number of undecayed nuclei at the subsequent time t; ″ is the decay constant of a radioactive nuclide having SI unit s^{-1}. The SI unit of activity, A, is Becquerel (Bq); where 1Bq = 1 decay per second. We can also use the unit Curie, Ci, where 1 Ci = $3.7\times10^{10}\,Bq$.

This exponential decay law is derived from the activity equation and is given by

$$N = N_0 e^{-\lambda t}$$

where N_0 is the number of undecayed nuclei at an initial time $t_0 = 0$.

The half-life is defined as the time at which half of the original nuclei have decayed. The half-life of a certain decay can be determined using $N = N\left(t_{1/2}\right) = N_0/2$, in to exponential decay law as:

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

For n integral numbers of half-lives, number of original nuclides left, can be calculated by

$$N = 2^{-n} N_0$$

Answer to Activity 7.6:

Facilitate or lead your students to perform experiments on Half life simulation using free applets available from the internet.

Answers to Review Questions/7.2

1. Total energy released by the decay of 1 mol of radon-222, is

   $E = 6.02214179 \times 10^{23}\text{nucleus} \times 8.2 \times 10^{-14}$ J/ nucleus

   $E = 49.381562678 \times 10^{9} J = 49.381562678 GJ$

2. Lighter nuclides tend to have equal number of protons and neutrons to be stable. For tritium - ${}^{3}_{1}H$ to attain this configuration needs to decay by beta minus emission.

$${}^{3}_{1}H \rightarrow {}^{3}_{2}H + {}^{0}_{-1}\beta + \overline{\nu}$$

Tritium is the only radioactive isotope of hydrogen. During its decay process, the tritium atom transforms into a nonradioactive helium atom and, in the process, emits a form of ionizing radiation known as a beta particle. The emission of this beta particle during the decay process is what makes tritium a potentially hazardous material.

3. Th-231 is the most stable isotope of Thorium. Pa-231 is the most stable isotope of Pa.
4. The actual risk depends on the specific types and quantities of radioactive materials, or isotopes, released how much radiation someone is exposed to and for how long and how a person comes in contact with the released radioactive materials (such as through contaminated food, water, air, or on the skin)
5. We cannot determine the time at which a given atom decays. We can determine the half life of the bulk of particles using a statistical method.
6. Uranium-238 decays through the-particle emission to form thorium-234 according to the equation:

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

Th-234 decays 100% by beta minus emission, basically to Pa-234 according to the equation:

$${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}\beta$$

7. The radioactive decay law states that "The probability per unit time that a nucleus will decay is a constant, independent of time". It is represented by ˜ (lambda) in the student's textbook and is called decay constant.
8. A Scintillator is a general term for substances that emit fluorescence when exposed to radiations of high energy- it is a type of phosphor. When a radiation collides with this substance, it absorbs its energy and internal electrons move from the ground state (stable state) to the excited state. When this electron returns to the original stable state, it releases its energy in the form of light emission (visible light or ultraviolet light), and this phenomenon is called scintillation.
9. In Geiger counter, when exposed to radioactive radiations, the stable gas within the chamber ionizes. This generates an electrical current that the counter records over a period of 60 seconds.
10. The operating medium should satisfy the following conditions.

- ▷ It should be chemically stable (or inert such as argon or helium) so that the moving ionization electrons are not easily captured by the molecules of that medium.
- ▷ It should have a low ionization potential value to maximize the amount of ionization produced per energy deposited by any incident particle.
- ▷ It should not be very sensitive to radiation damage so that its response to incident particles does not change markedly with use. Therefore, argon is chemically more stable.

11. The desired activity is,

$$A = \lambda N = \left(3.84 \times 10^{-12}\,Bq\right)\times 10^{8} = 3.84 \times 10^{-4}\,Bq$$

12. We can use $A = \lambda N_0 e^{-\lambda t}$. The ratio of activity $A_1 = 2000Bq$ to activity $A_2 = 1000$ Bq at $t_1 = 6$ hrs and $t_2 = 12$hrs, respectively, is

$$\frac{A_1}{A_2} = \frac{2000}{1000} = \frac{\lambda(4000)e^{-6\lambda}}{\lambda(4000)e^{-12\lambda}}$$

After simplification, we obtain

$$e^{6\lambda} = 2$$

Taking log of this at both sides and solving for λ, we obtain

The half-life is, then $\lambda = \frac{\ln 2}{6}\,hr^{-1} = 0.1155hr^{-1} = 415.8Bq$

$$\lambda = \frac{0.693}{t_{1/2}} = 415.8Bq \text{ , from this, we find } t_{1/2} = \frac{0.693}{415.8s^{-1}} = 1.667ms$$

13. Alpha is a positively charged particle, beta is negatively charged. On the contrary, gamma particle has no charge and so is neutral.
14. According to the currently valid definition, X-rays are emitted by electrons outside the nucleus, while gamma rays are emitted by the nucleus.
15. The proton stays in the nucleus but the electron leaves the atom as a beta particle. When a nucleus emits a beta particle, these changes happen: the mass number stays the same the atomic number increases by 1 the nuclear charge increases by 1.
16. Gamma rays have the highest penetration power. A living organism such as a human being exposed to gamma rays faces a high risk of having bone marrow and internal organs damaged. Gamma rays can pass through a body, damaging tissue and DNA in the process. Scientists consider gamma rays to be the most dangerous form of radiation.
17. Because neutrons are uncharged, they are more penetrating than alpha radiation or beta radiation. In some cases they are more penetrating than gamma radiation, which is impeded in materials of high atomic number. In materials of low atomic number such as hydrogen, a low energy gamma ray may be more penetrating than a high energy neutron.

7.3. Use of nuclear radiation

This section requires approximately 2 periods.

At the end of this topic, students will be able to:

- *Investigate the benefits and hazards (nuclear waste) of nuclear energy production;*
- *Discuss and appreciate the application of nuclear medicine*

Outside of nuclear power and some harmful applications such as nuclear weaponry, there remains a wide array/range of ways in which radioactive material and the radiation it gives off remain useful in the daily lives of people all over the world. The nuclear technologies are in use to improve agriculture, industries, medicine, water and sanitation and power generation.

In this section, students will learn only about uses of radiations of spontaneous emissions from radioisotopes. Other uses are included under induced nuclear reactions.

Teaching method

You can start this lesson by asking the brainstorming questions on Activity 7.3. Most people relate the term "nuclear" with devastating nuclear bombs. You need to brainwash on such issues that nuclear energy has tremendous uses.

Ask students what they know about radiation therapies and what they know about how ages of fossils such as Dinkinesh were measured. Let students say what they know on such questions. But you will not immediately rush into the answers. Tell them that they are going to learn about these step by step as they go down this section. Then, explain the different applications of radioactive nuclides, particularly, for diagnosis and treatment and for radioactive dating.

Some applications of nuclear radiation

Medical applications: Nuclear medicine uses radioactive material for diagnosis and for treatment. Details are given in student's textbook. You can also refer more to make your lesson clearer.

Answers to Activity 7.7:

Arrange a system so that students contact medical people having knowledge on nuclear radiation treatment or diagnosis in a nearby local hospital, so that they will follow demonstration regarding the use of nuclear medicine for diagnosis or treatment. If a tour cannot be arranged, try to invite a specialist to speak to the class.

For radioactive dating: Radioactive dating or radioisotope dating is a technique which is used to date materials by the use of naturally occurring radioactivity. Thus, once the isotopic abundances of each parent/daughter elements is determined using the mass spectrometer, the age (t), of the object can be calculated using the formula $t = (1/\lambda)\ln(N_0 / N)$, where N and N_0 are abundances of the parent and the daughter isotopes, respectively. Tell your students the discovery of age of Lucy was an application of radioactive dating but do not go through argon-argon dating employed to get the most precise age.

Answers to Review Questions/7.3

1. Students may give different answers to this question. Just list what they tell and make sure they have understood what they are learning. Here are some uses of radioactive isotopes. For example,

▷ In medicine,

- cobalt-60 is extensively employed as a radiation source to treat cancer; that is, to arrest the development of cancer.
- Radioactive isotopes are used as tracers for diagnostic purposes such as technetium-99m, is taken orally or is injected or is inhaled into the body. The radioisotope then circulates through the body or is taken up only by certain tissues. Its distribution can be tracked according to the radiation it gives off. The emitted radiation can be captured by various imaging techniques.
- Radioactive isotopes are used in research on metabolic processes. It is possible to trap the carbon dioxide evolved during the respiration of specifically labeled glucose (Example, $\left[{}^{14}_{6}C\right]$ glucose in which only the C-6 atom is radioactive) and obtain an evaluation of the contribution of each pathway to glucose oxidation.
- Carbon-14, can also be used in a breath test to detect the ulcer causing bacteria Heliobacter pylori.
- Iodine-131 has proved effective in treating hyperthyroidism.

▷ In industry, radioactive isotopes of various kinds:

- are used for measuring the thickness of metal or plastic sheets; their precise thickness is indicated by the strength of the radiations that penetrate the material being inspected.
- may also be employed in place of large X-ray machines to examine manufactured metal parts for structural defects.
- Other significant applications include the use of radioactive isotopes as compact sources of electrical power—example, plutonium-238 in spacecraft. In such cases, the heat produced in the decay of the radioactive isotope is converted into electricity by means of thermoelectric junction circuits or related devices.

2. Injected radioactive sources can be used as tracers to make soft tissues, such as blood vessels or the kidneys, show up through medical imaging processes. This

method is applicable in different diagnosis and treatments. For example, internal radiation can be used to give a higher dose of radiation over a shorter time. And the radiation only travels a short distance, so it kills the cancer cells with little damage to nearby tissues.

3. A radioactive tracer is a radioisotope that can be detected far from its original source to trace the path of certain chemicals. For example, Hydrogen-3 can be used to trace the path of water underground. They are also used to determine the location of fractures created by hydraulic fracturing in natural gas production. Radioactive tracers form the basis of a variety of imaging systems, such as, PET scans, SPECT scans and technetium scans. Radiocarbon dating uses the naturally occurring carbon-14 isotope as an isotopic label; and so on.
4. Radioactive dating is a process by which the approximate age of an object is determined through the use of certain radioactive nuclides. The basic logic behind radiometric dating is that if you compare the presence of a radioactive isotope within a sample to its known abundance on Earth, and its known half-life (its rate of decay), you can calculate the age of the sample.
5. The radioactive source used should emit gamma rays.
6. (a) It is because most rocks contain potassium! Potassium-40 is used for dating of rocks that are older than 100,000 years. (b) The reason why C-14 is very useful in the dating of fossils and some rocks is because it has a short half-life compared to other radioactive atoms.
7. Carbon-14 has a half-life of 5,730 years and is used to measure the age of organic materials. The ratio of carbon-14 to carbon-12 in living things remains constant while the organism is alive since fresh carbon-14 is entering the organism whenever it consumes nutrients. When the organism dies, this consumption stops, and no new carbon-14 is added to the organism. As time goes by, the ratio of carbon-14 to carbon-12 in the organism gradually declines, because carbon-14 radioactively decays while carbon-12 is stable. Analysis of this ratio allows archaeologists to estimate the age of organisms that were alive many thousands of years ago.
8. The table below shows some commonly used element pairs to establish absolute ages

Original element	Decay product	Half-life (years)	Dated materials
U-238	Pb-206	4.5 billion	Zircon
U-235	Pb-207	704 million	
Rb-87	Sr-87	48.8 billion	Many rock-forming minerals
K-40	Ar-40	1.25 billion	
Sm-147	Nd-143	106 billion	Common in very small concentrations in any rock
C-14	N-14	5,730	Previously living things

2.

9. Right after scanning using radiation for diagnosis,, the body will be very slightly radioactive but this wears off with time and is not directly harmful to others. Drinking a lot of water may help the radioactive material leave your body quicker.

7.4. Nuclear reaction and energy production

[3 periods]

At the end of this section, students will be able to:

- *Distinguish between the two types of nuclear reaction;*
- *Appreciate the sun as a big nuclear reactor.*
- *Discuss the use (energy production, production of important isotopes, etc.) and misuse (nuclear bomb) of artificial nuclear reaction.*

Students have learnt about spontaneous nuclear emissions, which is the prerequisite knowledge for this section. In this section, two types of reactions are treated-fission and fusion. Reaction processes and their uses are treated in depth.

Teaching method

Start your lesson by revising the spontaneous nuclear emissions, which is the prerequisite knowledge for this section. Then ask students what would happen is such radioactive nuclides are bombarded by particle radiations or if small nuclides are forced to fuse together.

Nuclear fission

Nuclear fission, the splitting of a heavy atomic nucleus into two fragments of roughly equal mass, can take place spontaneously or it can be induced by particle radiations such as protons, neutrons, alpha particles, and by electromagnetic radiations such as gamma radiations. In nuclear reactors, usually neutron induced reactions take place. Nuclear fission is accompanied by the release of a large amount of energy compared to the energy released by most chemical reactions. For example, the neutron induced reaction on U-235 is expressed as

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{144}_{56}\mathrm{Ba} + ^{89}_{36}\mathrm{Kr} + 3^{1}_{0}\mathrm{n} + 200\mathrm{MeV}$$

Answers to Activity 7.8: Simulating nuclear reactions

Set up a demonstration to simulate nuclear reactions produced by high speed particles using marbles accelerated down sloping aluminum channel into a saucer. Marbles in the saucer are analogous to target nuclei. Try using Include several marbles of differing sizes. Show the effect of speed by launching the marbles from different heights and angles and the effect of mass and the increased momentum of projectiles by using marbles of different sizes. Marbles coming down with sufficient momentum can cause ejection of one or more marbles from saucer. Discuss how this is analogues to bombarding nuclei with particles of ever increasing mass proton, deuteron, and alpha.

Applications of fission reaction

You do not need to discuss the details of nuclear chain reaction. Simply tell them that it is impossible to start nuclear reaction in nuclear reactors with any amount mass of radioactive substance.

Fission reaction has several real world applications. Some useful applications include electricity production using power reactors (PR), production of useful isotopes by using research reactors (RR) and so on. Fission reaction has also misused such as the production of nuclear and atomic bombs.

Answers to Activity 7.9:

Move on to discuss on nuclear power. This activity is an opportunity for students to research nuclear power in Africa. Allow time for the presentation of this research. Inevitably, students will be aware that nuclear power is not without controversy.

1.1.3. Nuclear fusion reaction and its uses

Nuclear fusion reaction is a process of making a single heavy nucleus from the combination of two or more lighter nuclei. The process releases energy because the total mass of the resulting single nucleus is less than the mass of the two original nuclei. The leftover mass becomes energy. In most cases, fusion reaction releases more energy than fission reaction.

The sun is a natural nuclear fusion reactor

The principal source of energy in the sun is a net fusion reaction in which four hydrogen nuclei fuses and produce a helium nucleus and two positrons. This is a net reaction of a more complicated series of events. The two important reactions are:

$$4\,{}_1^1\mathrm{H} \rightarrow {}_2^4\mathrm{He} + 2\,{}_{+1}^{0}\beta$$
$${}_1^2\mathrm{H} + {}_1^3\mathrm{H} \rightarrow {}_2^4\mathrm{He} + {}_0^1\mathrm{n}$$

The same processes undertake in all stars.

Answer to Activity 7.10:

Help students to find different useful software such as FET, and show them how to use it. Give them time to observe simulation of Nuclear Collisions using free applets available from the internet. Demonstrate reactions using virtual laboratory simulation software like PhET.

Answers to Review Questions/7.4

1. Radioisotopes , nuclear power process heat and non-stationary power reactors have essential uses across multiple sectors, including consumer products, food and agriculture, industry, medicine and scientific research, transport, and water resources and the environment.
2. Fission and fusion both are nuclear reactions and produce much energy, but their applicability is not the same. Fission is the splitting of an unstable and heavy nucleus into lighter nuclei, while fusion is the process of combining two light nuclei for releasing large amounts of energy. Because easy-controlling fission is used in nuclear power reactors, fusion is not employed to produce energy since the power is not easily controlled and is expensive to develop the required conditions for a fusion reaction. Fusion experiment stages are just started, and there is a long way to achieve what we need.
3. The answers in the following reactions are underlined.

   (a) ${}^{9}_{4}Be + {}^{1}_{1}H \rightarrow {}^{6}_{3}Li + \underline{{}^{4}_{2}He}$

   (b) ${}^{10}_{5}B + {}^{4}_{2}He \rightarrow {}^{13}_{7}N + \underline{{}^{1}_{0}n}$
4. Research reactors are simpler than power reactors and operate at lower temperatures. They need far less fuel, and far less fission products build up as the fuel is used. Like power reactors, the core needs cooling, typically natural or forced convection with water, and a moderator, is required to slow the neutron velocities and enhance fission. As neutron production is their main function, most research reactors benefit from reflectors to reduce neutron loss from the core.
5. Radioisotope power sources have been an important source of energy in space since 1961. Nuclear fission reactors for space have been used mainly by Russia, but new and more powerful designs are under development in both the USA and Russia. Plutonium-238 is a vital power source for deep space missions.
6. Nuclear power plant reactors produce low-level ionizing radiation, high level nuclear waste, and are likely to lead to catastrophic contamination events. Power generated from NPPs produce nuclear waste that should kept away from humans for thousands of years.
7. First let you find x and y in the equation:

$$ {}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{55}Cs + {}^{95}_{x}Rb + y\,{}^{1}_{0}n $$

   (a) From conservation of mass number: $235 + 1 = 137+95+1\times y$. From this, $y = 4$. From conservation of atomic number: $92 + 0 = 55+x+0\times y$. From this, $x = 37$. Then,

$$ {}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{55}Cs + {}^{95}_{37}Rb + 4\,{}^{1}_{0}n $$

(b) The activities at t = 0, $A_1 = 5.8 \times 10^{15}$ Bq, or $A_1 = -\lambda N_0$. The activity at the desired time is $A_2 = 1.6 \times 10^6$ Bq, or $A_2 = -\lambda N_0 e^{-\lambda t}$. Taking the ratio of the two, and taking the logarithm of the result, we get

$$t = \frac{1}{\lambda}\ln\left(\frac{A_1}{A_2}\right) = \left(\frac{t_{1/2}}{0.693}\right)\ln\left(\frac{A_1}{A_2}\right)$$

Substituting values, we obtain

$$t = \left(\frac{30\,yrs}{0.693}\right)\ln\left(\frac{5.8 \times 10^{15}\,Bq}{1.6 \times 10^{6}\,Bq}\right) = 1052.54\text{yrs}$$

(c) This waste is dangers for more than this amount of years.

8. Nuclear fission power plants have the disadvantage of generating unstable nuclei; some of these are radioactive for millions of years. Fusion on the other hand does not create any long-lived radioactive nuclear waste. A fusion reactor produces helium, which is an inert gas. It also produces and consumes tritium within the plant in a closed circuit. Tritium is radioactive (a beta emitter) but its half life is short. It is only used in low amounts so, unlike long-lived radioactive nuclei, it cannot produce any serious danger.
9. No chain reaction in nuclear fusion. Fusion cannot cause a nuclear accident because fusion energy production is not based on a chain reaction, as is fission. Plasma must be kept at very high temperatures with the support of external heating systems and confined by an external magnetic field.
10. No. Although hydrogen bombs do use fusion reactions, they require an additional fission bomb to detonate. Working conditions of a magnetically-confined fusion reactor require a limited amount of fuel in the reactor.
11. The mass of four hydrogen atoms is,

$$m(4H\text{-}1) = 4(1.007825\text{ u}) = 4.031300\text{ u}$$

The mass difference between four hydrogen atoms and one helium atom is

$$\Delta m = 4(1.007825\text{ u}) - (4.00260\text{ u}) = 0.02870\text{ u}$$

The energy released in the production

$$E = (0.02870\text{ u})(931\text{ MeV/u}) = 26.72\text{ MeV}$$

12. Hydrogen bomb vs. Atomic bomb

Atomic bomb	Hydrogen bomb
• Fission bombs or atomic bombs work by nuclear fission chain reaction. • The bombs dropped on Hiroshima and Nagasaki exploded with the yield of 15 kilotons and 20 kilotons of TNT, respectively, according to the Union of Concerned Scientists.	• Hydrogen bomb is a result of fusion reaction. Actual in hot nuclear reactions, the high temperature that accelerates hydrogen atoms is obtained by fission reaction. • Hydrogen bombs, or thermonuclear bombs, are more powerful than atomic or “fission” bombs. The first test of a thermonuclear weapon, or hydrogen bomb, in the United States in November 1952 yielded an explosion on the order of 10,000 kilotons of TNT.

7.5. Safety rules against hazards of nuclear radiation

[2 periods]

By the end of this section you should be able to:

- *Implement safety rules against hazards of nuclear radiation.*

The prerequisite knowledge for this section is starting with nuclear hazards to human beings, nature of ionizing radiations, effective doses and so on. This lesson deals with safety rules set by International Atomic Energy Agency (IAEA).

Teaching method

Then start by asking students the brainstorming questions in Activity 7._____. That is, ask them to discuss about safety rules. The depth of students reasoning in discussing such societal issues as nuclear energy generation, contraband nuclear medicine, or radiation damages, must be highly credited.

Nuclear Safety rules

Nuclear safety is defined by the International Atomic Energy Agency (IAEA) as "The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards". The IAEA defines nuclear security as "The prevention and detection of and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear materials, other radioactive substances or their associated facilities". This covers nuclear power plants and all other nuclear facilities, the transportation of nuclear materials, and the use and storage of nuclear materials for medical, power, industry, and military uses.

Among the IAEA's key publications are its Safety Standards, which provide the fundamental principles, requirements and recommendations to ensure nuclear safety. They serve as a global reference for protecting people and the environment. Refer to this publication so that you can help your students more.

Nuclear safety therefore covers at minimum:

- Extraction, transportation, storage, processing, and disposal of fissionable materials
- Safety of nuclear power generators
- Control and safe management of nuclear weapons, nuclear material capable of use as a weapon, and other radioactive materials
- Safe handling, accountability and use in industrial, medical and research contexts
- Disposal of nuclear waste

- ▷ Limitations on exposure to radiation
- ▷ Safety rules are given in the student's textbooks. You need to read more and give additional information to your students.

Answers to Activity 7.11:

Let students organize in small groups and gather information about the possible sources of nuclear radiation from the internet before they meet the guest.

- ▷ Let them enquire about radiation hazards in their locality by having a meeting with the nearby Radiation Protection Authority and let them ask what could be done to protect themselves and others from radiation hazards.
- ▷ If there is no nearby authority, help them to send their questions to an accessible body of authority by electronic media.
- ▷ Let students organize a report per group about what measures they need to take as school community and present it to the whole class.

Answers to Activity 7.12: Expert Guest:

Invite medical personnel from a nearby medical establishment who is knowledgeable about nuclear medicine, so that he/she answers questions for your students. Let students get prepared on the following questions for the guest.

- ▷ How and why nuclear medicine is practiced, where the medicine comes from and how it is transported; handled, stored.
- ▷ What measures should be implemented during use and disposal of these medicines. To actively engage with the guest, you need prior reading.

Discuss with your about hazards of nuclear radiations and safety.

Answers to Review questions/7.5

1. For low levels of radiation exposure, biological effects of radiations are so small that they may not even be detectable. In addition, the human body has defense mechanisms against many types of damage induced by radiation. Consequently, radiation may have one of three biological effects, with distinct outcomes for living cells:

    - ▷ injured or damaged cells repair themselves, resulting in no residual damage;
    - ▷ cells die, much like millions of body cells do every day, being replaced through normal biological processes; or
    - ▷ cells incorrectly repair themselves, resulting in a biophysical change.

    The exact effect depends on the specific type and intensity of the radiation exposure. Advice accordingly.

2. When handled correctly, radioactive materials have many beneficial uses; misused, however, it can pose a significant danger. Ionization can cause damage within a cell, which could eventually lead to cancer, a mutation in genetic material, or more immediate types of physical harm to humans.
3. Time, distance, and shielding measures minimize your exposure to radiation. In the case of containment, radioactive materials are confined in the smallest possible space and kept out of the environment. Rooms have a reduced air pressure so that any leaks occur into the room and not out of it.
4. Keep cuts and abrasions covered when handling contaminated items to avoid getting radioactive material in them. Wash all of the exposed parts of your body using lots of soap and lukewarm water to remove contamination. This process is called decontamination.
5. Yes. Nuclear waste must be processed to make it safe for disposal. This includes its collection and sorting; reducing its volume and changing its chemical and physical composition, such as concentrating liquid waste; and finally, its conditioning so it is immobilized and packaged before storage and disposal.
6. By contrast, most of an operating nuclear power plant's direct radiation is blocked by the plant's steel and concrete structures. The remainder dissipates in an area of controlled, uninhabited space around the plant, ensuring that it does not affect any member of the public.

Unit summary

▷ Atom and nucleus are assumed spherical and the atomic radius is estimated by:

$$R = R_0 A^{1/3} = \left(1.2\times10^{-15}\,\text{m}\right)A^{1/3}$$

where A is the mass number of the atom; R_0 is the radius of the nucleus which is roughly equal to $R_0 = 1.2\text{fm}$ and 1 femtometer (1 fm) = $10^{-15}\,\text{m}$.

▷ A member of a family of an element with the same number of protons but different number of neutrons is called an isotope.

▷ The strong nuclear force is a very short-range attractive force that acts between nucleons: protons and neutrons. The strong nuclear force is strong enough to withstand the electric repulsion force within a distance of slightly more than the radius of a nucleon, 10^{-15} m. Both nucleons are affected by the nuclear force almost identically.

▷ The weak nuclear force acts inside of individual nucleons, which means that it is even shorter ranged than the strong nuclear force. The weak nuclear force is a force that causes decay of an atom by beta emission.

▷ Nuclear binding energy is the energy that holds nucleons together. Another equivalent definition of binding energy is the minimum energy that is required to disassemble the nucleus of an atom into its constituent nucleons.

- The mass of an atomic nucleus is less than the sum of the individual masses of the free constituent protons and neutrons. The energy equivalent to this difference in mass can be calculated by the Einstein equation,

$$BE = \Delta mc^2$$

where BE is the nuclear binding energy, and c is the speed of light. This 'missing mass' is known as the mass defect, and represents the energy that was released when the nucleus was formed.

- The mass defect of an atom can be calculated by:

$$\Delta m = Zm_p + (A - Z)\, m_p - M$$

where Zm_p is the total mass of the protons; $(A - Z)m_n$ is the total mass of the neutrons, and M is the mass of the nucleus. Using this into the former equation, we obtain:

$$BE = \Delta mc^2 = [Zm_p + (A - Z)\, m_n - M]\, c^2$$

- Nuclear energy is usually expressed in atomic energy unit (aeu), where:

$$1\,\text{aeu} = c^2 \times 1\,\text{amu} = \left(9 \times 10^{16}\,\text{m}^2/\text{s}^2\right) \times \left(1.602 \times 10^{-27}\,\text{kg}\right) = 1.44 \times 10^{-10}\,\text{J}$$

Or, in megaelectron volt (MeV), where $1\text{MeV} = 1.602 \times 10^{-13}$ J, and

$$1\,\text{aeu} = 931.1\text{MeV}$$

- When mass is in amu/u, the nuclear binding energy in MeV becomes,

$$BE = [Zm_p + (A\text{-}Z)m_n \text{-} M] \times 931.1\text{MeV}$$

- Binding energy per nucleon (BEN) is the average energy required to remove an individual nucleon from a nucleus. It is given by

$$\text{BEN} = \frac{\text{BE}}{\text{A}}$$

- Radioactivity is the phenomenon of the spontaneous disintegration of unstable atomic nuclei to atomic nuclei to form more energetically stable atomic nuclei. Radioactive decay is a highly exoergic, statistically random, process that occurs with a small amount of mass being converted to energy.
- Representations of nuclear decay reaction of element with chemical symbol X by alpha (˜), or beta (β^-, or β^+) emission to give a daughter element Y are:

$$\alpha - \text{emission}: \; {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

$$\beta^- - \text{emission}: \; {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta + \overline{\upsilon}$$

$$\beta^+ - \text{emission}: \; {}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}\beta$$

- Gamma rays are high energy, high frequency, electromagnetic radiations. Gamma radiation usually accompanies alpha or beta decay.
- Radiations damage cells by ionizing atoms or molecules by removing electrons from them.
- **Absorbed dose** describes the amount of energy deposited per unit mass in an

object or person. The units for absorbed dose are gray (Gy, international unit) and rad; where 1Gy = 1J/kg and 1rad = 0.01 Gy = 0.01 J/kg.

▷ Radiation doses above 3 Gy (300 rad) can be fatal and doses above 6 Gy (600 rad) are almost certain to be fatal, with death occurring within several months (in shorter times at higher doses).

▷ A radiation detector is a device that measures the ionization of radiations (i.e., creating electrons and positively charged ions). Scintilator, and Gaseous ionization detectors such as Geiger counter.

▷ The rate of isotope decay is called the activity, A, and is given by

$$A = \frac{\Delta N(t)}{\Delta t} = -\lambda N(t)$$

where the negative sign shows the decrease in the number of the radioactive nuclei with time, N(t) is the number of undecayed nuclei at the subsequent time t, the decay constant ˜ of a radioactive nuclide is defined as its probability of decay per unit time; having SI unit s^{-1}. The SI unit of activity, A, is Becquerel (Bq); where 1Bq = 1 decay per second. We can also use the unit Curie, Ci, where 1 Ci $= 3.7\times10^{10}\,Bq$.

▷ If N_0 is quantity at time t =0, the quantity of the parent radioactive nuclei is subject to exponential decay given by

$$N(t) = N_0 e^{-\lambda t}$$

▷ The half-life is defined as the time at which half of the original nuclei have decayed. Or, it can also be stated somewhat differently as the time after which one half of the original number of nuclei remains untransformed. The half-life is related to the decay constant by

$$t_{1/2} = \ln 2/\lambda = 0.693/\lambda$$

▷ Fission occurs when a neutron slams into a larger atom, forcing it to excite and split into two smaller atoms—also known as fission products.

▷ Nuclear fusion reaction is a process of making a single heavy nucleus from the combination of two or more lighter nuclei.

▷ A nuclear reactor is a device used to initiate and control a fission nuclear chain reaction or nuclear fusion reactions.

Answers to End of Unit questions/7

1. Both Rutherford model and Bohr model explain the same concept of atomic structure with slight variations. The main difference between Rutherford model and Bohr model is that Rutherford model does not explain the energy levels in an atom whereas Bohr model explains the energy levels in an atom.
2. $R_{238} = R_0 A^{1/3} = \left(1.2\times10^{-15}\,m\right)\left(238\right)^{1/3} = 7.4366\times10^{-15}\,m$, and
$R_{235} = R_0 A^{1/3} = \left(1.2\times10^{-15}\,m\right)\left(235\right)^{1/3} = 7.4052\times10^{-15}\,m$

Have the same chemical properties but different in size.

3. **Solution:** Z = 1, A = 2, $m_p = 1.00728\ u$, $m_n = 1.00867\ u$, $m_{nuc} = 2u$

The mass defect is

$$\Delta m = Zm_p + (A - Z)m_n - m_{nuc}$$
$$\Delta m = 1 \times 1.00728\ u + (2 - 1) \times 1.00867\ u - 2u$$
$$\Delta m = 0.01595\ u$$

The mass defect in amu/u is 0.01595. The binding energy in deuterium is, then:

$$BE = [Zm_p + (A\text{-}Z)m_n \text{-} M] \times 931.1 MeV = \Delta m \times 931.1 MeV$$
$$BE = 0.01595 u \times 931.1 MeV/u = 14.851 MeV$$

The binding energy per nucleon in deuterium:

$$BEN = \frac{BE}{A} = \frac{14.851045\ MeV}{2} \approx 7.4\ MeV$$

4. The actual mass of the atomic nucleus is always less than the mass of protons and neutrons present in the nucleus. When a nucleus is formed, energy is released. This energy is removed in the form of a reduction in total mass. This missing mass is known as the 'mass defect' and it accounts for the energy released.

   The difference in mass corresponds to the nuclear binding energy. The larger the value of the mass defect, the greater the nuclear binding energy and the more stable the nucleus.

5. Radioactive isotopes have many useful applications. In medicine, for example, cobalt-60 is extensively employed as a radiation source to arrest the development of cancer. Other radioactive isotopes are used as tracers for diagnostic purposes as well as in research on metabolic processes. Another medically important radioactive isotope is carbon-14, which is used in a breath test to detect the ulcer-causing bacteria Heliobacter pylori. In industry, radioactive isotopes of various kinds are used for measuring the thickness of metal or plastic sheets; their precise thickness is indicated by the strength of the radiations that penetrate the material being inspected. Other significant applications include the use of radioactive isotopes as compact sources of electrical power—e.g., plutonium-238 in spacecraft.
6. Radiation can damage the DNA in our cells. High doses of radiation can cause Acute Radiation Syndrome (ARS) or Cutaneous Radiation Injuries (CRI). High doses of radiation could also lead to cancer later in life.
7. ${}^{42}_{19}K \rightarrow {}^{0}_{-1}\beta + {}^{42}_{20}Ca$, and ${}^{239}Pu \rightarrow {}^{4}He + {}^{235}U$

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