PHYSICS

CLASS

TEN

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Preface

This textbook is a progressive one from class IX Physics and all efforts are made to make linkages and progressions to scientific concepts learnt in the previous years. The chapter outlines and contents in this textbook are similar to the ones in the class IX textbook.

Teaching and learning of science in our country has under gone major changes in recent times. But it is the first time in Bhutan that text books for class IX to XII are adapted to our context. Theories and laws are universal but we strongly believe that experiments and activities to either introduce or consolidate these facts can be done through our own everyday experiences. Therefore, all efforts are made in these textbook to maintain these essence.

The selection of our Physics textbook in class IX has really encouraged us to continue our venture in writing this textbook, and we thought that we should not miss out on our attempts to put all out efforts to try our luck in Class X. Our hard work and effort is now paid as this textbook is selected in Class X. The advantage for students is that they shall experience the same style and flavour of writing.

Like the previous book, this textbook contains relevant solved examples after topics, topic end questions, competency based questions, and a model question paper at the end. Special efforts are made to introduce the new concepts by relating to the existing knowledge of the learners and suitable activities are in place to either induce or consolidate their learning. In this textbook too, students will have the opportunity to learn all the 21st century skills for learning through active learning strategies and assessment of their learning.

All suggestions and constructive feedbacks are welcome and we shall try our best to accommodate them in subsequent editions.

-Authors

SYLLABUS

Strand: Physical processes

1. Forces and Motion

(i) Force and acceleration

- State that the centre of gravity of an object is a point where the entire weight of an object appears to act.
- Describe a simple couple as a pair of equal and opposite parallel forces whose lines of action do not coincide, and results in rotation
- Explain the torque of a couple.
- Explain that a system is in equilibrium if there is no resultant force and no resultant moment.
- Explain the principle of moments to solve problems involving forces acting in two dimensions.

(ii) Force and non-uniform motion

- Explain that the forces acting on falling objects change with velocity.
- Describe terminal velocity in falling objects.

(iii) Pressure

- State and use the equation for pressure $P = \frac{F}{A}$
- State and apply the equation for density $\rho = \frac{m}{V}$
- Explain Pascal's law and its application e.g. in hydraulic systems, car brakes, diving, etc.

2. Energy

(i) Energy resources and energy transfer

- Describe efficient ways to use energy
- Describe the need for economical and sustainable use of energy resources, and the environmental implications of our current methods for generating energy.

(ii) Work and conservation of energy

- Apply the principle of the conservation of energy to gravitational potential energy, kinetic energy and work done against resistive forces.
- Calculate the work done by a constant force (to include examples where the force is not in the same direction as the displacement) using W=Fd(adjacent side/opposite side).
- State and use the equation for potential energy $PE=mgh$.
- State and use the equation for kinetic energy $K.E. = \frac{1}{2}mv^2$.
- Calculate the power of a machine using $P = \frac{W}{t}$
- Calculate the efficiency of a machine in $p = \frac{W_{out}}{W_{in}}$

3. Electricity and magnetism

(i) Circuits

- Describe that the flow of charges through a resistor results in heating of resistor.
- Describe the qualitative effect of changing resistance on the current in a circuit.
- Calculate the resistance, voltage and current from Ohm's law ($V=IR$) including potential drop, graph of ohmic and non-ohmic conductors.
- Describe the variation of current with voltage in a range of devices (e.g, resistors, filament bulbs, diodes, light dependent resistors (LDRs) and thermistors).
- Explain that voltage is the energy transferred per unit charge.
- Calculate power, voltage and current using $P=IV$.

(ii) Electromagnetic effects

- Explain the working of simple a.c. generators and transformers.
- Calculate the voltages across the coils in a transformer from the numbers of turns in the coils.
- Describe transfer of energy from power stations to consumers.
- Explain that electricity is transferred at high voltages in power supply systems.
- Explain the use of a.c. in power supply systems.

4. Waves

(i) The electromagnetic spectrum

- Name the different components of the electromagnetic spectrum: radio waves, microwaves, infrared, visible light, ultraviolet waves, X-rays and gamma rays.
- Describe the uses of microwaves, infrared and ultraviolet waves and their potential dangers.
- State some uses of X-rays and gamma rays in medical field.
- Explain the transfer of information along optical fibres.
- Explain that radio waves, microwaves, infrared and visible light carry information over large and small distances, including global transmission via satellites.
- Describe the ways in which reflection, refraction and diffraction affect communication.
- Describe the difference between analogue and digital signals and that more information can be transmitted using digital signals.

5. The Earth and beyond

- Explain that gravity acts as a force throughout the universe.
- Describe evolution of stars over a long timescale.
- Describe the search for evidence of life elsewhere in the universe.
- Describe ideas and evidences (e.g. microwave background, red shift) used to explain the origin and evolution of the universe.

Assessment

Assessment in science involves detailed process of measuring students' achievement in terms of knowledge, skills, and attitude. The progress of learning is inferred through analysis of information collected. The accuracy and objectivity of assessment determines its validity. The modality and components of assessment should be clearly conveyed to the students. The teacher's expectations should be made clear to students and appropriate learning outcomes should be set. The teachers can play an important role in the students' achievement by effectively monitoring their learning, and giving them constructive feedback on how they can improve, and provide the necessary scaffolding for the needy learners as identified through reliable assessment techniques and tools.

Purpose of Assessment

Assessment is used to:

- **inform and guide teaching and learning:** A good assessment plan helps to gather evidences of students' learning that inform teachers' instructional decisions. It provides teachers with information about the performance of students. In addition to helping teachers formulate the next teaching steps, a good classroom assessment plan provides a road map for students. Therefore, students should have access to the assessment so they can use it to inform and guide their learning.
- **help students set learning goals:** Students need frequent opportunities to reflect on what they have learnt and how their learning can be improved. Accordingly, students can set their goals. Generally, when students are actively involved in assessing their own next learning steps and creating goals to accomplish them, they make major advances in directing their learning.
- **assign report card grades:** Grades provide parents, employers, other schools, governments, post-secondary institutions and others with summary information about students' learning and performances.
- **motivate students:** Students are motivated and confident learners when they experience progress and achievement. The evidences gathered can usher poor performers to perform better through remedial measures.

The achievements and performances of the learners in physics are assessed on the following three domains:

- **Scientific knowledge:** Basic knowledge and understanding of energy and work, force and structures, electricity and magnetism, sound and light, thermodynamics, modern physics and inter-relationship of physical science with other branches of science, and their attributes to people and environment .

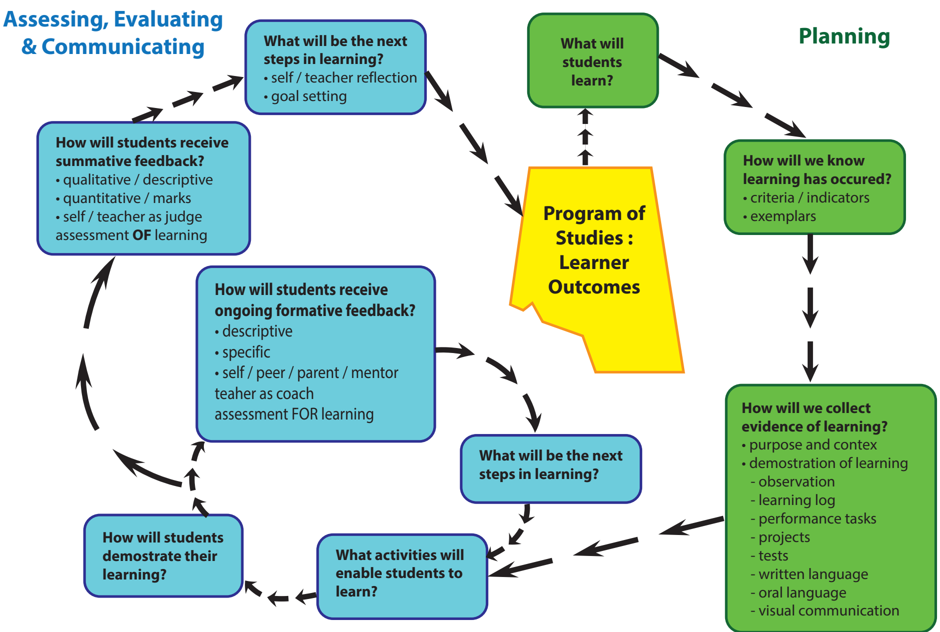
- **Working scientifically:** Basic understanding of the nature of science, and how science works. Demonstration of logical and abstract thinking and comprehension of complex situations. Explore how technological advances are related to the scientific ideas underpinning them. Compare, contrast, synthesize, question and critique the different sources of information, and communicate their ideas clearly and precisely in a variety of ways, including the use of ICT.
- **Scientific values and attitudes:** Consider the power and limitations of science in addressing social, industrial, ethical and environmental issues, and how different groups in the community and beyond may have different views about the role of science. They make informed judgments on statements and debates that have a scientific basis, and use their learning in science for planning positive action for the welfare of themselves, others in their community and the environment.

The Assessment Process

Effective classroom assessment in Science:

- assesses specific outcomes in the program of studies.
- the intended outcomes and assessment criteria are shared with students prior to the assessment activity.

Assessing Student Learning in Classroom



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- assesses before, during and after instruction.
- employs a variety of assessment strategies to provide evidence of students' learning.
- provides frequent and descriptive feedback to students.
- ensures students can describe their progress and achievement, and articulate what comes next in their learning.
- informs teachers and provides insight that can be used to modify instruction.

Scheme of assessment in science

The following schemes of assessment are used to assess students' performance:

1. Continuous Formative Assessment (CFA)

Formative assessment is used to provide feedback to teachers and students, so that teaching and learning can be improved through the provision of regular feedback and remedial learning opportunities. It also enables teachers to understand what teaching methods and materials work best.

CFA facilitates teachers to diagnose the learning needs of learners and recognize the individual differences in learning. Through the constructive feedback, students are able to understand their strengths and weaknesses. It also empowers them to be self-reflective learners, who monitor and evaluate their own progress.

CFA should happen daily throughout the teaching-learning processes of the academic year. It is NOT graded, as it is only to give continuous feedbacks to the students.

2. Continuous Summative Assessment (CSA)

Continuous Summative Assessment is another form of continuous assessment (CA). It helps in determining the student's performance and the effectiveness of instructional decisions of teachers. The evidences from this assessment help students to improve learning, and mandate teachers to incorporate varied teaching strategies and resources to ensure quality teaching and learning in the science classes. This assessment also empowers students to be self-reflective learners, who monitor and evaluate their own progress.

In CSA, the students' performances and achievements are graded. This ensures active participations of learners in the teaching and learning processes.

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3. Summative Assessment (SA)

Summative assessment (SA) is conducted at the end of the first term and at the end of the year to determine the level of learning outcomes achieved by students. The information gathered is used by teachers to grade students for promotion, and to report to parents and other stakeholders.

The identified techniques for SA are term examinations - first term and annual examinations. The questions for the term examinations should cover all the three domains of science learning objectives, using the principles of Bloom's taxonomy.

Assessment Matrix								
Types of assessment	CFA			CSA			SA	
Definition	It is a continuous process of assessing student's problems and learning needs and to identify the remedial measures to improve student's learning. It also enables teachers to understand what teaching methods and materials work best.			It is a continuous process of grading student's performances and achievements. Teachers provide feedbacks for improvement. It also enables teachers to understand what teaching methods and materials work best.			Assesses student's cumulative performances and achievements at the end of each term.	
Domains	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	SK, WS & SV	SK, WS & SV
Techniques	Quiz & debate,class presentation, homework, class work, immediate interaction with students.	Immediate interaction with students, class work, home work, experiments, exhibition, case studies	Observation of student's conduct, in group work, field trip, excursion, etc.	Home work and chapter end test.	Practical work	Project Work.	Term exam.	Term exam
Assessment Tools	Q&A, checklist and anecdotal records.	Checklist and anecdotal records.	Checklist and anecdotal records.	Rubrics (HW) and paper pencil test (Chapter end test).	Rubrics (Practical work)	Rubrics (Project work)	Paper pencil test	Paper pencil test
Frequency interval (when &how)	Checklists and anecdotal records must be maintained for each topic throughout the academic year.			HW-for every chapter, Chapter end test – for every chapter.	Practical work once in each term	Project Work –Once for the whole year but assessed two times (half yearly)	Once in a term.	Once in a year.
Format in Progress Report				SK	WS	SV	Mid-Term	Annual Exam
Weightings				T1= 2.5 T2= 2.5	T1= 5 T2= 5	T1= 2.5 T2= 2.5	T1=30	T2=50

Assessment Techniques and Tools

The following techniques and tools are used in assessing students' performance with objectivity.

1. Observation Check list

Observing students as they solve problems, model skills to others, think aloud during a sequence of activities, or interact with peers in different learning situations provides insight into student's learning and growth. The teacher finds out under what conditions success is most likely, what individual students do when they encounter difficulty, how interaction with others affects their learning and concentration, and what students need to learn next. Observations may be informal or highly structured, and incidental or scheduled over different a period in different learning contexts. Observation checklists are tools that allow teachers to record information quickly about how students perform in relation to specific outcomes from the program of studies. Observation checklists, written in a yes/no format can be used to assist in observing student performance relative to specific criteria. They may be directed toward observations of an individual or group. These tools can also include spaces for brief comments, which provide additional information not captured in the checklist.

Tips for using Observation Checklists

i. *Determine specific outcomes to observe and assess.*

ii. *Decide what to look for. Write down criteria or evidence that indicates the student is demonstrating the outcome.*

iii. *Ensure students know and understand what the criteria are.*

iv. *Target your observation by selecting four to five students per lesson and one or two specific outcomes to observe. Date all observations.*

v. *Collect observations over a number of lessons during a reporting period and look for patterns of performance.*

vi. *Share observations with students, both individually and in a group. Make the observations specific and describe how this demonstrates or promotes thinking and learning.*

vii. *Use the information gathered from observation to enhance or modify future instruction.*

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Sample Checklist

Name	Topic: Pressure									Teacher's comments
	Scientific knowledge			Working scientifically			Scientific values			
	Explains pressure and thrust per unit area	Lists down the significance of pressure in our daily lives	State Pascal's Law and describe its applications	Follows correct experimental procedures.	Handles equipment, apparatuses, and chemical safely.	Demonstrates ability to set up experiments.	Respects others ideas and views	Shows curiosity to learn science	Demonstrates concern for oneself and others	
Tandin										
Tshering										

2. Anecdotal notes

Anecdotal notes are used to record specific observations of individual student **behaviours, skills, and attitudes** in relation to the outcomes of the science teaching and learning process. Such notes provide cumulative information on students' learning and direction for further instruction. Anecdotal notes are often written as ongoing observations during the lessons, but may also be written in response to a product or performance of the students. They are generally brief, objective, and focused on specific outcomes. The notes taken during or immediately following an activity are generally the most accurate. Anecdotal notes for a particular student can be periodically shared with the student, or be shared at the student's request.

The purpose of anecdotal notes is to:

- provide information regarding a student's development over a period of time.
- provide ongoing records about individual instructional needs.
- capture observations of significant behaviours that might otherwise be lost.

Tips for maintaining Anecdotal Notes

i. *Keep a notebook or binder with a separate page for each student. Write the date and the student's name on each page of the notebook.*

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ii. *Following the observations, notes are recorded on the page reserved for that student in the notebook.*

iii. *The pages may be divided into three columns: Date, Observation and Action Plan.*

iv. *Keep notes brief and focused (usually no more than a few sentences or phrases).*

v. *Note the context and any comments or questions for follow-up.*

vi. *Keep comments objective. Make specific comments about student strengths, especially after several observations have been recorded and a pattern has been observed.*

3. Project work

Project work is one of the best ways to practice the application of scientific conceptual ideas and skills. The very purpose of including project work is to provide opportunity to explore and extend their scientific knowledge and skills beyond the classroom. Students learn to organize, plan and piece together many separate ideas and information into a coherent whole. Through project work, students learn various scientific techniques and skills, including data collection, analysis, experimentation, interpretation, evaluation and drawing conclusion; and it fosters positive attitude towards science and environment.

The science curriculum mandates students to carry out project work to help them to:

i. develop scientific skills of planning, designing and making scientific artefacts, carrying out investigations, observation, analysis, synthesis, interpretation, organization and recording of information.

ii. enhance deeper understanding of social and natural environment.

iii. develop student's ability to work in group and independently.

iv. provide opportunity to explore beyond the classroom in enhancing their scientific knowledge and skills, which will contribute towards the development of positive attitudes and values towards science and environment.

v. understand how science works and the nature of scientific knowledge.

vi. develop oral and written communication skills.

Teachers can facilitate students to carry out the project work by considering the following suggested guidelines.

- Allow students to select their own project ideas and topics.
- Encourage students to be scientifically creative and productive.
- Provide a clear set of guidelines for developing and completing projects.
- Help students to locate sources of information, including workers in science-

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related fields who might advise them about their projects.

- Allow students the option of presenting their finished projects to the class.
- Inform students about the general areas on which assessment may be made. For example, scientific content or concepts, originality of ideas, procedures, and the presentation.
- Advice students to contact their teacher for further assistance or consultations, for, students must be closely guided by the teacher starting from the selection of the topic, doing investigations, data collection, and analysis to writing report in a formal style.

Each student is assigned a Project Work for the academic year. The project work is assessed out of 28 marks, which should be converted out of 5 marks for the whole year. Students can share their project work findings, either in the form of class presentation or display.

At the end of the project work, every student must prepare a project work report, about 2000 to 2500 words, in the formal format, suggested in the following section. The product of the project work must be inclusive of write ups, illustrations, models, or collection of real objects.

Following are some of the useful steps that students may follow.

1. Select a topic for the science project

The first step in doing science project is selecting a topic or subject of your interest. Teachers guide students in identification and selection of the topic. The concerned teacher has to approve the topic prior to the commencement of the project work.

2. Gather background information

Gather information about your topic from books, magazine, Internet, people and companies. As you gather information, keep notes from where you got the information as reference list.

3. Write your hypothesis

Based on your gathered information, design a hypothesis, which is an educated guess in the form of a statement, about what types of things affect the system you are working with. Identifying variables is necessary before one can make a hypothesis. For example, depth of the fluid affects the fluid pressure. Develop a research question supported by a few questions to test your hypothesis. For example, how does the depth of fluid affect the pressure? Sub-questions may include, what is the fluid pressure at the same depth at different points? What is the fluid pressure as the depth increases?

4. Identify variables

The hypothesis and the research questions should guide you to identify

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the variables. When you think you know what variables may be involved, think about ways to change one at a time. If you change more than one at a time, you will not know what variable is causing your observation. Sometimes, variables are linked and work together to cause something. At first, try to choose variables that you think act independently of each other.

5. Design an experiment or observation method

Having made the hypothesis, design an experiment to test the hypothesis and devise the method of observation. Make a systematic list of what you will do or observe to answer each question. This list is known as experimental or observational procedure. For observations or an experiment to give answers, one must have a "control". A control is a neutral "reference point" for comparison that allows you to see what changing or dependent variable does by comparing it to not changing anything. Without a control, you cannot be sure what variable causes your observations.

6. Write a list of material

Make a list of materials useful to carry out your experiment or observations.

7. Write experiment results

Experiments are often done in series. A series of experiments can be done by changing one variable at a time. A series of experiments are made up of separate experimental "runs". During each run, you make a measurement of how much the variable affected the system under the study. For each run, a different amount of change in the variable is used. This produces a different degree or amount of responses in the system. You measure these responses and record data in a table form. The data from the experiments and observations are considered as a "raw data" since it has not been processed or interpreted yet. When raw data is processed mathematically, for example, it becomes result.

8. Write a summary of the results

Summarize what happened. This can be in the form of a table of processed numerical data, or graphs. It could also be a written statement of what occurred during experiments. It is from calculations using recorded data that tables and graphs are made. Studying tables and graphs, one can see trends or patterns that tell you how different variables cause to change the observations. Based on these trends, you can draw conclusions about the system under the study. These conclusions help to confirm or deny your original hypothesis. Often, mathematical equations can be made from graphs. These equations can help you to predict how a change will affect the system without the need to do additional experiments. Advanced levels of experimental science rely heavily on graphical and mathematical analysis of data. At this level, science becomes even more interesting and powerful.

9. Draw conclusions

Using the trends in your experimental data and your experimental observations, try to answer your original questions. Is your hypothesis correct? Now is the time to pull together what happened in the form of conclusion, and assess the experiments you did. Describe, how variables have affected the observations, and synthesize a general statement. For example, the pressure for the same fluid increases with the increase of depth!

10. Write a report on the project

Having completed all the steps of experiment and investigation with appropriate results and conclusion drawn, the last thing is to write a report. The report should start with an introduction on the topic related to your hypothesis, purpose of the study, literature review, methods used, findings, and conclude with conclusions. Do not forget to acknowledge the support provided by all individuals and organizations. Write a bibliography to show your references in any form. Such information includes the form of document, name of writer, publisher, and the year of publication.

The Format for Project Work write-up (report) should include the following aspects:

- The title of the project work.
- Acknowledgement: Show courtesy to thank the people and organizations for the help received.
- Table of content.
- Introduction: What is the topic about, and why was the topic chosen? hypothesis, research question.
- Background information: Scientific concepts, principles, laws and information on the topic.
- Methodology: Methods of data collection – sampling, tools used, etc; data sorting.
- Data analysis: Data tabulation, data processing, findings, etc. presented in a logical order with illustrations, photographs, and drawings where appropriate and necessary to support the findings.
- Conclusion: Reflection of the findings, learner's experiences and opinions regarding the project.
- Bibliography: List of the sources of the information.

The teacher uses the "Rubric for the Project Work" given below to assess the student's project work. Random viva voce is necessary to guide and support students' work during the course of project work.

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Criteria for the Project Work

Name	Criteria						Bibliography (4)	Total scores (28)
	Problem and hypothesis (4)	Background research on the hypothesis (4)	Experimental design / materials / procedure (4)	Investigation (4)	Analysis (4)	Format and editing (4)		
Nima								
Dawa								

Rubrics for the Project Work

Criteria	Scoring				Total Score (28)
	4	3	2	1	
Problem and Hypothesis	• Problem is new, meaningful and well researched. • Hypothesis is clearly stated in the "IF... THEN" format.	• Problem is not new but meaningful. • Hypothesis is clearly stated.	• Problem is stated but neither new nor meaningful. • Hypothesis is not clearly stated.	• Problem is not stated and • Hypothesis is unclear.	
Background research on the hypothesis	• Research is thorough and specific. • All the ideas are clearly explained.	• Research is thorough but not specific. • Most ideas are explained.	• Research is not thorough and not specific. • Few ideas are explained.	• Research not thorough and • Ideas are not explained.	
Experimental design / materials / procedure	• Procedure is detailed and sequential. • All materials are listed. • Safety issues have been addressed.	• Procedure is detailed but not sequential. • Most materials are listed. • Safety issues have been addressed.	• Procedure is not detailed and not sequential. • Few materials are listed. • Few safety issues have been addressed.	• A few steps of procedure are listed. • Materials list is absent. • Safety issues are not addressed.	

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<table>
<tr><th rowspan="2">Criteria</th><th colspan="4">Scoring</th><th rowspan="2">Total Score (28)</th></tr>
<tr><th>4</th><th>3</th><th>2</th><th>1</th></tr>
<tr><td>Investigation</td><td>• Variables have been identified, controls are appropriate and explained.
• Sample size is appropriate and explained.
• Data collected from at least 4 sources.</td><td>• Variables have been identified and controls are appropriate but not explained.
• Sample size is appropriate.
• Data collected from at least 3 sources</td><td>• Variables have somewhat been identified, controls are somewhat known.
• Sample size is not appropriate.
• Data collected from at least 2 sources.</td><td>• Missing two or more of the variables or the controls.
• Sample size is not considered.
• Data collected from only 1 source.</td><td></td></tr>
<tr><td>Analysis& conclusion</td><td>• Appropriate tool used for analysis.
• Explanation is made for how or why the hypothesis was supported or rejected.
• Conclusion is supported by the data.
• Reflection is stated clearly.</td><td>• Appropriate tool used for analysis.
• Conclusions are supported by the data.
• Not enough explanation is made for how or why the hypothesis was supported or rejected.
• Reflection is stated.</td><td>• No appropriate tool used for analysis.
• Not enough explanation is made for how or why the hypothesis was supported or rejected.
• Conclusion is not appropriate.
• Reflection is not clear.</td><td>• No appropriate tool used for analysis.
• Not enough explanation is made for acceptance and rejection of hypothesis.
• Conclusion is absent.
• Reflection is not stated.</td><td></td></tr>
<tr><td>Format and editing</td><td>• Correct format followed throughout.
• Report is free of errors in grammar, spelling or punctuation.</td><td>• Only one aspect of format is incorrectly done.
• Report contains a few errors in grammar, spelling, and punctuation.</td><td>• Only two aspects of format are incorrectly done.
• Report contains some errors in grammar, spelling, punctuation</td><td>• Three or more aspects of format are missing.
• Report contains many errors in grammar, spelling, and punctuation.</td><td></td></tr>
</table>

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Criteria	Scoring				Total Score (28)
	4	3	2	1	
Bibliography	• Five or more references are cited in APA format and referenced throughout the paper and presentation.	• Three or four references are cited and referenced throughout the paper and presentation.	• One or two references are cited and referenced throughout the paper and presentation.	• No references made.	
				TOTAL SCORE	

4. Practical Work

Learning by doing is fundamental to science education. Practical work is one of the means that helps students to develop their understanding of science, appreciate that science is evidence driven and acquire hands-on skills that are essential to science learning and in their future lives. The practical work as defined by SCORE (2009a) is '*a "hands-on" learning experience which prompts thinking about the world in which we live*'.Therefore, the purposes of doing practical in science classes are to –

i. help students to gain or reinforce the understanding of scientific knowledge.
ii. develop students' understanding of the methods by which the scientific knowledge has been constructed.
iii. increase a student's competence to engage in scientific processes such as in manipulating and/or observing real objects and materials with due consideration for safety, reliability, etc.
iv. develop technical and scientific skills that improve science learning through understanding and application.
v. develop manipulative skills, knowledge of standard techniques, and the understanding of data handling.
vi. Inculcate excitement of discovery, consolidation of theory, and the general understanding of how science works.

Practical work is integral to the aspects of thinking and working scientifically in science, and must be built in as a full learning experience for students. Students are engaged in a range of practical activities to enable them to develop their understanding through interacting with apparatus, objects and observations.

The assessment of students' scientific skills and their understanding about the scientific processes through practical work is crucial in the process of science learning. To ensure the validity, assessment needs to sample a range of activities in different contexts; and reliability is ensured through the appropriate moderation procedures so that fairness in assessment is maintained.

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The new science curriculum envisages that students are given the opportunity to undertake work in which they make their own decisions. They should be assessed on their ability to plan, observe, record, analyze, communicate and evaluate their works.

To ensure that the assessment in the practical is evidence-based and objective, rubrics is used. The rubrics are scored out of 16, which must be reduced to 5% each for the two terms.

Criteria for the Practical Work

Name	Criteria				Total scores (16)
	Scientific operation & report format (4)	Results & data representation (4)	Analysis & discussion (4)	Conclusions (4)	
Sonam					
Wangmo					

Rubrics for the Practical Work

Criteria	Scoring				Total Score (16)
	4 (Very good)	3 (Good)	2 (Fair)	1 (Poor)	
Scientific operation	• Purpose is clear purposeful. • All the procedures are followed systematically. • Full attention is given to relevant safety for oneself and others.	• Purpose is clear purposeful. • All the procedures are followed but not done systematically. • Work is carried out with some attention to relevant safety procedures.	• Purpose is inaccurate, general or extraneous. • A few procedures are skipped. • Safety procedures were frequently ignored	• Purpose is vague or inaccurate. • Procedures are not followed • Safety procedures are ignored completely.	
Results & data representation	• Representation of the data/results in tables and graphs with correct units of measurement. • Transformations in the results/data are evident. • Graphs and tables are scaled correctly, with appropriate titles and labels.	• Representation of the data/results in tables and graphs with some error in units of measurement. • Transformations in some of the results/data are evident. • Graphs and tables are scaled correctly with appropriate titles but no labels.	• Representation of the data/results in tables and graphs numerous error in units of measurement. • Transformations in most of the results/data are not evident. • Graphs and tables are scaled correctly, but without appropriate titles and labels.	• Representation of the data/results in tables and graphs are not relevant. • Transformations in the results/data are not evident. • Some attempts are evident to produce graphs from the data/results.	

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Analysis & discussion	• All the tools used for analysis are appropriate. • A comprehensive discussion, containing a comparative analysis is evident. • The experimental findings are significant to the purpose of the experiment.	• Most of the tools used for analysis are appropriate. • A comprehensive discussion, containing some comparative analysis is evident. • The experimental findings do not have strong significance to the purpose of the experiment.	• Only a few tools are used for analysis. • A comprehensive discussion, containing a few comparative analysis is evident. • The experimental findings have weak significance to the purpose of the experiment.	• No appropriate tools are used for analysis. • Comprehensive discussion is absent. • The experimental findings have no significance to the purpose of the experiment.	
Conclusions	• Conclusions are drawn from the findings and are significant to objectives of the experiment. • Limitations of experiment are identified, and ways to improve are evident.	• Conclusions are drawn from the findings but less significant to objectives of the experiment. • Limitations of experiment are identified.	• Conclusions are not drawn from the findings and have no significance to objectives of the experiment. • Some limitations of experiment are identified.	• No valid conclusions drawn from the findings. • Limitations of experiment are not identified.	
				TOTAL SCORE	

Chapter-wise Weighting and Time allocation

Chapters	Chapter title	Maximum time required (mins)	Weighting (%)
Chapter 1	Forces and Motion	605	14%
Chapter 2	Pressure in Fluids	432	10%
Chapter 3	Energy	950	22%
Chapter 4	Electricity and Magnetism	950	22%
Chapter 5	Waves	605	14%
Chapter 6	The Earth and Beyond	778	18%
	Total	4320	100%

The total time required to complete the topics is 4320 minutes or 96 periods of 45 minutes in a period.

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Contents

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1

FORCES AND MOTION

Earth attracts everything towards its centre. This force of attraction of the Earth is called gravitational force. The weight of all bodies is due to the gravitational pull of the Earth. All kinds of bodies have a point on them through which the entire weight of an object appears to act. The stability of bodies depends on the position of this point. This point is called centre of gravity.

Statics is a branch of mechanics which deals with the system in equilibrium. A system is said to be in equilibrium if there is no resultant force and no resultant moment. Resultant force displaces a body in linear direction, while resultant moment makes a body rotate in either clockwise or counter clockwise direction.

When objects fall freely, they experience various forces. The forces acting on falling objects change with velocity. When the resultant force on the falling objects become zero they attain maximum velocity called terminal velocity.

1. Gravitational Force

Learning Objectives

On completion of this topic, you should be able to:

- describe gravitational field.
- define centre of gravity of an object.
- explain the stability of a body.

Do you ever wonder how moon remains in place around the Earth in space? Sir Isaac Newton discovered that all the objects have mass and attract each other with certain amount of force called *gravity*. Every object around you attract each other with the force of gravity. However, this force is very negligible that it is not felt. The force acting between these bodies is determined by their masses and the distances

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between them. The region around a body where force of attraction is felt is the *gravitational field* of the body. The body with larger mass will have more gravity and larger gravitational field. For example, an aeroplane has more gravitational force of attraction than a car. Similarly, the Moon has less gravitational force and field than the Earth. The gravitational force of attraction is greater if the bodies are closer.

A. Centre of gravity and stability of bodies

The Earth pulls every mass towards its centre. This force is referred to as weight. The larger mass has more weight. Our body is a matter made up of tiny particles with individual mass. Each of these small mass has weight. Therefore, the total weight must act downward as if the whole weight is located at a single point.

Activity 1.1 Locating centre of gravity of a body

Materials required:

A paper card board of uniform thickness, nails, retort stand with clamp, small weight or stone, thread, cork, pencil, ruler, and scissors.

Precaution

Be careful while using knife and sharp objects.

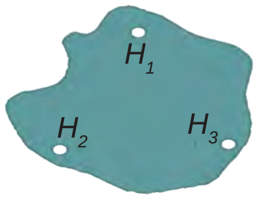

Figure 1.1

Procedure

Step 1 Cut out an irregular shaped lamina from a paper cardboard, similar to the one in Figure 1.1.

Step 2 Using the nail; make three holes (H_1, H_2 and H_3) on the lamina near the edge as shown in Figure 1.1.

Step 3 Tie a small weight or a stone to the end of a thread to make a major plumb line.

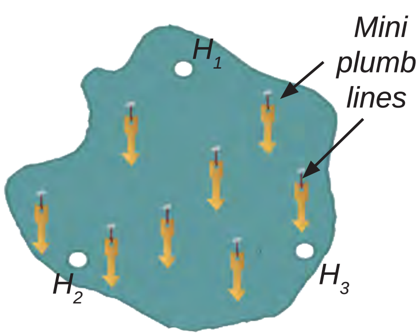

Figure 1.2

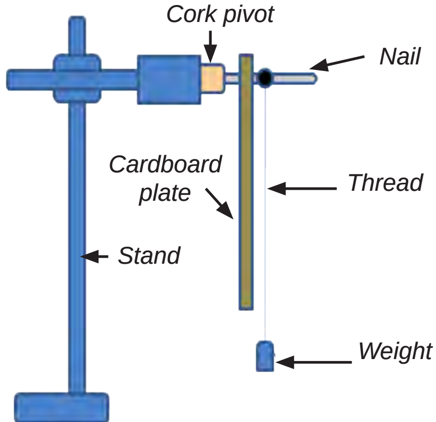

Figure 1.3

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Step 4 Make mini plumb lines by tying thread to the tail of small arrows made up of card board.

Step 5 Fix the mini plumb lines at different locations on the lamina as shown in Figure 1.2.

Step 6 Pierce a nail through a cork and clamp it on the retort stand to set up a pivot as shown in Figure 1.3.

Step 7 Hang the lamina on the pivot at hole H_1.

Step 8 Suspend the plumb line from the pivot at H_1. Slightly displace the lamina and release it. Allow it to swing freely until it comes to rest. After it comes to rest, mark three dots at three different locations on the lamina, directly behind the thread of the plumb line.

Step 9 Remove the plumb line and the lamina from the pivot and join the three dots with a straight line using a ruler.

Step 10 Repeat steps 7 to 9 through hole H_2 . Mark the point of intersection of the two lines as G.

Step 11 Hang the lamina at hole H_3, and repeat steps 8 and 9.

Step 12 Try to balance the lamina at G on the tip of a drawing pin as shown in Figure 1.4.

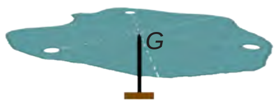

Figure 1.4

Answer the following questions.

1. What do mini plumb lines represent?
2. What are the directions of mini plumb lines when the lamina hangs from holes H_1, H_2 and H_3?
3. What conclusion would you draw from the behaviour of mini plumb lines?
4. What does the major plumb line represent?
5. Did the third line intersect at G? Why?
6. What does G represent?
7. Did the lamina balance at point G?
8. Where would the line drawn intersect if we hang lamina by any other point H_4?
9. What conclusion can you draw from the experiment?

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10. Locate the point of balance (point G) for the lamina given in Figure 1.5.

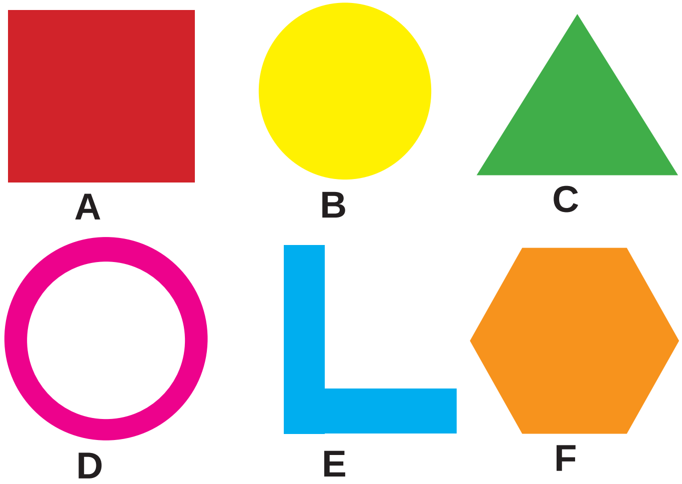

Figure 1.5

In Activity 1.1, we find that the irregular paper board lamina balances on the single point G and the whole weight of the paper board lamina appear to act from point G, even though the Earth attracts every part of plate at different locations. Thus, a point on a body through which the whole weight of a body appears to act is known as *Centre of Gravity* of the body. It is usually represented as '**C.G**'. The point can be either within or outside the body.

A bowl usually do not tumble easily compared to a tumbler kept on the same surface level. This is because a bowl is more stable than the tumbler. The stability of a body is determined by its position of centre of gravity.

The stability of a body is determined by the following:

(a) Position of C.G. of a body

The stability of a body depends upon its position of centre of gravity (C.G.). The body is more stable if the position of C.G. is at its lower part.

Let us consider an empty container A as shown in Figure 1.6(a). In this case, the C.G. is somewhere at the middle and the container is stable. When the bottom compartment of the same container is filled with marbles as in Figure 1.6(b), the position of C.G. is lowered and the container becomes more stable. Similarly, if the middle compartment of the same container is filled with marbles as in Figure 1.6(c), the position of the C.G. is raised higher. Hence the body becomes unstable.

Now, if the topmost compartment of the same container is filled with marbles as shown in Figure 1.6(d), then the position of C.G. is raised even higher than in

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third case. Hence the body becomes more and more unstable.

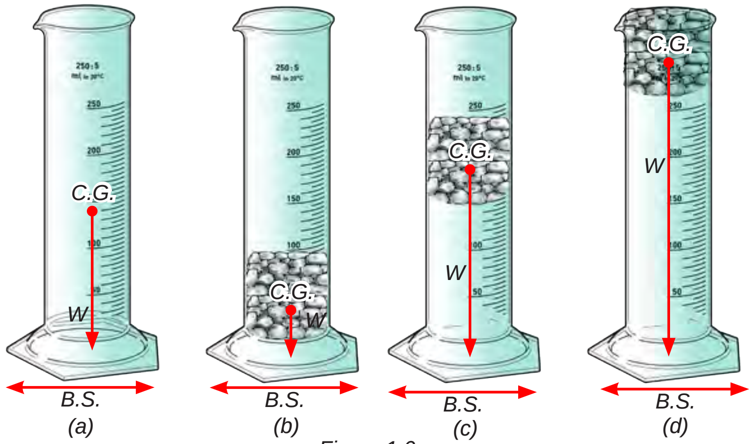

Figure 1.6

(b) Area of the Base of Support (B.S.)

The surface area in contact with another surface which supports a body is the area of base of support.

For example, State A of the upright bottle in Figure 1.7 has larger B.S. than the bottle upside down in State B, thus making State A of bottle more stable than State B. Even when bottle in State A is slightly tilted as shown in state C, the bottle do not tumble because the line of gravity due to the weight of body acts vertically downward through its base. In case of State B, the B.S. is narrow and on slight disturbance as shown in state D, the line of gravity due to the weight of body will not act through the base of the bottle, making it tumble.

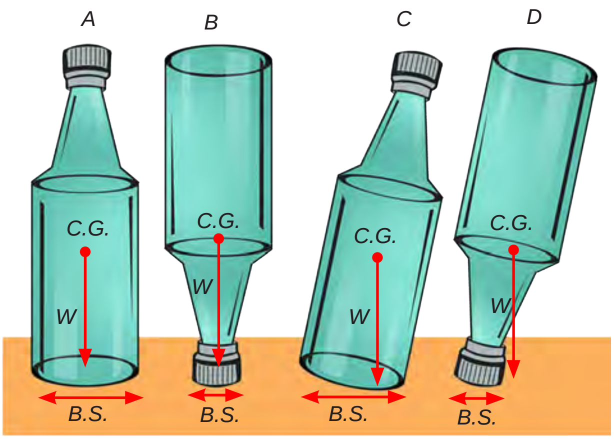

Figure 1.7

The stability of a body depends upon the position of C.G. and the area of B.S.

B. Equilibrium

When a body is balanced, it is said to be in equilibrium. If a force is applied to a body in equilibrium, the body either tilts, topples or rolls. Therefore, the equilibrium of a body is categorised in the following states.

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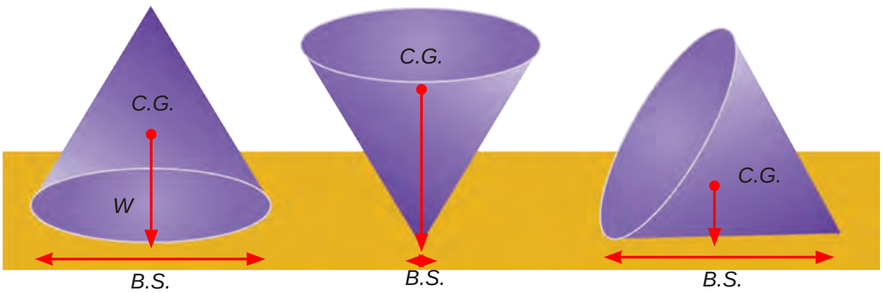
(i) Stable Equilibrium

A body is said to be in stable equilibrium when a body has an ability to regain its original position even when displaced by an external force. This state is achieved when the line of gravity due to the weight of body acts vertically downward through its B.S., at all positions. The body becomes more stable when the position of C.G. is lowered. For example, a cone in Figure 1.8(a) is in stable equilibrium. The C.G. rises when the tip of the cone is slightly pushed, however, the line of gravity due to the weight of the body still passes through its B.S. In such state, when the cone is released C.G. brings it back to its initial position.



(a)Stable Equilibrium (b) Unstable Equilibrium (c) Neutral Equilibrium

Figure 1.8

(ii) Unstable Equilibrium

A body is in state of unstable equilibrium when the line of gravity of its weight falls outside the B.S. on slight displacement and it loses its ability to regain its original position. In this condition, the body takes up new position. A body with narrow B.S. and C.G at high position is usually unstable. For example, a cone in Figure 1.8(b) is in unstable equilibrium. The C.G. of the cone is at the highest point. When the cone is slightly pushed the line of gravity due to the weight of the body no longer passes through its B.S.,therefore, the cone topples. In such state, the cone takes up new position which has lower C.G.

(iii) Neutral Equilibrium

If a body neither takes a new position nor regains its original position when displaced slightly by an external force, then the body is said to be in neutral equilibrium. In this case, the position of the C.G. and B.S. do not change when displaced. For example, a cone in Figure 1.8(c) is in neutral equilibrium. When the cone is pushed, the position of C.G. remains at the same level. In such state, the cone does not take up new position. Similarly, if a ball is pushed slightly to roll over a horizontal surface, it will not come back to its original position and C.G. of the ball is neither raised nor lowered.

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Questions

1. Why would you advice a person to sit rather than stand in a moving bus?
2. “The centre of gravity of a body may not be necessarily on the body”. Justify.
3. Why do dzongs have broader base?

http://alexei.nfshost.com/PopEcol/lec9/equilib.html
http://www.citycollegiate.com/staticsXb.htm
https://www.youtube.com/watch?v=muM4hhwqEwE

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2. Moment of Force

Learning Objectives

On completion of this topic, you should be able to:

- describe statics, and system in equilibrium.
- describe resultant, moment and parallelogram law of forces.
- explain the couple, torque of a couple and the principle of moments.

A. Forces and equilibrium

The simple descriptions of motion that we have used so far implicitly treated the motion of only one point in a body. It is a good description provided that all points in the body follow similar, parallel paths. This kind of motion is called *pure translational motion*. Along with translational motion, a body can also execute *rotational motion* (like that of a spinning wheel) and *vibrational motion* (like that of a shaking jelly). A body which cannot vibrate noticeably is said to be rigid; its shape and size do not change significantly when it is acted on by a system of forces. Therefore, the general kind of motion of a rigid body is a combination of translation and rotation. For example, the flight of boomerang executes translational motion due to its rotation.

A couple of forces may act on a body at a same time at different or same lines of action. Figure 1.9(a) shows two forces; 8 N and 10 N, acting on a rigid body in straight line in the same direction. The total magnitude of these two forces on the body is numerically equal to the sum of the magnitudes of these individual forces and the body moves in the direction of the greater force. The net force of these forces is referred to as *resultant force*.

The resultant force in case of Figure 1.9 (a) is 18 N and the rigid body moves in the direction of the greater force, 10 N.

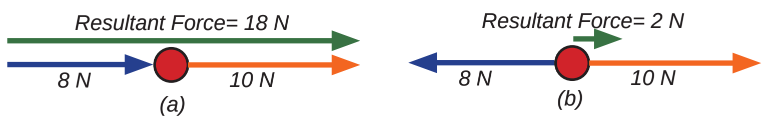

Figure 1.9

If two equal forces act in opposite direction in the same line of action, as shown in Figure 1.9 (b), then the magnitude of resultant force is equal to the difference of the magnitude of two forces, i.e., 2N and the body moves in the direction of the greater force, 10 N.

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When a couple of forces act on a non-rigid (elastic) body, the resultant force generally tends to change the dimension of the body and at the same time, it may execute rotational, translational and vibrational motion. For example, bouncing of a soft rubber ball undergoes all these motions.

A rigid body which is currently stationary will remain stationary if the resultant force is zero for all the forces applied on it. Similarly, a moving rigid body will remain in uniform motion if the resultant force is zero for all the forces applied on it. In both the cases, the body is said to be in *equilibrium*. Statics is a branch of mechanics that deals with the study of forces in equilibrium. The general conditions for equilibrium are as follows:

(i) The total force must be zero.

(ii) The total turning effect of force about any axis must be zero.

If a resultant force acts on a body then that body can be brought into equilibrium by applying an additional force that exactly balances this resultant. Such a force is called *equilibrant* and is equal in magnitude but opposite in direction to the original resultant force acting on the body.

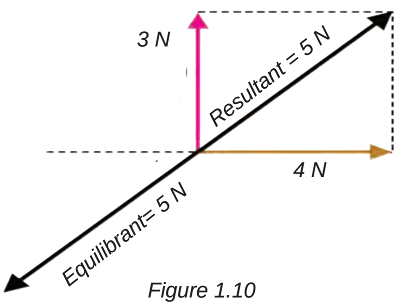

Figure 1.10

Force is an influence which causes motion of any rigid object. Force is a vector quantity, which has both magnitude and direction. Hence, it follows all the properties of vectors, such as vector addition and vector subtraction. One of the vector addition technique is known as the *parallelogram law of vector addition*. It is a graphical representation of vectors that is used to determine the magnitude and direction of the resultant vector. This method can be easily used to determine the magnitude and direction of the resultant force.

Activity 1.2 Verifying the law of parallelogram of forces

Materials required:

A drawing board, a sheet of plain paper, pencil, protractor, drawing pins.

Procedure

Step 1 Using the drawing pins, mount the sheet of plain paper on the drawing board.

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Step 2 ☞ Consider two force vectors A of 10 N and B of 5 N. Draw arrows to represent these forces in such a way that these force vectors are tail to tail in contact with each other and inclined to each other at an angle of 50^0. Let.1 cm = 1 N of force as shown in Figure 1.11.

Step 3 ☞ Complete the parallelogram by drawing these vectors as adjacent sides of the parallelogram.

Step 4 ☞ Now draw the diagonal originating from the touching tails. The diagonal represents the resultant force vector. Note the magnitude of resultant force.

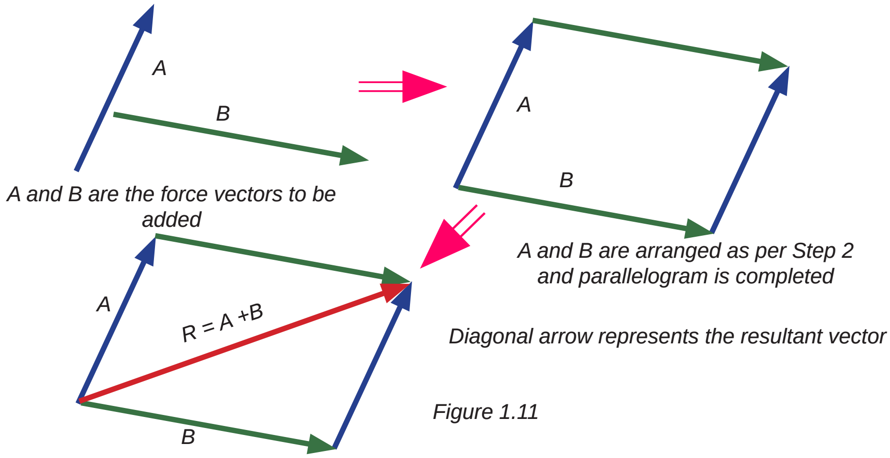

Figure 1.11

Step 5 ☞ Draw an arrow from the tails of the two vectors equal in length as the diagonal but in exactly opposite direction to it.

Answer the following questions.

1. Find the resultant of vectors 7 N and 12 N inclined at an angle of 60^0 with each other.
2. Find the resultant of vectors 5 N and 10 N inclined at an angle of 45^0 to each other.
3. What are the factors on which the resultant of vectors depend?
4. What does the arrow drawn in step 5 represent?

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B. Couple

If two forces are not acting in a straight line, then the resultant effect of the force is different. For example, when a water tap is turned to open or close, we apply two forces at the two ends of the bip cock. Here the forces are applied simultaneously, parallel and in opposite direction to each other. Thus, it results in rotational motion of bip cock. A few such examples from our day to day activities are shown in Figure 1.12. In these pictures, we use a pair of forces which are parallel to each other, equal in magnitude, and acting in the opposite directions.

A pair of equal and parallel forces, acting in opposite directions is called a *couple*.

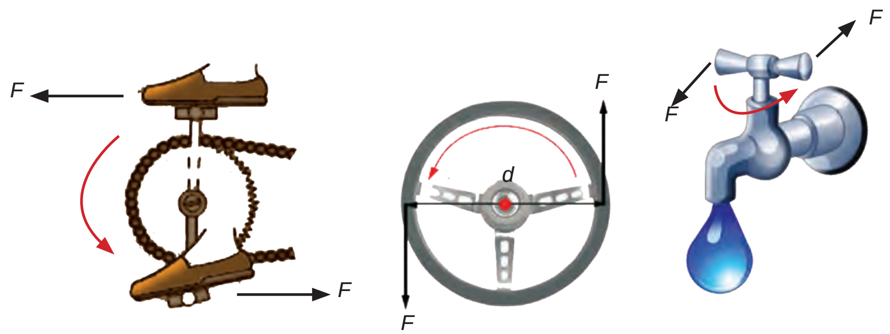

Figure 1.12 Couples

In Figure 1.12, two equal and opposite forces 'F', which are parallel to each other act on a body. The resultant force makes a body turn. The turning effect of a force is known as the *moment*. If the perpendicular distance between these forces is 'd', then the product of the magnitude of one of the forces (F) and the perpendicular distance from the line of action of the forces give the turning effect of the force called *moment of couple*. The moment of couple is also called *torque* and is usually represented by 'τ' (tau).

Mathematically,

Moment of couple (τ) = Force (F) x Perpendicular distance (d) between forces.

Example 1.1

Two forces each of 20 N is applied to a car steering wheel that has a diameter of 40 cm. If the two forces act tangentially to the steering wheel and in anti-parallel directions calculate the torque applied.

Solution:

$$Torque = F \times d = 20\ N \times 0.4\ m = 8\ Nm$$

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C. Principle of moments

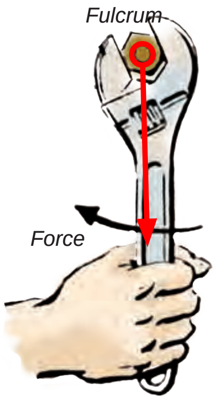

Figure 1.13 Torque

It is everyday experience that the handles on doors are usually located at the outer edge, so that it is easier to open or close. It is difficult to open a door if the handle is located near the hinge, that is, a much larger force is needed to open the same door. Likewise, it is easier to loosen a nut on a bolt by using a long spanner than with a short one. In all these cases, the applied force produces a turning effect about a pivot called *moment of force*. The moment of force is determined by the magnitude of force and distance of the applied force from the pivot. Similar to moment of couple, moment of a force is the product of force and the perpendicular distance of the line of action of force from the pivot.

Mathematically,

Moment of force (τ) = Force (F) x distance from the fulcrum (d)

If the force is measured in newton (N) and distance in metre(m), then the unit of moment of force is newton-metre (Nm).

The moment of force brings about counter clockwise or clockwise rotation of the body. A body will not turn when it is in equilibrium even when forces act on it about a fixed pivot. This state of equilibrium is explained by the principle of moments.

The principle of moments states that the total counter clockwise moment is equal to the total clockwise moment when the body is in equilibrium.

In equilibrium,

Total Counter Clockwise Moment = Total Clockwise Moment

In case of Figure 1.14

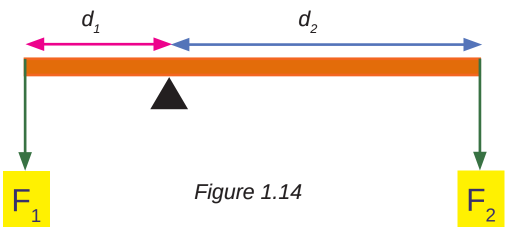

Figure 1.14

total counter clockwise moments = total clockwise moments

$$F_1 \times d_1 = F_2 \times d_2$$

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In case of Figure 1.15

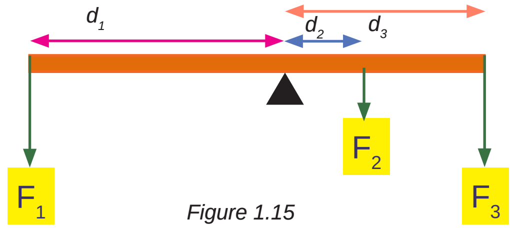

Figure 1.15

total counter clockwise moments = total clockwise moments

$$F_1 \times d_1 = (F_2 \times d_2) + (F_3 \times d_3)$$

Activity 1.3 Verifying the principle of moments

Materials required:

A metre ruler, wedge, five weights of 100 g, clamp and stand, and thread.

Procedure

Step 1 Balance the ruler on the wedge so that it is perfectly horizontal as shown in Figure 1.16.

Step 2 Take two different weights of your choice and note down their values as W_1 and W_2.

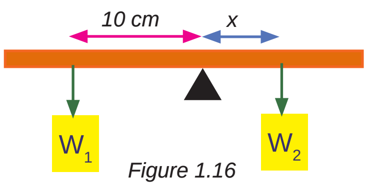

Figure 1.16

Step 3 Hang the two weights on either side of the pivot as shown in Figure 1.16.

Step 4 Adjust the distance of the two weights from the pivot until the ruler becomes perfectly horizontal again.

Step 5 Record the distance of the two weights from the pivot.

Answer the following questions.

1. Calculate the moment of force in clockwise direction.
2. Calculate the moment of force in counter clockwise direction.
3. Compare the magnitude of moment of force in clockwise direction and counter clockwise direction.
4. What do you conclude from the comparison of clockwise and counter clockwise moments?

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Questions

1. Figure 1.17 shows two forces acting on the edge of a disc making it rotate.

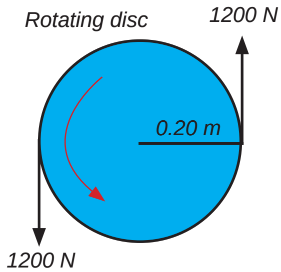

Figure 1.17

   a) Define torque of a couple.
   b) Calculate the torque produced by these forces.

2. Write down five examples of couple.

http://www.splung.com/content/sid/2/page/moments
http://physicsnet.co.uk/a-level-physics-as-a2/mechanics/moments/
http://www.tutorvista.com/physics/parallelogram-law-of-forces

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3. Falling Objects

Learning Objectives

On completion of this topic, you should be able to:

- explain that the forces acting on falling objects change with velocity.
- describe terminal velocity of falling objects.

A. Force on falling objects

Hundreds of years ago, people thought that the mass or weight of an object was the main thing that determined how fast it would fall. This idea was put forth by the Greek philosopher Aristotle, who said that the speed of a falling object was directly proportional to how heavy it was. Although this seems reasonable at first glance, there are some big problems with this idea. The scientist Galileo Galilei (1564-1642) disproved this idea by showing that objects of the same size and shape but with different masses would hit the ground at the same time when dropped from the same height. Later, Isaac Newton (1643-1727) demonstrated not only which type of object falls fast, but also answered why do objects fall in the first place. Earth exerts a force on all objects near it which causes falling objects to speed up as they fall. He called this force as gravity. Whenever, we describe about falling object, two forces come into picture, namely; the weight of the object and the air resistance. The weight of the object acts downwards. The air resistance is the frictional force acting in the opposite direction to the movement of the object.

(i) Free falling object

A free falling object is an object that is falling under the sole influence of gravity. Any object that is being acted upon only by the force of gravity is said to be in a state of free fall. There are two important motion characteristics that are true of free-falling objects:

- Free-falling objects do not encounter air resistance.
- On Earth, all free-falling objects accelerate downwards at a rate of 9.8 m/s^2.

A dot diagram of motion of free-falling objects could be used to depict an acceleration of the object. The dot diagram in Figure 1.18 depicts the acceleration of a free-falling object.

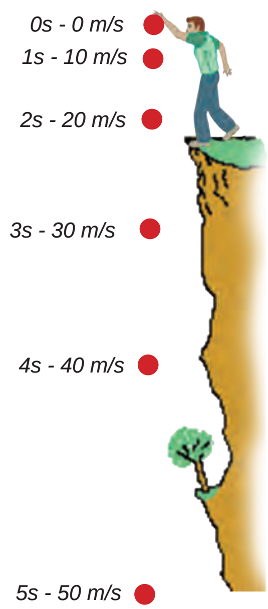

Figure 1.18

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The position of the object at regular time intervals of 1 second is shown. The increasing distance travelled by the object at equal interval of time shows that the ball is speeding up as it falls downward. If an object travels downward and speeds up, then its acceleration is downward.

(ii) Drag force

As objects fall through air due to Earth's gravitational force, they experience *drag force* or air resistance forces that act upward and oppose the force of gravity. The air drag force depends on several factors, including the speed at which the object is falling (v), the surface area of the object (A), the density of the air (d), and the drag coefficient (C), which is determined by how aerodynamic the object is.

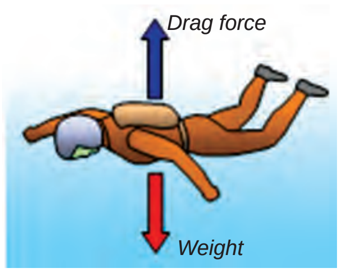

Figure 1.19

Drag Force= 0.5 x d x v^2 x A x C

The most important factor in determining the air drag force is the velocity of the object. As the body speeds up, the drag force becomes larger and larger.

(iii) Terminal velocity

Consider an object falling with increasing velocity under the influence of gravity or a constant driving force. The object experiences drag force due to air resistance. It will ultimately reach a maximum velocity where the drag force is equal to the driving force. This final, constant velocity of motion is called *terminal velocity*.

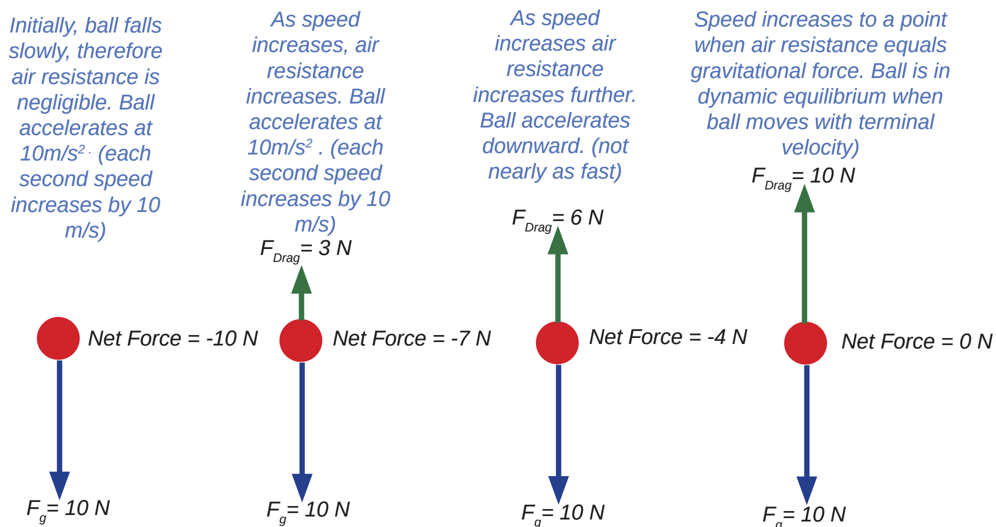

Figure 1.20

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Objects falling through a fluid eventually reach terminal velocity, when the resultant force acting on them is zero and they are moving at a steady speed.

For example, when a feather and a coin of roughly same surface area is dropped from a height, they experience the same air resistance. During the fall, the air resistance increases and soon balances the weight of the feather. So the feather now falls at its terminal velocity. On the other hand, the coin continues to move downward with increasing velocity, because it is relatively heavier. The coin travels faster since a larger air resistance is needed to balance its weight. The coin hits the ground before it reaches its terminal velocity.

(iv) Stages of falling objects

We can identify three stages of a falling object before it hits the surface of the Earth:

1. At the start, the object accelerates downwards due to its weight. At this point the air resistance is very minimal or absent. Therefore, a resultant force acts downward that makes the object to accelerate downward.
2. With acceleration, the velocity of the falling object increases. The air resistance on the object increases but its weight remains same. At this stage, the weight of the object is still greater than the air resistance and the fall continues.
3. The air resistance continues to increase, and eventually it balances the object's weight. At this stage the resultant force is zero and the object reaches a constant velocity called *terminal velocity*.

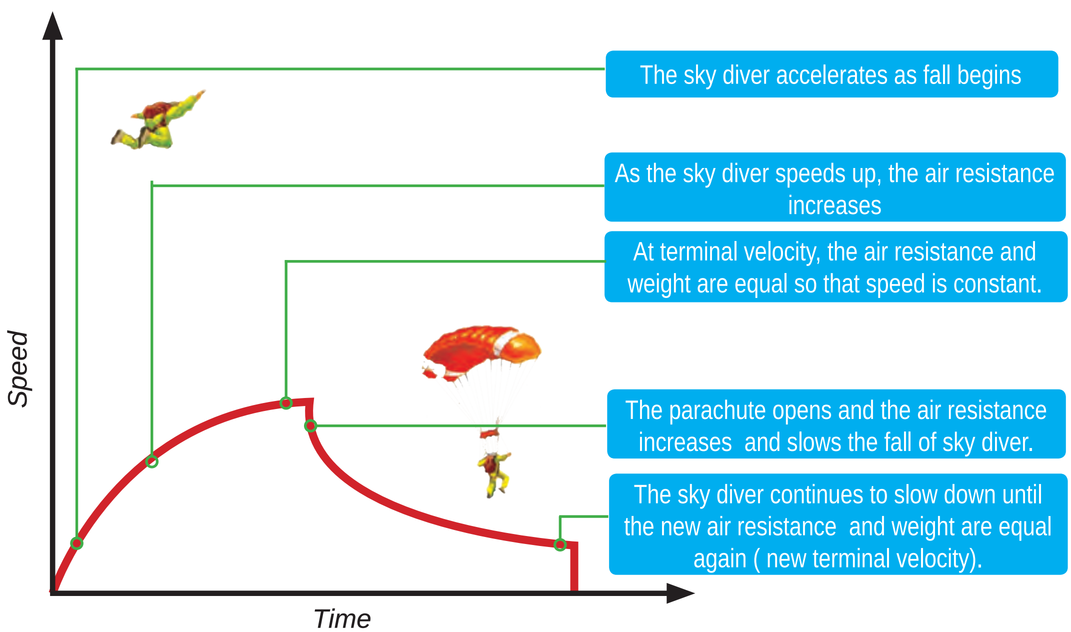

Figure 1.21 Speed-time graph for a skydiver's descent

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Summary

- The body with larger mass will have more gravity and larger gravitational field.
- A point on a body through which the whole weight of a body appears to act is known as centre of the gravity of the body. It is usually represented as C.G. The point can be either within or outside the body.
- Lower the C.G. of the body, more stable is the body and vice versa.
- The surface area in contact with another surface which supports a body is the area of base of support.
- Increasing the base of a body increases the stability of a body.
- The study of forces in equilibrium is called statics.
- A body is said to be in stable equilibrium when a body has an ability to regain its original position even when displaced by an external force.
- A body is in state of unstable equilibrium when the line of gravity of its weight falls outside the B.S. on slight displacement and it loses its ability to regain its original position.
- If a body neither takes a new position nor regains its original position when displaced slightly by an external force, then the body is said to be in neutral equilibrium.
- A pair of equal and parallel forces, acting in opposite direction is called a couple.
- A body is said to be in equilibrium if both the sum of forces acting on it and the sum of moments of forces is also zero.
- The equilibrant of any number of forces is the single force required to produce equilibrium, and is equal in magnitude but opposite in direction to the resultant force.
- If two forces simultaneously acting at a point, can be represented in magnitude and direction by two adjacent sides of a parallelogram, then the resultant will be represented by diagonal of the parallelogram passing through the intersection point of these two sides.
- The constant maximum velocity reached by a body falling through the atmosphere under the attraction of gravity is known as its terminal velocity.

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Exercises

I. *Fill in the blanks.*

1. A cone on its base is in ....equilibrium.
2. Stability of bodies depends upon …………………and ……………………
3. A body is said to be in equilibrium if the resultant forces acting on the body is…………
4. If we suspend lamina at different positions, its center of gravity will still lie along the line of ....
5. To form a couple, forces should be................ in magnitude.

II. *Match the following.*

Column A	Column B
1. Torque	A. Line of centre of gravity
2. Centre of gravity	B. Maximum constant velocity
3. Plumb line	C. Not in motion
4. Terminal velocity	D. Point of action of weight
5. Statics	E. Turning effect of force
	F. Study of forces

III. *Multiple Choice Questions.*

1. Two forces of equal magnitude in opposite direction and acting along the different line of action give rise to

   A torque.

   B couple.

   C motion.

   D rotation.

2. A force of 2 N applied by Tshomo brings about 16 N m moment of force . At what distance from the pivot is Tshomo applying the effort?

   A 32 m.

   B 8 m.

   C 14 m.

   D 18 m.

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3. The centre of gravity is usually located where

   A no mass is concentrated.

   B average mass is concentrated.

   C less mass is concentrated.

   D more mass is concentrated.

4. A body in motion is said to be in equilibrium when it is

   A moving with uniform velocity.

   B at rest.

   C accelerated by a force.

   D moving in an indefinite path.

5. Pair of forces that cause steering wheel of a car to rotate is called

   A couple.

   B friction.

   C normal force.

   D weight.

6. When the net force acting on a droplet of water becomes zero, then it falls with

   A final velocity.

   B initial velocity.

   C terminal velocity.

   D zero velocity.

7. Dorji is turning a wheel in clockwise direction with a force of 10 N, while Pema applies a force of 15 N in opposite direction. What additional force must be added to produce equilibrium?

   A 5 N acting in the same direction as the 10N force

   B 5 N acting in the same direction as the 15 N force

   C 10 N acting in the same direction as the 10 N force

   D 25 N acting in the same direction as the 15 N force

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8. The greater the force, the larger will be the
   - A axis of rotation.
   - B torque.
   - C mass.
   - D centre of mass.
9. Karma applies a force of 4 N on a handle that is about 1.5 m away from door hinge. The moment of force will be
   - A 5.50 Nm.
   - B 2.66 Nm.
   - C 6.00 Nm.
   - D 2.50 Nm.

IV. State 'True' or 'False'. Rewrite the false statements correctly.

1. The body at terminal velocity will have less weight than the drag force.
2. The line of gravity is always within the base of support of the body in stable equilibrium.
3. The centre of gravity of objects will be always on the body itself.
4. The force that accelerates a falling body is the force of friction.
5. A couple always turns the body in a single direction.

V. Answer the following questions.

1. Explain the term 'equilibrant'.
2. The Figure 1.22 shows a body A of weight 400N placed on the left of a seesaw, 2.5 m away from the pivot. A body B of weight 300 N is placed on the right hand side 3.5m away from the pivot.

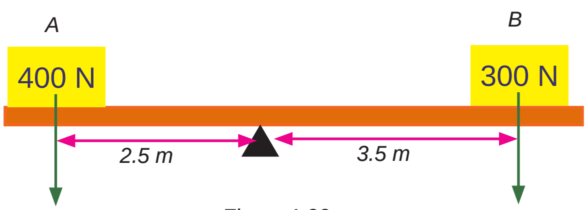

Figure 1.22

   a) Who will turn the seesaw clockwise?

   b) What is the clockwise moment?

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c) What is the counter clockwise moment?

d) Where must a body C of weight 10 N be placed to balance the see saw?

3. A uniform metre ruler, acted upon by three forces is balanced on a pivot as shown in Figure 1.23.

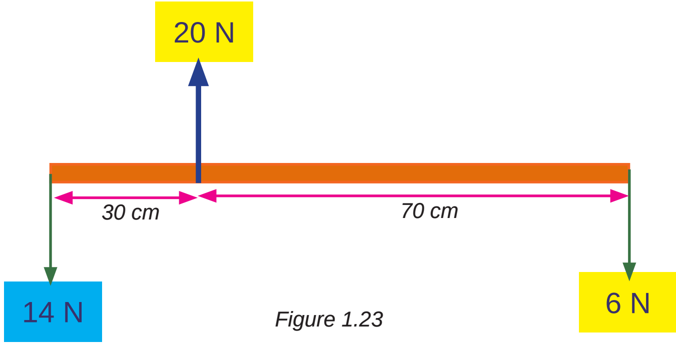

Figure 1.23

a) Which one of the forces has no moment about the pivot? Explain your answer.

b) Calculate the moments of the other two forces about the pivot.

c) Will the ruler turn? Explain.

4. The velocity of free-falling ball at different time intervals on unknown planet is shown in Figure 1.24.

a) What is the acceleration due to gravity of the planet?

b) What is the velocity at positions A and B?

c) What happens to the magnitude of velocity with passage of time? Why?

d) What factor(s) can influence the falling object on the Earth?

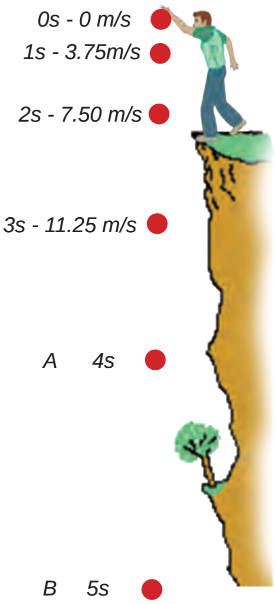

Figure 1.24

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2

PRESSURE AND ITS APPLICATIONS

The words "force" and "pressure" have many shades of meaning in English. However, they are generally associated with agents of change. Thus, with force or pressure, we can change the state of a body. They can also be used to resist or prevent the change. Pressure is a measurement of effects of force on a surface area.

Pressure is exerted not only by solids, but also by liquids and gases. When we place a solid object on a table, the pressure is exerted on the table because the force acting on the table due to the weight of the object spreads over the total contact area between the object and the table. A fluid like liquid or gas has no definite shape. It applies pressure in all directions. Fluid pressure can be amplified through hydraulic mechanisms or changing the velocity of the fluid. Generally pressure due to fluids plays a number of important roles in daily life through various applications, such as hydraulic machines, diving, working of syringes, etc.

1. Pressure

Learning Objectives

On completion of this topic, you should be able to:

- define pressure.
- describe the factors affecting the magnitude of pressure.
- state and apply the equation for pressure.

A. Thrust on a surface area

Thrust is a force acting perpendicular to a surface area. Pressure is defined as the thrust per unit area.

Consider a 20 N force acting perpendicularly on a 4 m^2 surface due to weight of an object as shown in Figure 2.1. The force (weight) is shared equally by the surface.

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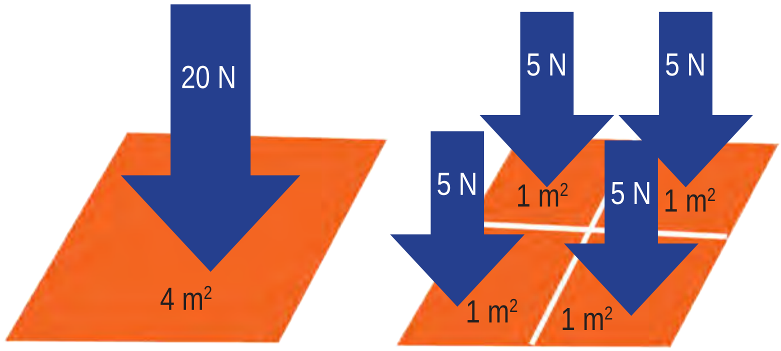

Figure 2.1

$$Pressure(Force\ on\ unit\ area) = \frac{Total\ perpendicular\ force}{Total\ area} = \frac{20\ N}{4\ m^2}$$

Hence each 1m² of the surface withstand a force of 5 N (20 N/4 m²). In other words, a force of 5 N acts on a unit area (1 m²) of the surface. Therefore, the pressure acting on the surface is 5 N/m².

In general,

$$Pressure = \frac{Force\ (Thrust)}{Area}$$

$$or\ P = \frac{F}{A}$$ ......***equation 1***

If the force of 1 N is acting on the surface area of 1 m², then the pressure exerted on the surface is 1 pascal (Pa). Therefore, in the SI (Système International or International System of Units) of measurement, the unit of pressure is pascal or N/m².

Pressure is also measured in bar, such that 1 bar = 10^5 Pa.

The pressure exerted by fluid is similar to that of solid. When a solid is placed onto the top of another solid, the pressure is exerted on the surface in contact due to weight of upper solid. In case of fluid, pressure on solid is exerted due to the weight of the fluid column over the solid. Therefore, the magnitude of pressure due to solid and fluid are influenced by many factors.

i. Magnitude of pressure due to solid

The magnitude of pressure on a surface due to a solid depends on the following:

a. *Magnitude of the force*

It is evident from ***equation 1*** that pressure is directly proportional to the

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magnitude of the force (thrust). The larger the force, the higher is the magnitude of pressure on the surface.

For example: The force applied by the iron hammer on a nail is more than the force applied by a wooden hammer of the same size. Therefore, the thrust exerted by heavier objects is greater than the lighter objects.

b. *Contact area*

From ***equation 1***, we know that pressure is inversely proportional to surface area of contact. The larger the contact area, lower is the magnitude of the pressure. Pressure is generally varied by changing the surface area of contact.

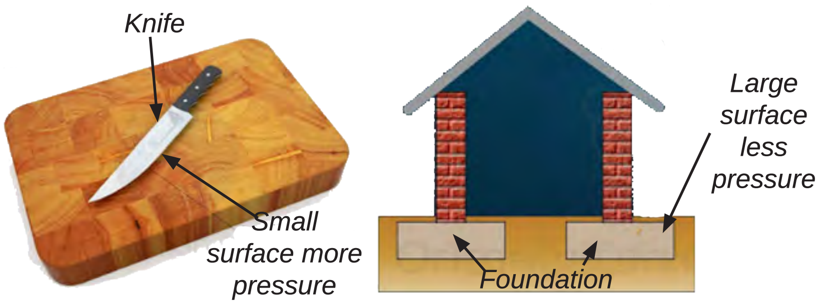

Figure 2.2 Varying pressure by changing contact area

For example: In case of knives, the area of contact is very small. Therefore, a small force can apply large amount of pressure making it easy to cut vegetables and fruits. Conversely, the building foundations are made broad to increase the surface area of contact so that pressure due to huge force (weight) of the building can easily be withstood and prevent the house from sinking into the ground.

Example 2.1

A cube of mass 1 kg with each side of 1cm is lying on a table. Find the pressure exerted by the cube on the table. Take g = 10 ms^{-2}.

Solution:

$$Pressure = \frac{Force}{Area}$$

$$But,\ F = mg = 1\,kg \times 10\,ms^{-2}$$

$$and\ Area, A = 1\,cm \times 1\,cm \quad = 1\,cm^2 = 1 \times 10^{-4}\,m^2$$

$$Thus,\ P = \frac{1 \times 10}{1 \times 10^{-4}}$$

$$or\ P = 1 \times 10^5\ Pa$$

Example 2.2

A 60 kg girl wearing high heel shoes balances on a single heel. The heel is circular with a diameter of 1.5 cm. Find the pressure exerted by the heel on the horizontal floor?

Solution:

Given:

Mass, $m = 60\ kg$

Radius, $r = \frac{D}{2} = \frac{1.5 \times 10^{-2}}{2}\ m = 0.75 \times 10^{-2}\ m$

Force, $F = mg = 60 \times 10 = 600\ N$

Area, $A = \pi r^2 = 3.141 \times (0.75 \times 10^{-2})^2 = 1.77 \times 10^{-4}\ m^2$

$\therefore$ Pressure, $P = \frac{F}{A} = \frac{600}{1.77 \times 10^{-4}} = 3.39 \times 10^6\ Pa$

ii. Magnitude of fluid pressure

The pressure exerted on a body by the confined liquid is known as hydrostatic pressure. It is given by

Pressure(P)= depth (h) x density of fluid (ρ) x acceleration due to gravity (g)

$P = h \rho g$……equation 2

Therefore, the magnitude of the pressure exerted on a body by a fluid depends on the following:

a. *Depth inside the fluid*

It is evident from the ***equation 2*** that force is directly proportional to the depth at which the body is located in a liquid. The greater the depth, the higher the magnitude of pressure on the body.

For example: When a submarine plunges deeper into the ocean, the pressure exerted by the column of water above the submarine increases.

b. *Density of fluid*

Density of substance is given by mass per unit volume. It is measured in kg/m^3.

Mathematically,

$$Density(\rho) = \frac{Mass\ (m)}{Volume\ (V)}$$

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Density of substances of fixed volume increases with increase in its mass. As the density of fluid of fixed volume increases, the mass increases, thereby, the thrust (weight) exerted increases the pressure. Therefore, greater the density of fluid, higher is the magnitude of pressure on the body.

For example: The pressure exerted on a body at equal depth in sea water and river water would be different. The pressure is more due to sea water as it is denser than the river water.

c. *Acceleration due to gravity*

The acceleration due to gravity increases as we move closer to the centre of the Earth. Closer to centre of Earth, greater is the pressure due to fluid.

For example: At higher altitudes, the acceleration due to gravity of Earth is less compared to the lower altitudes. The mass of column of air exerts less thrust as the weight is less due to lower value of acceleration due to gravity.

It is important to note that these factors affecting the pressure are not independent of each other. Pressure depends on density as the thrust depends on mass of solid or fluid column. The pressure does not depend on the size and the shape of the solid.

Example 2.3

A tank is filled with water to a height of 1 m. Calculate the pressure exerted at the bottom of the tank by the water. (Density of water = 1000 kg/m^3, Acceleration due to gravity = 9.8 m/s^2).

Solution:

Given: Density of water $= 1000\ kg\ m^{-3}$,

Acceleration due to gravity $= 9.8\ m/s^2$

The pressure is given by $P = \rho \times g \times h = 1000 \times 9.8 \times 1$

$= 9800$ *pascal.*

Example 2.4

The pressure exerted by 15 cm of a liquid is 1500 Pa. The acceleration due to gravity g = 10 m/s^2 . Calculate the density of liquid and name it.

Solution:

The pressure at the depth of 15 cm:

$P = \rho \times g \times h$

$1500 = \rho \times 10 \times 0.15$.

$\therefore\ \rho = 1000\ kg\ m^{-3}$, *which is the density of water*

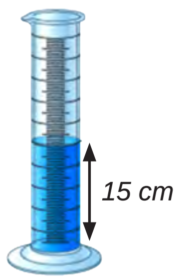

Figure 2.3

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B. Body in a fluid

Archimedes, the ancient Greek mathematician, first stated that when a body is completely or partially submerged in a fluid (gas or liquid) at rest, it is acted upon by an upward force or buoyant force. The magnitude of this force is equal to the weight of the fluid displaced by the body. The volume of displaced fluid is equal to the volume of an object submerged in a liquid. The buoyant force is also known as upthrust.

The buoyant force is given by $F = \rho g V$ ***......equation 3***

where, V= Volume of the displaced fluid or volume of submerged body
g = acceleration due to gravity
ρ = density of fluid

If the body is completely immersed in a fluid, the volume of fluid displaced by the body will be equal to its own volume. Buoyancy is a force exerted by a liquid or gas that opposes an object's weight. Pressure in a fluid increases with depth as a result of the weight of the overlying fluid. Thus an object submerged in a fluid, experiences greater pressure at the bottom of the fluid than at the top. This difference in pressure results in a net force that tends to accelerate an object upwards. The magnitude of that force is proportional to the difference in the pressure between the top and the bottom of the column, and is also equivalent to the weight of the fluid that would otherwise occupy the column, i.e. the displaced fluid. It is for that reason that an object whose density is lower than that of the fluid will float.

For example, hot air balloons rise into the air because the density of the air (warmer air) inside the balloon is less dense than the air outside the balloon (cooler air). The balloon and the basket displaces a fluid that is heavier than the balloon and the basket, so it has a buoyant force acting on the system making it float in air.

The body in fluid generally appear to be lighter than its own weight due to the upthrust. The apparent weight (W') of a body submerged in a fluid is equal to the difference of upthrust from the original weight (W) of the body.

i.e., ***Apparent weight (W')= Original weight (W) - Upthrust***

The original weight of the body is generally taken as the weight of the body in air or vacuum.

If a body of volume V and density ρ_b is completely immersed in fluid of density ρ_f, then the apparent weight is given by

$$W' = W - \text{Upthrust}$$

$W' = \rho_b g V - \rho_f g V$, where g is the acceleration due to gravity

$$\therefore W' = (\rho_b - \rho_f) g v \quad \text{......equation 4}$$

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Example 2.5

A wooden log of density 200 g cm^{-3} and volume 50 cm^3 fall on the surface of water of density 1000 kg/cm^3. Calculate its buoyant force. (g = 9.8 m/s^2)

Solution:

Given: Density $\rho = 1000\ kg/m^3$, *acceeration due to gravity* $g = 9.8\ m/s^2$

Volume $V = 50\ cm^3 = 50 \times 10^6\ m^3$

Buoyant force is given by $F = \rho\, g\, V$

$= 1000\ kg/m^3 \times 9.8\ m/s^2 \times 50 \times 10^{-6}\ m^3$

$= 0.49\ N.$

Example 2.6

A piece of marble of volume 3 x 10^{-6} m^3 and density of 2.2 x 10^3 kgm^{-3} is completely immersed in water of density 1000 kg m^{-3}. Calculate:

(a) Buoyant force.

(b) Apparent weight of the marble piece.

(Take g= 10 m/s^2)

Solution:

(a) Given: Density of water $\rho_w = 1000\ kg/m^3$,

Volume of marble, $V = 3 \times 10^{-6}\ m^3$,

Buoyant force is given by $F = \rho_w\, g\, V = 1000\ kg/m^3 \times 10\ m/s^2 \times 3 \times 10^{-6}\ m^3$

$= 3 \times 10^{-2}\ N$

(b) Given: Density of marble, $\rho_m = 2.2 \times 10^3\ kg/m^3$,

Density of water, $\rho_w = 1000\ kg/m^3$,

Volume of marble, $V = 3 \times 10^{-6}\ m^3$,

Apparent weight $= (\rho_m - \rho_w)\, g\, V = (2.2 \times 10^3 - 1000)\ kg/m^3 \times 10\ m/s^2 \times 3 \times 10^{-6}\ m^3$

$= 1200 \times 10 \times 3 \times 10^{-6}$

$W' = 3.2 \times 10^{-2}\ N.$

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Questions

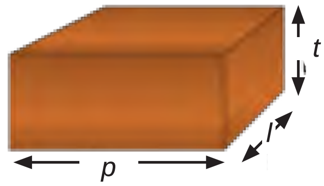

Figure 2.4

1. A block with length of p = 1.5 m, width l = 1 m, height t = 0.5 m and mass, m = 300 kg lays on the table. What is the pressure at the bottom surface of the block?

2. Find the weight of the air in a room with dimensions of 8 m x 12 m x 15 m. The density of air at sea level is 0.08 kg/m^3.

3. An iron anchor has a density of 480 kg/m^3 and weighs 250 kg in air. If it is immersed in sea water that has a density of 64 kg/m^3, how much force would be required to lift it while it is immersed?

4. An aluminium bar weighs 17 kg in air. How much force is required to lift the bar while it is immersed in gasoline? The density of aluminium is 170 kg/m^3 and that of gasoline is 42 kg/m^3.

5. How much does a 20 m x 10 m x 8 m swimming pool filled with water weigh? Assume that water has a density of 62 kg/m^3.

6. A balloon weighing 80 kg has a capacity of 1200 m^3. If it is filled with helium, how much of payload can it support? The density of helium is 0.18 kg/ m^3 and the density of air is 1.30 kg/ m^3. Express your answer in newton.

https://www.princeton.edu/~asmits/Bicycle_web/pressure.html
http://www.schoolphysics.co.uk/age11-14/Matter/text/Pressure_/index.html

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2. Transmission of pressure inside a liquid

Learning Objectives

On completion of this topic, you should be able to:

- state Pascal's law.
- explain the applications of Pascal's law.

A. Pascal's Law

Figure 2.5 shows a cylinder with a piston, connected to a container containing a liquid. When pressure is exerted on one part of the liquid by means of a plunger, the pressure is passed on equally throughout the liquid in the container.

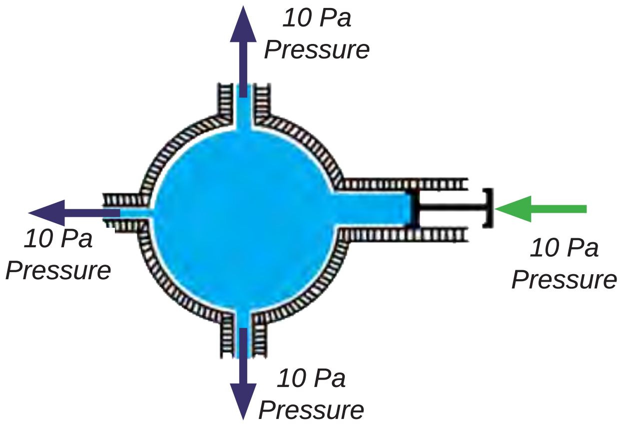

Figure 2.5 Transmission of pressure in fluid

This fact was first discovered by a French scientist Blaise Pascal. The conclusion drawn from the observation is known as the Pascal's law.

Thus, Pascal's law is stated as, *the pressure exerted to a confined liquid is transmitted equally and undiminished in all directions throughout the mass of the liquid.*

For example, if water contained in a can with four holes of same size, at an equal depth, is made to flow from the four holes at the same time, the water spouting from the four holes covers equal distance from the can. This indicates that the water is forced out from the four holes with equal pressure.

B. Application of Pascal's law

Hydraulic machines are commonly used in excavators, car brakes, cranes, dentist chair, etc. With the help of these machines, heavy weights are lifted or substances are pressed hard, because hydraulic machines act as force multipliers. The basic construction and working of such a machine is shown in Figure 2.6.

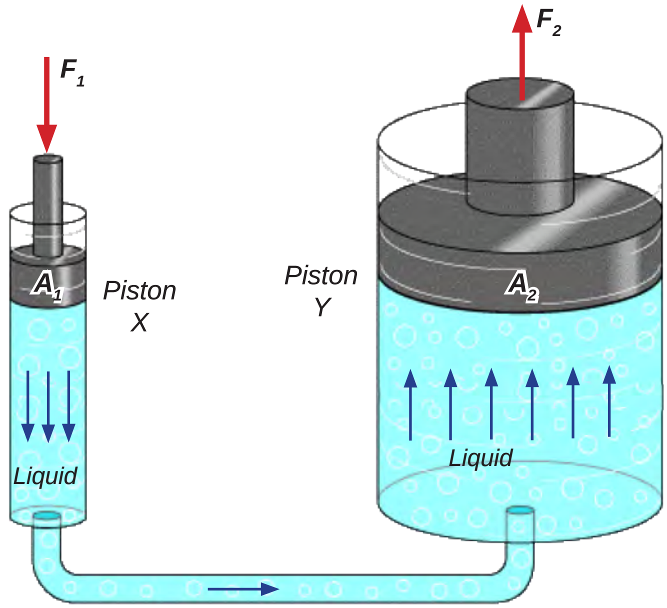

Figure 2.6 Principle of hydraulic machine

Usually, it consists of two cylindrical vessels filled with liquid and connected by a tube. Two pistons X and Y are fitted to the vessels and the area of these pistons are different. In Figure 2.6, the area A_1 of piston X is less than the area A_2 of the piston Y. If a force F_1 is applied on the piston X, then the pressure (P_X) exerted is given by:

$$P_X = \frac{F_1}{A_1}$$

The pressure P_X is transmitted throughout the liquid equally, and thus an upward pressure (P_Y) acts on the piston Y, with an area of A_2.

By applying Pascal's law, $P_Y = P_X = \frac{F_1}{A_1}$

Due to this pressure, there is an upward force F_2 that acts on the piston Y.

i.e., F_2 = Pressure on the piston Y × Area of the piston Y = $P_X \times A_2$

i.e., $F_2 = \frac{F_1}{A_1} \times A_2$

or, $\frac{F_2}{F_1} = \frac{A_2}{A_1}$

The area $A_2 > A_1$, therefore, the force $F_2 > F_1$. This implies that, a small force applied on a piston of smaller area is amplified into a bigger force. Thus, a small effort is used to raise a big load by using a hydraulic machine.

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i. Hydraulic Brake System

In most vehicles, hydraulic system is used in the brake system, as shown in Figure 2.7.

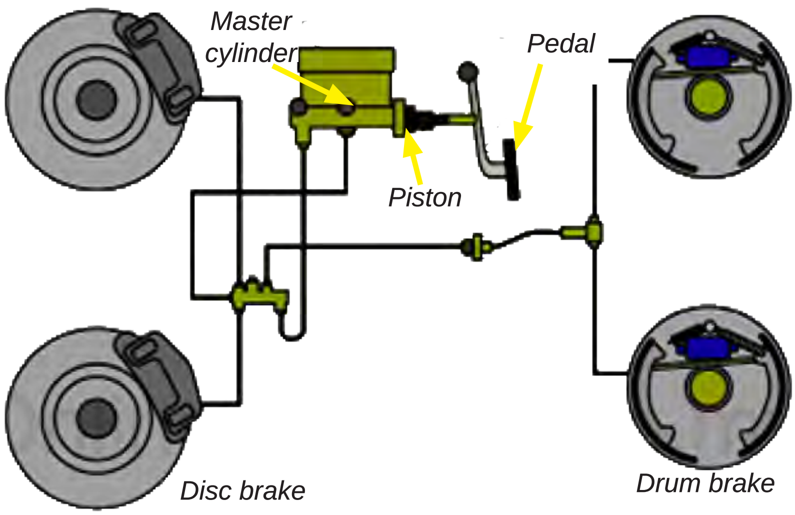

Figure 2.7 Hydraulic brake system

Usually, a disc brake is used in the front wheel of a car while a drum brake is used in the back wheel of a car. When the brake pedal is pressed, the piston of the master cylinder applies a pressure on the brake fluid. This pressure is transmitted uniformly to each cylinder at the wheel, which causes the pistons at the wheels to press the brake shoes against the surface of the disc and drum brakes. The friction between the disc and drum brakes and brake shoes causes the vehicle to slow down and stop.

ii. Hydraulic Jack

When the handle is pressed down, valve A is closed whereas valve B is opened. The hydraulic fluid is forced into the large cylinder and hence pushes the piston upward.

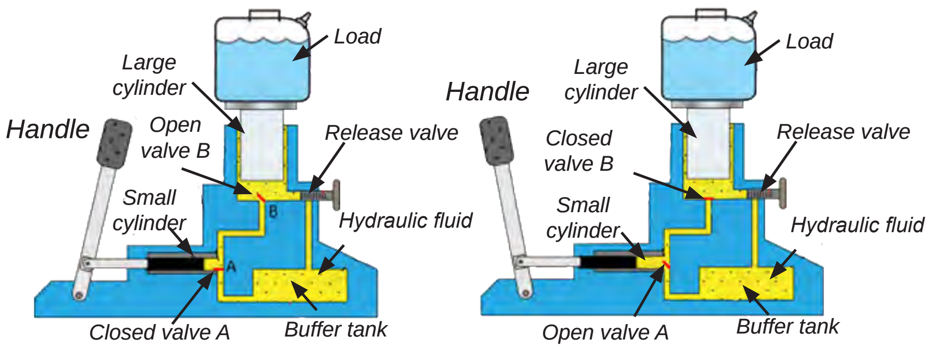

Figure 2.8 Hydraulic jack

When the handle is raised, valve B will be closed while valve A will be opened. Hydraulic fluid from the buffer tank will be sucked into the small cylinder.

This process is repeated until the load is sufficiently lifted up.

The large piston can be lowered down by releasing the hydraulic fluid back to the buffer tank through the release valve.

Example 2.7

Figure 2.9 shows the construction of a certain hydraulic machine. The areas of piston A and piston B are 4 cm² and 320 cm² respectively.

Answer the following questions.

i. State the law on which it is based.
ii. Calculate the pressure at A.
iii. Calculate the maximum load that it can lift on the piston B with the effort given in Figure 2.9.

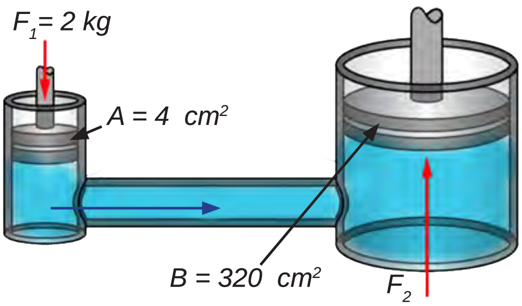

Figure 2.9

Solution:

i. Pascal's law states the pressure exerted to a confined liquid is transmitted equally and undiminished in all directions throughout the mass of the liquid.

ii. Given:

Area of the piston A = 4 cm²,

Thrust on the piston A = 2 kgf

$$\therefore \text{Pressure on the piston A} = \frac{\text{Thrust on piston A}}{\text{Area of piston A}} = \frac{2\ kgf}{4\ cm^2} = 0.5\ kgf\ cm^{-2}$$

iii. We know pressure on piston A = 0.5 kgf cm⁻².

Applying the Pascal's law, pressure on piston B is same as that on the piston A.

That is, pressure on the piston B = 0.5 kgf cm⁻².

$$\therefore \text{Pressure on the piston B} = = \frac{\text{Thrust on piston B}}{\text{Area of piston B}}$$

$$\text{i.e.,}\quad 0.5\ kgf\ cm^{-2} = \frac{F_2\ kgf}{320\ cm^2}$$

$$\therefore F_2 = 320\ cm^2 \times 0.5\ kgf\ cm^{-2}$$

$$F_2 = 160\ kgf$$

Therefore, the maximum load that can be lifted by the effort of 0.5 kgf is 160 kgf.

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Example 2.8

A hydraulic lift with piston of diameters D_1= 5 cm and D_2= 15 cm is shown in Figure 2.10. If the weight of the block W = 1800 N, find the minimum force F to lift up the weight W.

$$\frac{F_1}{(D_1)^2} = \frac{F_2}{(D_2)^2}$$

$$\frac{F}{5^2} = \frac{1800}{15^2}$$

$$F = 1800 \times \frac{5^2}{15^2} = \frac{1800}{9} = 200\ N$$

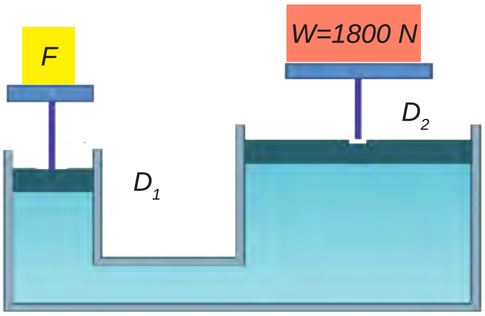

Figure 2.10

Questions

1. The fluid inside the hydraulic jack has a pressure of 30,000 Pa. If the surface of the piston that is used to lift an object is 0.1 m^2 in area, how much weight can the jack lift?
2. Describe the application of Pascal's law in a hydraulic excavator.

https://www.grc.nasa.gov/www/k-12/WindTunnel/Activities/Pascals_principle.html
http://www.engineeringtoolbox.com/pascal-laws-d_1274.html
http://global.britannica.com/science/Pascals-principle
http://www.tutorvista.com/content/physics/physics-iii/solids-and-fluids/pascals-law-applications.php
http://study.com/academy/lesson/applications-of-pascals-principle.html

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Summary

- Pressure is defined as the force acting normally per unit area.
- If the force of 1 N is acting on the surface area of 1 m^2, then the pressure exerted on the surface is 1 pascal (Pa).
- The magnitude of pressure on a surface due to a solid depends on magnitude of force and contact area.
- The pressure exerted on a body by the confined liquid is known as hydrostatic pressure.
- The magnitude of the pressure exerted on a body by a fluid depends on depth inside a liquid, density and acceleration due to gravity.
- .Archimedes' principle states that when a body is completely or partially submerged in a fluid (gas or liquid) at rest, it is acted upon by an upward force called buoyant force.
- The magnitude of buoyant force is equal to the weight of the fluid displaced by the body.
- The buoyant force is given by the product of density of fluid, acceleration due to gravity and the volume of fluid displaced.
- A body in fluid generally appear to be lighter than it own weight due to the upthrust.
- The apparent weight of a body submerged in a fluid is equal to the difference of upthrust from the original weight of the body.
- Pascal's law states that the pressure exerted to a confined liquid is transmitted equally and undiminished in all directions throughout the mass of the liquid.
- Liquids are nearly incompressible, and they pass on any pressure applied to them.
- Hydraulic machines are force multipliers.

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Exercises

I. *Fill in the blanks*

1. If the area of contact is increased, the pressure exerted by a thrust.....................
2. Hydraulic jack works on the principle of ....
3. The .... of water at the bottom of lake is more than at the surface.
4. If a metal block applies a force of 20 N on an area of 5 m^2, then the pressure is ……………..
5. The increase in upthust due to liquid will decrease the …………… weight of a body.

II. *Match the following.*

Column A	Column B
1. pascal	A. force acting normal to the surface
2. Thrust	B. upward force
3. Pascal's Law	C. determines the magnitude of pressure.
4. Density	D. apparent weight of a body.
5. Buoyant force	E. explains the transmission of pressure in fluids
	F. measurement of pressure

III. *Multiple Choice Questions.*

1. The Pascal's law explains the transmission of
   A force.
   B pressure.
   C heat.
   D light.

2. A hydraulic machine multiplies
   A energy.
   B power.
   C force.
   D work.

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3. The formula for pressure in liquids is
   - A p = hPg, where h is height, P is density and g is gravity.
   - B p = Pg/h, where P is density, g is gravity and h is height.
   - C p = hg/P, where h is height, g is gravity and P is density.
   - D p = hP/g, where h is height, P is density and g is gravity.

4. In case of pistons of hydraulic machines, which one of the following statement is TRUE?
   - A Pressure transmitted increases
   - B Pressure transmitted is equal
   - C Force transmitted is equal
   - D Area of pistons are equal

5. The amount of pressure of liquid increases with
   - A volume of body.
   - B surface area of liquid.
   - C mass of body.
   - D depth in the liquid.

6. Given that both liquid A and liquid B exert the same amount of pressure, what would be the height of column of liquid A if the density of liquid A is twice the density of liquid B and the height of column of liquid B is 10 cm?
   - A 5 cm
   - B 10 cm
   - C 20 cm
   - D 40 cm

7. If the density of a liquid is 20 g cm^{-3}, height is 4 cm and gravitational field strength is 10 N kg^{-1}, the pressure of the liquid is
   - A 0.8 Pa.
   - B 0.5 Pa.
   - C 8000 Pa.
   - D 2 Pa.

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IV. State 'True' or 'False'. Rewrite the false statements correctly.

1. Pascal's law states that pressure is produced by the pump and motor of a hydraulic system.
2. Pressure at a point in the liquid is greater in the upward direction.
3. If the area of an object is less, then the pressure acting on that object will be more.
4. When a body is placed in a liquid, the buoyant force experienced by it is equal to the volume of body.
5. When a body is submerged in a liquid, its weight reduces to zero.

V. Answer the following questions.

1. Why must a liquid and not a gas be used as 'fluid' in a hydraulic machine?
2. In a hydraulic press a force of 20 N is applied to a piston of area 0.20 m^2. The area of other piston is 2 .0 m^2. What is
   a) the pressure transmitted through the liquid?
   b) the force on the other piston?
3. Explain the working of a hydraulic jack.
4. A box has a mass of 120 kg and the bottom of the box is 12 m^2. What is the pressure the box exerts on the floor?
5. What is the weight of an object that has a base which is 3 square centimetre and which exerts a pressure of 210 newton per square metre?
6. What does a car weigh if its tires cover an area of 4 square cm and each tire exerts a pressure of 1000 newton per square centimetre on the ground?
7. To pop a balloon you poke it with a pencil. If the area of the pencil tip is 0.001 cm^2 and the pressure applied by the pencil on the balloon is 100 N/cm^2, what is the minimum force must you apply on the pencil to make the balloon pop?
8. A round tube weighs 30 kg. If the tube is stood on end, it pushes down on the floor with a pressure of 20 N/m^2. How many square inches is the end of the tube?
9. If the inside of a container has a surface area of 20 cm^2, what will be the pressure on each square inch of the container if 1176 N of force are applied to the container?

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10. A woman walking in high heels can damage a hardwood floor by making small dimples in the floor since her weight is concentrated on such a small area (the tip of the high heel). If the woman weighs 50 kg and the tip of the high heel is 10 mm^2 what is the pressure exerted on the floor by her high heel?

11. Look at Figure 2.11 and find the following.
    a) Pressure P_1.
    b) Pressure P_2.
    c) Force F_2.

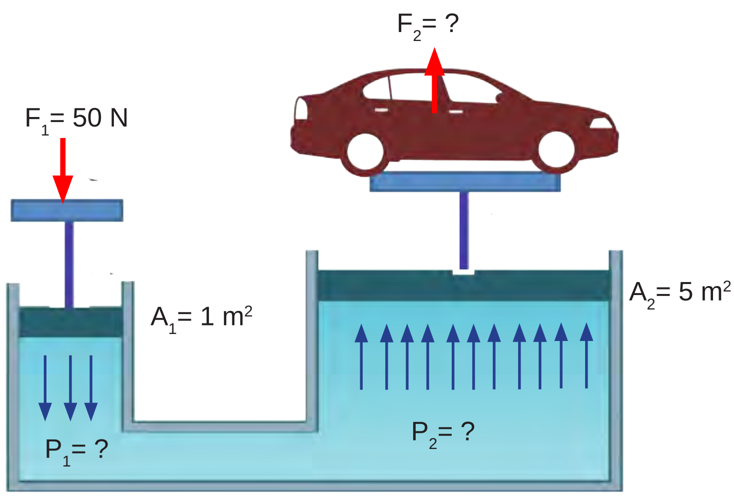

Figure 2.11

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3

ENERGY

We are familiar with different kinds of energy like heat energy, light energy, sound energy, electrical energy and so on in our every day life. Our food is cooked using heat energy. We are able to talk to each other using sound energy. We are able to see each other due to light energy and all our electronic devices like mobile phones, televisions, computers, etc., work on electrical energy. Hence all these different forms of energy are essential for us to survive. There are various sources of energy available on this earth. They may be renewable source or non-renewable source of energy. We need to take good care of these sources of energy so that they can last for a longer time. This chapter deals with the importance of energy and, the need for economical and sustainable use of energy resources.

1. Work and Energy

Learning Objectives

On completion of this topic, you should be able to:

- calculate the work done by a constant force using W=Fd (adjacent side)/(hypotenuse side).
- calculate the power of a machine as a rate of work done.
- calculate the efficiency of a machine as a ratio of work output and input.
- state and use the equation for potential energy PE=mgh.
- state and use the equation for kinetic energy K.E.= $\frac{1}{2}mv^2$.
- state the principle of conservation of energy.
- Apply the principle of the conservation of energy to gravitational potential energy, kinetic energy and work done against resistive forces.

We need energy to perform all kinds of work right from picking up a pencil from the floor to lifting heavy loads. Work cannot be done without energy. Humans derive

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energy from the food they eat. Machines are generally run by chemical energy from fossil fuel and electrical energy generated from hydropower plants, solar energy, wind energy, etc.

A. Work and Power

All the changes that take place around us are the result of forces. Forces can make something move, change the shape of a body, change the position of a body, and the direction. If the force is very small, it may not be able to bring about any change in the huge body even though the force is being constantly applied to it. In such a case no work is done by the force.

i. Work Done

Generally, we consider all kinds of actions or activities as work being done where force is applied. In physics, *work* is said to be done only when a body is displaced under the application of a force. It is a scalar quantity. For example, a farmer carrying a sack of potatoes from his house to the market is said to have done some work.

The amount of work done by a force on a body depends on the following:

- magnitude of applied force (F),
- displacement of the body (d) and
- the angle (θ) at which the body is displaced in relation to the direction of applied force.

Suppose a body is displaced from position A to position B when a constant force (F) is applied along AC. Let the displacement made by the body be 'd', at an angle θ(*theta*) with the direction of force (F). Geometrically, the function of angle equals to the ratio of the adjacent side (AB)to the hypotenuse side (AC).

Therefore, the work done is given by

$$W = F \times d \times \frac{\text{adjacent side}}{\text{hypotenuse side}}$$

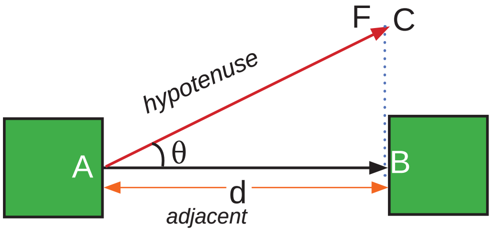

Figure 3.1 Work done by force F

The following are some of the special conditions that determine the magnitude of work done:

Case (i)

When the displacement is along the direction of force as shown in Figure 3.2, the length of adjacent side is equal to length of hypotenuse side and hence the ratio of adjacent side to hypotenuse side is equal to 1. Therefore, the work done is given by

$W = F\,d.1 = F\,d$

For example, when a boy pushes a box along a horizontal surface, the length of the vectors representing force and displacement are equal. Therefore, the magnitude of work done depends only on the magnitude of force and displacement.

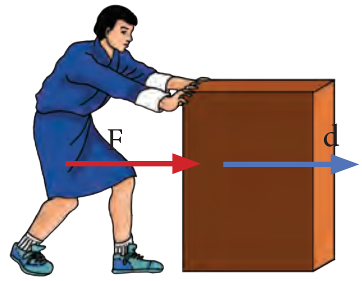

Figure 3.2 Work done is maximum, when displacement is along Force

Case (ii)

When the displacement is perpendicular to the direction of the force applied as shown in Figure 3.3, then the work done is found to be equal to zero. In this case, the body is not displaced with respect to force. Hence, the length of adjacent side representing displacement is zero, while force is represented by vector of any length.

Therefore, the ratio of the length of the adjacent side to the hypotenuse side is zero. The work done is given by

$W = F\,d.0 = 0$

For example, a person carrying a box and walking along a horizontal road continuously applies force, while the box is not displaced from the point of application of force, even when the person walks. Here, the length of force vector is fixed while the length of the displacement vector is zero. Therefore, the work done is zero.

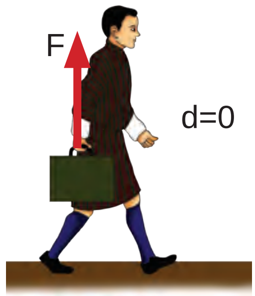

Figure 3.3 Work done is 0, when displacement is perpendicular to Force

Case (iii)

When the displacement is zero even when the force is applied as shown in figure 3.4, then the work done will also be zero. The work done is given by

$$W = Fd\frac{adjacent\ side}{hypotenuse\ side}$$

$$= F.0.\frac{adjacent\ side}{hypotenuse\ side} = 0$$

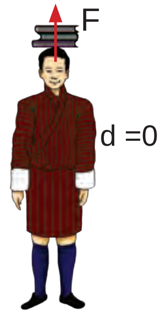

Figure 3.4 Work done is 0, when displacement is zero due to Force

For example, a man standing with books over his head does no work. He has to constantly apply force to carry the books over his head but his displacement is zero. Hence the work done is zero.

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Case (iv)

When a body displaces without the application of force, then the work done is zero.

$$W = Fd\frac{adjacent\ side}{hypotenuse\ side}$$

$$= 0.d.\frac{adjacent\ side}{hypotenuse\ side} = 0$$

For example, a ball rolling over a smooth frictionless horizontal road requires no force as it will continue to roll due to inertia of motion. Since no force is applied, the work done is zero.

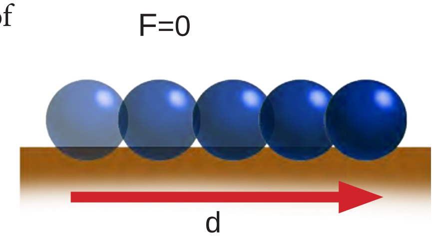

Figure 3.5 Work done is 0, when no force is applied

The unit of work can be determined as follows.

If force is in newton (N) and the displacement in metre (m), then the work done is measured as

$$W = F.d = newton.\ metre = Nm\ or\ joule\ (J)$$

Similarly, if force is in dyne and the displacement is in centimetre (cm), then the work done is measured as

$$W = F.d = dyne.\ centimetre = erg$$

One joule is the work done when a mass of 1 kg is moved through a displacement of 1m on applying a force of 1 newton on it. Similarly, 1 erg is the work done when a mass of 1 g is moved through a displacement of 1cm on application of a force of 1 dyne on it.

$$1\ J = 1\ N \times 1\ m$$

$$= 10^5\ dyne \times 100\ cm$$

$$Therefore,\ 1\ J = 10^7\ erg$$

ii. Work done against gravity

When a body is raised to a certain height, work is being done against gravity. This is because the force of gravity tries to pull the mass downward towards the centre of the Earth when the mass is being raised upward against it. In such a case, the force required will be equal to the weight of the body being raised. From Newton's law of motion we know that $F = ma$ and here $a = g$ (acceleration due to gravity).

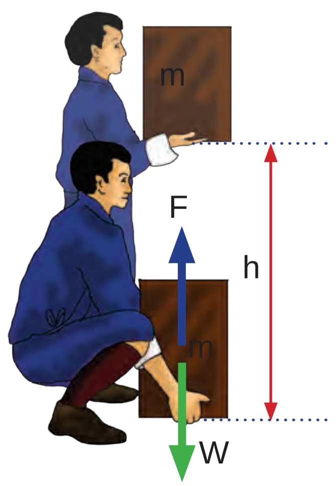

Figure 3.6 Work done against gravity

Therefore,

$$F = m\,g$$

Work done against gravity,

$$W = \text{force x displacement} = m\,g\,h$$

where ***h*** is the height (displacement) to which the mass ***m*** is raised and the ratio of length of adjacent side to length of hypotenuse side is equal to 1 as the displacement and the force are along same direction.

Example 3.1

Passang pushes a large rock of mass 150 kg through a distance of 2 m with a force of 100 N. The rock moves along the direction of force. Calculate the work done by him.

Solution:

$$F = 100\ N$$

$$d = 2\ m$$

$$\frac{\text{Adjacent side}}{\text{Hypotenuse side}} = 1$$

$$W = F \times d \times \frac{\text{Adjacent side}}{\text{Hypotenuse side}}$$

$$W = 100\ N \times 2\ m \times 1$$

$$W = 200\ J.$$

Example 3.2

Deki takes out 5 kg of water from a well of 20 m depth. How much work has been done by Deki? (Take g= 9.8 m/s^2)

Solution:

$$F = mg = 5\ kg \times 9.8\ ms^{-2} = 49\ N$$

$$h = 20\ m$$

$$W = m\,g\,h$$

$$W = 49\ N \times 20\ m$$

$$W = 980\ J.$$

iii. Power

Power is the measure of work being done in certain interval of time. For example, if the work done by Dorji is 10 J and the work done by Karma is 8 J in 10 seconds,

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then we state that Dorji has more power than Karma. If the work is done in less time then the power is more. Therefore, *power* is defined as the rate of doing work. It is a scalar quantity.

$$\boldsymbol{Power(P) = \frac{Work\ done(W)}{time(t)}}$$

If the work done is measured in joule and time in second then the unit of power is given by

$$P = J/s = watt\ (W).$$

Power is also measured in kilowatt (kW), megawatt (MW), gigawatt (GW) and horsepower (hp.).

$$1\ kW = 10^3\ W,\ 1MW = 10^6\ W,\ 1\ GW = 10^9\ W\ and\ 1\ hp = 746\ W.$$

We use machine to make our work easier. A machine may be a simple lever, combination of pulleys, a gear system or any complex machine. Some machines multiply applied force; some change the direction as per our convenience and some bring about gain in torque or speed. Different types of machines may vary in their power and efficiency.

The power of a machine is the rate at which work is done by it. The machines generally take less time to perform the work. For example, two vacuum cleaners can be compared with each other in terms of their power. The 1000 W vacuum cleaner can clean the room faster than the 500 W vacuum cleaner in equal interval of time. Therefore, 1000 W vacuum cleaner is considered more powerful than the 500 W one.

$$Power\ of\ a\ machine = \frac{Work\ done\ by\ machine\ (W)}{Time\ taken(t)}$$

When the displacement is along the direction of force,

$$Power\ of\ a\ machine = \frac{Force\ (F) \times displacement\ (d)}{Time\ taken(t)}$$

But, $\frac{displacement(d)}{Time\ taken(t)} = velocity(v)$

Therefore,

$$\boldsymbol{Power\ of\ a\ machine = Force\,(F) \times velocity\,(v)}$$

The power of a machine can also be measured in terms of force and velocity.

Two types of force are involved while using machines to perform work. They are input force (F_I) and output force (F_O). The effort force or the force applied to the

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machine is called *input force*. While the force applied by the machine or the force experienced by the load is called *output force*. Based on these two types of force, we find two types of work being done in the case of machines. Work done on the machine is called *input work*. It is the product of input force and the distance moved by the effort (d_E). Work done by the machine is called *output work*. It is the product of output force and the distance moved by the load (d_L).

Efficiency of a machine is the ratio of output work to input work. It is represented by Greek letter 'η' (eta). Efficiency is usually expressed in terms of percentage and is given by the relation,

$$\eta = \frac{load \times displacement\ of\ load}{effort \times displacement\ of\ effort} = \frac{L \times d_L}{E \times d_E}$$

$$\eta = \frac{output\ work}{input\ work}$$

$$\therefore \eta\,\% = \frac{output\ work}{input\ work} \times 100\,\%$$

The efficiency of machine in terms of energy is given by

$$\eta = \frac{Energy\ Output}{Energy\ Input}$$

$$\eta\,\% = \frac{Energy\ Output}{Energy\ Input} \times 100\,\%$$

Output work can never be greater than the input work. Some of the input work is spent in the form of heat in order to overcome the force of friction between the various moving parts of the machine. Hence the efficiency of a machine is always less than 100 %. A machine having 100 % efficiency is called *ideal machine*. Practically, it does not exist.

Example 3.3

A fire brigade pumps 18000 kg of water to a height of 25 m in 30 s in order to put off the fire. What is the power of the pump of the fire brigade? Take g = 9.8 m/s^2.

Solution:

mass of water, m=18000 kg, Height, h=25 m, Time taken, t=30 s

$$Power = \frac{Work\ done\ (W)}{Time\ (t)} = \frac{mass \times acceleration\ due\ to\ gravity \times height}{Time\ (t)}$$

$$Power = \frac{18000 \times 9.8 \times 25}{30} = 147,000\ W$$

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Example 3.4

A heat engine gives out 400 J of heat energy as the useful work. Calculate the energy given to it as input if its efficiency is 40%.

Solution:

Given: Energy output = 400 J,

Energy Input = ?

Efficiency, $\eta = 40\ \% = 0.40$

$$\eta = \frac{Energy\ Output}{Energy\ Input}$$

$$\therefore Energy\ Input = \frac{Energy\ Output}{\eta} = \frac{400}{0.40} = 1000\ J$$

Example 3.5

Tshewang lifts a load of 50 N using a single fixed pulley of 80% efficiency. How much of force must Tshewang apply to lift the load to a height of 2 m.

Solution:

Given: Load = 50 N,

Displacement of load= displacement of effort= 2 m

Effort = ?

Efficiency, $\eta = 80\ \% = 0.80$

$$\eta = \frac{load \times displacement\ of\ load}{effort \times displacement\ of\ effort}$$

$$= \frac{L \times d_L}{E \times d_E}$$

$$\therefore effort = \frac{L \times d_L}{\eta \times d_E}$$

$$= \frac{50 \times 2}{0.80 \times 2}$$

$$= 62.5\ N$$

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B. Energy

We need energy to perform any kind of work. Energy can be defined as the capacity of a body to do work. There are different forms of energy like light energy, chemical energy, sound energy, heat energy, mechanical energy, electrical energy, etc. We will be mostly dealing with mechanical energy in this chapter.

Mechanical energy is energy possessed by a body due to its motion or its position. It is of two types: potential energy and kinetic energy.

i. Potential energy

The energy possessed by a body due to its position or state is called *potential energy*. Any object at a height or that has been raised through a certain height against gravity possesses potential energy. For example a rock on the edge of a cliff has potential energy due to its position. A wound up key of a toy car has potential energy due to its state. Similarly, a stretched spring possesses potential energy due to its stretched state.

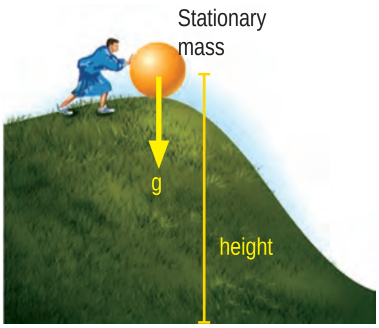

Figure 3.7 Potential Energy

Potential energy is measured by the amount of work done in taking the body to the required state or position. Suppose a body of mass ***m*** is raised to a height ***h*** against the force of gravity. Then the work done in raising the body is

Work done = Force x displacement

Work done = mass x acceleration due to gravity x height

Since potential energy = work done in raising the body

Potential energy (P.E.) = m g h .....equation 1

From ***equation 1***, we can conclude that the potential energy increases with increase in the mass of a body and increase in height from the surface of the Earth. Since potential energy is equal to the work done, potential energy is measured in joule (J) or erg.

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Example 3.6

Pemba placed a container of 1 kg mass on the shelf at a height of 5 m. Calculate the potential energy possessed by the container.(Take g = 9.8 m/s^2)

Solution:

Mass, m = 1 kg

Height, h = 5 m

$g = 9.8\ m/s^2$

Potential energy (P.E.)=mgh

$P.E. = 1 \times 9.8 \times 5$

$\therefore P.E. = 49\ J.$

ii. Kinetic energy

A body in motion can apply force on another body and bring about displacement. Therefore, a moving body has the capacity to do work. For example a moving ball can break the window glass. When a moving car hits a parked car, it can make the parked car to move. This means that the moving body possess certain energy. Such energy possessed by a body due to its motion is called *kinetic energy*.

Kinetic energy is measured by the amount of work done in order to bring a moving body to rest. Suppose a body of mass m is moving with a velocity u. The body is brought to rest, therefore, $v = 0$.

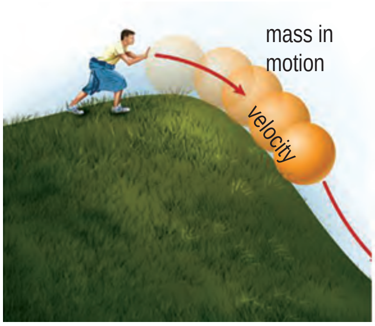

Figure 3.8 Kinetic Energy

Using the Newtons' equation of motion

$v^2 - u^2 = 2aS$, where v is the final velocity, a is the acceleration and S is the displacement of the body.

$0 - u^2 = -2aS$ (a is negative as it is retardation)

$$S = \frac{u^2}{2a}$$

Work done in opposing the motion of the body = Force (F) x displacement(S)

$$W = \frac{ma \times u^2}{2a} \text{ (Since F = m a)}$$

$$W = \frac{1}{2} mu^2$$

Since kinetic energy (K.E.) = work done in opposing the motion of the body

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$$K.E. = \frac{1}{2} mu^2$$

Or, $$K.E. = \frac{1}{2} \times mass \times velocity^2 \text{ .....equation 2}$$

We can conclude from ***equation 2*** that a massive moving body has more kinetic energy. Similarly, a body moving with greater velocity possesses more kinetic energy than the slow moving body.

Example 3.7

A ball of mass 0.5 kg is moving with a velocity of 6 m/s. What is its kinetic energy?

Solution:

Mass, $m = 0.5\ kg$

Velocity, $v = 6\ m/s$

$$K.E. = \frac{1}{2} \times mass \times velocity^2$$

$$K.E. = \frac{1}{2} \times 0.5 \times (6)^2$$

$$\therefore K.E. = 9\ J.$$

iii. Law of conservation of energy

According to the *law of conservation of energy*, the energy can neither be created nor can it be destroyed. It can only be transformed from one form to another form. So the total quantity of energy in our universe or any isolated system always remains constant.

The principle of conservation of energy is seen in our everyday lives. Some of the examples are given below:

- *When a rock is at the edge of a cliff, it has potential energy. As it rolls down a cliff, its potential energy is transformed into kinetic energy. The potential energy of the rock is less than when it was at greater height at the edge of the cliff. This is because some amount of energy possessed by rock may be transformed into sound, heat and even light. Therefore, the total energy remains the same in the system or the environment.*
- *A body moving over a surface has kinetic energy. Most of this kinetic energy translates into motion, while rest of the kinetic energy is converted into heat, sound and light in overcoming the frictional force. The sum of transformed energies like heat energy, sound energy, light energy and final kinetic energy equals to the initial kinetic energy of the body.*
- *A swinging pendulum has only potential energy at its extreme ends which changes into kinetic energy as it moves towards the mean position. So when it reaches the mean position whole of the potential energy is converted into kinetic energy. It has both potential energy and kinetic energy in between the mean and the extreme positions. In this manner the mechanical energy of the pendulum remains conserved.*

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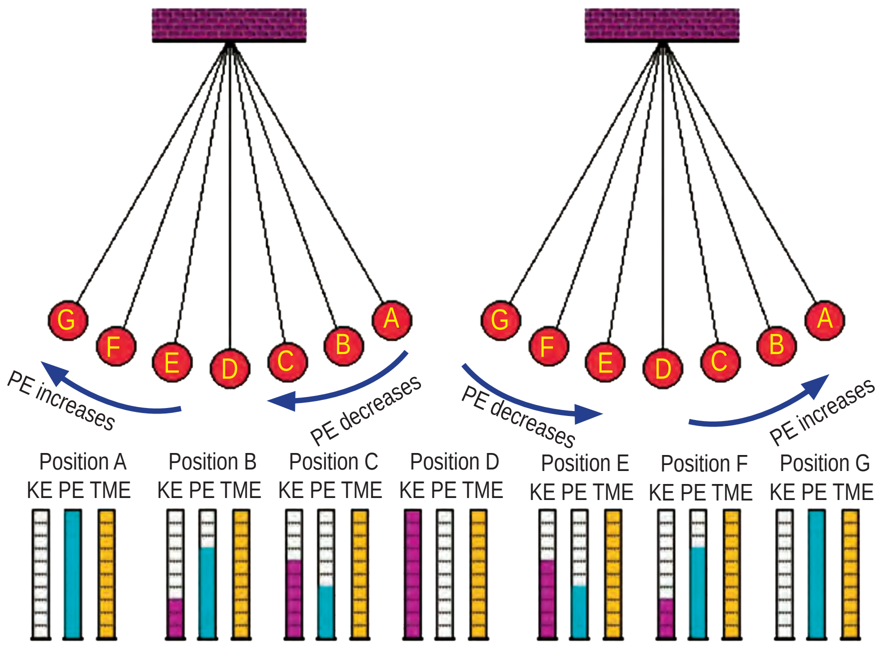

Figure 3.9 Energy conservation in a swinging pendulum

a. Conservation of energy in a freely falling body

Let a body of mass ***m*** be at a height ***h*** above the surface of the Earth. At this stage, the body has only potential energy due to its position. When it is made to fall freely under the action of gravity, the potential energy of the body starts changing to kinetic energy as shown in Figure 3.10.

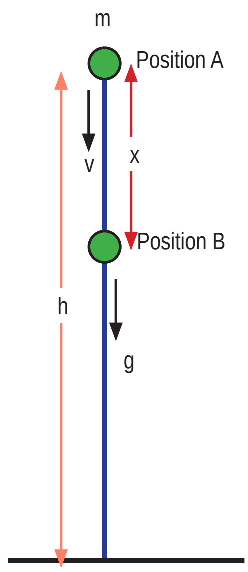

Figure 3.10 Energy conservation in free falling body

At the position A,

$P.E. \text{ of the body} = mgh \text{ and } K.E. = 0.$

So,

$\text{Total energy of the body at } A = P.E. + K.E. = mgh + 0 = mgh.$

At the position B,

$P.E. \text{ of the body} = mg(h-x) \text{ and } K.E. = \frac{1}{2}mv^2.$

Using equation of motion, $v^2 - u^2 = 2aS$

$v^2 - 0^2 = 2gx$

$v^2 = 2gx$

Substituting this value of v in equation of K.E., we have

$K.E. = \frac{1}{2} \times m \times 2gx$

$K.E. = mgx$

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Now,

Total energy of the body at B = P.E. + K.E. = mgh - mgx + mgx = mgh

Therefore, the total energy of the body at A and B are same i.e. mgh. So we can conclude that the energy of the body may change from one form to another form but the total energy of the body is always conserved.

b. Dissipation of energy due to resistive force

A resistive force is a force that slows down a moving body or prevents a stationary object to move. Some examples of resistive forces are frictional force, gravitational force, air resistance, water resistance, etc.

The resistive force always opposes the motion of a body. Hence, some work has to be done in order to overcome the resistive force. Such work done is referred as work done against resistive force. We can calculate the work done against resistive force by using the following relation.

$$\text{Work done against resistive force}(W_{res}) = \text{resistive force}(F_{res}) \times \text{displacement}(d)$$

The work done against resistive force is generally dissipated in the form of heat energy, light energy or sound energy.

Example 3.8

Nima pushes a 50 kg rock with a force of 300 N along a horizontal surface for a distance of 2 m. The force of friction between the rock and the horizontal surface is 25 N.

(i) Calculate the work done by Nima.
(ii) How much of work is done by Nima against frictional force?
(iii) Find the net work done on the rock.

Solution:

Given, Mass, $m = 50\ kg$

Force, $F = 300\ N$

displacement, $d = 2\ m$

Frictional force, $F_{res} = 2\,5\ N$

(i) Work done on horizontal surface, $W = F\,d$

$W = 300 \times 2$

$\therefore\ W = 600\ J$

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(ii) *The work done against the frictional force,* $W_{res} = F_{res} \times d$

$$W_{res} = 25 \times 2$$

$$\therefore W_{res} = 50\ J$$

(iii) *The net work done is given by,* $W_{net} = W - W_{res}$

$$W_{net} = 600\ J - 50\ J$$

$$\therefore\ W_{net} = 550\ J$$

Questions

1. Phurba rolls 100 kg barrel up a ramp of length 4.4 m into the truck at a height of 2.2m. What is the work done by Phurba?
2. A truck of mass 8000 kg and a car of mass 1000 kg are travelling at the same speed. Which one has greater kinetic energy? Why?
3. Ap Dorji carries a 45 kg rock halfway up a hill of height 650 m. What is the potential energy of the rock? If the rock falls to the bottom of the hill, what will be its new potential energy?
4. Karma was driving a 1800 kg car at a speed of 35 m/s. When he reached near a school, he slowed down his car to 15 m/s. What was the change in the kinetic energy of the car?
5. Explain law of conservation of energy with an example.

http://www.physicsclassroom.com/class/energy/Lesson-1/Calculating-the-Amount-of-Work-Done-by-Forces
http://www.nuffieldfoundation.org/practical-physics/work-done-force
http://hyperphysics.phy-astr.gsu.edu/hbase/work.html
http://www.nyu.edu/classes/tuckerman/adv.chem/lectures/lecture_2/node4.html

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2.Energy Conservation

Learning Objectives

On completion of this topic, you should be able to:

- describe efficient ways to use energy.
- describe the need for economical and sustainable use of energy resources.
- describe the environmental implications of our current methods for generating energy.

There are various sources of energy on our Earth. Some are renewable like hydroelectricity, wind energy, solar energy, tidal power, bio-energy, geothermal energy, and some are non-renewable like fossil fuel. Each one of us should realize that these energy sources are not going to last forever. We cannot afford to waste energy at any cost and should consume only the required amount of energy. Therefore, we need to use energy efficiently and economically for the sustainability of the energy resources.

A. Sustainable use of energy

Although electricity has reached majority of households in Bhutan, many households still use firewood, kerosene and liquid petroleum gas for heating and cooking purposes. Bhutan imports fossil fuels like kerosene, diesel, petrol and liquid petroleum gas from India. Most of the imported fossil fuels are for vehicles. The combustion of these fuels result in emission of green house gases into the atmosphere causing green house effect which leads to global warming and climate change.

The warmer climate is melting the glaciers and increasing the sea level and the occurrence of floods and hurricanes. Plants and animal species may migrate or may lead to the extinction of some species. It is a big concern for the countries all over the world. The only solution is to cut down the energy consumption and adopt sustainable use of energy.

The energy efficiency and renewable energy are the twin pillars of sustainable energy policy. Both the strategies are required to slow down the growth in the demands of fossil fuels.

There are many advantages of energy efficiency and its sustainability.

- It reduces the expenditure of the consumers.
- It reduces carbon dioxide emission and helps to protect the environment.

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- It also reduces mining and drilling. So it slows down the rate at which domestic energy resources are depleted.
- In many countries energy efficiency is also seen to have a national security benefits because it can be used to reduce the level of energy imports from foreign countries.

i. Efficient ways to use energy

We can start saving energy right from our home. Whenever we save energy, we do not only save money but also reduce the consumption of fossil fuels such as coal, oil, natural gas, etc. As a result, we contribute in saving our environment by reducing emissions of greenhouse gases.

There are lots of opportunities to be energy efficient in use of home and office equipment and other appliances in lighting, heating, cooling, etc. Energy efficiency can be achieved by either reducing the quantity of energy consumption to produce certain quantity of products or by producing increased number of products from the same quantity of energy.

Some of the methods for efficient use of energy are given below:

(a) Using energy-efficient appliances

Modern appliances like refrigerators, fluorescent bulbs, ovens, stoves, washing machines and dryers consume less energy compared to older appliances. Current energy efficient refrigerators consume almost 40% less energy than the conventional ones. For example, incandescent light bulbs produce light when the filament wire is heated to red hot by electric current. Thus, a lot of energy dissipates in the form of heat energy in case of incandescent light bulbs. Compact fluorescent light (CFL) is a low pressure mercury-vapour discharge lamp which produces light due to fluorescence. It converts electrical energy into light more efficiently than incandescent light with little loss of energy as heat. Light emitting diode (LED) bulbs are solid bulbs with no filament and are made up of diodes. Hence, LED bulbs are more durable and

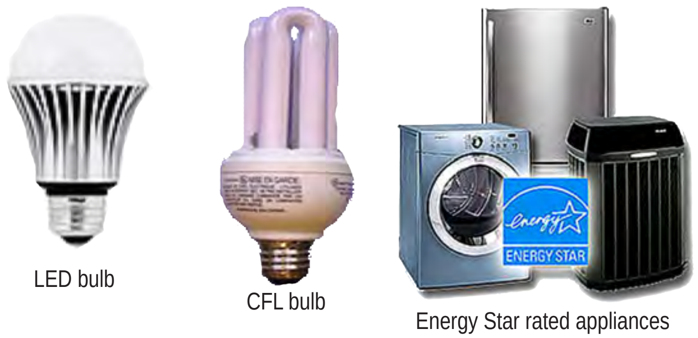

Figure 3.11 Energy efficient appliances

energy-efficient compared to incandescent and CFL bulbs. CFL use two-third less energy than incandescent light bulbs. LED bulbs use $\frac{1}{3}rd$ to $\frac{1}{30}th$ of energy used by incandescent bulbs or CFL. light emitting plasma (LEP) bulbs are popularly used in many places as it is durable, energy efficient and produce light spectrum close to the light from the Sun.

Similarly, conventional ovens take hours for baking while the latest microwave ovens can bake within minutes. Hence, the modern ovens are faster and hence consume less energy.

(b) Insulation

Most of the places in our country are at higher altitudes and hence become quite cold in winter. We usually consume lots of firewood and kerosene in heating our houses. We can use electrical energy which is totally environment-friendly compared to wood and kerosene. But we still use huge amount of energy that is expensive.

Similarly, we consume lots of energy for keeping our houses cool in hot places in various parts of our country. Therefore, the best way to reduce energy consumption is to insulate our homes from cold or heat.

Activity 3.1 Insulating our house

Look at the following Figure 3.12 showing different insulations and some of the insulating materials used in building a house to prevent energy loss. Visit your library or browse Internet and answer the following questions.

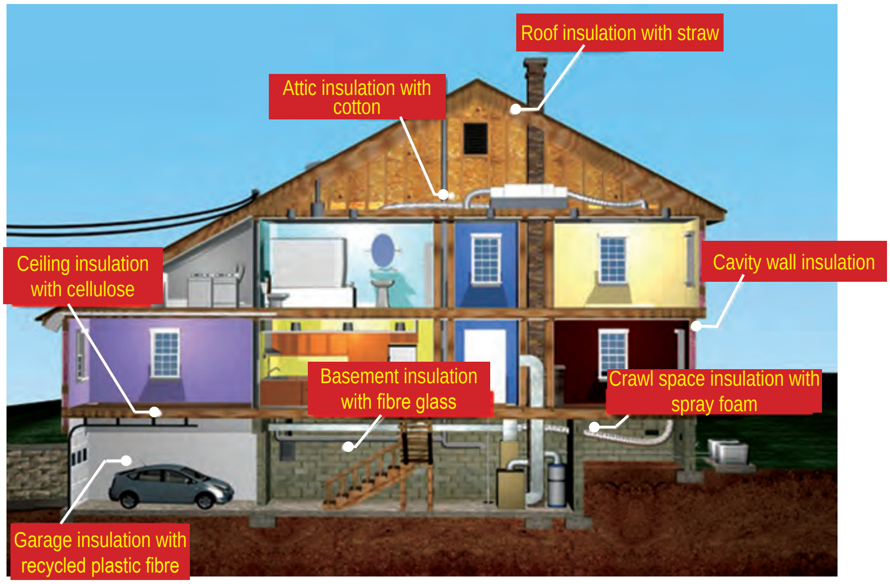

Figure 3.12 Types of insulation at homes

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1. List down the areas that can be insulated in the house.
2. From which part of the house the maximum loss of heat energy take place?
3. Name five natural insulating materials that can be used at different locations of house.
4. Name five synthetic insulating materials that can be used at different locations of house.
5. Which of the insulating materials you listed do you think have potential risk to our health and why?
6. "We can insulate our houses by painting the walls with coloured paint". Explain the statement.

(c) Technology

Technology is very important tool today by which we can reduce energy consumption and use it efficiently. These days most of the electronic devices are energy efficient. Modern power management systems reduce energy consumption by appliances like laptops, televisions, computers, etc, by automatically turning them off or putting them into low-energy mode when not in use.

Another technological advancement is in automobiles. Every new model of cars and other vehicles consume less fuel or consume alternative fuel like bio fuel, hydrogen fuel, electricity, etc. Vehicle's energy efficiency is also improved by reducing the weight of the vehicle and improved aerodynamics design that reduces the friction.

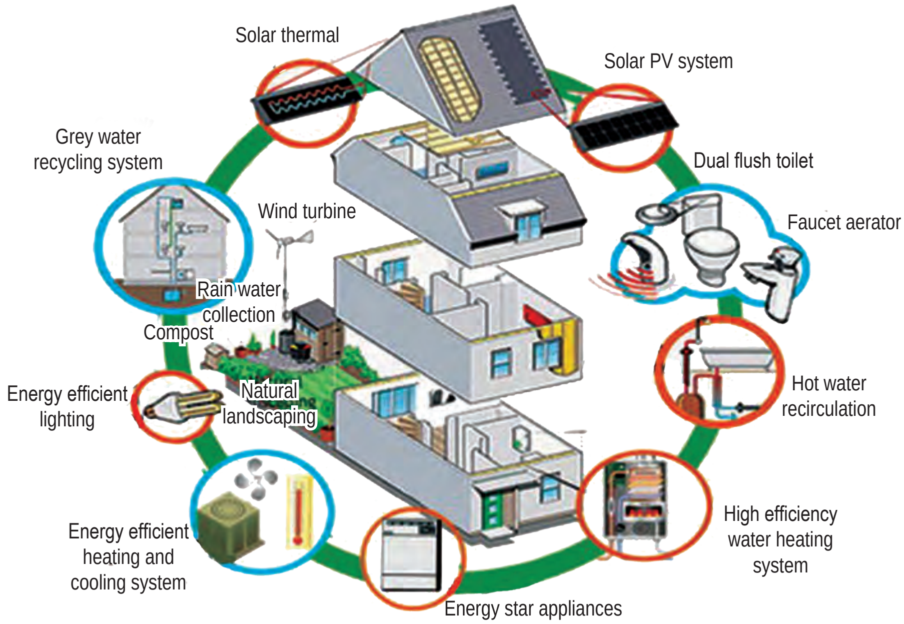

Figure 3.13 Energy saving technology

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In many countries, buildings are equipped with sensors that monitors and controls all the appliances, heating and cooling systems, entertainment systems, escalators, elevators, etc., reducing the energy consumption and wastage. The light in the rooms are automatically made brighter, dimmer or switched off as per the requirement with the help of sensors thereby minimising wastage of energy.

Advanced architectural designs of buildings also reduce energy use. For example windows and roofs are rightly placed and even made transparent so that enough light enters the room which prevents the use of artificial lighting during day time.

Everyday, scientists, inventors and innovators are coming up with lighter and more durable materials, efficient designs, and eco-friendly devices.

Saving and consumption of energy is crucial and the technology makes it all possible.

ii. Impacts of Power generation on Environment

There is a higher demand for energy due to increasing population and productions. Fossil fuel is rapidly decreasing resource of energy and at the same time, it is the cause of adverse impact to our environment. To improve environmental conservation the role of technology must be to address and help create alternative and sustainable energy sources.

Sustainable energy sources can be divided into two categories:

- *Energy created from biological or chemical reactions, such as ethanol production from corn, energy from chemical cells, biogas, etc.*
- *Energy created from natural occurrences in nature such as wind power, solar power, geothermal power, and hydro power.*

These are all possible technological advances that can be improved on in the future. As of now, the viability of some of these is less than others because the technological progress have not reached an advanced point or it is not widespread.

Renewable energy sources are the sources which can be replenished within a short period of time. Bhutan has many renewable energy sources. Some of the useful sources are discussed below.

(a) Hydroelectricity

Bhutan is a mountainous country with many high current rivers with potential of generating electricity. Currently, Bhutan has tapped over 1500 MW of electrical energy from hydroelectric plants like Kurichhu hydropower plant, Chhukha hydropower plant, Basochhu hydropower plant, Tala hydropower plant, etc. Hydroelectricity is one of the cleanest sources of energy. Electricity is the ultimate

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form of energy which can be used for many purposes. Therefore, the requirement of fossil fuel is being replaced more and more by the electricity generated from renewable sources. This is another large step in conserving energy and the environment.

Electricity generated using fossil fuel dominates electricity generated from other sources. Fossil fuel generated electricity has enormous environmental consequences. Hydropower is considered 'renewable' because of its dependency on hydrological cycle of rainfall and evaporation. However, although the resources exploited by hydropower is renewable, the technology itself in many cases is non-renewable.

Figure 3.14 Hydropower dam

The most evident advantages of hydropower generation are:

1. Clean, efficient, and reliable form of energy.
2. Does not emit any direct pollutants or greenhouse gases.
3. While the initial cost is high, they are very inexpensive to operate.

Hydropower does not pollute the water or the air in the environment. However, huge structures like dam and reservoir of hydropower plants occupy large area which have many environmental impacts. The natural timing of flow of water, nutrient and sediments may be disturbed. All these changes may affect the agriculture, homes, and natural habitats in the dam area. Sometimes important natural and archaeological sites may also get affected due to the construction of hydropower plants.

The huge structures of hydropower plants obstruct the migration of fishes and affect their population. During the operation of hydropower plants, there may be a change in the temperature and the flow of river. These changes may affect the normal life of both aquatic and terrestrial plants and animals.

Specific ecosystem impacts caused by a single hydroelectric project largely depend on the following variables:

- the size and flow rate of the river or tributary where the project is located,
- the climatic and habitat conditions that exist,
- the type, size, design, and operation of the project, and
- whether cumulative impacts occur because the project is located upstream or downstream of other projects.

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(b) Solar energy

The energy harnessed from the sun is called solar energy. It can be used for various purposes like heating, cooking, lighting, etc. Sunlight can be trapped by using solar panels and converted into electrical energy. Currently, two methods of harnessing solar energy exist: concentrated solar power (CSP) and solar photovoltaics (PV). The former involves focusing, or concentrating, solar energy to heat a working liquid to produce steam which in turn powers a turbine. The latter, photovoltaics, uses cell arrays to capture solar energy and convert it into direct current electricity.

Solar energy can also be directly used for heating purposes like in solar water heater. Solar energy systems (photo voltaic, solar thermal, solar power) provide significant environmental benefits in comparison to the conventional energy sources, thus contributing to the sustainable development of human activities.

Concerning the environment, the use of Solar energy technologies (SETs) has positive implications such as:

- reduction of the emissions of the greenhouse gases (mainly CO_2, N_2O) and prevention of toxic gas emissions (SO_2,particulates);
- reclamation of degraded land;
- reduction of the required transmission lines of the electricity grids;
- improvement of the quality of water resources;
- absence of any air emissions or waste products during their operation.

Solar panels in solar power plants consist of a series of photovoltaic cells. Each photovoltaic cell is responsible for the conversion of solar energy to electrical energy. It is made up two layers of semiconducting material usually silicon. The upper layer has excess of electrons which is called n-type semiconductor and the lower layer has deficit of electrons which is called p-type semiconductor. These difference in the density of electrons in the two layers sets up an electric field within the photovoltaic cell. When sunlight falls on the photovoltaic cell, the light energy knocks out the electrons in the semiconductor and these electrons are pushed into the external conducting wires due to the electric field. Thus an electric current is generated due to the flow of electrons in the conducting wires.

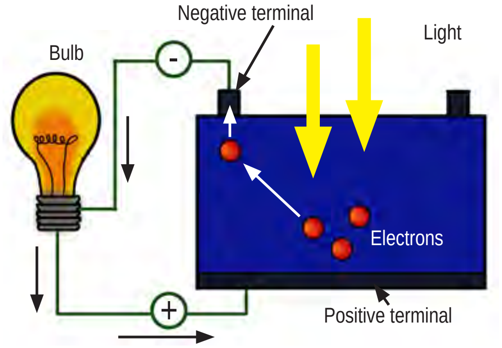

Figure 3.15 Photovoltaic cell

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Solar power plants are being developed in a wide range of locations and ecosystems, ranging from forests to deserts.

Despite large number of benefits, there are some environmental impacts depending on its location and scale.


Figure 3.16 Solar power installation

Large-scale solar power installations cover very large area. It requires clearing of trees and bushes under and around the solar panels and other equipment. This may lead to destruction of ecosystem and habitats of native plants and animals. The power plant is generally enclosed by a fence, limiting movement of animals. The solar panels themselves cast shadows and may cause some effects on the growth of vegetation.

Solar panels have anti-reflective surface and convert a large amount of radiation into heat, which leads to concern that they may affect global or local climate. Solar technology is preferred to traditional means of power generation even in terms of land use and wildlife impacts.Solar power plants located in deserts and other locations where solar radiation is intense and wildlife is absent, have the least environmental impact. The solar power plants are encouraged mainly to reduce emissions of carbon dioxide from traditional power generation.


Figure 3.17 Biogas

(c) Bioenergy

Bioenergy is the energy derived from plants. Wood is one form of biomass but it releases carbon dioxide in the atmosphere when it burns. In order to reduce the emission of carbon dioxide, biomass can be converted into other forms like biogas and bio-fuels. Biogas can be used for cooking and lighting purposes just like LPG. The use of biogas helps in reducing the emission of harmful methane gas into the atmosphere. The most common bio-fuel is ethanol. Bio-fuels can also be used in running cars and machine.

Bhutan has almost 65% of its area covered by forest. So biomass is one of the largest sources of energy.

Biomass in the form of manure, industrial food waste, agricultural residues and sewage can also be anaerobically digested to produce biogas. Biogas consists mainly

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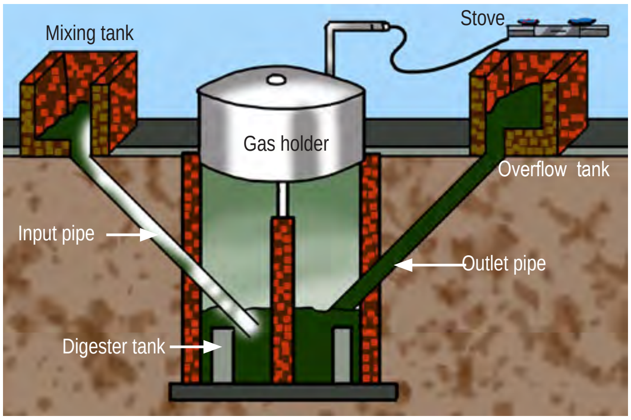

Figure 3.18 Working of biogas plant

of methane (CH_4), carbon dioxide (CO_2) and water. Trace contaminants, such as ammonia and sulphides may also be present.

Biomass is generally looked favourably upon as a renewable energy source. One reason this source is frequently promoted is that much of the CO_2 emitted from its combustion, is offset by the CO_2 absorbed by the plant during its life cycle to produce biomass. The chemical composition of biomass is also low in sulphur, resulting in lowered SO_2 emissions over those of fossil fuels.

The traditional use of biomass considered is the combustion of biomass, used for heating and cooking. In developing countries where biomass is still used in open-air stoves, pits and fireplaces, there is concern with emitted air pollutants such as, particulate matter, volatile organic compounds (VOCs), dioxins, etc,. resulting from incomplete combustion. These pollutants affect both environment and health of people.

(d) Wind energy

Some places in Bhutan are quite windy. We can even harness this wind energy and use it to generate electricity. Wind energy is harnessed using wind turbines on land or at sea (offshore). Kinetic energy from the wind is converted to mechanical energy in a gearbox. The majority of modern wind turbines consist of three-bladed rotors. The rotors are connected to a low-speed shaft. In order to increase the speed of the shaft, the gearbox increases the shaft speed to match the rotational speed of a induction

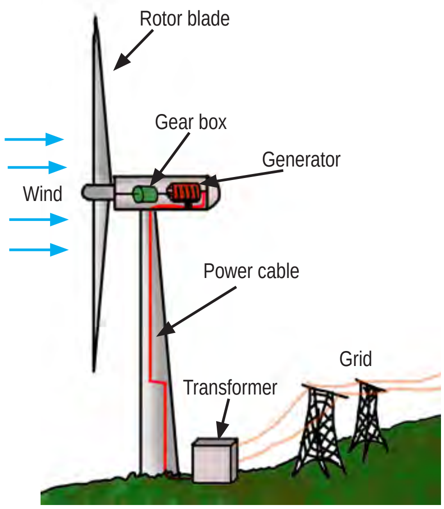

Figure 3.19 Generating electricity using wind turbine

generator. While wind farms require a large area to produce a commercially viable quantity of electricity, very little of the land is actually occupied by the turbines. As a result, most of the land the wind farm occupies may still be used for grazing or cultivation.

Figure 3.20 Wind turbines

Although wind power plants have relatively little impact on the environment compared to fossil fuel power plants, concerns have been raised over the noise produced by the rotor blades and deaths of birds and bats that fly into the rotors.

Unlike most other generation technologies, wind turbines do not use combustion to generate electricity, and hence do not produce air emissions. The only potentially toxic or hazardous materials are relatively small amounts of lubricating oils and hydraulic and insulating fluids. Therefore, contamination of surface or ground water or soils is highly unlikely. The primary health and safety considerations are related to blade movement and the presence of industrial equipment in areas potentially accessible to the public. An additional concern associated with wind turbines is potential interference with radar and telecommunication facilities. Like all electricity generating facilities, wind generators produce electric and magnetic fields.

(e) Geothermal energy

Geothermal energy has been used for centuries throughout the world. Recently, because of a need to diversify forms of energy away from fossil fuels, geothermal energy has been researched and utilized to great effect. Geothermal energy is considered a renewable resource and the emissions from plants are very less to none when compared with other fossil fuel powered plants. Although geothermal energy is much more environment- friendly than other types of energy production, there are still aspects of geothermal energy plants that can be harmful towards the environment.

Geothermal energy is power derived from the Earth's own internal heat. This heat, or thermal energy, is contained within the Earth's rocks and in the fluids and water that are under the crust of the Earth. Geothermal energy can be found at varying depths from the surface, from fairly shallow reservoirs to very deep ones. The hottest depository of heat is the molten rock or magma. Since it is clean and renewable, geothermal energy is being promoted as one of the best alternatives to fossil fuels.

The difference in temperature between the core and the surface of the earth is known as the geothermal gradient which drives a continuous conduction of thermal

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energy as heat to the surface of the Earth. Thermal energy generated from radioactive decay depends on the presence of radioactive isotopes present since the formation of the Earth with the major heat-producing isotopes being potassium-40, uranium-238, uranium-235, and thorium-232.

Figure 3.21 Geothermal plant

In order to access this energy, wells are drilled into areas below the crust where there are aquifers of already heated water, or steam. Pressure increases as we go deeper into the Earth's crust. Water at this depth does not vaporise due to the high pressure. As a result, 'superheated water' is produced at very deep depths of the Earth. As wells are drilled into the rock that contains this

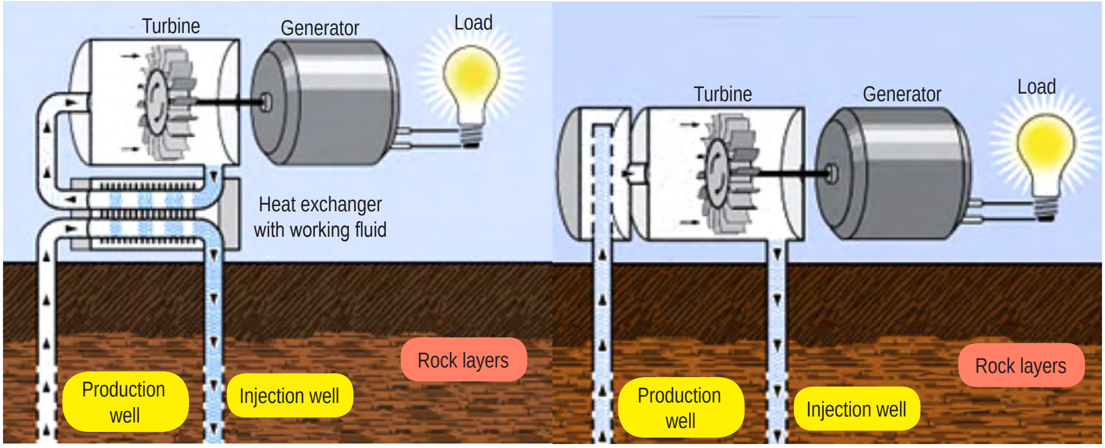

Figure 3.22 Diagrams of a binary cycle power plant (left) and of a flash steam power plant (right)

water, its heat energy is converted into mechanical energy for utilization. There are three main types of geothermal plants: direct dry steam, flash, and binary plants.

In a direct dry steam plants, steam goes directly to a turbine which drives the generator that produces electricity.

Flash plants utilize man-made changes in pressure to vaporize the hydrothermal fluid. The fluid is placed in a tank that is held at a much lower pressure than the fluid causing it to vaporize, and this vapour then moves the turbine which then generates the electrical power.

In a binary cycle plant, hot water and steam rises through the production well. The hot water and steam are directed to the working fluid which turns it into steam.

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The steam is made to rotate the turbine connected to the generator at a high speed which in turn generates electricity. The steam and hot water is then condensed and returned to the ground via a re-injection well.

The utilization of energy from geothermal wells releases greenhouse gases trapped in the earth core such as carbon dioxide, hydrogen sulphide, methane, and ammonia. These emissions are lower than those associated with the use of fossil fuels. Geothermal water pose a large potential risk to water quality, if released into the environment, due to high concentrations of toxics including antimony, arsenic, lead, and mercury.

Questions

1. Explain renewable energy with examples.
2. Explain the environmental impacts of hydropower generation in Bhutan. Suggest some ways to mitigate these impacts.
3. Explain the possibilities of generating geothermal energy.
4. Why do you think Solar energy is not feasible for large power generation in Bhutan?
5. Compare the working principle of generation of electricity using hydropower, wind and geothermal energy

http://energy.gov/eere/renewables
http://www.alternative-energy-news.info/technology/future-energy/
http://www.makeuseof.com/tag/8-unbelievable-new-ways-generating-electricity/

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Summary

- Work is said to be done by a body only when it is displaced under the application of a force. It is measured in joule or erg.
- Power of a machine is the rate at which work is done by the machine. It is measured in watt.
- Power is a scalar quantity.
- Efficiency of a machine is the ratio of useful output work to the input work. Its value is always less than 1 or 100%.
- A 100% efficient machine is called an ideal machine. It does not exist practically.
- Energy is the capacity of a body to do work. It is measured in joule or erg.
- Mechanical energy is the energy possessed by a body due to its position or state.
- There are two types of mechanical energy namely potential energy and kinetic energy.
- Potential energy is calculated by using the formula P.E. = mgh.
- Kinetic energy is calculated by using the formula K.E. = $\frac{1}{2}mv^2$.
- The law of conservation of energy states that energy can neither be created nor destroyed. There is only transformation of energy from one form to another.
- A resistive force is a force that slows down a moving body or prevents a stationary object to move. Some examples of resistive forces are frictional force, gravitational force, air resistance, water resistance, etc.
- The combustion of fossil fuels results in global warming and climate change.
- Carbon dioxide gas is one of the primary greenhouse gases which leads to global warming.
- Greenhouse effect is the phenomenon of keeping the heat energy trapped within the earth with the help of greenhouse gases in the atmosphere. It is beneficial for regulating the temperature of the earth at night.
- When the average temperature of the earth increases due to excessive trapping of the heat energy within the earth due to increase in the carbon dioxide content in the atmosphere, it may lead to global warming and climate change.
- There are various methods for efficient use of energy in our households, offices and industries.
- Using renewable energy is one way of reducing fossil fuel consumption and there are many renewable energy resources in our country.
- Some of the examples of renewable sources of energy are hydropower, solar, bioenergy, geothermal and wind.
- Besides numerous advantages of renewable sources of energy, they also have some environmental impacts.

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Exercises

I. Fill in the blanks.

1. Potential energy of a body increases with the increase in ....
2. Work done against gravity is equal to the .... energy of the body.
3. Pema performs 2000 J of work in 10 minutes. The power developed by Pema is ....
4. Photovoltaic cells convert .... energy to electrical energy.
5. LED bulbs are energy-efficient compared to ....

II. Match the following.

Column A	Column B
1. Hydroelectric power plant	a. destruction of habitat
2. Solar power plant	b. volatile organic compounds
3. Bio-gas plant	c. noise pollution
4. Wind energy plant	d. affect marine life
5. Geothermal energy	e. smoke
	f. arsenic

III. Multiple Choice Questions.

1. Sonam throws a ball with a force of 70 N to distance of 20 m. Chencho throws the same ball with the same force, but the ball rolls to a distance of only 16 m. Which of the following statements are correct?
   - A Work done by Chencho and Sonam are equal.
   - B Neither of them does any work.
   - C Sonam does less work.
   - D Chencho does less work.

2. A force acting on an object does no work when
   - A the force is directed along the motion of the object.
   - B the force is directed perpendicular to the motion of the object.
   - C a machine is used to move the object.
   - D the applied force overcomes the force of friction.

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3. Work output is less than work input in a Bunsen burner used in chemistry laboratories. Which of the following best explains about the lost energy?
   A The lost energy is converted into sound energy.
   B The lost energy is converted into mechanical energy.
   C The lost energy is used in overcoming the force of friction.
   D The lost energy is used in heating the surrounding.

4. What kind of energy is transferred from the wind to the blades of a wind turbine?
   A Potential energy.
   B Sound energy.
   C Kinetic energy.
   D Chemical energy.

5. Sun is one of the renewable sources of energy. Renewable source means it
   A can be reused.
   B can be recycled.
   C does not cause pollution.
   D can be replaced.

6. The graph shown in Figure 3.23 shows a relationship between the work done by a girl and the time taken for her to climb a flight of stairs. The unit of the slope of the graph will be
   A joule.
   B newton.
   C second.
   D watt.

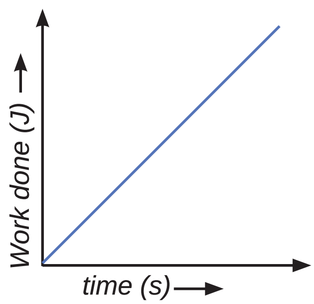

Figure 3.23

7. The major impact of hydropower plants towards environment is due to the
   A change in the timing of the flow of river.
   B obstruction of the migration of the fishes.
   C change in the temperature of the water.
   D occupation of large land areas by its huge structures.

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8. A 50 kg box is initially at rest on a smooth frictionless horizontal surface. Lhaden pushes the box with a force of 200 N through a distance of 3 m in 20 seconds. The power developed by Lhaden is

   A 10 W.

   B 20 W.

   C 30 W.

   D 40 W

9. Biomass used in open-air stoves is a concern because it

   A consumes more energy.

   B emits air pollutants.

   C is low in sulphur content.

   D is a fossil fuel.

10. One advantage of using electric cars over petrol cars is that electric cars

    A are more energy-efficient.

    B has low maintenance cost.

    C do not pollute air.

    D produce less noise.

IV. State 'True' or 'False'. Rewrite the false statements correctly.

1. The rate of doing work varies inversely with the velocity of the body.
2. Potential energy of a heavy body raised to a certain height is less than that of lighter body raised to the same height.
3. Geothermal energy cannot be replenished within a short period of time.
4. Work done against frictional force is converted into potential energy and kinetic energy.
5. Spray foam, cotton, plastic fibre and straw are mainly used as decorating materials.

V. Answer the following questions.

1. Define work. What are the conditions when the work done by the body is zero?
2. Compare work and power.
3. Why is the efficiency of machines always less than 1 or 100%?

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4. Swinging pendulum in vacuum obey conservation of energy. Explain.

5. A weightlifter lifts a barbell of mass 50 kg to a height of 2m in 3s. (Take g = 9.8 m/s^2.)

    a) What is the weight of the barbell?

    b) What is the work done by the weightlifter?

    c) Calculate the power developed by the weightlifter?

6. Prakash kicks a ball of mass 500 g which moves with a velocity of 10 m/s. Passang kicks the same ball and it moves with a velocity of 20 m/s. Compare the kinetic energy acquired by the ball in the two cases.

7. Three students carry out an experiment to compare their power. They measure their individual masses and then time taken to run up a flight of stairs 10 m high. Their results are shown in the table given below. Copy and complete the table.

Name	Mass in kg	Weight in newton	Time in seconds	Potential energy gained in joules	Power in watt
Kezang	45		12		
Phuntsho	50		14		
Galay	55		15		

8. An archer pulls an arrow in his bow to a distance of 0.5 m against a force of 150 N. What is the potential energy gained?

9. Jigme is driving his 800 kg car at a speed of 10 m/s. When Jigme applies brake, the ground offers a frictional force of 8000 N to bring the car to rest.

    a) Determine the initial kinetic energy of the car.

    b) Calculate the work done by the friction on the car if the car stops after travelling a distance of 2 m on applying the brakes.

    c) What happens to the kinetic energy when the car comes to a stop?

10. Which source of energy would you prefer for cooking and why?

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11. Pema uses a petrol engine which converts the chemical energy in the fuel into useful forms of energy such as mechanical energy and some energy is dissipated as sound and heat energy. For every 800 J of chemical energy input only 750 J of useful output energy is produced.

    a) How much of energy is dissipated per 1000 J of input energy by the engine?

    b) What is the efficiency of the petrol engine?

12. Why is there a need for economical and sustainable use of energy resources?

13. What are the environmental implications of our current methods for generating energy?

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4

ELECTRICITY AND MAGNETISM

Electricity has become an indispensable part of our life. Most of the appliances that we use in our homes and offices function on electricity. It is very important to know how electricity makes things work. The flow of electricity in a conductor gives rise to electric field and magnetic field. The change in magnetic field also induces electric current in a circuit. Therefore, electricity and magnetism are interrelated to each other and coexist together.

In this chapter, we will learn about different components of an electric circuit and their behaviour. We will also learn the working of power system and its distribution including the common devices used in transfer of electricity to our homes.

1. Electric Circuits

Learning Objectives

On completion of this topic, you should be able to:

- explain resistance, power, voltage and current.
- describe that the flow of charges through a resistor results in heating of resistor.
- explain and verify Ohm's Law.
- interpret the graph of ohmic and non-ohmic conductors.
- describe the variation of current with voltage in a range of devices.

A. Flow of electric current

In a circuit, conductors are used to make the current flow from one terminal of a power supply to another. The conductors generally have lots of free electrons that can flow. Some materials cannot conduct as they have no free electrons, therefore they are referred to as insulators.

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i. Potential difference and electric current

Electric current is conducted due to the flow of charges in a conductor. In solid conductors, the free electrons are responsible for the flow of electric current. In liquids and gases, there is movement of both positively and negatively charged ions during the flow of current.

Electric current (I) is the rate of flow of charge (Q) across any cross-section of a conductor

i.e. $$I = \frac{Q}{t}$$

Current is measured in ampere (A). Flow of charges is similar to the flow of water. Water always flows from higher level to lower level. In order to have continuous flow of water, there should always be difference in the level of water as shown in Figure 4.2. Similarly, electrons also flow from the region of higher concentration to the region of lower concentration of electrons. The difference in concentration has to be maintained across a conductor or circuit in order to have continuous flow of electrons. When electrons flow, the conventional current flows in the circuit but in opposite direction as shown in Figure 4.3. The region with high concentration of electron is considered as "low potential region" while the region with low concentration of electron as "high potential region". Electric current flows from region of high potential to low potential and will continue to flow so long as the potential difference exists.

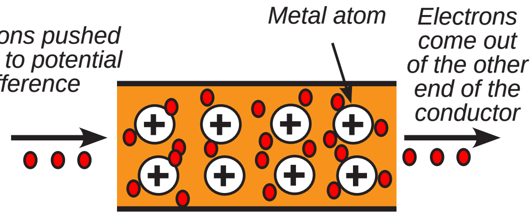

Figure 4.1 Flow of charges

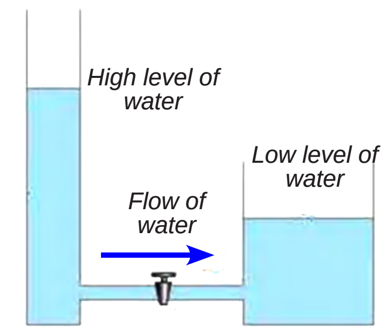

Figure 4.2 Potential difference analogy

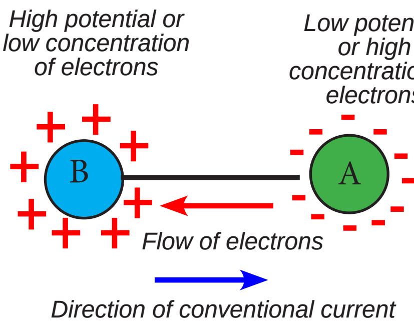

Figure 4.3 Conventional Current

The difference in potential can be maintained in the electric circuit either by connecting a cell in the circuit or by connecting the circuit to the mains supply. A cell has the potential difference between its two terminals. It drives the charges from one point to another point in the circuit. This potential difference (p.d.) between the

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two terminals of a cell in an open circuit is called *electromotive force or emf (E)* of a cell. The potential difference between the terminals of the cell in closed circuit is called *terminal voltage (V)* of the cell. The terminal voltage is usually less than the emf of the cell. The terminal voltage and the emf of a cell are equal when the internal resistance of the cell is zero. *Internal resistance (r)* of a cell is the opposition offered to the flow of electric current by the electrolyte of the cell.

$$emf = Terminal\ Voltage + Current \times internal\ resistance\ of\ cell$$

$$\boldsymbol{E = V + Ir}$$

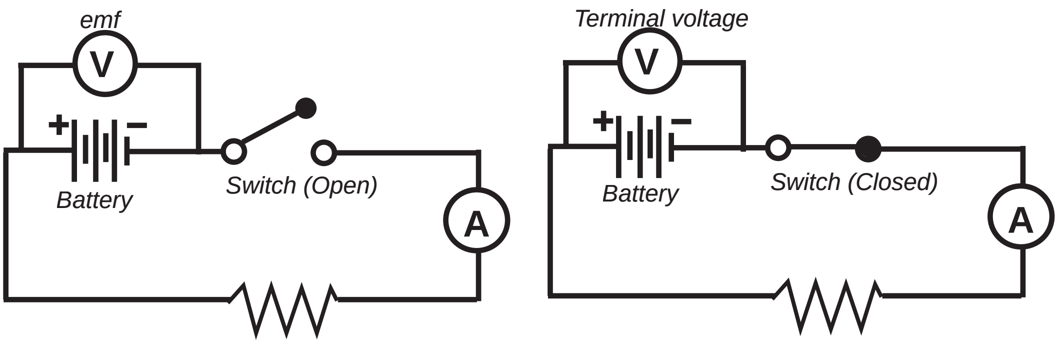

Figure 4.4 Potential difference

Potential difference is measured in volt (V) and it is also referred to as *voltage*.

If 1 joule of work is done in moving a charge of 1 coulomb between two points, the potential difference between the two points is said to be 1 volt. This means '***n***' J of work is done if '***n***' C charge is moved between the same two points. Thus work done is the product of charge and voltage.

Work done (W) = Charge (Q) × Voltage (V)

Or, $$\boldsymbol{Voltage(V) = \frac{Work\ done(W)}{Charge(Q)}}$$

Therefore, voltage can also be defined as work done per unit charge or energy transferred per unit charge.

In an electric circuit, electric current flows from high potential i.e. positive terminal of the cell to the low potential i.e. negative terminal of the cell. This is called conventional direction of current. It is opposite to the direction of flow of electrons.

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ii. Resistance and resistor

A metallic conductor contains numerous free electrons moving randomly in all possible directions. When the ends of the conductor are connected to a cell or other sources of potential difference, all these free electrons will be drifted towards the positive terminal of the cell. Since these electrons move in one direction, they collide with other free electrons or positively charged ions. It is due to these collisions of electrons that the resistance arises in the circuit. The opposition offered to the flow of electric current in a conductor is called *resistance (R)*.

Resistance of a conductor depends upon the following:

- nature of material of the conductor,
- length of the conductor,
- thickness of the conductor and
- temperature of the conductor.

The resistance of the conducting wire depends on the nature of the material. Copper and aluminium have lots of free electrons that can move and conduct electric current and offer less resistance as compared to iron and nickel.

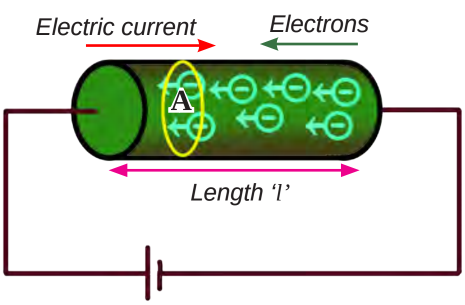

Figure 4.5 Resistance

Experimentally it is found that the resistance of a wire increases with the increase in length. The collision of electrons increases with the increase in length of the conductor, thereby offering large net resistance to the flow of electric current.

i.e, $R \propto l$

The resistance of a conducting wire also increases with increase in temperature of the conducting wire. The electrons gain external energy from the heat and therefore possess large amount of kinetic energy to move randomly colliding with each other. The resultant collision is more and therefore, the net resistance of the wire increases.

The resistance is found to decrease with increase in thickness of a conducting wire. The increase in thickness of the conducting wire increases the cross-sectional area (A) of the wire which allows electrons

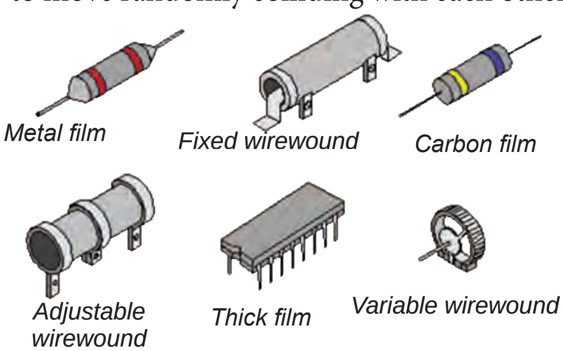

Figure 4.6 Types of resistors

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to flow more smoothly. This mean less collisions of electrons resulting into low net resistance offered to the flow of current.

$$R \propto \frac{1}{A}$$

Resistance is measured in ohm and it is denoted by the symbol Ω (omega).

In an electric circuit, a current flows as long as potential difference exists. The conducting wire offers constant resistance to the flow of current. In electronic devices, we may need different value of current to operate which can be achieved only by changing the resistance offered. However, we cannot have conducting wires with varying resistances assigned for different circuit. One of the best ways to offer external or additional resistance is by using a device. This device used to obstruct or regulate the passage of electric current is called a *resistor*. Resistors are the fundamental component of all the electronic appliances and electric circuits. They are made up of various materials like carbon or graphite, nickel-chromium alloy, nickel, tin oxide, etc.

iii. Potential drop

Conductors carrying current always have inbuilt resistance to oppose the current flow. *Voltage drop* is defined as the amount of voltage loss that occurs through all or part of a circuit due to resistance. It is also known as *potential drop*. The greater the resistance of the circuit, the higher the voltage drop that occurs.

When the voltage drop is too high, it can bring down the efficiency of the equipment or appliances. The electrical energy loss due to voltage drop is generally transformed to some other forms of energy like heat energy, light energy, mechanical energy, etc., in the various appliances. When the voltage drop is too steep, it can cause the equipment to operate on less voltage that leads to poor efficiency and wasted energy. A low voltage supply to the equipment due to voltage drop can also cause improper, erratic, or ceased operation, which can ultimately damage the equipment. It can also result in a fire if it is in contact with a combustible material or there isn't enough air flow to dissipate the heat. In electric design and power transmission, voltage drop needs to be taken into consideration. The most simple technique used is by increasing the diameter of the conductor between the source and the equipment, thereby lowering the overall resistance.

B. Ohm's Law

Ohm's law explains the behaviour of flow of electric current through a conductor in relation to the potential difference maintained across the terminals of the electric circuit.

According to *Ohm's law*, the current flowing through any cross-section of the conductor is directly proportional to the potential difference applied across its ends, provided physical conditions like temperature and pressure remain constant.

$$V \propto I$$

Or, $\boldsymbol{V = IR}$,where R is a constant called resistance.

Or, $R = \frac{V}{I}$

Therefore, resistance offered by a conductor is a ratio of potential difference applied across its terminals to the electric current flowing through the conductor.

Activity 4.1 Verification of Ohm's law

Materials required:

A rheostat, voltmeter of (0-3) V, ammeter of (0-3) A, two fresh dry cells, a coiled resistor of length 50 cm, a plug key (switch) and connecting wires.

Procedure

Step 1 ☞ Record the range and the least count of voltmeter and ammeter with correct units.

Step 2 ☞ Set up the circuit as shown in Figure 4.7 and show the circuit connections to your teacher before you switch on the circuit.

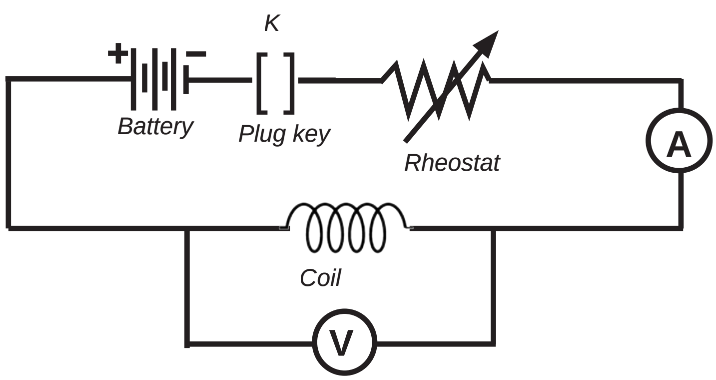

Figure 4.7

Step 3 ☞ Plug in the key K and adjust the rheostat with the help of its slider for minimum reading in voltmeter and ammeter.

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Step 4 Move the slider of the rheostat at five different length and record the voltmeter and ammeter readings at each position in the table given below:

Sl. No.	Voltmeter reading(V)	Ammeter reading (I)	V/I	Mean V/I
1				
2				
3				
4				
5				

Step 5 Plot a graph by taking V along y-axis and I along x-axis. Draw a line of best fit if all the five points are not on the same line.

Step 6 Calculate the slope of the graph as,
Slope= change in voltage/ change in current

Answer the following questions.

1. How is the value of voltage changing with respect to current?
2. What did you observe in the values of V/I for the five sets of readings? Give reason for your answer.
3. What is the nature of the graph between V and I?

Example 4.1

A telephone circuit draws 0.016 A of current through a resistance of 13750 ohm. Find the voltage applied across the telephone circuit.

Solution:

$$I = 0.016\ A,\ R = 13750\ \Omega,\ V = ?$$

$$V = IR$$

$$or,\ V = 0.016 \times 13750 = 220\ V$$

Example 4.2

An electrical kettle draws 2 A when a voltage of 230 V is applied to it. Find the resistance of the kettle.

Solution:

$$V = 230\ V,\ I = 2\ A,\ R = ?$$

$$R = \frac{V}{I} = \frac{230}{2}$$

$$\therefore R = 115\ \Omega$$

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Example 4.3

A 240 V geyser has a resistance of 2000 Ω. How much current does it draw?

Solution:

$V = 240\ V, R = 2000\ \Omega$

$I = \frac{V}{R} = \frac{240}{2000}$

$\therefore I = 0.12\ A$

i. Types of conductors

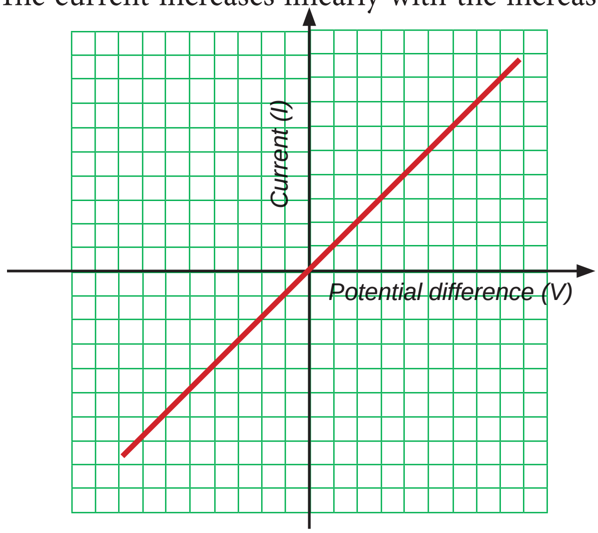
The conductors which obey Ohm's law are called *ohmic conductors*. All metallic conductors like copper, aluminium, silver, etc., are ohmic conductors. The resistance offered by ohmic conductors remain almost constant over a wide range of current and voltage at a fixed temperature.

Ohm's law is not a universal law. Some conductors like liquid electrolytes, diode, thermistor, LDR, etc., do not obey Ohm's law. Such conductors are called *non-ohmic conductors*. For such conductors, their resistance varies with change in current and voltage.

The voltage-current graphs for some of the ohmic and non-ohmic conductors are discussed below:

a. I-V graph for a resistor at constant temperature

The graph drawn between voltage and current for a resistor like constantan at a constant temperature is a linear graph passing through the origin as shown in Figure 4.8. The current increases linearly with the increase in voltage. Therefore, it obeys



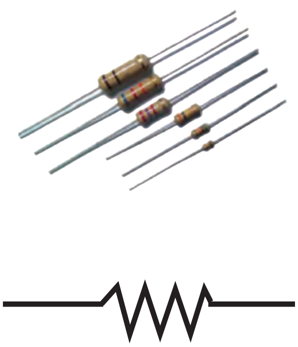


Figure 4.8 I-V graph for a resistor at constant temperature

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Ohm's law. In other words, we can determine the behaviour of a conductor by the nature of the graph. The linear graph shows the behaviour of Ohmic conductors.

The potential drop across a resistor is uniform at a constant temperature as the potential drop depends upon the magnitude of resistance in a circuit which is relatively fixed.

b. I-V graph for a filament lamp

The filament lamp is a common type of light bulb. It contains a thin coil of wire called the filament. This heats up when an electric current passes through it and produces light as a result. The current- voltage graph for a filament lamp is not linear and hence does not obey Ohm's law. With the increase in the current, the filament becomes hotter and the collision between the electrons increases. Thus, there is corresponding increase in the resistance of the filament and the graph is flattened at higher current.

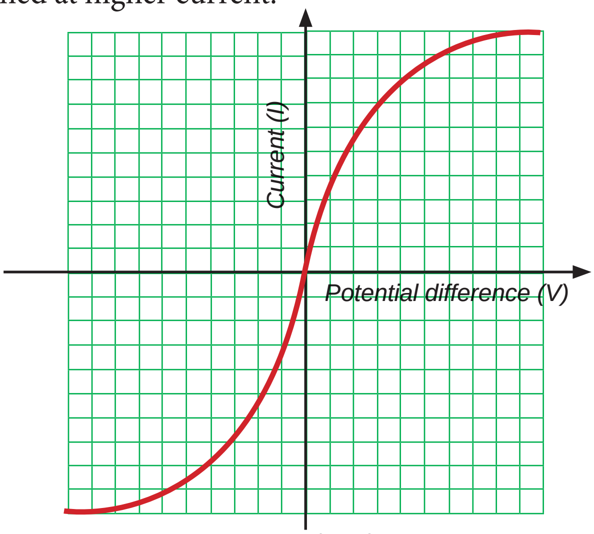

Figure 4.9 I-V graph for a filament lamp

At lower temperatures the potential drop across a filament lamp remains almost constant. But at higher temperatures, the potential drop across the filament lamp increases due to increase in resistance of the filament.

c. I-V graph for a diode

A *diode* is an electronic device which allows electric current to flow through it in only one direction. There are two types of diodes. They are vacuum tube diode and pn junction diode. Vacuum tube diodes comprise of metal electrodes in a chamber evacuated or filled with a pure gas at low pressure. Pn junction diodes are made up of semiconductor materials such as silicon, germanium, or selenium.

Diodes can be used as rectifiers, signal limiters, voltage regulators, switches, signal modulators, signal mixers, signal demodulators, and oscillators.

A diode in an electric circuit either allows the current or stops the current through it depending upon the polarity of the potential difference applied to it. If the anode of the vacuum tube diode or the p-region of the p-n junction diode is connected to the positive terminal of the applied voltage, the diode is said to be forward biased. In this condition the diode allows current to flow through it. If the anode of the vacuum tube diode or the p-region of the p-n junction diode is connected to the negative terminal of the applied voltage, the diode is said to be reverse biased. In this state it does not allow any current to flow through it.

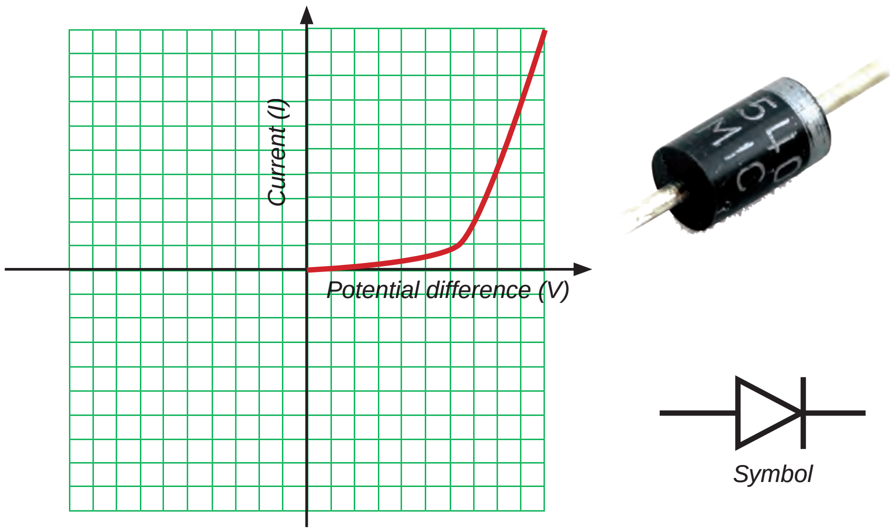

Figure 4.10 I-V graph for a diode

The I-V graph for a diode given in Figure 4.10 is not linear and hence a diode does not obey Ohm's law.

The potential drop across a diode is low in forward bias and very high in reverse bias as it offers low resistance in forward bias and a very high resistance in reverse bias.

d. I-V graph for a thermistor

Thermistors are temperature sensitive resistors. The resistance of all the resistors vary with temperature, but thermistors are made up of semiconductor material with a resistance that is especially sensitive to temperature. However, unlike most other resistive devices, the resistance of a thermistor decreases with increasing temperature. That is due to the properties of the semiconductor material that the thermistor is made from. Thus the graph becomes steeper at high current. This is

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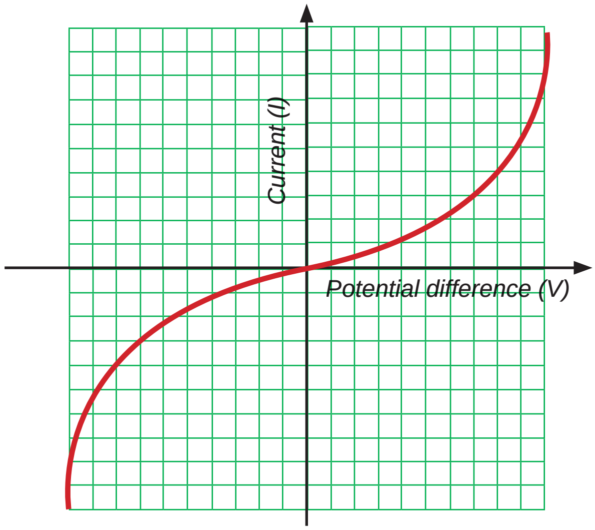

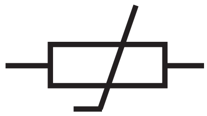

Figure 4.11 I-V graph for a thermistor

because more number of free electrons are available at higher temperature in the case of a semiconductor. The graph is reverse to that of filament lamp. Since the current- voltage graph for a thermistor is not a straight line, it also does not obey Ohm's law. They are inexpensive, rugged, reliable and respond quickly. The potential drop across a thermistor decreases with increase in temperature as its resistance decreases with increasing temperature.

e. I-V graph for LDR

A *photoresistor* or *light-dependent resistor (LDR)* or photocell is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photoresistor can be used in light-sensitive detector circuits, and light-activated and dark-activated switching circuits.

A photoresistor is made of a high resistance semiconductor. In the dark, a photoresistor can have a resistance as high as 1012 Ω, while in the light, a photoresistor can have a resistance as low as a few hundred ohms. In the presence of light, free electrons are available for the conduction of electric current which decreases the resistance. In the absence of light, the free electrons are not available for conduction of current and thus increase the resistance of the LDR. The current- voltage graph for an LDR does not obey Ohm's law as the resistance does not remain constant.

The potential drop across a LDR is high in the absence of light and low in the presence of light. This is because LDR has high resistance in the absence of light and low resistance in the presence of light.

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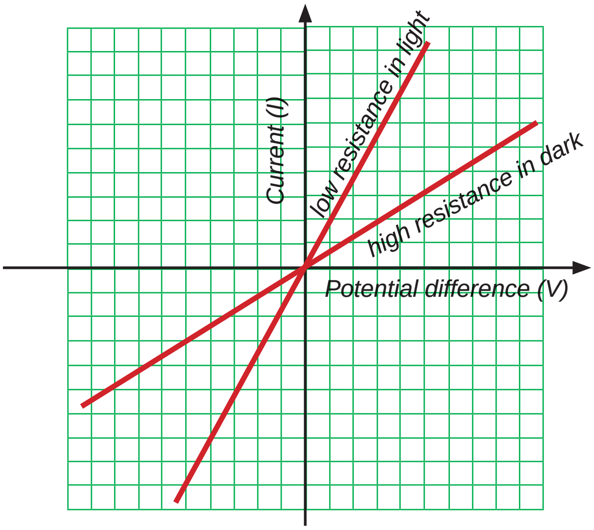

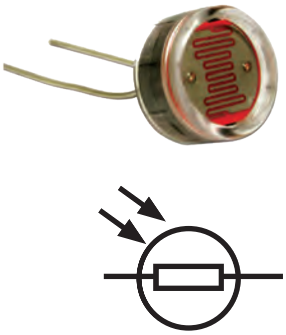

Figure 4.12 I-V graph for LDR

ii. Resistivity

Some materials are better conductors than others and offer less resistance to the flow of charge. Silver is one of the best conductors but is never used in wires of household circuits due to its cost. Copper and aluminium are among the less expensive materials compared to silver and gold, and with suitable conducting ability to permit their use in wires of household circuits. The conducting ability of a material is often indicated by its resistivity.

Experimentally it has been observed that the resistance of a conductor varies directly with the length (l) of a conductor and inversely with the cross-sectional area (A) or thickness of the wire.

$$R \propto l$$

$$R \propto \frac{1}{A}$$

Combining, we get, $R \propto \frac{l}{A}$

$$\therefore \boldsymbol{R = \rho \frac{l}{A}}$$

Here, the constant of proportionality '**ρ**'(rho) is called resistivity of the conductor.

If the conductor is of a unit length, l = 1 and a unit cross-sectional area, A = 1, then resistivity of the conductor is equal to the resistance of the conductor.

$$\mathbf{R = \rho}$$

Therefore, the *resistivity* of the conductor is defined as a resistance of a wire of unit

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length and unit cross-sectional area. Resistivity of a conductor is also called *specific resistance* of the conductor. It is measured in ohm-metre.

The resistivity of a material does not depend upon the shape and size of the conductor. It depends only upon the resistance and nature of material of the conductor. The reciprocal of resistivity is called electrical conductivity (σ =1/resistivity).

Resistivity for most materials increases with increase in temperature. An exception is semiconductor (e.g. silicon) in which the resistivity decreases with decrease in temperature.

Activity 4.2 Investigating variation of current with change in resistance

Materials required:

A voltmeter of (0- 3) V, ammeter of (0-3) A, two dry cells, a resistance box of (1-10) ohm, a plug key and connecting wires.

Procedure

Step 1 ☞ Record the range and the least count of ammeter and voltmeter.

Step 2 ☞ Set up the circuit as shown in Figure 4.13 and show the circuit connections to your teacher before you switch on the circuit.

Step 3 ☞ Plug in the key K and record voltmeter reading (V).

Step 4 ☞ Take out 1 ohm from the resistance box and plug in the key K. Read the ammeter reading and record in the table given below:

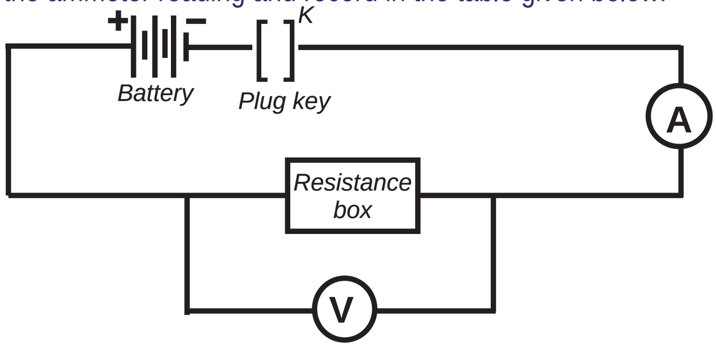

Figure 4.13

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Sl. No.	Resistance from the resistance box (R)	Ammeter reading (I)

Step 5 Repeat step 4 by taking out 2 ohm,3 ohm, 4 ohm and 5 ohm from the resistance box. Record the ammeter readings in the table.

Step 6 Plot a graph between I and R.

Answer the following questions.

1. What happened to the ammeter reading when the resistance in the resistance box was increased? Can you suggest an explanation for your observation?
2. What is the value of current when resistance is 3.5 ohm?
3. How do voltmeter readings change with the change in applied resistance?
4. What conclusion can you draw from this activity?

C. Heating effect of current

When electric current flows in a circuit, the electrons collide with other electrons in the course of their motion. During the collisions, some of the kinetic energy transforms into heat energy increasing the temperature of the conductor. This phenomenon in which heat is produced by the passage of electric current in a conductor is called *thermal effect of current* or *heating effect of current*.

The amount of heat produced in a conductor is given by

$$H = I^2 R t \text{ ... equation 1}$$

In ***equation 1*** , 'H' is the heat energy produced, 'I' is the electric current passing through the conductor, 'R' is the resistance of the conductor and 't' is the duration for which the current is passed. Therefore, the heat produced depends upon the strength of current flowing through it, the resistance of the conductor and the time for which the current is passed through it.

Heating effect of current has numerous applications in our daily life. For example:

- Electrical appliances like rice cookers, curry cookers, electric stoves and ovens consist of resistor of high resistance. When current flows through this resistor, it gets heated and it in turn heats up the metal container or hot plate in which the food is cooked.

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- Filament bulbs consist of a tungsten filament which becomes red hot and glows when current is passed through it.
- Electric iron also has a heating element made up of nichrome wire inside it. As the current flows through the heating element, it produces heat that is used for ironing clothes.
- Hair dryers, immersion rod heaters, geysers and electric heaters all have high resistance coil in them which becomes hot when electric current passes through them. This heat produced dries our wet hair, heats up water and keeps our rooms warm respectively.

Figure 4.14 Heating appliances

The resistance wire used in all the appliances given above generally have high resistance and high melting point.

i. Electric Power

Power is the rate of doing work. In case of electrical circuits, the work is done in moving the charge through the circuit from one terminal to another terminal of the battery or source of emf. Therefore,

$$Power(P) = \frac{Work\ done\ on\ the\ charge\ (W)}{Time(t)}$$

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From the definition of potential difference,

$$Work\ done\,(W) = Charge\,(Q) \times Voltage\,(V)$$

$$P = \frac{QV}{t}$$

$$Since\ , Q = I\,t$$

$$P = \frac{I\,tV}{t}$$

$$\therefore \boldsymbol{P = VI}$$

Thus electrical power is the product of voltage and electric current.

Electrical power of an appliance or circuit is also explained as the rate at which energy is being consumed by the appliance or the rate at which electrical energy of the charges is converted into other forms of energy like heat energy, light energy, mechanical energy, etc.

Just like mechanical power, electrical power is also measured in watt (W).

Example 4.4

A 12 V car battery delivers a current of 200 A. What is its power?

Solution:

$$V = 12\ V, I = 200\ A, P = ?$$

$$P = V\ I$$

$$P = 12\ V \times 200\ A$$

$$\therefore P = 240\ W$$

Example 4.5

An electrical appliance is rated 100 W- 12 V. What amount of current is required for the appliance to operate?

Solution:

$$V = 12\ V, P = 100\ W, I = ?$$

$$I = \frac{P}{V} = \frac{100}{12}$$

$$\therefore I = 8.33\ A$$

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Example 4.6

Sonam uses a toaster of 550 W and a current of 2.5 A flows through it. What is the voltage of the power supply?

Solution:

$$P = 550\ W,\ I = 2.5\ A,\ V = ?$$

$$V = \frac{P}{I} = \frac{550}{2.5}$$

$$\therefore V = 220\ V$$

Questions

1. The sets of wire of same material are given below in Table 4.1. Copy and complete the table.

Table 4.1

Sl.No.	Sets of wire	Condition	Higher resistance	Reason
1	Wire A of 2 cm diameter and wire B of 4 cm diameter	Equal length		
2	Wire C of 100 cm length and wire D of 150 cm length	Equal diameter		
3	Resistance coil in a heater when cold and when hot	Equal length and diameter		

2. An air-conditioner in Phuentsholing operates on a 220 V circuit and draws 15 A current. Determine the power rating of such a conditioner.
3. Sherab uses an iPod of power 0.3 W and a current of 0.005 A flows through it. What voltage power supply does it need? What is the resistance of the iPod?
4. A television is plugged into the mains power supply of 220 V. If the television has a power of 110 V, what is the current flowing through it?

http://physics.nayland.school.nz/VisualPhysics/NZ-physics%20HTML/14_Electronics/chapter14a.html
http://science.jrank.org/pages/2324/Electrical-Conductivity-Non-ohmic-conductors.html
http://www.facstaff.bucknell.edu/mastascu/elessonshtml/Resist/Resist2.html
http://www.electronics-tutorials.ws/resistor/res_5.html
https://www.physics.uoguelph.ca/tutorials/ohm/Q.ohm.intro.combo.html

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2. Electromagnetic Effects

Learning Objectives

On completion of this topic, you should be able to:

- explain the working of simple a.c. generators and transformers.
- calculate the voltages across the coils in a transformer from the numbers of turns in the coils.
- describe transfer of electrical energy from power stations to consumers.

A. Electromagnetic induction

We know that magnetism is induced due to flow of current in a circuit as in electromagnets. This phenomenon is called magnetic effects of current. Similarly, current can be generated using the magnets.

The phenomenon of producing electric current by induced potential difference or electromotive force (emf) due to changing magnetic field lines passing through a circuit is called *electromagnetic induction*. The magnetic field lines passing through a circuit can be changed as follows:

- by moving a magnet to and fro near a coiled conductor,
- by moving the coiled conductor near a magnet, or
- by changing the magnitude of current in the neighbouring circuit.

These methods were first discovered by a scientist named Faraday,who concluded the following laws:

- Whenever there is a change in the number of magnetic field lines passing through the conductor, emf is induced in the conductor.
- The induced emf exists in the circuit so long the change in the magnetic field continues.
- The magnitude of induced emf is directly proportional to the rate of change of the magnetic field through the circuit.

The direction of the current due to induced emf can be determined by using Fleming's right hand rule.

Fleming's right hand rule states that if the thumb, fore finger and the middle finger of right hand are stretched at right angles to each other such that the fore finger indicates the direction of the magnetic field and the thumb shows the

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direction of motion of the conductor, then the middle finger will indicate the direction of the induced current.

The principle of electromagnetic induction is used in devices like electric generators and transformers.

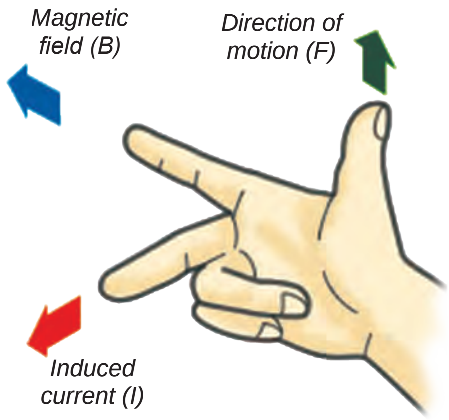

Figure 4.15 Fleming's right hand rule

i. a.c. generator

We have learnt that electrical energy is converted into mechanical energy by motors. A generator or dynamo is a device for producing electrical energy from mechanical energy. An a.c. generator produces an alternating current. It works on the principle of electromagnetic induction i.e. whenever there is a change in the number of magnetic field lines passing through a conductor, voltage is induced in it.

Just like an electric motor, an a.c. generator consists of an armature coil made up of several turns of insulated copper wire wound over a soft iron core, strong magnetic field, slip rings and carbon brushes. The armature coil is made to rotate in a strong magnetic field as shown in Figure 4.16. As the coil rotates due to external force such as water in hydropower plant, the number of magnetic field lines passing through the coil changes. Hence an emf or voltage is induced in the circuit.

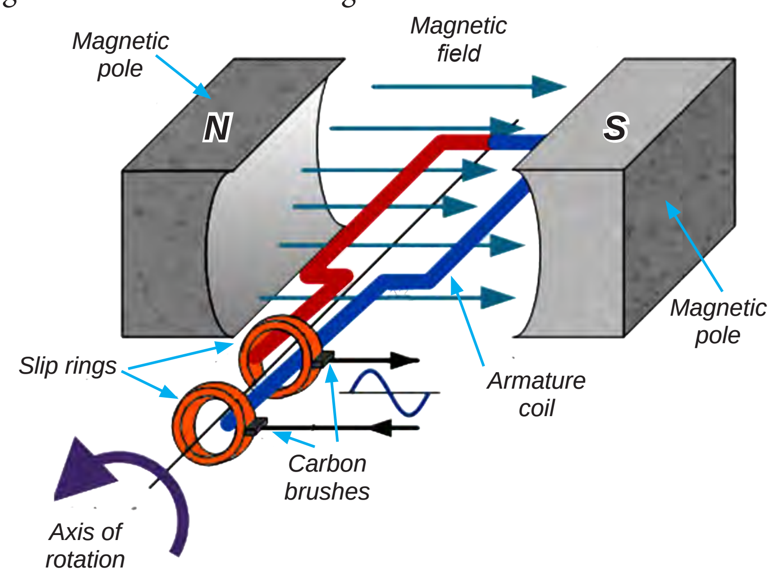

Figure 4.16 a.c. generator

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Let the armature coil ABCD be initially parallel to the magnetic field lines as shown in Figure 4.17 (a). Let arm AB and arm CD turn, such that arm AB is coming out perpendicular to the plane of the paper and the arm CD is going into the plane of the paper. Using Fleming's right hand rule it is observed that the current will be induced along ABCD as shown in figure 4.17 (a). The direction of the current generated is from B_2 to B_1. On completing half of the rotation of the armature coil, the arm AB and arm CD interchange their positions as shown in Figure 4.17 (b). Now the direction of induced current reverses from B_1 to B_2. Thus an alternating current is obtained as an output.

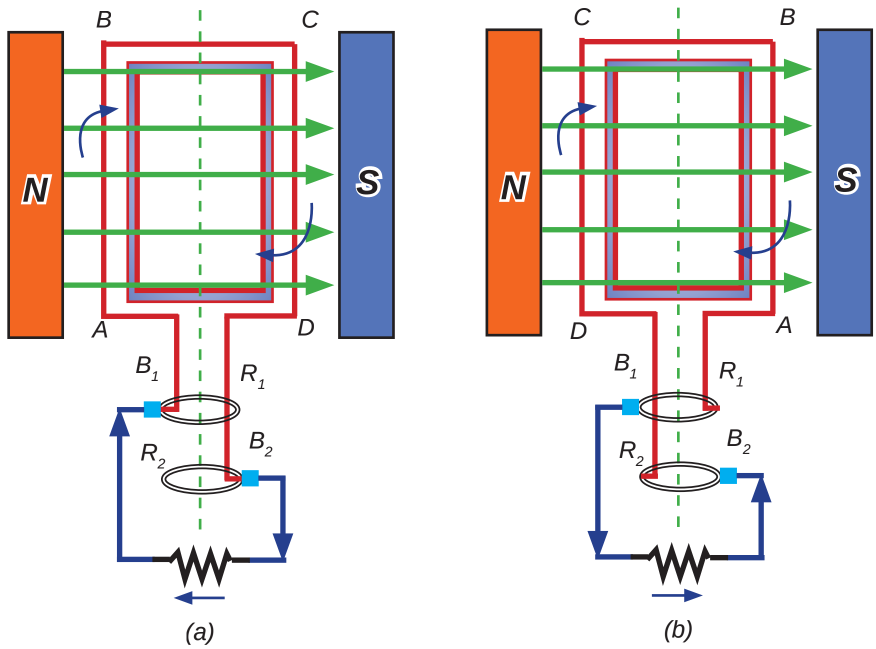

Figure 4.17 Working of an a.c. generator

As the coil rotates, the number of magnetic field lines passing through the coil continuously changes from minimum to maximum as shown in Figure 4.18. The number of field lines is minimum when the coil is parallel to the magnetic field and maximum when it is perpendicular to the field lines. Therefore, induced voltage is maximum when the coil is parallel and minimum when the coil is perpendicular to the magnetic field lines. Hence an alternating voltage of changing magnitude and direction is induced in the circuit.

The induced voltage depends upon the following:

(a) *speed of rotation of the armature coil:- faster the armature coil rotates, greater is the generation of electricity.*

(b) *number of turns of the armature coil:- More the number of turn in the armature coil, larger will be the amount of electricity generated.*

(c) *strength of the magnetic field:- Stronger the magnetic field, greater is the generation of electricity.*

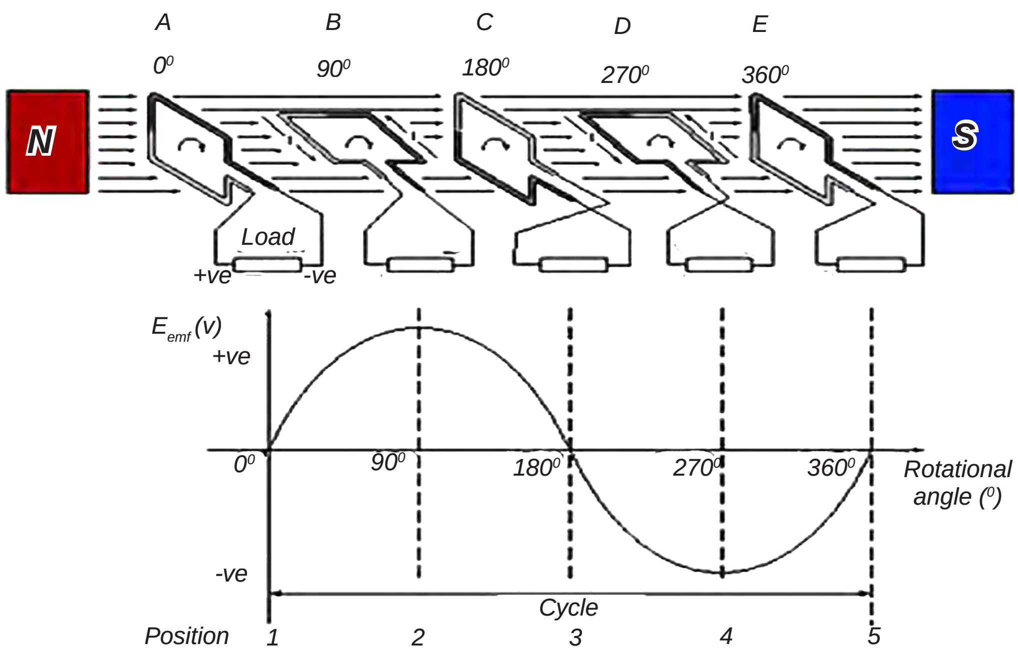

Figure 4.18 Position of the rotating coil and induced alternating voltage

From Faraday's laws it is already known that in order to induce electric current or voltage, there should be continuous change in the number of magnetic field lines passing through the armature coil. This may be done by either moving the armature coil in the magnetic field or by moving the magnet near the coil. Thus a mechanical energy is required for the motion of the coil or the magnet. In hydropower plants, the mechanical energy is derived from water to turn the turbines attached to the armature of the dynamo.

ii. Transformer

We use several electrical appliances in our homes and offices designed and made for different purposes. Not all the electrical appliances operate on the same voltage and current. Some electrical appliances may need lower voltage and the others may need higher voltage. Generally, electrical appliances operate at a voltage of 220V - 240V mains a.c. supply. The electrical power at the stations is usually generated at a high voltage of 11 kV. This voltage is further increased to 132 kV using a special device called transformer and then it is transmitted over long distances to the main-substations. The electrical power is transmitted over long distances at a high voltage and low current so that the loss of energy in the form of heat is minimised. This also reduces material for the wires as high current would require thicker wire. The voltage is brought down from 132 kV to 33 kV by transformer at the main-substation.


Figure 4.19 Transformer

This voltage cannot be used directly by electrical appliances at home or offices. Therefore, transformer is again required to bring down the voltage to a standard operating voltage of 220 V- 240 V.

A transformer is a device used for changing the magnitude of voltage. It can increase or decrease the input voltage. It works on the principle of electromagnetic induction i.e. whenever there is a change in the number of magnetic field lines in the neighbouring circuit then the voltage is induced in the other circuit.

A transformer consists of two sets of coils: a primary coil (P) and a secondary coil(S). These coils are wound over a common soft iron core, such that turnings of coils are insulated from each other. The core is formed by laminated sheets insulated from each other to reduce the loss of energy as heat. The input voltage is generally fed into the primary coil and the output voltage is obtained from the secondary coil. The alternating current in the primary coil makes it an electromagnet of varying strength, thereby producing magnetic field of varying strength. These changing magnetic field lines induce voltage into secondary coil due to electromagnetic induction and the output voltage is obtained. The number of turns in both primary coil and secondary coil vary depending on the capacity of the transformer.

There are two types of transformer: step-up transformer and step-down transformer.

A *step-up transformer* increases the input voltage to produce higher output voltage.

Step-up transformer has more number of turns in the secondary coil than the number of turns in the primary coil. The primary coil is also thicker compared to the secondary coil.

A *step-down transformer* decreases the input voltage to produce lower output voltage.

Step-down transformer has greater number of turns in the primary coil than in the

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secondary coil. Its secondary coil is thicker compared to the primary coil.

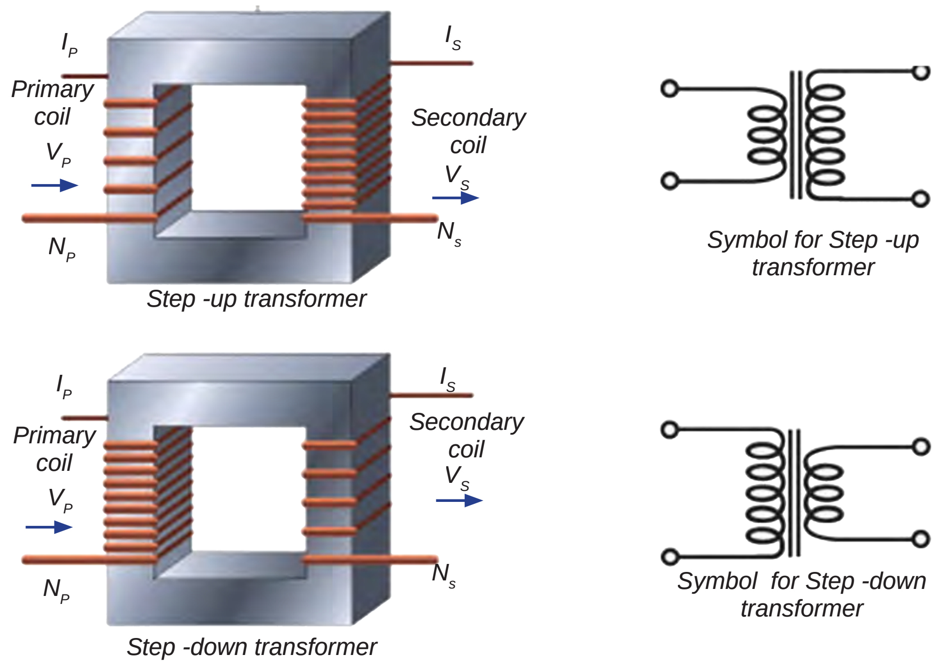

Figure 4.20 Types of transformer

Greater the number of turns in the secondary coil compared to primary coil, larger is the output voltage obtained. Therefore, the ratio of the input voltage to output voltage is equivalent to ratio of number of turns in primary coil to secondary coil.

$$\frac{V_s\,(\textit{Voltage output})}{V_p\,(\textit{Voltage input})} = \frac{N_s\,(\textit{Number of turns in the secondary coil})}{N_P\,(\textit{Number of turns in the primary coil})}$$

This ratio is called transformer ratio (k).

Under ideal condition i.e. if the transformer is 100% efficient, the output power across secondary coil and input power across primary coil are equal. Hence,

Output power across secondary coil = Input power across primary coil

Secondary voltage × secondary current = Primary voltage × primary current

$$Or, \quad \frac{\textit{Secondary voltage}\,(V_S)}{\textit{Primary voltage}\,(V_P)} = \frac{\textit{Primarycurrent}\,(I_P)}{\textit{Secondarycurrent}\,(I_S)}$$

Therefore ,when the voltage is stepped down, the corresponding current is stepped up and vice versa. This is also the reason for taking thicker primary coil in step-up transformer and thicker secondary coil in step-down transformer in order to withstand heavy current.

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A transformer can never be 100 % efficient. This is due to the following energy losses in a transformer:

- energy lost in the form of heat due to resistance of the wire.
- energy lost due to incomplete transfer of magnetic field as a result of the imperfect windings of primary coil and secondary coil.
- energy lost in the form of heat due to induced current in the core of the transformer.

The alternating current (a.c.) is preferred over direct current (d.c.) in the power supply systems, as alternating voltage can be increased or decreased by using transformers unlike in the case of d.c. voltage.

Example 4.7

In the main sub-station, a transformer has 200 turns in the primary coil and 50 turns in the secondary coil. If the voltage across the primary coil is 132 kV, what is the voltage across the secondary coil?

Solution:

$N_p = 200, N_s = 50, V_p = 132\ kV \text{ and } V_s = ?$

$$\frac{V_s}{V_p} = \frac{N_s}{N_P}$$

$$\frac{V_s}{132000} = \frac{50}{200}$$

$$V_s = \frac{50}{200} \times 132000$$

$$\therefore V_s = 33000\ V$$

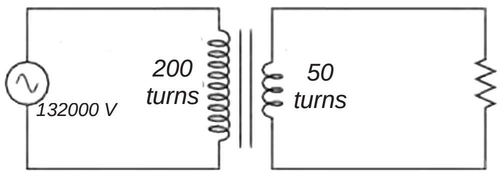

Figure 4.21

Activity 4.3 Investigating the working of a simple transformer

Materials required:

A pair of insulated copper coils, a galvanometer, battery (3-6V) and rheostat.

Procedure

Step 1 Connect one of the coils to the battery, rheostat and a key as shown in the figure 4.22.

Step 2 Connect the second coil to a galvanometer and place it near the first coil.

Step 3 Close the key and see what happens to the pointer in the galvanometer.

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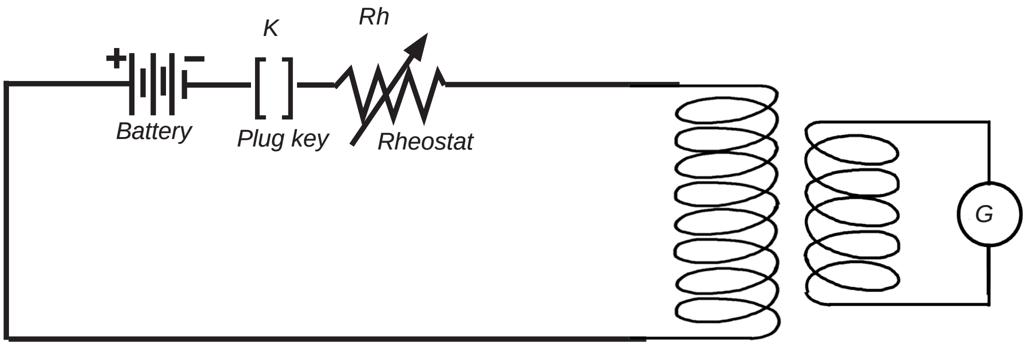

Figure 4.22

Step 4 Keeping the key closed, change the resistance in the rheostat from minimum to maximum and then to minimum to complete a cycle. Repeat this cycle for couple of times and note down the observation.

Answer the following questions:

1. What happened to the galvanometer pointer in step 3? Give a possible explanation.
2. What changes do you see in step 4?
3. How is this circuit different from that of transformer?
4. What is the role of rheostat in this experiment?
5. What type of transformer have you made?

Questions

1. Both an electric motor and a generator consist of similar parts like armature coil, magnetic field, slip rings and wire brushes. In what ways are they different from each other?
2. In what ways can a generator be made to produce voltage of higher magnitude?
3. Thinley wants to decrease an a.c. voltage from 220 V to 55 V. What should be the ratio of the number of turns in the primary coil and the secondary coil?
4. Pemba wants to decrease a d.c. voltage from 220 V to 110 V. Can he use a step-down transformer for this purpose? Support your answer with a reason.
5. Study Figure 4.23 and explain the transmission of power from power station to the households.

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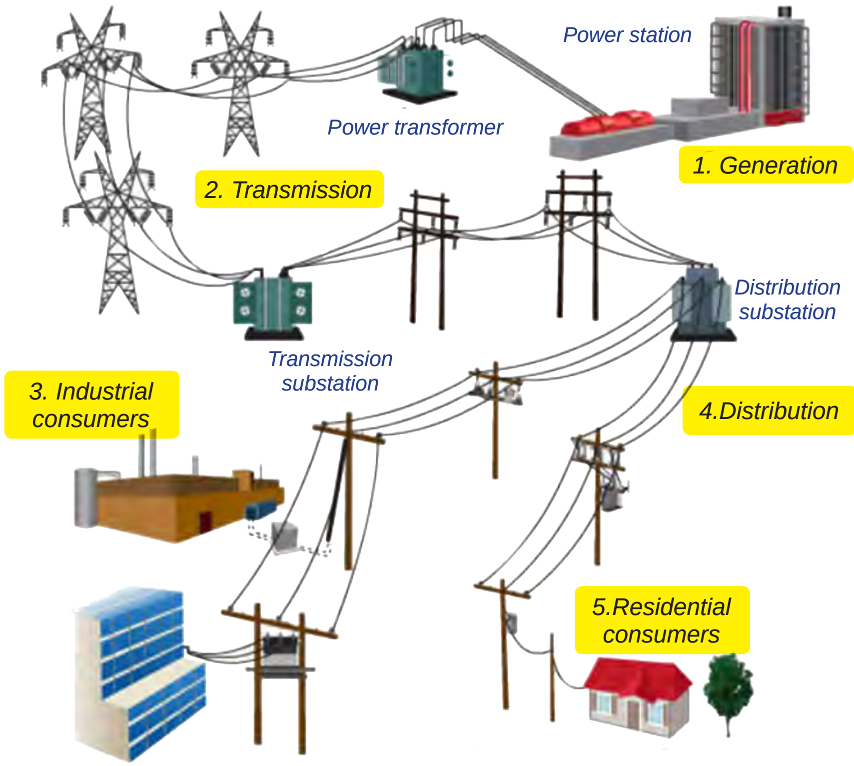

Figure 4.23 The grid system

http://www.learnnext.com/nextgurukul/wiki/concept/CBSE/X/Science/Heating-Effect-of-Electric-Current.htm
http://www.electrical4u.com/electric-current-and-theory-of-electricity/
https://www.youtube.com/watch?v=RMM-TVtmRgQ
http://www.edisontechcenter.org/generators.html

http://www.physicsclassroom.com/class/energy
http://www.physicsclassroom.com/class/circuits/power/Lesson-3/Power-Revisited
http://www.physicsclassroom.com/class/cirsuits/Lesson-4/Combination-Circuits
http://www.schoolphysics.co.uk/age16-19/Electricity and magnetism/
http://www.passmyexams.co.uk/GCSE/physics/ohms-law.html
http://www.kkhsou.in/main/index.html
http://www.electronics-tutorials.ws/resistor/res_1.html

Summary

- Voltage is defined as work done per unit charge or energy transferred per unit charge.
- The opposition offered to the flow of electric current in a conductor is called resistance (R). It depends upon the nature of material of the conductor, length of the conductor, thickness of the conductor and its temperature.
- A device used to offer resistance in the circuit is called a resistor.
- The conductors which obey Ohm's law are called ohmic conductors and those conductors which do not obey Ohm's law are called non-ohmic conductors.
- The resistivity of a conductor is defined as the resistance of a wire of unit length and unit cross-sectional area.
- The phenomenon of heating of conductor due to passage of electric current through it is called heating effect of current.
- Electrical power is the rate at which electrical energy of the charges is converted into other forms of energy like heat energy, light energy, mechanical energy, etc.
- The phenomenon of producing electric current by changing the magnetic filed lines passing through a circuit is called electromagnetic induction.
- The direction of the induced current can be determined by using Fleming's right hand rule.
- A generator is a device for producing electrical energy from mechanical energy. It consists of an armature coil, strong magnetic field, slip rings and wire brushes.
- A transformer is a device used for increasing or decreasing the magnitude of voltage. It consists of a primary coil and a secondary coil wound over a common soft iron core insulated from each other.
- There are two types of transformer: step-up transformer and step-down transformer.
- Transformers are used in many electrical appliances in our homes, offices, hospitals and industries.
- The electrical power is transmitted over long distances at a high voltage so that the loss of energy in the form of heat is minimised.
- The alternating current (a.c.) is preferred over direct current (d.c.) in the power supply systems.

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Exercises

I. *Fill in the blanks.*

1. The current through an electric circuit will decrease if the ________________ across the circuit decreases, keeping the resistance of the circuit constant
2. The resistance of a wire is directly proportional to its ______________.
3. The rate at which electrical energy is consumed by an electrical device is called __________.
4. A generator generates _________________ energy from _____________ energy.
5. The potential difference between the terminals of a cell in closed circuit is ______________ than that in open circuit.

II. *Match the items of Column A with correct answers of Column B.*

Column A	Column B
i. Resistivity	a. variable resistance
ii. Internal resistance	b. high voltage
iii. LDR	c. high current
iv. Long distance power transmission	d. electrolyte of a cell
v. Faraday's laws	e. dependent of size and shape
	f. independent of size and shape
	g. electromagnetic induction

III. *State 'True' or 'False'. Rewrite the false statements correctly.*

1. The current flowing through the secondary coil of a step-down transformer is less than in its primary coil.
2. The current-voltage graph for a thermistor is a linear graph as it obeys Ohm's law.
3. Diodes allow the electric current to flow in only one direction in an electric circuit.
4. According to Fleming's right hand rule, the thumb points towards the

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direction of induced voltage.

5. With increase in temperature, the number of collisions between free electrons in a copper wire decrease thereby increasing the conductivity of copper wire.

IV. Multiple Choice Questions.

1. The potential difference is measured in

   A joule.

   B watt.

   C volt.

   D ampere.

2. The resistivity of a conductor depends upon its

   A length.

   B thickness.

   C nature of material.

   D shape.

3. When the length of a conductor is doubled by keeping its thickness same, its resistance changes to

   A one-fourth of its initial value.

   B half of its initial value.

   C two times its initial value.

   D four times its initial value.

4. Sita uses a 1100 W microwave oven to heat her food at 220 V. The current flowing through the oven is

   A 2 A.

   B 3 A.

   C 4 A.

   D 5 A.

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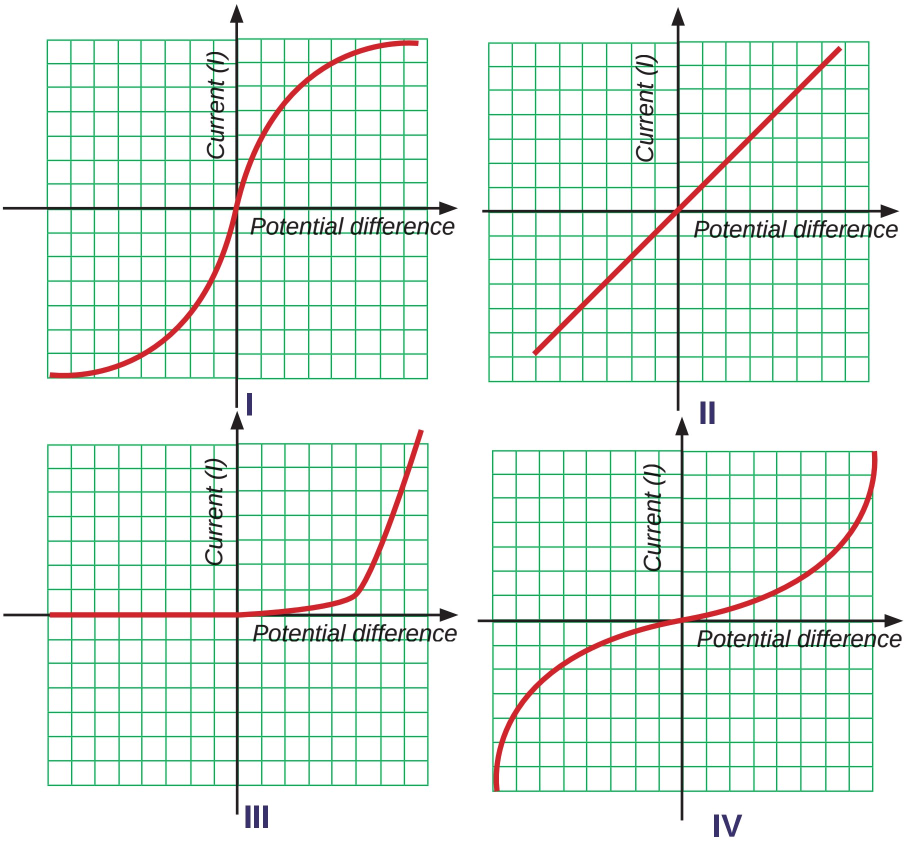
5. Pem wanted to study the variation of current with potential difference. She did an experiment on the filament bulb in her torch and plotted a graph between current and potential difference. Which of the following graph was obtained by Pem?



A I

B II

C III

D IV

6. Bikram uses electric iron to iron his shirt. The resistance coil used in electric iron has

A high resistance and low melting point.

B low resistance and high melting point.

C low resistance and low melting point.

D high resistance and high melting point.

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7. The amount of heat produced in a curry cooker is directly proportional to the ________________ current passing through the coil inside it.

   A magnitude of

   B square root of magnitude of

   C square of magnitude of

   D cube of magnitude of

8. Voltage can be induced in a circuit when the number of magnetic field lines passing through the circuit changes. This induced voltage exists in the circuit as long as a

   A magnet continues to move near a coil.

   B magnet and a coil continue to move together.

   C magnet and coil are kept close to each other.

   D coil is placed in a strong magnetic field.

9. An a.c. generator produces alternating voltage due to the rotation of armature coil in a strong magnetic field. The magnitude of induced voltage is maximum when the plane of the armature coil is making an angle of

   A 180° with the magnetic field.

   B 90° with the magnetic field.

   C 0° with the magnetic field.

   D any magnitude with the magnetic field.

10. The following statements describes the induced voltage in a generator:

    I. The magnitude of induced voltage depends upon speed of rotation of the armature coil.
    II. The direction of induced voltage depends upon the number of turns of the armature coil.
    III. The direction of induced voltage depends upon strength of magnetic field.
    IV. The magnitude of induced voltage depends upon number of turns of the armature coil.

    Which of the above statements are TRUE for a generator?

    A I and II.

    B II and III.

    C III and IV.

    D I and IV.

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V. *Answer the following questions.*

1. State Ohm's law. Is this law obeyed by all types of conductors? Give examples to support your answer.
2. State the factors affecting resistance of a conductor.
3. An electrical device with a resistance of 100 Ω allows a current of 2 A to flow through it. What is the voltage drop across the device?
4. All electrical appliances when used for a longer time get heated. What could be the reason for this?
5. What do you mean by electrical power?
6. Heating effect of current is not always useful for us. Support your answer with an example.
7. Jigme is driving from Thimphu to Paro at night. He uses his car's headlights in both high beam and low beam settings. The power rating of the high beam headlight is 65 W and that of low beam headlight is 45 W. If the car battery supplies a voltage of 12 V, what is the current flowing through the filament of the headlight for both these settings?
8. State the main parts of an a.c. generator and write down the function of each part.
9. A torch bulb draws a current of 0.2 A from a source of 3 V and glows. What is the resistance of the bulb when it glows?
10. Why is a.c. preferred over d.c. in long distance transmission of electricity?
11. Draw and explain the types of transformer.
12. A transformer is never 100 % efficient? Give reasons.
13. A transformer raises a voltage from 10 V to 220 V and there are 200 turns in the primary coil.
    a) How many turns are there in the secondary coil?
    b) If the current in the primary coil is 2 A, what is the current in the secondary coil?
14. Copper is better conductor than aluminium. Why is aluminium wires preferred over copper wires in long distance transmission of electricity?

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5

WAVES

We come across different types of waves such as, water waves, seismic waves, sound waves, light waves, X-rays, etc. Water waves, seismic waves and sound waves require material medium for their transmission. Such waves are called mechanical waves. Other waves like light waves and X-rays do not require any material medium for their transmission. They can travel through vacuum. These waves are called electromagnetic waves.

Scientists have explored and discovered different types of wave in nature and studied them. They have identified various applications of these waves from cooking to communication and then to medical purposes.

1. The Electromagnetic Spectrum

Learning Objectives

On completion of this topic, you should be able to:

- *identify different components of the electromagnetic spectrum.*
- *identify the electromagnetic waves based on frequency and wavelength.*
- *describe the uses of microwaves, infrared and ultraviolet waves and their potential dangers.*
- *state some uses of X-rays and gamma rays in medical field.*

Sun is the source of all types of electromagnetic waves but most of them are absorbed by the atmosphere on its way to the Earth. All the electromagnetic waves of the Sun arranged in order of their wavelength or frequency is called *electromagnetic spectrum*.

We are mostly familiar only with the visible part of electromagnetic spectrum i.e. visible light, but electromagnetic spectrum of light includes both the visible and

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invisible components. Visible region consists of the seven colours of visible light i.e. red, orange, yellow, green, blue, indigo and violet, which can be detected by our eyes. Invisible region consists of gamma rays, X-rays, ultraviolet radiations, infrared radiations, microwaves and radio waves. These waves cannot be seen with our eyes but they can be detected by means of special instruments.

All the electromagnetic waves possess some common properties.

- They are transverse in nature i.e. they vibrate perpendicular to the direction of their propagation.
- They do not require any material medium for their transmission i.e. they can travel through vacuum.
- They travel with the same velocity in vacuum i.e. 3×10^8 m/s.
- They undergo phenomena of reflection, refraction, diffraction, interference and polarisation.

Activity 5.1 Identifying the electromagnetic waves

Study the electromagnetic spectrum given below and answer the questions that follow.

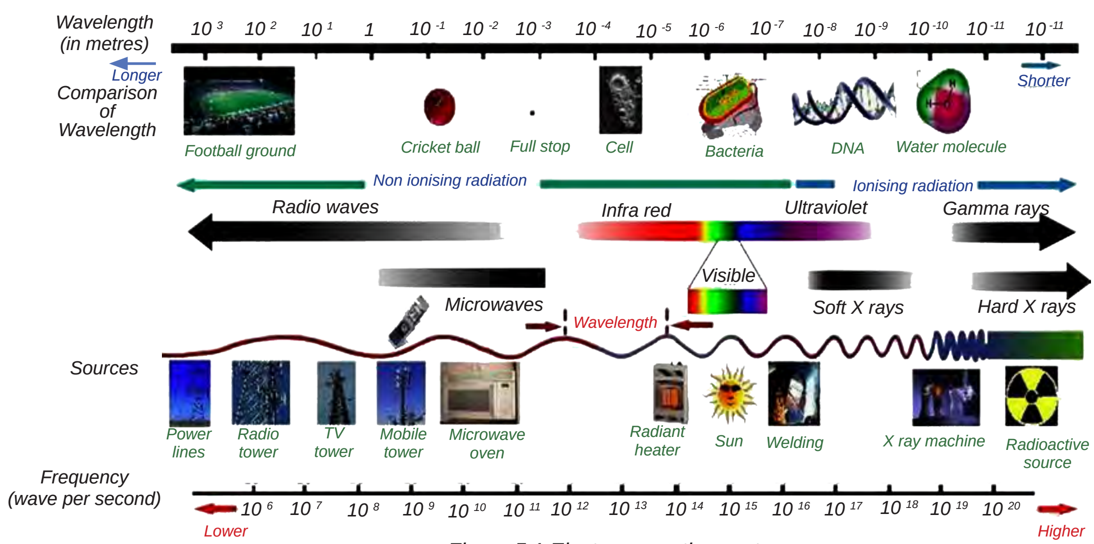

Figure 5.1 Electromagnetic spectrum

Answer the following questions.

1. How is frequency related to wavelength of a wave?
2. Name three types of electromagnetic waves that have wavelength shorter than visible light.
3. Which type of electromagnetic wave has highest frequency?

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4. Which type of electromagnetic wave has longest wavelength?
5. What happens to the energy of electromagnetic waves with increase in frequency?
6. What is the wavelength of visible spectrum?

A. Types of electromagnetic waves

i. Radio waves

Figure 5.2 Radio tower

Radio waves are the longest electromagnetic waves in the electromagnetic spectrum. They have frequency up to 3×10^{10} Hz and wavelength greater than 10 mm. Radio waves are closely associated with broadcasting media, such as radio and television. There are several applications of radio waves.

They are used in broadcasting television and radio programmes. The cable operators have antennas or dishes which receive signals broadcast by local television stations in the form of radio waves. These signals are then sent to our homes through cables. Similarly, the radio signals sent from the radio stations are received by the antenna of our radio and hence we are able to listen to the news or music broadcast from the local radio stations. They are used in hospitals in MRI (magnetic resonance imaging) to detect tumours, to see inside joints, cartilage, ligaments and tendons.

No definitive truth exists on the safety from radio waves in the environment around us. But we should be aware that there could be possible ill-effects. Some studies suggest that exposures to radio waves may lead to sleep disorders, headaches, and other neurological problems.

ii. Microwaves

Microwaves have frequency from about 3×10^{9} Hz to 3×10^{13} Hz and wavelengths of about 10^{-2} m to 10^{-4} m. There are several ways in which microwaves are used:

- Microwaves are used in point-to-point communication system i.e. communication between two mobile phones or two computers.
- Longer microwaves are used in microwave ovens for cooking. The microwaves vibrate the water molecules present in the food producing heat which helps in cooking.
- Television and telephone information are transmitted through long distances

from ground stations to communication satellites through microwaves. Microwaves can be used for transmitting information from one place to another as they can penetrate through fog, clouds, smoke, snow, etc.

Microwave oven

Communication satellite disc

Figure 5.3 Microwave uses

- Mobile phones, bluetooth and Wi-Fi use microwaves to transfer information like data, video and voice.
- Shorter microwaves are used in remote sensing. Remote sensing means to gather information about a place or weather conditions from a distance. Microwaves are used in RADAR to control air traffic, forecast weather, detect speed of vehicles, etc.

Since microwaves are extensively used in day to day life application, it would be wiser to be careful of its potential dangers. Till date there is no strong evidence that microwaves used in various appliances are harmful to us. But we cannot be totally sure that these waves are safe for us. It is predicted that the prolonged exposure to microwave may cause internal heating of body tissues and may lead to cancer. Some claims also suggest that cell phone microwaves may instigate brain tumours and cancer.

iii. Infrared radiation

Infrared (IR) radiations lie just beyond the red end of visible part of the spectrum. They have longer wavelength compared to the red light and hence, are called *infrared radiations*. These waves are also called heat waves as they produce heating effect. Their frequency ranges from 3×10^{13} Hz to 4×10^{14} Hz and wavelength ranges from about 10^{-4} m to 7.8×10^{-7} m. They are radiated by all hot bodies. IR ray s are also very useful in many applications as follows.

- Infrared radiations help to keep us warm. They produce heating effect. The heat that we get from sunlight, fire, heater, etc is infrared radiation.
- Shorter infrared waves do not produce heating effect. Such waves are used in television remote controls.

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- IR radiations are used in short range communication.
- They are used in cooking as they produce heating effect.
- They are used to transmit signals through optical fibres.

TV remote

Night photography

Figure 5.4 Infrared uses

- They are also used in security systems. If the infrared ray barrier is crossed, it triggers an alarm to alert the security personnel of the trespasser.
- They are used in taking photographs at night or in mist or fog. They can penetrate through thick fog or mist as they are not scattered easily. Therefore, they are used in astronomy.
- They produce greenhouse effect. Hence they are used in greenhouse to provide the right temperature for the growth of vegetables.

There are also some harmful effects of IR radiations. They may cause cataracts, corneal ulcers and retinal burns. Exposure to IR waves for long duration of time may cause skin burns.

iv. Visible light

The visible light region lies in the middle of the electromagnetic spectrum. Its frequency ranges from about 4×10^{14} Hz to 8×10^{14} Hz and wavelength ranges from 7.8×10^{-7} m to 3.8×10^{-7} m. The visible light consists of seven colours of light i.e. violet, indigo, blue, green, yellow, orange and red. The visible light emitted or reflected by objects enables us to see things around us.

The uses of visible light are as follows:

- The visible light is used in electric bulbs, tubelights and lasers.
- It is used in photography.

Bright light affects visibility or may even damage our eyes.Therefore, we should never look directly into the Sun or other sources of bright light with our naked eyes.

v. Ultraviolet radiations

Ultraviolet radiations lie beyond the violet end of visible light. They have shorter wavelength compared to violet light of visible spectrum. So they are called

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ultraviolet (UV) rays. They have frequency of about 8×10^{14} Hz to 3×10^{16} Hz and wavelength of about 3.8×10^{-7} m to 1.0×10^{-8} m. They are produced by the Sun and also artificially by special lamps called UV lamps. UV rays of shorter wavelength that are harmful to us are mostly absorbed by the ozone layer in the atmosphere. So only the longer wavelength UV rays can penetrate through the atmosphere and reach our Earth.

UV rays are also used for various purposes.

- They are used in fluorescent lighting. Many substances are able to absorb UV rays and convert them into visible light. This is called fluorescence. The coatings inside the fluorescent tubes or bulbs absorb UV light and re-emit it as visible light.
- They produce vitamin D in our body.
- They are used for sterilising equipment in hospitals and laboratories.
- They are used to detect forged documents and counterfeit money. The authentic documents and money will fluoresce in the UV light.
- They are used in hospitals to cure neonatal jaundice in infants and in the treatment of skin disease called psoriasis.
- They are used in forensics. Crime investigators use UV light to detect fingerprints, body fluids, shoe prints, drugs, etc at the crime scenes.
- They are used in burglar alarms, automatic door openers and counters.
- They are also used to detect defects in construction and production in factories.

DNA structure study

Detect counterfeit money

Figure 5.5 Ultraviolet radiation uses

The shorter wavelength UV rays are more harmful to us. They have ionising effect. These rays are usually absorbed by the ozone layer in the atmosphere. Many researchers are of the opinion that ozone layer depletion is taking place due to air pollution and therefore, these harmful rays are reaching our Earth in small amounts. The acute effects of UV rays are sun burns and tanning of the skin. The chronic effects of UV rays include premature aging of skin, suppression of immune system, damage to the eyes and skin cancer. Welding torch can produce UV rays and harm the eyes. Hence a welder uses a mask while welding metals in workshops.

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vi. X-rays

X-rays are high energy electromagnetic waves as they have high frequency. It can penetrate through soft tissues and skin. There are two types of X-rays: soft X-rays and hard X-rays. Soft X-rays have frequency of about 3×10^{16} Hz to 10^{18} Hz and wavelength ranges from 10^{-8} m to 10^{-10} m. Hard X-rays have same frequency range and wavelength as the gamma rays. They are produced in X-ray tubes by bombarding energetic electrons with high atomic weight metal target. X-rays are used for following purposes:

- X-rays are used in airport security scanners. The passengers, luggage and sealed packets are scanned with X-rays to detect metals, explosives or any illegal items and substances.
- Internal structures of objects can be observed with the help of X-rays. Engineers use X-rays to detect cracks or defects in metal objects.
- X-rays are used in medical diagnosis. They can pass through flesh but not through bones. Hence they are used to locate fractures and diseased organs in the body. High frequency X-rays are used in computed tomography (CT scans) for the detection of tumours and strokes.

Airport security

Medical diagnosis

Figure 5.6 X- ray uses

Since X-rays are high energy electromagnetic waves, they also have harmful effects. They have ionising effects. They can damage cells causing mutations and cell death which may lead to cancer.

vii. Gamma rays

Gamma rays have frequency greater than 10^{18} Hz and wavelength less than 10^{-10} m. Gamma rays occupy the same range of electromagnetic spectrum as hard X-rays. The only difference between gamma rays and hard X-rays is their source. Gamma rays are produced by radioactive nuclei but hard X-rays are produced by accelerating electrons. Gamma radiation readily penetrates through most of the materials. Gamma rays are also useful in following ways.

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- They are used in sterilising medical equipment as their high energy can kill germs and bacteria.
- They are used in the treatment of cancer. The cancerous cells can be killed by controlled exposure of these cells to the gamma rays.

Cancer treatment *Sterilisation*

Figure 5.7 Uses of Gamma ray

They are very harmful to us as they are the most energetic of all the electromagnetic waves. They also have ionising effects. They damage the cells causing mutation and cell death ultimately leading to cancer. Therefore, people involved in handling these types of rays are provided with lead coated clothes and equipment. Gamma rays and X-rays can not penetrate through lead. Rooms having X-rays and gamma rays equipment are properly designed with safety measures to prevent the exposure to these rays.

Questions

1. Identify the type of electromagnetic radiations used in the following situations:
   a) Changing channels on television with the help of a remote.
   b) Making international calls.
   c) Tanning of skin in the sun.
   d) Using barcode-reader in supermarket.
2. What safety measures would you suggest to protect from harmful waves?

http://missionscience.nasa.gov/ems/01_intro.html
http://csep10.phys.utk.edu/astr162/lect/light/spectrum.html
http://www.ducksters.com/science/physics/types_of_electromagnetic_waves.php

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2. Communication through Waves

Learning Objectives

On completion of this topic, you should be able to:

- explain the transfer of information along optical fibres.
- explain that radio waves, microwaves, infrared and visible light carry information over large and small distances, including global transmission via satellites.
- describe the ways in which reflection, refraction and diffraction affect communication.
- verify laws of reflection of sound.
- describe the difference between analogue and digital signals.

During the olden days, people used to send and receive messages through messengers. They used to walk on foot for days and delivered their messages. The messengers used to take several days to reach their destinations. It was a tiring and difficult task and took a long time. Delivery of messages on horses made the communication much faster. Soon post offices, telegrams and telephones came into existence. These days the messages are sent in the form of electrical signals through high frequency carrier waves like radio waves and microwaves. The messages are then received by the receiver through electronic gadgets.

As electromagnetic waves travel, they interact with different objects and media through which they travel. In the process they get reflected, refracted and diffracted. These interactions cause the electromagnetic waves like radio waves to change their direction and reach in areas otherwise inaccessible to them. When the electromagnetic waves get reflected or diffracted from surfaces, they reach to places which are not in direct line of sight with the transmitter. The refraction of waves usually make the signals weak due to absorption.

A. Communication over short distances

The communication between devices used to be done by connecting the devices with the help of wires and cables. But these days the communication has become wireless called wireless communication. The electromagnetic waves like radio waves, microwaves and infrared waves are used in wireless communication systems.

Wireless communication is widely used these days. Almost all electronic devices used for communication have a wireless feature. Wireless communication over short distances from few centimetres to some metres can be done using infrared waves

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and microwaves. Some of the examples of short range wireless communications are Bluetooth, infrared, Wi-Fi, etc. This type of communication is also used in the network of electronic devices called Internet of Things (IoT)

Figure 5.8 Wireless communication

Bluetooth is a type of wireless communication used to transfer data or video or images using microwaves. It can be used to exchange data between devices like mobile phones, computers, televisions and other electronic devices. The devices should be generally within 10 metres from each other for using Bluetooth communication. It is widely used in mobile phone headsets which allow us to make phone calls without placing our phone to our ears. It is also used to establish a wireless connection between computer and other peripheral devices like mouse, keyboard, printers, digital cameras, etc. So Bluetooth has eliminated cables for the connection between different electronic devices at short distances.

Wi-Fi (wireless fidelity) is the most widespread wireless technology similar to Bluetooth. It also uses microwaves. It can establish Internet connection for mobile electronic devices like laptops, mobile phones, tablets, etc. Wi-Fi serves as a replacement for cables in local area network. The range is generally up to 100 metres.

Infrared waves are used to transmit information from remote controls. They are also used to exchange data between computers, TV, mobile phones and other communication devices. We can change the channels, adjust the volume and put on or off electronic devices like television and DVD players with the help of remote controls. IR devices must have clear line of sight.

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B. Communication over long distances

Radio waves are used to broadcast radio and television programs and for communication over long distances. The radio waves easily diffract around the hills and buildings allowing it to reach all places. Diffraction is the phenomenon of bending and spreading of waves passing through gaps, corners or edges of obstacles. The effect of diffraction is more when the size of the gaps or corners is same as the wavelength of the waves. The radio waves of shorter wavelength of about 5 m can be diffracted around the buildings and longer wavelength radio waves can be diffracted around the hills. Hence, radio waves can reach far flung places due to diffraction and are suitable for broadcasting radio and television programs. Radio waves are reflected from the charged layer of the atmosphere called ionosphere and hence, the reflected signals can cover larger area.

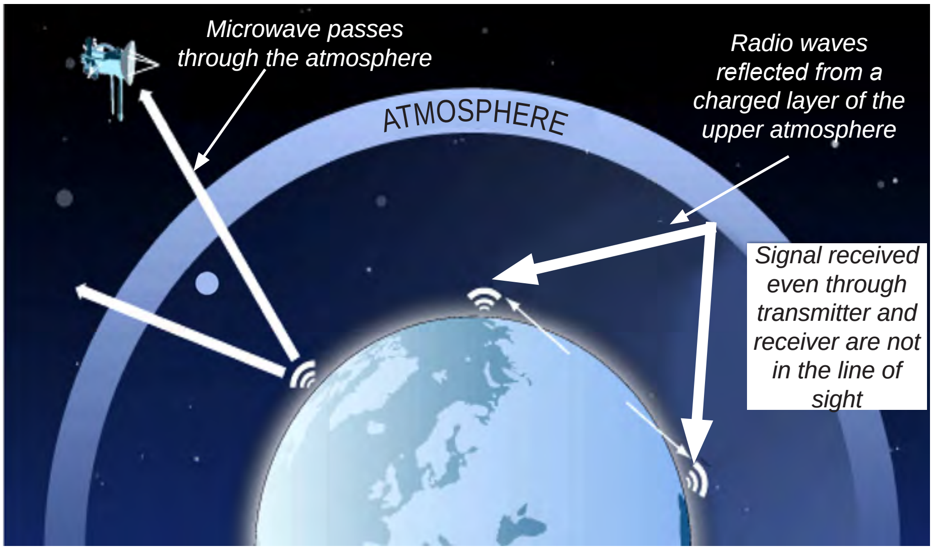

Figure 5.9 Long distance communication

Microwaves are used in mobile phones, televisions and radar. They have shorter wavelength compared to radio waves and hence they cannot be diffracted around buildings or hills. So they are not suitable for broadcasting programs. Microwaves can pass through the atmosphere and hence can be used to send signals to the satellites and receive the reflected signal from the satellite as well. They need transmitters and receivers in line of sight. Therefore the transmitters for mobile phones are generally kept high up on tall masts. When phone calls are made, microwaves from mobile phones reach the nearest transmitter tower. Then the information is relayed through a network of transmitter tower to reach the information to the receiving phone.

Radio waves get refracted as they travel through different layers of atmosphere and the signal becomes weak after travelling through long distances. But microwaves are not refracted by the different layers of the atmosphere and hence they can be used in satellite communications.

Signal and information are weakened as they travel long distances. In case of wired communication, optical fibres are the preferred medium for the transmission of information. Infrared waves can be used to transmit multiple phone calls, Internet signal and cable television signal through optical fibre. Optical fibre is made up of flexible glass. The core is made up of slightly higher refractive glass than the outer cladding. The light signal is first modulated and then transmitted through the optical fibre from one end to the other end. The light signal gets transferred inside the fibre due to series of total internal reflection. A very little energy is absorbed by the glass. So the signals do not weaken over long distances as much as in the case of copper cables. Hence the signals do not need to be amplified as often as in the case of copper cables. They carry the signal in the form of light or invisible infrared waves. They also carry more information compared to copper cables.

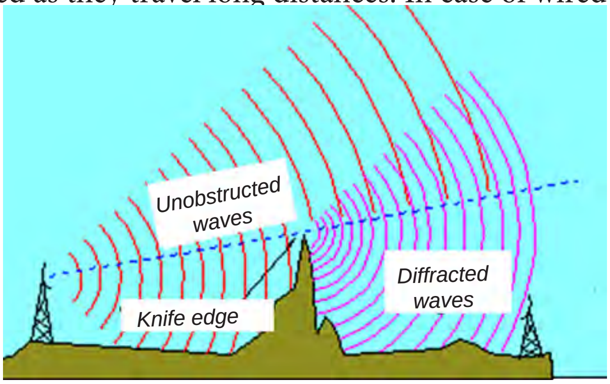

Figure 5.10 Diffraction of waves

http://managementstudyguide.com/different-types-of-communication-system.htm
https://www.tycosimplexgrinnell.com/how-we-can-help/protect-your-business/sound-and-communication/telephone-networks
http://www.electroschematics.com/5231/mobile-phone-how-it-works/
http://www.fao.org/docrep/003/w9633e/w9633e09.htm
http://www.thebigger.com/physics/principles-of-communication/what-is-satellite-communication/

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C. Communication through sound waves

Like electromagnetic waves, sound waves are also used for communication purposes. The sound waves are mechanical waves which require material medium for their propagation. They are longitudinal waves i.e. they vibrate along the direction of propagation of the waves. They travel through the medium in the form of compressions and rarefactions and make our ear drum to vibrate causing the sensation of hearing in our ears.

These waves also undergo the phenomena of reflection, refraction and diffraction. It is due to the diffraction of sound waves that we are able to talk or hear to person in adjacent rooms without seeing him or her. The sound waves easily get diffracted compared to electromagnetic waves because of their longer wavelength. Sound waves obey the same laws of reflection and refraction just like light waves. The sound waves are also easily reflected by a rigid surface (reflector). The reflected sound from the rigid obstacle is called *echo*. The minimum distance between the source and reflector should be 17 metres for the echo to be heard clearly. Sound waves obey the same laws of reflection just like light waves.

Activity 5.2 Verifying laws of reflection of sound

Materials required:

A cardboard, chart paper, a table clock, a polished wooden board (reflector), two transparent tubes of about 3 feet in length and 2 inches in diameter.

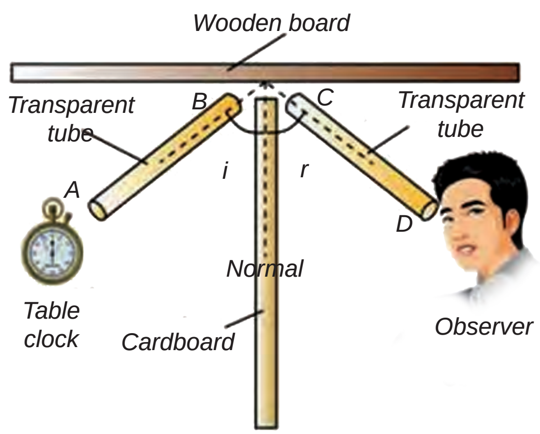

Figure 5.11

Procedure

Step 1 Draw a horizontal line such that line is 2 cm from the edge of chart paper. Now draw a perpendicular bisector (Normal) through the horizontal line.

Step 2 Draw a line inclined at an angle of incidence 30˚ to the normal on its left side and place the tube AB on top of the line so that the line falls exactly on the axis of the tube. Record the angle of incidence (i) in Table 5.1.

Step 3 Place a table clock near the mouth of the tube AB as shown in Figure 5.11.

Step 4 Place tube CD on the other side of the Normal such that its axis coincides at point of incidence. Listen to the ticking sound of the clock as you turn and adjust the angle of inclination of tube CD. Stop and mark the position at which you hear the loud and clear sound of the clock.

Step 5 Draw line CD such that it coincides exactly with the axis of tube CD. Measure and record the angle of reflection (r) as angle between the line CD and the normal in Table 5.1.

Step 6 Repeat steps 2 to 5 two more times taking angles of incidence at 45˚ and 60˚. Record the observations in Table 5.1.

Table 5.1

Sl. no.	Angle of incidence (i)	Angle of reflection (r)
1		
2		
3		

Answer the following questions:

1. In the above experiment, how is the angle of incidence related to the angle of reflection of sound?
2. Are the laws of reflection of sound verified in the above experiment? Explain.
3. Give an example of an application of reflection of sound.

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D. Analogue and digital signals

Over the years the analogue devices are rapidly replaced by digital electronic devices to have better quality of information display and transmission.

The information carried by the electromagnetic waves like radio waves, microwaves, infrared waves and visible light may be pictures, video, sound or texts. These information are transmitted in the form of signal. The signal is added to an electromagnetic wave called carrier wave so that it can be transmitted. The carrier wave is removed when the signal is received. The signal may be of two types- analogue signal and digital signal.

An *analogue signal* changes its frequency and amplitude continuously just like that of the sound being transmitted. Speech is an analogue signal, and varies in amplitude (volume), frequency (pitch), and phase. It is represented by a sine wave.

Radio uses analogue signals for broadcasting programs. The signals are transmitted through carrier wave. A carrier wave is a pure wave of constant frequency which does not carry information but helps in transmitting information. The input signals of speech or data information are imposed on top of the carrier wave before they are transmitted. This process of imposing input signals into a carrier waves is called *modulation*. The modulation of the signal improves the transmission significantly. The two most common types of modulation of signals are amplitude modulation (AM) and frequency modulation (FM).

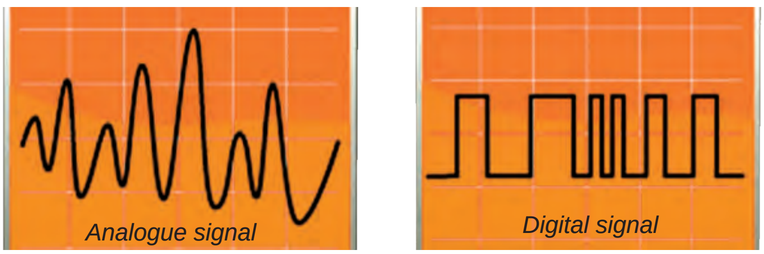

Figure 5.12 Signals

When the information signal is mixed with high frequency carrier wave in such a way that the frequency of the modified signal is same as that of the carrier wave but its amplitude is modified in accordance to the modulating wave or information signal, the process is called *amplitude modulation*. Similarly, when the information signal is mixed with high frequency carrier wave in such a way that the amplitude of the modulated wave is same as that of the carrier wave but its frequency is modified in accordance to the modulating wave, then process is called *frequency modulation*. When the signal is received, it is demodulated back to the original signal.

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A *digital signal* has just two values 0 and 1(binary digits) to represent information. The information is converted into codes formed by combination of 0s and 1s. These codes are transmitted as combination of low and high voltages through the carrier wave and decoded back to original signal. A digital signal is represented by a square wave.

Both analogue signal and digital signal pick up the unwanted signal which can distort the original signal. Such unwanted signal is called *noise*. It is quite difficult to remove noise from an analogue signal as compared to removing from a digital signal. This is because original digital signal can be easily extracted from the distorted signal by removing the noise using digital processing or filter. The digital signal maintains the quality of the information over long distances.

The frequency range for transmission called *bandwidth* is used more efficiently in digital signals than in analogue signals. This means more information can be made to fit in a smaller space in digital signals compared to analogue signals. Therefore, digital signals can carry more information per second than analogue signals.

Questions

1. Telecom companies are trying to improve the quality of telecommunication services by replacing copper cables with optical fibres. What are the advantages of using optical fibres compared to copper cables?
2. Name some devices where you use Bluetooth. Can it be used for large distances? Why?
3. Are Bluetooth and Wi-Fi the same? Give a reason to support your answer.
4. Why is digital signal preferred over an analogue signal in transferring information by telecommunication technology from one place to another?

http://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/images/emschart.jpg
www.bbc.co.uk/schools/gcsebitesize/science
http://www.radio-electronics.com/info/propagation/em_waves/electromagnetic-reflection-refraction-diffraction.php
http://science.hq.nasa.gov/kids/imagers/ems/waves2.html
http://missionscience.nasa.gov/ems/index.html
http://www.livescience.com/38169-electromagnetism.html
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http://farm4.static.flickr.com/3444/3348244651_fef16ef641.jpg

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Summary

- Electromagnetic spectrum consists of radio waves, microwaves, infrared waves, visible light, ultra-violet rays, X-rays and gamma rays arranged in increasing frequency.
- All electromagnetic waves do not require any material medium for their transmission. They can travel through vacuum.
- Electromagnetic waves are useful to us in many ways.
- Infrared waves are also called heat waves as they produce heating effect.
- Ultraviolet rays, X-rays and gamma rays are ionising rays. They have harmful effects on our body tissues.
- Radio waves, microwaves, infrared and visible light are mostly used for communication purposes.
- Sound waves obey the same laws of reflection like light waves.
- Sound waves undergo the phenomena of reflection, refraction and diffraction.
- Diffraction is the phenomenon of bending and spreading of waves passing through gaps or around corners of obstacles.
- There are two types of signals and they are analogue signal and digital signal.
- An analogue signal changes its frequency and amplitude continuously.
- A digital signal has just two states. There is no continuous change in its frequency or amplitude.
- Digital signals can transmit more amount of information as compared to analogue signals.

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Exercises

I. *Fill in the blanks.*

1. The wavelength of electromagnetic wave varies inversely to its ____________.
2. Ionising rays have ____________ effects on our body.
3. The waves used in airports for scanning luggage are ___________.
4. A type of wireless communication used to exchange data between electronic devices within a distance of about 10 m is called ______________.
5. The process of mixing the information signal to a carrier wave for the transmission is called _________________ .

II. *Match the items of Column A with correct answers of Column B.*

Column A	Column B
i. Radio waves	a. Wi-Fi
ii.Gamma rays	b. Production of vitamin D
iii. Infrared waves	c. MRI
iv. Ultraviolet rays	d. CT scans
v. Microwaves	e. Radiation therapy
	f. Location of bone fractures
	g. Optical fibre

III. *State 'True' or 'False'. Rewrite the false statements correctly.*

1. Electromagnetic waves can travel through vacuum.
2. Infrared radiation are used to establish internet connection between mobile electronic devices.
3. Optical fibres are preferred over wires in long distance transmission as they are stronger than wires.
4. Noise is an unwanted signal that distorts original signal.
5. Echo is produced due to the diffraction of sound waves by the rigid obstacle.

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IV. *Multiple Choice Questions.*

1. Which of the following is the correct order for electromagnetic waves from lowest to highest frequency?

   A Radio waves, infrared radiations, gamma rays, ultraviolet rays.

   B Gamma rays, ultraviolet rays, radio waves, infrared radiations.

   C Ultraviolet rays, gamma rays, radio waves, infrared radiations.

   D Radio waves, infrared radiations, ultraviolet rays, gamma rays.

2. The device which uses microwave is

   A MRI

   B TV remote

   C Mobile phones.

   D Computer tomography (CT scans).

3. When a radio signal undergoes refraction through different layers of the atmosphere, the signal becomes

   A shorter.

   B longer.

   C weaker.

   D stronger.

4. A welder uses a mask while welding metals. This is done to protect himself from the harmful effects of

   A radio waves.

   B microwaves.

   C infrared radiation.

   D ultraviolet radiation.

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5. When an analogue signal undergoes amplitude modulation (AM),

   A only its amplitude is changed.

   B only its frequency is changed.

   C both its amplitude and frequency are changed.

   D nothing is changed.

6. The meteorology department forecasts weather by using RADAR. The waves used by RADAR is

   A sound waves.

   B X-rays.

   C infrared rays.

   D microwaves.

7. Sonam could hardly see her friend Rinzin who was in the other room but she could easily talk to her. This is because sound waves could be easily

   A reflected compared to the light waves.

   B diffracted compared to the light waves.

   C refracted compared to the light waves.

   D transmitted compared to the light waves.

8. A transmitter produces a wave of 10^{20} Hz. The type of wave produced is

   A infrared radiations.

   B ultraviolet rays.

   C gamma rays.

   D radio waves.

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9. Radio waves are used to broadcast television and radio programs. A radio program receiver need not be in line of sight with the transmitter because radio waves are

   A diffracted.

   B refracted.

   C reflected.

   D absorbed.

10. When phone calls are made, the signals in the form of microwaves are

    A directly sent to the receiving phone from the caller's phone.

    B diffracted around nearby hills and reach the receiving phone.

    C relayed through a network of transmitters to the receiving phone.

    D reflected from the ionosphere to the receiving phone.

V. Answer the following questions.

1. Define electromagnetic spectrum. Name the different regions of electromagnetic spectrum.
2. State some common features of electromagnetic waves.
3. Which is more harmful, gamma ray or hard X-ray? Support your answer with a reason.
4. Bhutan Broadcasting Service (BBS) uses radio waves for broadcasting radio programs in FM radio. Why are radio waves used in broadcasting?
5. Why are microwaves used to send signals to the satellites instead of radio waves?
6. Sound waves bend around the obstacles more than the light waves. Why is it so?
7. In an optical fibre, the core has slightly higher refractive index than the cladding. Why is it constructed in that manner?

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8. Sangay converses with her parents in Australia through video call on her laptop. How is she able to see and talk to her parents far away from her? Give an explanation of how the transfer of information takes place from Bhutan to Australia and vice versa.

9. How do reflection, refraction and diffraction of waves affect communication?

10. Which type of signal would you prefer analogue or digital? Give at least two reasons.

11. Why are more number of transmission towers of equal transmitting strength required for mobile phone communication in Bhutan compared to India?

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6

EARTH AND BEYOND

All matter has mass. Gravity is a result of mass and all matter is affected by gravity. The gravitational force pulls bodies towards each other.

Gravity affects smaller bodies too. At present, you are being pulled towards this book and every other object around you because of gravity. These bodies are also being attracted towards you and towards each other. All the objects on Earth are under the influence of gravity. So, why don't we notice bodies moving towards each other? The reason is that the mass of most bodies is too small to cause a noticeable large force. However, the object that is massive enough like our Earth causes a noticeable attraction. All the bodies on the Earth are pulled towards centre of the Earth. Gravity holds the Moon in orbit about the Earth, the Earth in orbit about the Sun, and the Sun in orbit about the center of the Milky Way. Gravity holds groups of galaxies together in clusters in the universe.

1. Gravity and Universe

Learning Objectives

On completion of this topic, you should be able to:

- explain that gravity acts as a force throughout the universe.
- explain the role of gravity in the formation of solar system, planets, stars and the universe.

A. Gravitational force

Compared to all bodies around us, Earth has a huge mass. The gravitational attraction of Earth is an important force that we experience. Earth's gravitational force pulls everything towards the center of Earth. Because of this force, the books, tables, and

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chairs in the room stay in place, and dropped bodies fall to Earth rather than move together or towards us. We must apply forces to overcome Earth's gravitational force any time that you lift bodies or even parts of your body.

Gravitational forces exist when one object attracts another. Any two bodies, regardless of their composition, size, or distance apart, feel a force that attracts them towards one another. The force acting between these bodies is determined by their masses and the distances between them. The region around a body where force of attraction is felt is the *gravitational field* of the body. The body with larger mass will have more gravity and larger gravitational field. For example, an aeroplane has more gravitational force of attraction than a car. Similarly, the Moon has less gravitational force and gravitational field than the Earth. The gravitational force of attraction is greater if the bodies are closer t each other.

The study of gravity has played a central role in the history of science from the 17th century. Galileo Galilei compared bodies falling under the influence of gravity and Sir Isaac Newton proposed the law of universal gravitation. In 20th century, Albert Einstein proposed the theory of relativity. Today, intense research in gravitational physics focuses on topics such as black holes, gravitational waves, and the composition and evolution of the universe.

Figure 6.1 Newton realized that the unbalanced force affected the motions of the apple and the moon.

For thousands of years, people asked two very puzzling questions: why do bodies fall towards Earth, and what keeps the planets moving in the sky? The two questions were treated separately. But in 1665, Sir Isaac Newton, a British scientist, realized that they were two parts of the same question.

The legend is that Newton made the connection between the two questions when he watched a falling apple from a tree, as shown in Figure 6.1. He knew that unbalanced forces are needed to change the motion of bodies by changing the velocity of the bodies. He concluded that an unbalanced force on the apple made the apple fall. Newton said that these two forces are actually the same force that he called *gravity*. Newton reasoned that an unbalanced force on the moon kept the moon moving circularly around Earth.

i. Law of Universal Gravitation

Newton summarized his ideas about gravity known as the *law of universal gravitation*. This law describes the relationships between gravitational force, mass,

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and distance. The law is considered universal because it is thought to apply to all bodies in the universe.

The law of universal gravitation states that "***Every particle in the universe attracts every other particle in the universe with a force that is proportional to the product of the masses and inversely proportional to the square of the distance between the particles.***"

If two masses 'm_1' and 'm_2' are separated by a distance '**r**', the magnitude of the gravitational force, '**F**', between them is

$$F = G\frac{m_1 m_2}{r^2} \quad \text{..... equation 1}$$

where **G**= 6.6726 x 10^{-11} Nm^2kg^{-2} is a proportionality constant which is the same for all objects in the universe. **G** is called the *universal gravitational constant*.

This equation assumes that the masses are "point masses", that is, masses having a negligible physical size. For most practical purposes, the equation will hold true if the distance separating the masses is considerably larger than the objects' physical size.

The magnitude of the gravitational force depends on the masses of the bodies and the distance between the bodies. The law is easier to understand by considering it in two parts.

Part 1: Gravitational Force and Mass

From ***equation 1***, we can see that the gravitational force between two bodies depends on the product of the masses of the bodies. So, the gravity between bodies increases as the masses of the bodies increase.

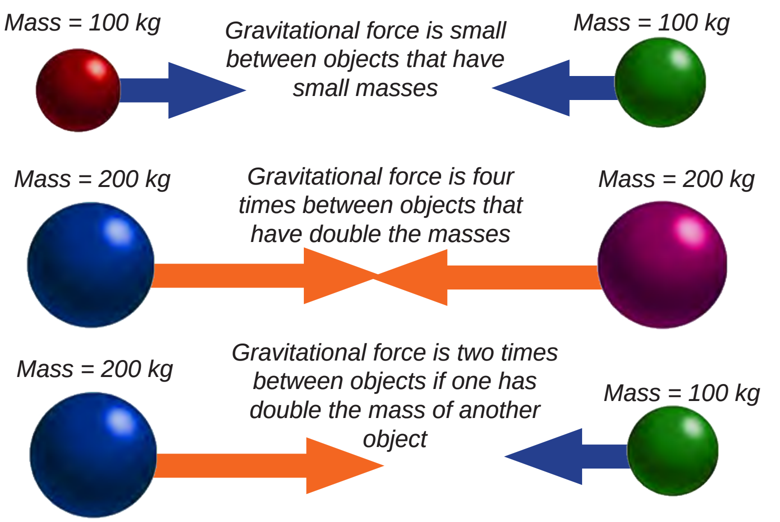

Figure 6.2 The gravitational forces between two objects of varied masses

In Figure 6.2, two bodies of equal mass will attract each other with equal force. However. if the masses of two bodies are doubled, keeping the distance fixed, then using ***equation 1***, the gravitational force between them becomes four times the initial value.

The gravitational force of attraction between two bodies of different masses is proportional to the product of the masses of the two bodies. Both the bodies attract each other with equal force but the lighter body will be pulled towards the heavier body as the influence of force of attraction is more in the case of lighter body. This explains why the astronauts on the moon bounce so easily. The gravity of the Moon is less than gravity of the Earth as the Moon has less mass than Earth.

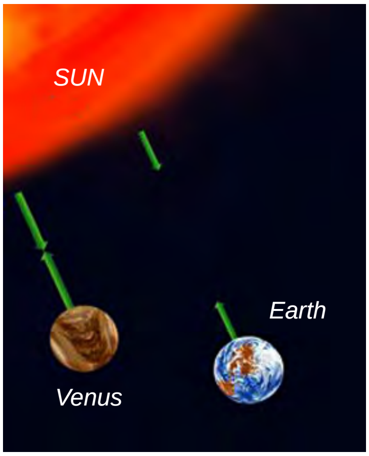

Figure 6.3. Venus and Earth have approximately the same mass. But because Venus is closer to the sun, the gravitational force between Venus and the sun is greater than the gravitational force between Earth and the sun.

Part 2: Gravitational Force and Distance

The force of gravity depends on the distance between two bodies. The Sun and the Moon are very far away from us. The gravitational forces of the Sun and the Moon on our body are very small. However, if we jump up, we fall back due to Earth's gravitational force, which is very large on our body as we are very close to centre of Earth.

The force of gravity changes with change in distance between the bodies. As the distance between two bodies becomes larger, the force of gravity becomes smaller. The force of gravity follows inverse square law. For example, if the distance between two bodies is doubled, the force of gravity becomes one-fourth as large. Figure 6.4 shows how the force of gravity gets smaller as the distance between bodies gets larger.

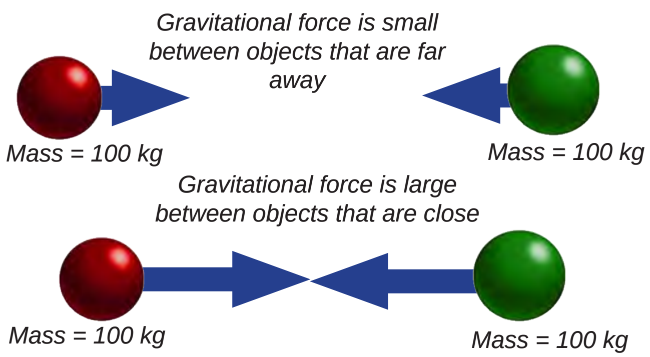

Figure 6.4 The gravitational forces between two objects at different distances

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The relationship between the force of gravity '**F**' between the Earth and any other body and the distance that separates their centres '**r**' can be expressed as

$$F \propto \frac{1}{r^2} \text{ ..... } \textit{equation 2}$$

where 'F' represents the force of gravity between two objects and

'r' represents the distance separating the objects' centres.

Since the distance '*r*' is in the denominator of this relationship, the force of gravity is inversely proportional to the square of the distance. This mathematical relationship is sometimes referred to as an inverse square law since one quantity depends inversely upon the square of the other quantity.

The gravitational force between the Sun and the planets is large even though they are at large distance. This is because they all have large masses. The large gravitational force of the Sun affects the movement of all the planets. This force helps them stay in orbit around the Sun. So, the gravitational force has an important role in maintaining the shape of the solar system.

ii Acceleration due to gravity

Mass is one of fundamental attributes of a particle. These fundamental attributes are defined based on their interactions we observe in nature. For example, charge is defined based on electromagnetic interaction. We observe the motion of particles under electromagnetic interaction and assign charge value based on this observation.

The mass of an object which gives rise to its gravitational force of attraction on other objects is gravitational mass. The more gravitational mass of the body, stronger the attractions of other bodies towards it.

In other words, force of attraction due to the gravitational mass, the weight is defined by relation

$$F = mg \text{ ..... } \textit{equation 3}$$

A body in motion possesses inertial mass which describes an object's resistance to change in velocity. The more inertial mass a body has, the harder it will be to change its velocity. The force described by Newton's second law of motion, F = ma refers to inertial mass. Our Earth is always in motion. If we consider that the inertial mass and the gravitational mass are the same, then the weight of an object may be equalled to the force exerted on the object by the Earth's gravitational field as

$$mg = G\frac{Mm}{R^2}$$

$$\text{Hence, } g = G\frac{M}{R^2} \text{ ..... } \textit{equation 4}$$

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where **M** is the mass of the Earth
R is the mean radius of the earth, and
m is the mass of the object.

From ***equation 4***, it is clear that the acceleration due to the earth's gravitational field is independent of the mass of the object.

Placing the values of **G** = 6.67×10^{-11} Nm^2kg^{-2}, **M** = 5.98×10^{24} kg, and **R** = 6.38×10^6 m in ***equation 4***, we get value for **g** = 9.80 ms^{-2}. The acceleration due to the Earth's gravity, **g**, is not constant, and varies with the altitude and location on the Earth's surface.

It has the value of 9.78039 ms^{-2} at the equator and 9.83217 ms^{-2} at the poles (since the Earth is slightly flattened at the poles). The convenient value g =10 ms^{-2} is generally used in calculations.

Example 6.1

Calculate the gravitational force acting between the Earth, with mass $m_e = 5.98 \times 10^{24}$ kg, and the Moon, with mass $m_m = 7.35 \times 10^{22}$ kg. (G = 6.67×10^{-11} Nm^2kg^{-2}, mean Earth-Moon distance = 3.84×10^8 m.)

Solution:

The force of gravity between the spheres will be

$$F = \frac{Gm_e m_m}{r^2} = \frac{6.67 \times 10^{-11}\ Nm^2kg^{-2} \times 5.98 \times 10^{24}\ kg \times 7.35 \times 10^{22}\ kg}{(3.84 \times 10^8)^2\ m^2}$$

$$\therefore F = 2.0 \times 10^{20}\ N$$

Example 6.2

Calculate the acceleration due to gravity of the Moon of mass $m_m = 7.35 \times 10^{22}$ kg and radius r = 1.74×10^6 m. (G = 6.67×10^{-11} Nm^2kg^{-2}). Compare the value of acceleration due to gravity of Moon and Earth.

Solution:

The acceleration due to gravity on the Moon is given by

$$g_m = \frac{Gm_m}{r^2}$$

$$g_m = \frac{6.67 \times 10^{-11}\ Nm^2kg^{-2} \times 7.35 \times 10^{22}\ kg}{(1.74 \times 10^6\ m)^2}$$

$$\therefore g_m = 1.62\ m/s^2$$

Therefore, ratio of acceleration due to gravity on earth (g_e) to the acceleration due to gravity on moon (g_m) is

$$\frac{g_e}{g_m} = \frac{9.80}{1.62} = 6 : 1$$

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B. The role of gravity in universe

Although by far the weakest of the known forces in nature, gravity spreads over the universe and plays an essential role in the evolution of the universe.

For centuries, astronomers and philosophers wondered how our solar system and its planets formed and evolved. As telescopes advanced and space probes were developed and sent out to explore, more and more about our solar system and formation of planets were learned. However, these exploration and studies revealed only the end result of planet and solar system formation, not the process itself. Until recently, we had only one and our own planetary system to study in our attempt to understand how planets form. But the Hubble Space Telescope working along with other telescopes has opened a window into the mystery of planet formation. Hubble's ability to peer into deep regions around neighboring stars has shown us planetary systems under construction, the conditions planets form in, and even a planet orbiting another star.

i. Formation of Universe

Gravity causes stars and galaxies to form in the first place. The standard model of cosmology has the universe beginning in a Big Bang roughly 14 billion years ago, followed by an expansion that continues today. At an early age, before stars existed, the universe is described as a nearly homogeneous gas of matter and radiation. The matter consisted mostly of hydrogen atoms, helium atoms, neutrinos, and dark matter. In regions of space where the density of matter is slightly more than the average, the gravitational attraction between the constituents of the matter caused the gas to fuse into large clouds. Friction inside these clouds caused by collisions of atoms increased gravitational attraction resulting into densities so high as to ignite nuclear fusion, which is the energy source of stars.

Figure 6.5: Hubble Space Telescope image of a star-forming region in the Small Magellanic Cloud.
Source: © NASA/ESA and A.Nota (STScI/ESA).

As clouds of matter and stars started gathering together under the force of gravity, the formation of galaxies started. Galaxy is unit of the universe and the star system is the unit of a galaxy. Our star system is known as

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Solar System and our galaxy is the *Milky Way* which is a part of universe. The universe encompasses everything in existence, from the smallest atom to the largest galaxy. The part of the universe of which we have knowledge is called observable universe. It is evident from studies and observations that the expansion and cooling of the universe continues.

The galaxy-formation process has not stopped. Our universe continues to evolve. About 11 to 15 billion years ago, all of the matter and energy in the universe were concentrated into an area the size of an atom. At that moment, matter, energy, space and time did not exist and then the Big Bang occurred. Matter, energy, space and time came into existence and the universe began to expand at an incredible rate. Expanding universe means that it has been growing in size ever since its beginning with the Big Bang. The galaxies outside of our own are moving away from us, and the ones that are farthest away are moving the fastest. This means that the universe has no center and everything is moving away from everything else.

The effective analogy to explain the expanding universe is imagining the universe like coloured dots on a balloon. As the balloon is blown, it expands and the colour dots move farther away from each other, but they are still on the surface of the balloon. Gravity is in control of things and keeps everything together.

Figure 6.6: Galaxy formation

Cosmologists have postulated two endings to the universe. If the universe is infinite or has no edge, it should continue to expand forever and if a universe is finite or closed then it is theorized to collapse because of gravity when expansion stops. The collapse of the universe ends when all matter and energy is compressed into the high energy, high-density state from which it began. This scenario is called the *Big Crunch*. Some theorists have suggested that the Big Crunch will produce a new Big Bang and the process of an expanding universe will begin again. This idea is called *oscillating universe theory*.

http://www.scienceclarified.com/Ga-He/Gravity-and-Gravitation.html
http://www.hq.nasa.gov/pao/History/SP-4026/noord1.html
http://www.school-for-champions.com/science/gravitation_influence_in_universe.htm#.Vlmkv3YrLDc
http://www.theguardian.com/science/2010/sep/02/stephen-hawking-big-bang-creator

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ii. Formation and evolution of stars

The majority of the stars were formed between two to six billion years after the Big Bang. New stars are still forming in the galaxies across the universe. Stars form inside the relatively dense concentrations of interstellar gas and dust known as *molecular clouds*. These regions are at extremely cold temperature about 10K to 20K, just above absolute zero. At these temperatures, the atoms of gas and dust bind together. The extreme cold temperatures also increase the gas densities.

Figure 6.7: Hubble Space Telescope view of a distant cluster of galaxies near the beginning of time. (Source:AURA/STScI)

Since the regions are dense, they are opaque to visible light and are known as *dark nebula*. Star formation begins when the denser parts of the cloud core collapse under their own gravity. The cores are denser than the outer cloud, so they collapse first. As the cores collapse they fragment into clumps. Once a clump has broken free from the other parts of the cloud core, it has its own unique gravity and identity and

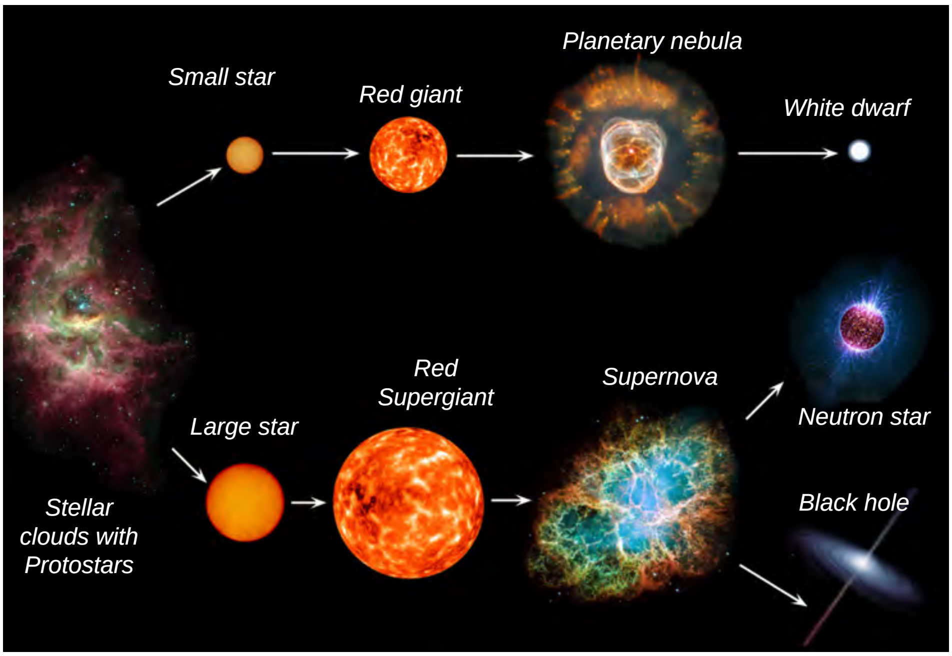

Figure 6.8 Evolution of stars

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we call it a *protostar* and the whole process takes about 10 millions years.

The protostar, at first, only has about 1% of its final mass. After a few million years, thermonuclear fusion begins in its core, and the protostar now becomes a young star since its mass is fixed, and its future evolution is now set.

Often in galaxies clusters of young stars are found near other young stars. This phenomenon is called supernova induced star formation. The very massive stars form in the beginning and then explode into supernova. A supernova is a catastrophic explosion in which a star ejects most of its mass. While the causes for a star to explode is still unknown, it is assumed that it is a gravitational collapse. This makes shock waves into the molecular cloud, causing nearby gas to compress and form more stars. This allows a type of stellar coherence (young stars are found near other young stars) to build up, and is responsible for the pinwheel patterns we see in galaxies.

iii. Formation of Solar System

Planet Earth is held in its orbit around the Sun by the gravitational force. Without gravity, Earth would fly off into outer space and we would fly off the Earth. Massive objects exert a greater gravitational pull than less massive objects. Compared to the Earth, the Sun is vast. If the Sun was the size of a basketball, Earth would be the size of the head of a pin. One million Earths could fit inside the Sun. The Sun has a great mass, thus it exerts a very powerful gravitational pull on the Earth and on the other planets in the solar system. This pull keeps the planets in their orbits. The magnitude of the Sun's gravitational pull depends on the distance between it and the planet, and on the mass of the planet. It pulls closer planets more strongly than distant planets and it pulls massive planets more than small planets. Orbits are not usually perfect circles and most planets travel in an elliptical orbit around the Sun.

Activity 6.1 Analyse the formation of the planets

Procedure

Step 1 ☞ Read the text on the formation of our solar system.

Step 2 ☞ Describe the formation of the Solar System by drawing the time line and the brief description of the evolution stages.

Step 3 ☞ Write down the aspects of the nebula theory that you do not agree with. Give the possible alternate explanations.

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Our Solar System

Figure 6.9 The Orion Nebula

The most widely accepted model for the origin of the Solar System is called the nebula theory which states that the Solar System condensed from a large, lumpy cloud of cold gas and dust. Extensive observations since then have confirmed that the nebula theory is the best explanation for the origin of the Solar System. According to the nebula hypothesis, the Solar System began as a nebula, an area in the Milky Way Galaxy that was a swirling concentration of cold gas and dust. Due to some disturbance, possibly from a nearby supernova, this cloud of gas and dust began to condense, or pull together under the force of its own gravity. Condensation was slow at first, but its pace increased as more material was drawn toward the center of the nebula. This made gravity stronger, making condensation faster.

The nebula also began to spin counterclockwise, as it conserved the angular momentum of the material drawn toward the center. This spinning made the material around the center of the condensing nebula flatten out into a disk-like shape. The center of the nebula continued to contract due to gravity. Eventually, pressure and temperatures in this mass became high enough that nuclear fusion started. The central mass became a star, the Sun.

While this was happening, condensation was also occurring in the disk. Gas and dust came together to make tiny particles, which gradually joined with other particles, making larger and larger objects. These objects grew to be several hundred kilometers in diameter; they became protoplanets. The protoplanets had much stronger gravity than the very small particles of gas and dust around them. The accretion process began to attract the small particles around them. Protoplanets also collided from time to time. These phenomenon formed the planets of the Solar System.

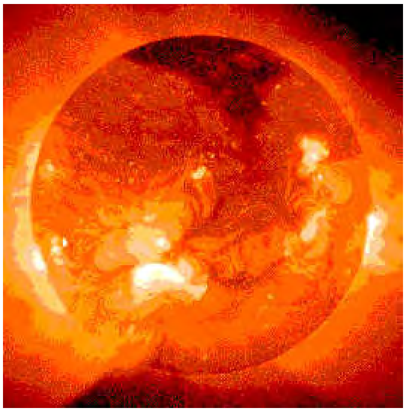

Figure 6.10 The Sun formed from material that condensed in the center of the spinning disk.

The protoplanets revolve around the newly evolved Sun. In addition, the protoplanets, and the planets, as they formed, began to rotate, or spin on an internal axis. This took place as some of the force from collisions was converted into rotational energy.

The force of gravity is responsible for the three dimensional global spherical shapes of planets. This is due to a natural attribute of gravity that acts as if it

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originates from the center of a planet and pulls all of the planet's mass towards its center in a spherical pattern. The greater the mass of the planet, the greater the force of gravity.

The planets were very hot in the beginning. Slowly the planets began to lose heat by conduction, convection, eruption and radiation. The smaller planets lost the heat and cooled faster and crust of solid rock formed on the surface. The largest planets like Jupiter still retain much of their primordial heat of its formation.

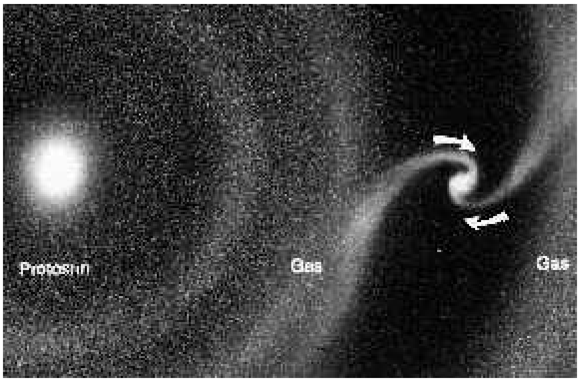

Figure 6.11 The planets formed from gas and dust in the disk

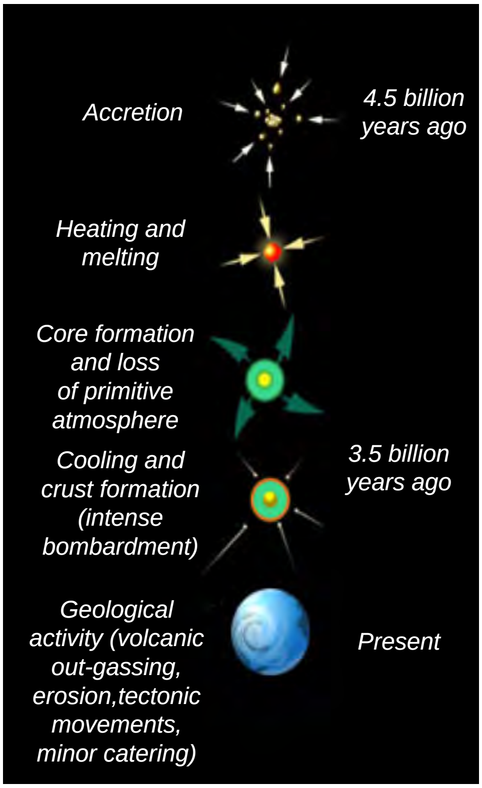

Figure 6.12 Planetary formation

The large moons of the gas giant planets (Jupiter, Saturn, Uranus, and Neptune) formed in a similar fashion to the planets. The small are probably leftover debris from formation of the planets that were captured by their respective planets' gravity. The Earth's Moon probably formed a third way, from a collision between the Earth and a large protoplanet.

The Solar System has continued to evolve since its formation. It is likely that the orbits of the planets were originally more oval-shaped, and have changed to their current nearly circular shapes with time. The number of moons around some planets has increased through gravitational capture and collisions. The strength of the Sun (the amount of solar radiation emitted) has also likely changed.

In addition, each of the planets has evolved as well. The evolution of life on Earth has radically changed the composition of the Earth's atmosphere and oceans. It has also greatly modified how rocks are weathered and eroded, and how elements cycle through the hydrosphere and lithosphere. Each of the other planets has its own story of evolution.

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Answer the following questions:

1. Go to library and find out at least one theory, other than nebula theory, that suggests the formation of our solar system. Share your findings in the class.
2. Gather different stories your elders have to say in the formation of solar system.

Questions

1. How did the universe begin?
2. What happened during the Big Bang?
3. How do the stars evolve?
4. What are some of the problems with the 'Big Bang' hypothesis?

https://www.youtube.com/watch?v=GaAVc46dK8o
https://www.spacetelescope.org/science/formation_of_stars/
https://www.youtube.com/watch?v=_mcC8kFacrk

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2. Evolution of Stars and Galaxies

Learning Objectives

On completion of this topic, you should be able to:

- describe cosmic microwave background and redshift that explain the origin and evolution of the universe.
- describe the search for evidence of life elsewhere in the universe.

The Big Bang created universe and emitted all the types of invisible radiations and visible light. Every moment throughout our universe, light is bursting from stars, bouncing off planets, diving into black holes, wandering into nebulae, and generally going everywhere. However, only a little amount of radiation actually reaches the Earth.

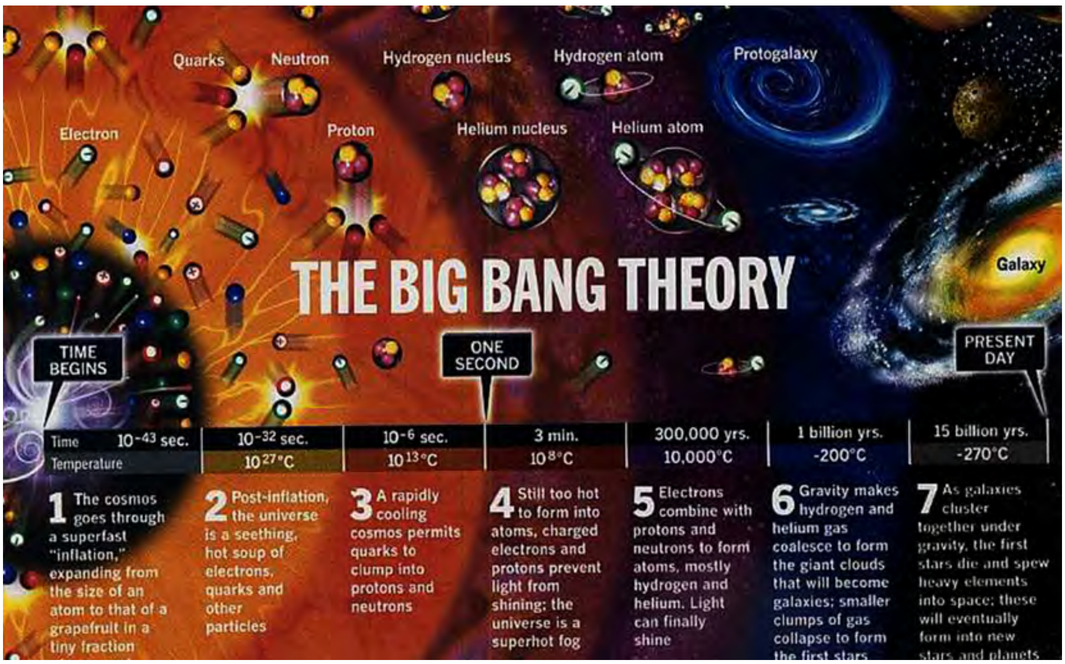

Figure 6.13 The Big Bang

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A. Cosmic Microwave Background and Redshift

Cosmic Microwave Background (CMB) is the thermal radiation that was created shortly after the universe came into being in the Big Bang. CMB fills the universe but is invisible to the naked eye. The CMB is the earliest radiation that can be detected.

When the universe was young, before the formation of stars and planets, it was denser, much hotter, and filled with a uniform glow from a white-hot fog of hydrogen plasma. Photons could not travel freely, so no light escaped into the space. As the universe expanded, both the plasma and the radiation filling it grew cooler. When the universe cooled enough, protons and electrons combined to form neutral atoms. These atoms could no longer absorb the thermal radiation, and so the universe became transparent instead of being an opaque fog. Cosmologists refer to the time period when neutral atoms first formed as the recombination epoch and shortly afterwards the photons started to travel freely through space.

Since light travels at a finite speed, astronomers observing distant objects are looking into the past. Most of the stars that are visible to the naked eye in the night sky are 10 to 100 light years away (1 light year = 9.46 x 1012 kilometers). Thus, we see them as they were 10 to 100 years ago. We observe Andromeda, the nearest big galaxy, as it was about 2.5 million years ago. Astronomers observing distant galaxies with the Hubble Space Telescope can see them as they were only a few billion years after the

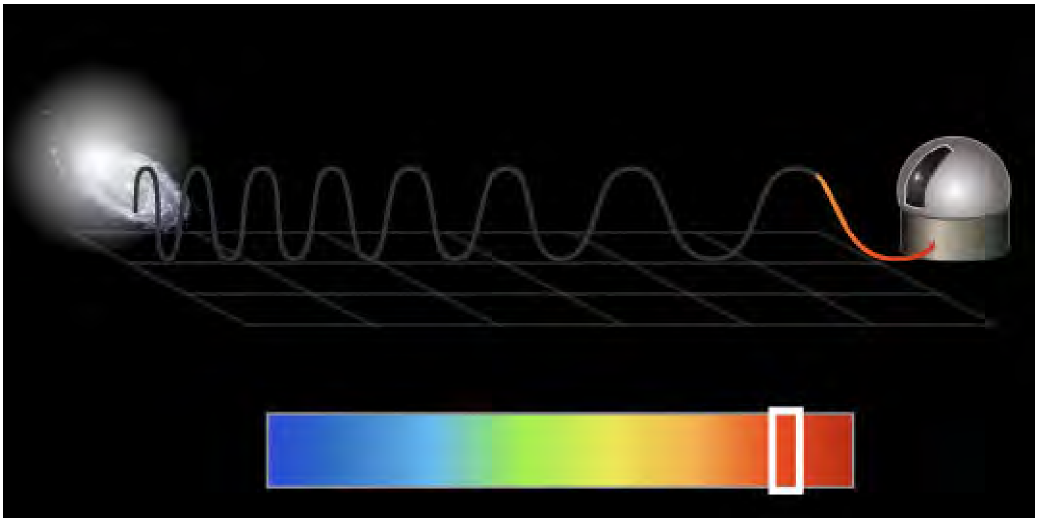

Figure 6.14 CMB radiation

Big Bang.

The CMB radiation was emitted 13.7 billion years ago, only a few hundred thousand years after the Big Bang, long before stars or galaxies ever existed. Thus, by studying

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the detailed physical properties of the radiation, we can learn about conditions in the universe on very large scales at very early times, since the radiation we see today has traveled over such a large distance.

Precise measurements of the CMB are critical to cosmology, since any proposed model of the universe must explain this radiation. Most cosmologists consider the Big Bang model of the universe to be the best explanation for the CMB.

Supernovae are explosions caused when massive stars collapse under their own gravity. The light produced from these explosions can outshine a whole galaxy for several weeks or months. The study of light emitted by a star in the universe

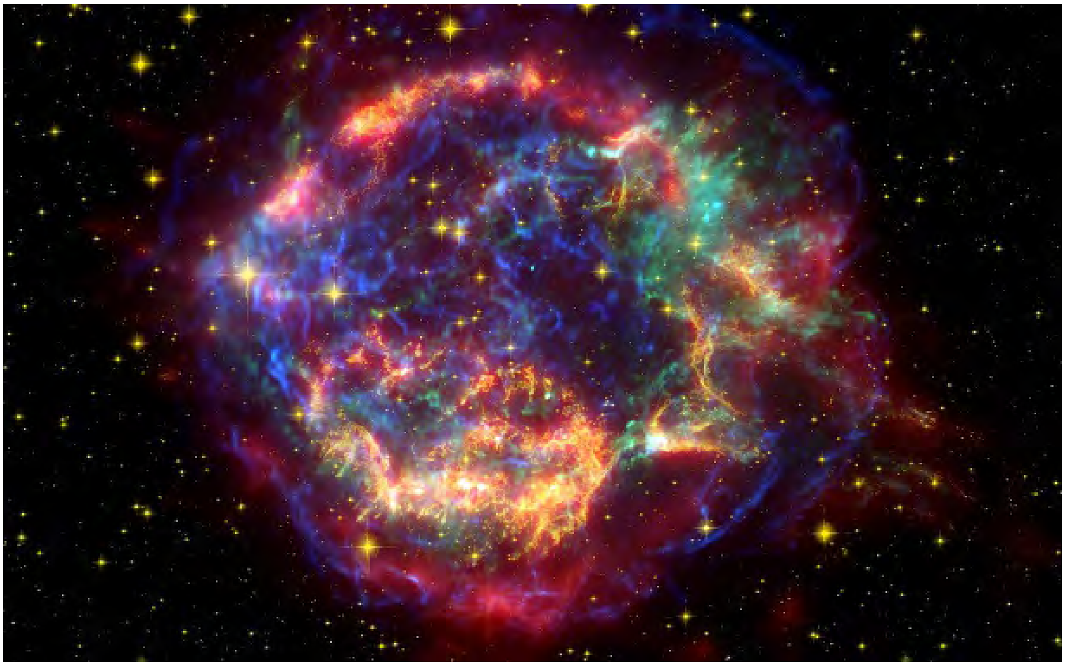

Figure 6.15 Images obtained by the Hubble Space Telescope of three stars- each went supernova independent of one another, deep space between galaxies

is another important field of study to measure the status of our universe and its evolution.

Visible light is a spectrum of seven colours, which is clearly evident in a rainbow. When an object moves away from us, the light is shifted to the red end of the spectrum or redshifted, as its wavelengths get longer. This phenomenon is called *cosmological redshift*. If an object moves closer, the light moves to the blue end of the spectrum or blueshifted, as its wavelengths get shorter. Surprisingly, the light from the galaxies throughout the universe are almost all redshifted. This indicates that the galaxies are moving away from us. The galaxies far away are more redshifted

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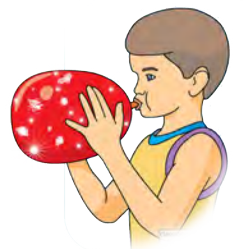
than the closer ones. This is the key to the concept that the universe is expanding.

Activity 6.2 Demonstrate expanding universe

A common analogy used to model the Universe is the balloon model. Stickers stuck on the surface of a balloon represent galaxies in our Universe and the balloon itself represents space. When the balloon is blown up, it simulates how space between the galaxies is thought to be expanding. (Note that the galaxies are not all on the outside of the Universe as the balloon analogy suggests.)



Materials required:

Big balloons, white or coloured circular stickers, marker pen, string and ruler.

Procedure

Step 1 Draw and label galaxies of different shapes and sizes on separate stickers.

Step 2 Blow up the balloon to a diameter of about 20 cm, and stick the galaxy stickers all over the balloon

Step 3 Shrink the balloon to about 10 cm and draw a wave of light connecting the two galaxies.

Step 4 Use the string and ruler to measure the distances between the labelled galaxies.

Step 5 Blow the balloon up fully and measure the new distances between the galaxies.

Step 6 Tabulate your results for easy comparison.

Answer the following questions.

1. What happened to the physical distance between two points on your balloon?
2. What happened to the wavelength of their light wave?
3. Explain redshift and expanding universe with the help your balloon model.

http://skyserver.sdss.org/dr1/en/astro/universe/universe.asp
https://www.aip.org/history/cosmology/ideas/expanding.htm
https://www.youtube.com/watch?v=YJJK9x1Ffhw

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Activity 6.3 Simulating the Big Bang using ICT

The previous activity used a very simplistic model to illustrate the Big Bang theory. Today's technology allows us to use far more sophisticated models simply by accessing the Internet.

Materials required:

Access to the Internet, note book and a computer.

Procedure

Step 1 ☞ Use a suitable search engine to find a Big Bang simulation.

Step 2 ☞ Select a simulation that makes the concept of Big Bang easier for you to understand and present your simulations in your class to explain the Big Bang.

Step 3 ☞ Some sites to get you started:

http://users.telenet.be/nicvroom/progrm18.htm

http://faculty.washington.edu/jcramer/BBSound.html

http://www.meta-library.net/media/bbang-body.html

http://news.bbc.co.uk/1/hi/sci/tech/4600981.stm

http://www.allaboutscience.org/big-bang-theory-video.htm

http://hubblesite.org/education_and_museums/

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B. Evidence of life elsewhere in the universe

Astronomers have confirmed the existence of more than 1,700 planets beyond the solar system, and may soon prove the existence of thousands more of such exoplanets. They are positive to discover world that resemble Earth to some degree. But this raises the question of whether or not such exoplanets could support life and what kind of life might live there.

To understand whether life might exist on alien worlds, scientists should evaluate both the requirements for life on Earth and the limits of life on Earth. Our information about life is limited to one planet, the Earth and the scientific understanding of the requirements for life has not changed in many years, while thoughts on the limits of life have altered significantly in the past few decades.

Figure 6.16 Artistic representation of the exploration of Mars for existence of life

To investigate the limits of life on Earth, researchers look at extremophiles, organisms that have adapted to live in environmental extremes, such as extremes of heat, cold and radiation. The highest temperature at which scientists know life can live has increased significantly, from 176 degrees F (80^0C) to a 251 degrees F (122^0C), or well above boiling point of water. Recently, investigators also discovered microbes can live in temperatures as cold as 5^0F (minus 15^0C), or well below freezing point.

Therefore, it is understood that the habitable planet should have:

- *a stable temperature environment provided by an energy source external to the life forms such as the star.*
- *a liquid water for biochemical reactions.*
- *the essential building block elements like carbon, hydrogen, nitrogen, oxygen, phosphorus, sulphur, and transition metals like iron, chromium, and nickel. Carbon is the base of life because of its great versatility to form compounds with other elements and even with itself.*
- *a solid surface to concentrate the building block elements together.*
- *have enough gravity to keep an atmosphere to exist on the surface.*
- *a relatively large moon nearby to keep the planet's rotation axis from tilting too much and too quickly which prevents large differences in temperatures over short timescales. Life needs sufficient time to adapt to temperature changes.*
- *Plate tectonics that may be needed to:*

  1) regulate the surface temperature of the planet via its crucial role in the carbon cycle;

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2) create a magnetic field to shield the planet from the deadly stellar winds;

3) create dry land on a water-covered world; and

4) promote a high level of biodiversity across the planet by creating new environments that organisms would have to adapt to.

However, the possibilities of life on planets or moons without an atmosphere is not ruled out. It may be possible to have life existing below the surface if the planet or moon have a planetary heating source. An example of this would be Jupiter's moon Europa. It has a water ice crust and a liquid water ocean below and is kept warm despite its great distance from the Sun because of tidal heating from Jupiter's large gravity.

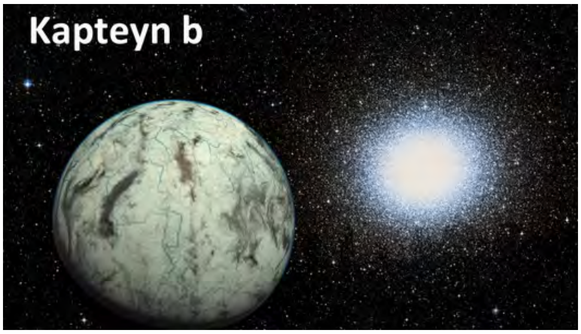

Figure 6.17 Artistic representation of the potentially habitable world Kapteyn b with the globular cluster Omega Centauri in the background.

The discovery of existence of methane lakes and rivers on Titan (the largest of the satellites of Saturn) in our solar system compels us to consider life that could use liquid methane as the solvent to mix the organic chemicals about in its biochemistry. The methane-based life would have a ready supply of food from the acetylene and ethane raining down to the surface as a result of the photochemistry of ultraviolet light in sunlight breaking apart the methane vapour in Titan's atmosphere. Titan life would need to develop special enzymes to extract oxygen from the water-ice rocks but the other essential elements such as carbon, hydrogen, and nitrogen would be easy to come by in the environment of Titan's surface.

While it may be possible for life to exist on a planet or moon below its surface, we will not be able to detect its presence from a great distance away like in another star system beyond our solar system. In our fastest rocket-propelled spacecraft, it would take us over 70,000 years to travel to the next star system (Alpha Centauri). By analyzing the spectrum of the planet's atmosphere, we may be able to detect spectral signatures, called **bio-markers,** of certain compounds in certain proportions that could not be produced by non-biological processes.

The detection of spectral lines from water would say that a planet has a vital ingredient for life, but it does not mean that life is present. If oxygen, particularly ozone is found in the atmosphere, then it would be very likely that life is indeed on the planet.

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Hunting for evidence of alien life is a much trickier proposition than identifying potentially habitable environments. But researchers are working steadily toward that more involved and ambitious goal. These are the following developments in the exploration of evidence of life elsewhere in the universe.

- *NASA's next Mars rover is scheduled to launch in 2020, will search for signs of past life and collect samples for a possible return to Earth for analysis. NASA also aims to land astronauts on Mars in the 2030s, a key to the search for Mars life.*
- *NASA's James Webb Space Telescope (JWST) scheduled to launch in 2018, will scope out the atmospheres of nearby "super-Earth" alien planets, looking for gases that may have been produced by life.*
- *NASA's potential Wide-Field Infrared Survey Telescope, which may launch in the mid-2020s if given the official go-ahead, would include a coronagraph for exoplanet observations.*

We have no direct evidence yet, that there is life on other planets, moons, or in interstellar space. Nevertheless, there are some compelling reasons to believe that eventually we will discover some, or even in our own solar system.

Questions

Carry out the following laboratory work in the computer Laboratory. Follow the directions carefully as stated in the following worksheet. Answer the questions given in the worksheet.

Work Sheet: My Solar System

1. Go to: http://phet.colorado.edu/new/simulations/
2. Click the Motion menu item and start the applet "My Solar System."
3. Move the slider all the way to accurate, click on the tape measure and the grid.
4. Click the radio button for 3 objects and run the simulation until the purple planet (body 2) has made one complete revolution (one year).
5. After the first orbit (year), turn off the traces (show traces box) and watch another orbit (year) of the purple planet (body 2).

Question 1 . Is blue moon (body 3) circling the yellow sun (body 1) or the purple planet (body 2)? Explain your answer.

____

____

6. Increase the mass of the sun (body 1) to 400 and allow the simulation to run for one complete orbit of the purple planet (body 2).
7. Decrease the mass of the sun (body 1) to 175 and allow the simulation to run for one complete orbit of the purple planet (body 2). (~90 seconds)

Question 2 . How do the orbits of the planets change when the mass of the sun is increased or decreased? Why? Explain your answer.

Question 3 . Why does the sun (body 1) follow a circular path? How does the path change as its mass changes? Why? Explain your answer.

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http://www.esa.int/Our_Activities/Human_Spaceflight/Exploration/Life_in_the_Universe_-_Is_anybody_out_there
http://www.windows2universe.org/cool_stuff/tour_search_ET_life_1.html
http://www.astrobio.net/topic/deep-space/

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Summary

- Law of universal gravitation describes the relationships between gravitational force, mass, and distance.
- The magnitude of the gravitational force depends on the masses of the bodies and the distance between the bodies.
- The mass of an object which gives rise to its gravitational force of attraction on other objects is gravitational mass.
- A body in motion possesses inertial mass which describes an object's resistance to change in velocity.
- The value of acceleration due to gravity of Earth is 9.78039 ms^{-2} at the equator and 9.83217 ms^{-2} at the poles.
- Expanding universe means that it has been growing ever since its beginning with the Big Bang.
- The universe encompasses everything in existence, from the smallest atom to the largest galaxy.
- The universe has no center; everything is moving away from everything else.
- Stars form inside the relatively dense concentrations of interstellar gas and dust known as molecular clouds.
- Supernova is a catastrophic explosion in which a star ejects most of its mass.
- Orbits are not usually perfect circles and most planets travel in an elliptical orbit around the Sun.
- When the universe was young, before the formation of stars and planets, it was denser, much hotter, and filled with a uniform glow from a white-hot fog of hydrogen plasma.
- Cosmic Microwave Background (CMB) is the thermal radiation that fills the universe that was created shortly after the universe came into being in the Big Bang.
- When an object moves away from us, the light is shifted to the red end of the spectrum or redshifted, as its wavelengths get longer. This phenomenon is called cosmological redshift.
- To understand whether life might exist on alien worlds, scientists should evaluate both the requirements for life on Earth and the limits of life on Earth.
- We have no direct evidence yet that there is life on other planets, moons, or in interstellar space.

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Exercises

I. Fill in the blanks.

1. The cosmic microwave background radiation comes from ....
2. Our Sun is just one of many millions of stars in a group of stars called ....
3. The unit of measurement of gravitational constant is....................
4. Theories of the origin of the universe have to take into account that light from other galaxies is shifted to the .... end of the spectrum.
5. If the radius of the Earth were to shrink and its mass were to remain the same, the acceleration due to gravity on the surface of the earth will ....

II. Match the following.

Column A	Column B
1. Supernova	A. expanding universe
2. Redshift	B. unit of universe
3. Dark nebula.	C. contains 1% of mass
4. Milky Way	D. opaque to visible light
5. Protostar	E. throws dust and gas into space
	F. is an exploded star

III. Multiple Choice Questions.

1. An astronaut weighs 8.00 x10^2 newton on the surface of Earth. What is the weight of the astronaut 6.37 x10^6 meters above the surface of Earth?

   A 8.00 x10^2 N

   B 1.60 x10^3 N

   C 2.00 x10^2 N

   D 3.20 x10^3 N

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2. Which of the following statements about the Moon are true?

   I   The Moon is the Earth's natural satellite.

   II   We can see a full Moon every night.

   III There is no oxygen to support life on Moon.

   IV The Moon is twice the size of the Earth.

   A   I and III

   B   II and IV

   C   I, II, and III

   D   II, III and IV

3. If the Sun's gravity were to suddenly turn off, the Earth would move

   A   in a perfect circle around the Sun.

   B   in a straight line at constant speed, in whichever direction it happened to be headed at that instant.

   C   at a constant speed in a straight line, directly away from the Sun.

   D   away from the Sun in a spiral motion.

4. Which planet besides the earth has evidence of erosion by running water?

   A   Mars

   B   Neptune

   C   Uranus

   D   Venus

5. Modern cosmology supposes that the Universe came from a "Big Bang" event about 13 billion years ago. Evidence for this is

   A   the uniformity of the abundance of hydrogen and helium.

   B   the cosmic background radiation.

   C   the pictures from Hubble telescope.

   D   the Solar system.

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6. The Sun derives its energy from

   A chemical reactions that convert hydrogen and oxygen into carbon, accompanied by the release of neutrinos.

   B the fusion of hydrogen into helium.

   C the conversion of energy into mass.

   D a steady gravitational contraction of its core.

7. Cosmological redshift is the result of the

   A expansion of the universe.

   B supermassive black holes.

   C galaxies speeding away from us.

   D contraction of universe

8. Why is the cosmic background radiation so cool?

   A Interstellar dust grains absorbs and cools it.

   B We are moving through it so fast it just looks cool.

   C The expansion of the Universe has lengthened its wavelength.

   D It is emitted by cool stars.

9. According to Newton's law of gravitation, if the distance between two masses is doubled, the gravitational force between them

   A decreases by a factor of two.

   B decreases by a factor of four.

   C increases by a factor of two.

   D increases by a factor of four.

10. Which of the following is true of our solar system?

   A Not all known planets orbit in the same direction around the sun.

   B Not all planets spin in the same direction as they orbit.

   C It has an equal number of stars and planets.

   D There is no evidence for liquid water having ever existed on any planet other than Earth.

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IV. State 'True' or 'False'. Rewrite the false statements correctly.

1. During the formation of stars smaller masses may also form and be attracted by a larger mass to become planets.
2. The Sun is at an unbalanced stage of its life.
3. The evidence suggests that the solar system was formed from the material produced when earlier stars exploded.
4. The Big Bang predicts that one in four atoms in the universe is helium.
5. The observed composition of ordinary matter in the universe–roughly 75 % hydrogen and 25% helium–closely matches theoretical predictions based on the Big Bang model.

V. Answer the following questions.

1. How does the Cosmic Microwave Background (CMB) Radiation prove the big bang?
2. Can the big bang explain the origin of galaxies? Justify.
3. Is Earth at the centre of the Universe? Why?
4. What are red-shifts and how do they really support the 'big bang' evolutionary idea for the origin of the Universe?
5. What is meant by the microwave observations of the cosmic background radiation revealing the "genetic code" of the universe?
6. What are the two key observational facts that led to widespread acceptance of the Big Bang model?
7. What is the gravitational force of attraction between two people, one of mass 80 kg and the other 100 kg if they are 0.5 m apart?
8. What are the two possible fates of the Universe in the Big Bang model? What is the main factor that will determine which of the two will ultimately occur?
9. Describe briefly the currently accepted theory of the origin of the Solar System.
10. Describe the two main stages that our Sun will go through as it burns out.
11. Explain the evolution of stars.

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12. What is the force of attraction between the Earth and the Sun? Given that Mass of the Sun = 2×10^{30} kg, mass of the Earth = 6×10^{24} kg, distance from the Earth to the Sun = 1.5×10^{11} m.

13. How did our solar system form?

14. The American space agency, NASA, plans to send a manned mission to Mars later this century. Mars has a mass 6.42×10^{23} kg and a radius 3.38×10^{6} m. $G = 6.67 \times 10^{11}$ N m^2 kg^{-2}.

    a) The mass of a typical astronaut plus spacesuit is 80 kg. What would be the gravitational force acting on such an astronaut standing on the surface of Mars?

    b) State whether an astronaut on Mars would feel lighter or heavier than on Earth.

15. Explain the formation of planets.

16. Describe briefly the possibilities of life elsewhere in universe.

17. Explain the law of universal gravitation.

18. Communication satellites orbit the Earth at a height of 36,000 km. How far is this from the centre of the Earth? If such a satellite has a mass of 250 kg, what is the force of attraction on it by the Earth?

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Specimen Question Paper

Physics **Writing Time**: 2 Hours
Class X **Total Marks**: 100

READ THE FOLLOWING DIRECTIONS CAREFULLY:

1. Do not write during the first fifteen minutes. This time is to be spent on reading the questions. After having read the questions, you will be given two hours to answer all questions.
2. In this paper, there are two sections: A and B. Section A is compulsory. You are expected to attempt any five questions from Section B.
3. The intended marks for questions or parts of questions, are given in brackets [ ].
4. Read the directions to each question carefully and write all your answers in the answer sheet provided separately.

Section A (50 Marks)
Compulsory: Attempt **all** *questions.*

Question I

a. *Each question in this section is provided with four possible options. Choose the most appropriate option.* [1×25=25]

i. Pair of forces that makes a water tap to open or close is called
   A. couple.
   B. friction.
   C. normal force.
   D. weight.

ii. The amount of pressure of liquid increases with
   A. volume of liquid.
   B. surface area of liquid.
   C. mass of liquid.
   D. depth in the liquid.

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iii. A rock climber weighs 500 N and is carrying a backpack that weighs 40 N. How much work has to be done to climb10 m?

A. 50 J

B. 500 J

C. 540 J

D. 5400 J

iv. Voltage can be induced in a circuit when the number of magnetic field lines passing through the circuit changes. This induced voltage exists in the circuit as long as a

A. magnet continues to move near a coil.

B. magnet and a coil continue to move together.

C. magnet and coil are kept close to each other.

D. coil is placed in a strong magnetic field.

v. X-rays and infrared waves are both electromagnetic waves. Which of the following describes another property shared by X-ray and infrared waves?

A. Both waves are longitudinal.

B. Both waves have the same frequency.

C. Both waves have the same wavelength.

D. Both waves travel at the same speed in vacuum.

vi. The distance of the star Vega from Earth is 1.6 million times the distance of the Sun from the Earth. Which of the following best describes the gravitational influence of Vega on Earth?

A. It is roughly equal to that of the Sun.

B. Its influence is greater than that of the Sun.

C. Its influence is small because of its distance.

D. It influences the magnitude of Earth's mass.

vii. When the net force acting on a droplet of water becomes zero, then it falls with

A. final velocity.

B. initial velocity.

C. terminal velocity.

D. zero velocity.

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viii. A hydraulic machine multiplies

A. energy.

B. power.

C. force.

D. work.

ix. The motor of one car is more powerful than the motor of another car. Which of the following must be true of the more powerful motor?

A. It can do work more quickly.

B. It can operate for a longer time.

C. It can burn fuel more efficiently.

D. It can store more potential energy.

x. The following statements describes the induced voltage in a generator:

I. The magnitude of induced voltage depends upon speed of rotation of the armature coil.

II. The direction of induced voltage depends upon the number of turns of the armature coil.

III. The direction of induced voltage depends upon strength of magnetic field.

IV. The magnitude of induced voltage depends upon number of turns of the armature coil.

Which of the above statements are TRUE for a generator?

A. I and II.

B. II and III.

C. III and IV.

D. I and IV.

xi. Suppose a scientist detects an electromagnetic wave with a frequency higher than those of gamma rays. The scientist labels this wave as Z-ray. Which of the following would always be true of a Z-ray?

A. Z-ray would have a lesser amplitude than gamma rays.

B. Z-ray would have a greater amplitude than gamma rays.

C. Z-ray would have a shorter wavelength than gamma rays.

D. Z-ray would have a longer wavelength than gamma rays.

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xii. Cosmological redshift is the result of the
- A. expansion of the universe.
- B. supermassive black holes.
- C. galaxies speeding away from us.
- D. contraction of universe.

xiii. Lhendup applies a force of 5 N on a handle that is about 0.6 m away from the hinge of window. The moment of force will be
- A. 3.0 Nm.
- B. 4.4 Nm.
- C. 5.6 Nm.
- D. 8.3 Nm.

xiv. A rock at the top of a hill is released and rolls down the hill. Which of the following describes the energy of the rock just as it reaches the bottom of the hill?
- A. The rock has no energy.
- B. The rock has maximum kinetic energy.
- C. The rock has maximum potential energy.
- D. The rock has equal potential energy and kinetic energy.

xv. When the length of a conductor is halved by keeping its thickness same, its resistance changes to
- A. one-fourth of its initial value.
- B. half of its initial value.
- C. two times its initial value.
- D. four times its initial value.

xvi. Given that both liquid X and liquid Y exert the same amount of pressure, what would be the height of column of liquid X if the density of liquid X is twice the density of liquid Y and the height of column of liquid Y is 5 cm?
- A. 2.5 cm
- B. 5 cm
- C. 10 cm
- D. 20 cm

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xvii. When an analogue signal undergoes amplitude modulation (AM),then

A. only its amplitude is changed.

B. only its frequency is changed.

C. both its amplitude and frequency are changed.

D. both its amplitude and frequency remain unchanged.

xviii. Why is the cosmic background radiation so cool?

A. It is emitted by cool stars.

B. Interstellar dust grains absorb and cool it.

C. We are moving through it so fast it just looks cool.

D. The expansion of the Universe has lengthened its wavelength.

xix. A body in motion is said to be in equilibrium when it is

A. moving with uniform velocity.

B. at rest.

C. accelerated by a force.

D. moving in an indefinite path.

xx. The two resistors shown in Figure 1.1 are connected to identical power sources. Resistor 1 has a resistance of 3 Ω, and resistor 2 has a resistance of 5 Ω. The current in resistor 1 is 0.2 A. What is the current in resistor 2?

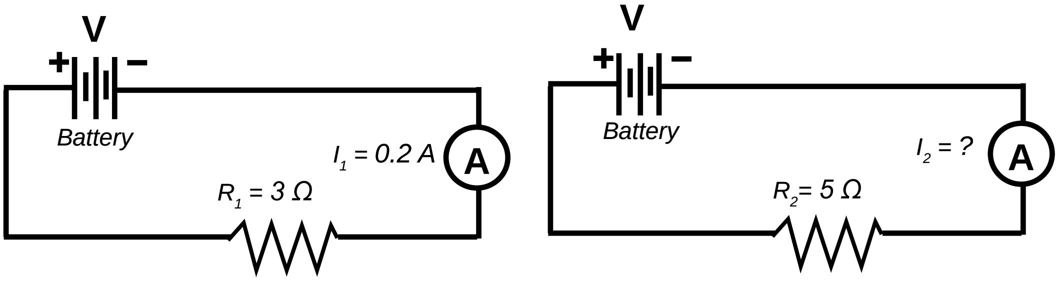

Figure 1.1

A. 0.6 A

B. 0.3 A

C. 0.2 A

D. 0.1 A

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xxi. Radio waves are used to broadcast television and radio programs. A radio program receiver need not be in line of sight with the transmitter because radio waves are

A. diffracted.

B. refracted.

C. reflected.

D. absorbed.

xxii. Which planet besides the earth has evidence of erosion by running water?

A. Mars

B. Neptune

C. Uranus

D. Venus

xxiii. Biomass used in open-air stoves is a concern because it

A. consumes more energy.

B. emits air pollutants.

C. is low in sulphur content.

D. is a fossil fuel.

xxiv. The amount of heat produced in an electric iron is directly proportional to the ________________ current passing through the coil inside it.

A. magnitude of

B. square root of magnitude of

C. square of magnitude of

D. cube of magnitude of

xxv. The graph given in Figure 1.2 shows a relationship between the work done by a student and the time taken for him to climb a flight of stairs. The unit of the slope of the graph will be

A. joule.

B. newton.

C. second.

D. watt.

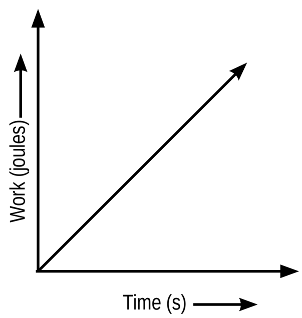

Figure 1.2

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b. *Match each item under Column A with the most appropriate item in Column B. Rewrite the correct matching pairs in the answer sheet provided.* [5]

Column A	Column B
1. Plumb line	a. Variable resistance
2. LED bulb	b. Exploded star
3. LDR	c. contains 1% of mass
4. Radio waves	d. Energy efficient
5. Protostar	e. Line of centre of gravity
	f. CT scans
	g. MRI
	h. Fixed resistance
	i. Line of buoyancy

j. *Fill in the blanks by writing suitable word(s).* [5]

i. The increase in ………….. due to liquid will decrease the apparent weight of a body.

ii. The combustion of fossil fuels results in …………………........

iii. The potential difference between the terminals of a cell in closed circuit is………….. than that in open circuit.

iv. A type of wireless communication used to exchange data between electronic devices within a distance of about 10 m is called ………………………..

v. The cosmic microwave background radiation comes from ....

k. ***State whether the following statements are 'True' or 'False' and correct the false statements:*** [5]

i. The centre of gravity of objects will be always on the body itself.

ii. A resistive force accelerates a moving body.

iii. The current-voltage graph for a diode is a linear graph as it obeys Ohm's law.

iv. The wave used in airports for scanning luggage is microwave.

v. Nebula is a catastrophic explosion in which a star ejects most of its mass.

l. *Answer the following questions:*

i. Define equilibrant. [1]

ii. What is the use of a transformer? [1]

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iii. What is the gravitational force of attraction between two people, one of mass 50 kg and the other 70 kg if they are 1.5 m apart? [2]

iv. Why is the efficiency of machines always less than 100%? [2]

v. State Pascal's law. [1]

vi. Mention two renewable sources of energy. [1]

vii. A 220 V geyser has a resistance of 1500 Ω. How much current does it draw? [2]

SECTION B (50 Marks)

*Attempt only **five** questions.*

Question 2

a. State the factors affecting the magnitude of pressure on a surface due to a solid.[2]

b. Locate the centre of gravity for the following lamina: [2]

(a) (b)

c. A tank is filled with water to a height of 2 m. Calculate the pressure exerted at the bottom of the tank by the water. (Density of water = 1000 kg/m^3, Acceleration due to gravity = 9.8 m/s^2). [2]

d. Is Ohm's law obeyed by all types of conductors? Give examples to support your answer. [2]

e. Heating effect of current is not always useful for us. Support your answer with an example. [2]

Question 3

a. Define torque of a couple. [1]

b. Why would you advice a person to sit rather than stand in a moving bus? [2]

c. A 10 kg model airplane flies horizontally at a constant speed. If the plane suddenly dives from its altitude of 40 m and levels off at 20 m, how much potential energy

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does it lose in the dive? [3]

d. Draw a labeled diagram of an a.c. generator. [2]

e. How does the Cosmic Microwave Background (CMB) Radiation prove the big bang? [2]

Question 4

a. State the principle of moment. [1]

b. Figure 1.3 given below shows two boys Tenzin and Nima on a seesaw. Tenzin of weight 350 N is sitting on the left side of the seesaw, 1.5 m away from the pivot and Nima of weight 300 N is sitting on the right hand side, 2.5 m away from the pivot. [2½]

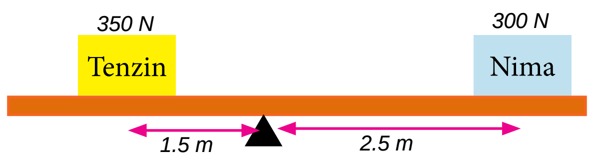

Figure 1.3

i. Who will turn the seesaw clockwise?

ii. What is the clockwise moment?

iii. What is the counter clockwise moment?

c. Why is a.c. preferred over d.c. in long distance transmission of electricity?[2]

d. Identify the type of electromagnetic radiations used in the following situations: [1½]

i. Switching on television with the help of a remote.

ii. Making international calls.

iii. Tanning of skin in the sun.

e. Can the big bang explain the origin of galaxies? Justify. [3]

Question 5

a. Telecom companies are trying to improve the quality of telecommunication services by replacing copper cables with optical fibres. What are the advantages of using optical fibres compared to copper cables? [2]

b. Why is it easier to cut vegetables with a sharp knife than with a blunt one?[2]

c. In the main sub-station, a transformer has 500 turns in the primary coil and 100

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turns in the secondary coil. If the voltage across the primary coil is 132 kV, what is the voltage across the secondary coil? [2]

d. Is solar energy feasible for large power generation in Bhutan? Justify your answer. [3]

e. What do you mean by diffraction? [1]

Question 6

a. Explain the law of universal gravitation. [2]

b. An air-conditioner in Gelephu operates on a 220 V circuit and draws 10 A current. Determine the power rating of such a conditioner. [2]

c. State one difference between step-up transformer and step-down transformer. [1]

d. Explain any two environmental impacts of hydropower generation in Bhutan. Suggest a way to mitigate these impacts. [3]

e. Why are microwaves used to send signals to the satellites instead of radio waves? [2]

Question 7

a. Explain law of conservation of energy with an example. [2]

b. Compare the working principle of generation of electricity using wind and geothermal energy. [2]

c. Why is more number of transmission towers of equal transmitting strength required for mobile phone communication in Bhutan compared to India? [2]

d. The American space agency, NASA, plans to send a manned mission to Mars later this century. Mars has a mass 6.42 x 10^{23} kg and a radius 3.38 x 10^{6} m. G = 6.67 x 10^{11} N m^2 kg^{-2}.

   i. The mass of a typical astronaut plus spacesuit is 80 kg. What would be the gravitational force acting on such an astronaut standing on the surface of Mars? [2]

   ii. State whether an astronaut on Mars would feel lighter or heavier than on Earth. [1]

e. What is the source of Sun's energy? [1]

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Glossary

Acceleration	The rate of change of velocity.
Antenna	A metallic device for sending or receiving electromagnetic waves usually radiowaves.
Astronomer	A person who observes celestial phenomena.
Bibcock	A tap having a nozzle bent downward.
CFC	Chlorofluorocarbons- a compound of chlorine, fluorine and carbon.
CFL	Compact fluorescent light. It emits light due to fluorescence of some materials coated inside it.
Conductors	Substances which allow easy flow of electric current through them.
Cosmologist	A person who studies theories of the universe.
Couple	A pair of equal and parallel forces acting in opposite direction.
Dzong	A fort.
Forensics	Scientific tests or techniques used in connection with the detection of crimes.
Gasoline	Petrol.
Geyser	A device for heating water.
Gravitational field	Region around a body where gravitational force of attraction is felt by another body.
Insulators	Substances which do not allow flow of electric current through them at all temperatures.
iPod	A small electronic device for playing and storing digital audio and video files.
Lamina	Thin plate or layer.
Laser	Light amplification by stimulated emission of radiation. It is a device giving strong light in one direction.
LED	Light emitting diode. It emits light due to the change in the energy level of electrons.

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LDR	Abbreviation for light dependent resistor. It allows the flow of electric current through it only in the presence of light.
Masts	Long posts to support television or radio transmitter.
Nebula	Massive cloud of dust, hydrogen, helium and other ionized gases.
Neonatal jaundice	Yellow discoloration in the newborn baby's skin and eyes.
Piston	Sliding cylinder fitting closely in tube and moving up and down in it.
Pivot	A short pin or shaft on which something turns or oscillates.
Plumb line	A vertical line passing through the point of centre of gravity. It is usually used to check whether a wall is vertical or not.
Protostar	A star in its initial stage of formation.
Psoriasis	Skin disease with red scaly patches.
Ramp	A slope connecting two levels of surfaces usually higher level and lower level.
Redshift	Movement of spectrum towards longer wavelength in light from distant stars.
Rubber bung	Stopper for closing hole in container.
Satellite	A heavenly or artificial body revolving around the earth or other planets.
Seismic waves	Waves produced on the earth by earthquakes or any other earth vibrations.
Semiconductors	Substances which obstruct the flow of electric current at low temperature and allow easy flow of electric current at higher temperature.
Sensor	A device to detect or record or measure physical property.
Sky diver	A professional person who jumps from helicopter or airplane from a moderate or high altitude.
Skylight	A window in the roof.
Spanner	Tool for turning nut on a bolt.

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Syringe	Device for drawing in liquid by suction and ejecting it in fine stream.
Supernovae	Large explosion that takes place at the end of a star's life cycle.
Terminal velocity	The maximum velocity attained by a body falling freely under the action of gravity when the drag force becomes equal to the driving force.
Thermistor	A temperature sensitive device. It offers high resistance at low temperature and low resistance at high temperature.
Thermostat	A device for automatic regulation of temperature.
Thrust	Perpendicular force.
Torque	Turning effect of force.
Valve	A device for controlling passage of fluid by allowing it to flow in only one direction.
Vacuum cleaner	An electrical device for removing dust and other small particles from floors and other surfaces by suction.

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