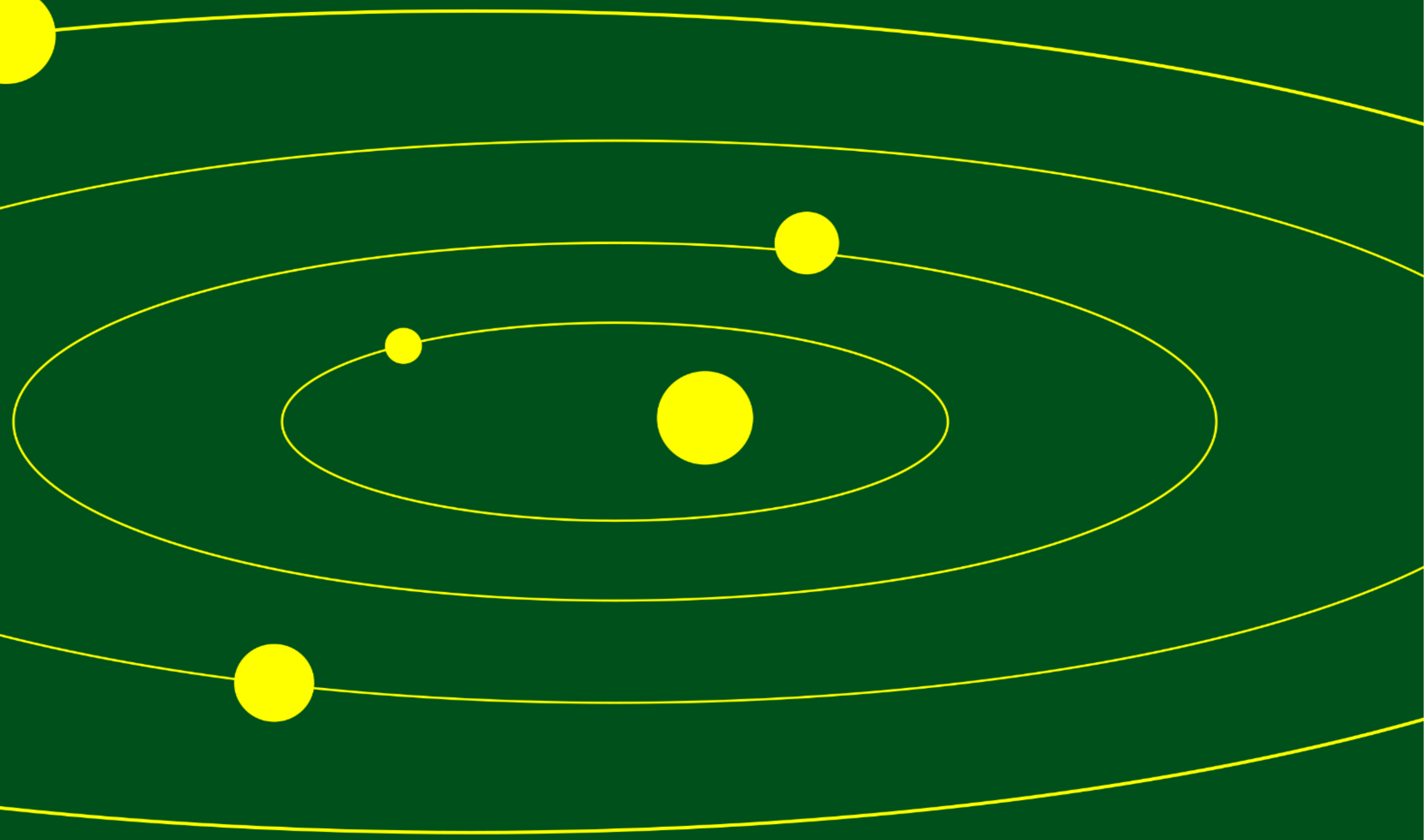
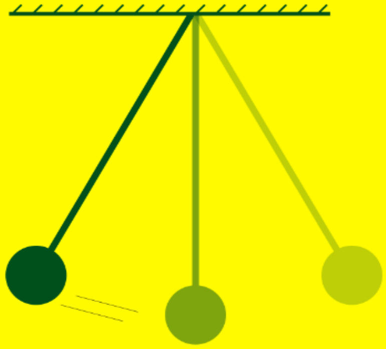


# REPORT ON :

# Training Higher Secondary Teachers in Content and Methodology of



# TEACHING PHYSICS

## (Telangana State)

October 01 - 05, 2018

विद्यया ऽमृतमश्नुते

एन सी ई आर टी
NCERT

**REGIONAL INSTITUTE OF EDUCATION MYSURU**

**(NCERT) Mysuru - 570006**

# Acknowledgment

I sincerely acknowledge the whole-hearted support provided by our honorable **Principal, Prof. Y Sreekanth**, for the program, starting from conceptualizing to developing the Training material for **Training higher secondary teachers in content and methodology of teaching Physics (Telangana)** as well as organizing various workshops and training programme.

I also thank **Prof. C G V Murthy, Head, Department of Extension**, for the guidance and support for organizing various workshops. I am very grateful to **Prof. C Padmaja, Telangana state coordinator** for providing appropriate inputs to carry on the training programme.

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I also thank **Prof. A Sukumar, Head DESM**, faculty of **DESM** and **DE** and all **resource persons** for their valuable contribution in the development of the training module and their valuable guidance.

I also thank Department of extension and accounts department staff of the institute for their timely help and support.

I also want to thank all the **Key Resource Persons**, **PU Lecturers in Physics** of Telangana State for their cooperation and valuable discussions by which this programme leads to a great success.

The Coordinator wishes to thank **NCERT** for giving opportunity to conduct the program.

# Preface

The programme "**Training higher secondary teachers in content and methodology of teaching Physics (Telangana)**" was held in the RIE Mysore during **2017-2018**. The main objective of the programme was to enrich the content level of the teachers as per their syllabus, and provide them training in conducting experiments and projects in innovative nature. The programme was arranged at the request Telangana states. A careful planning by the faculty members of the Physics section and resource persons to ensure maximum participation and encourage active involvement of the teachers at every stage of the programme was done, before the programme was executed. In all, there were 14 lectures and 4 laboratory sessions. Three lectures on the Pedagogical Approaches for Teaching Physics at Higher Secondary Level, Reflective Practice in Teaching, Conception and Misconception/Alternate Conceptions in Physics to provide the basic aspects of pedagogy of teaching, reflective practices and idea about alternate conceptions at higher secondary level. Giving due weightage to the units of Class XI and Class XII. The following topics were selected for lecture sessions- Wave Optics, Moving Charges and Magnetism, Current Electricity, Electric Charges and Fields, Electrostatic Potential and capacitance, Alternating Current, Electromagnetic induction, Semiconductor Electronic, Motion in a plane, Gravitation, Mechanical Properties of fluids, Mechanical Properties of solids, System of particles and rotational motion, Laws of Motion, Thermodynamics. The content was discussed to a level that is greater than required for teaching at higher Secondary level. To ensure participatory and interactive approach, each session was followed by a discussion where doubts were clarified. During laboratory session content mapping was done by the teachers for all the experiments and hands on experience provided to all the participants to perform the experiments. During lunch hour and free time, exposure to Studio of RIE Mysuru was given to teachers regarding how to make e-content using it. Some participants Laboratory work and panel discussion was recorded using the Studio facilities and the e-content material was discussed with all the teachers. Thus, a variety of activities were provided to the participant teachers to interact with the resource persons and equip themselves to face the classroom challenges. It is hoped that the programme has sufficiently enriched the participants teachers to teach the Physics with zeal and enthusiasm by adopting a variety of techniques. The present booklet is the outcome of this programme which contains a detailed report as well as the content enrichment module provide to the teachers.

Suggestions/comments of the users, experts and others will be solicited for improving it further.

**Santosh Kumar**

**Coordinator**

## ABOUT THE CONTENT ENRICHMENT MATERIAL

This content enrichment material is an outcome of series of workshop held at Regional Institute of Education, Mysore. This handbook gives an orientation to constructivism in Physics and its use in classroom. The main objectives of the content enrichment material are to:

- Facilitate the organizations which conduct training programme for teachers on a regular basis
- Equip teachers to understand the nuances of the components of Physics and develop a scientific perspective.
- Acquaint with the new development and changes in the field of knowledge and constructivism as reflected in the NCF 2005 syllabi and textbooks.
- Making teachers understand not only the subject but enable to analyze the topic through interdisciplinary approach
- Empower teachers to know how learners construct knowledge and facilitate the process in classroom
- Help them to acquire different strategies, competencies and skills for transacting new upcoming areas.
- Develop the competencies among the teachers to relate the topic in context of their experiences
- Enable teachers to promote self-learning/ team work in and outside the classroom for effective transaction of the curriculum
- Develop competencies to monitor the progress of each child in the classroom as well as to manage with remedial inbuilt mechanism.
- Facilitate peer group teaching and encouraging cooperative learning in the classroom.

## Contents

# 1. Planning of the Training Programme

The present training programme was planned at the Regional Institute of Education, Mysuru, A two days' inhouse meeting from 3rd May 2018 and 4th May 2018 conducted on different aspects like to select the hardspots for training and training module development on the basis of google form or the list supplied by the Telangana State Board of Intermediate Education, finalization of topic as per the priority through relevant methodologies, final list of resource persons for training programme, communication with SCERT Telangana for deputation of teachers, etc. This meeting was attended by Prof. C Padmaja, State coordinator Telangana state, Dr. Raman N C K, Dr. T V Somashekher, Dr. Sujatha B Hanchinallkar and Mr. Santosh Kumar, Co-ordinator of the programme.

Further, a two days' workshop conducted for preparation of training package on 17th September and 18th September 2018. This was attended by 13 Resource Persons. They were Dr. Raman N C K, Dr. T V Somashekher, Dr. Sujatha B Hanchinallkar, Dr. Pramod Tadapatri, Dr. Sankarshan B M, Dr. Karthik Kumara, Mr. Noufal P, Dr. B. V. Sadashivamurthy, Dr. Niranjana K M, Mr. V. Manohar Kumar, Dr. Biju K., Mr. Justin John and Mr. Santosh Kumar, Co-ordinator. In this meeting the basic issues related to the training programme was presented by the coordinator. This included, the activity-based module development, lab area concept, documentation and dissemination of module. All these issues were discussed and a formal schedule for the training programme was also drawn. An approach paper prepared was presented before all the resource persons which is as follows.

## Background

Higher Secondary stage is the bridge between the general information of the mind and personality which school education is and the higher learning specializations which the college and university represent. This stage is on the one Hand as strong or as weak as the school stage is and is simultaneously a test of the soundness of the learning culture developed at the school. The higher secondary is in relation to the school both a mirror and a reflector. On the other hand the foundations for higher learning are laid at this stage.

So contents in higher secondary Physics are the foundations for more mature Physics. For better understanding of concepts taught in Higher secondary, learner has to recollect the basic ideas from lower level as well as refined his/her knowledge. For direct learner towards more serious Physics teacher has to give special attention in thinking process of the learner. During the teaching learning process there are many areas which can be considered as hardspots to learner and to teacher. In this connection State Government of Telangana has requested to conduct a training programme at Higher Secondary level.

**Objectives**

The main objective of this program is the content enrichment in physics through different methodologies of teaching of physics. The specific objectives are to:

Identify hardspots in teaching Physics at Higher secondary level.

Develop the module on the identified hardspots through constructive approach/relevent methodologies.

Train key resource persons on the identified hardspots topics through relevant methodologies.

## Methodology

The training was based on participatory approach and adult learning techniques. The objectives sought full participation of the trainees. For this different stage are: -

Two days in house Planning meeting to chalk out the plan for training programme for Key resource persons like preparation of items for google form, list of resource persons, communication with SCERT Telangana for getting email id's of teachers, etc.

Identification of the hardspots from getting filled goggle form from physics teachers of Telangana state as per the items prepared.

Two days planning meeting to select the hardspots for training and package development on the basis of google form, finalization of topic as per the priority through relevant methodologies, final list of resource persons for training programme, communication with SCERT Telangana for deputation of teachers, etc.

Two days' workshop to develop the training module on identified area through relevant methodologies, preparation of list of material required for training by resource persons, preparation of items for pre-test and posttest, schedule of training programme, etc.

Five days training programme for Key resource persons on the identified hardspots through relevant methodologies.

## Training Methods

Varied training methods were incorporated as per the demand and situation of the training contents which were Illustrated talk, Group Discussion, Experimentation, demonstration, Group Work, Brainstorming, Lecture, Game Simulation, Project Work, Modeling, Individual/ group Assignments, etc.

## Training Module

The training package that will be used during training. The training package consist of a write up on each module consist of-

*Topic*

*Introduction*

*Essential Previous Knowledge*

*Learning objectives*

*Major Concepts*

*Teaching Methodology*

*Materials Required*

*Content Descriptions and activities* (consist of detailed descriptions of the content and how to transact to teachers with activities, different numerical or questions to be taken during the program).

*Key points*

*Exercise questions*

*Concept map*

## 2. Training Module

## Module Development Team

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| 3 | Conception and Misconception/Alternate Conceptions in Physics | Dr Biju K<br>Assistant Professor<br>Department of Education<br>School of Education & Training,<br>Central University of Tamilnadu,<br>Thiruvarur - 610005 Tamilnadu | 8943327651<br>bijuk@cutn.ac.in<br>bijukvr@gmail.com |
| 4 | Mechanical Properties of Fluids | | |
| 5 | Electromagnetic Induction | Mr V K Manohar Kumar<br>PGT<br>JNV, DMG Halli, Bogadi<br>Gaddige Road, Mysuru 570 026 | 9611473525<br>jmanohar@gmail.com |
| 6 | Gauss's Law and Applications | Justin John<br>Assistant Professor<br>Department of Physics, St Berchmans College,(Autonomous)<br>Changanacherry, Kerala | 9447803668<br>jusinpjohn@gmail.com |
| 7 | Phasor representations and LCR circuits | | |
| 8 | Semiconductor Electronics | Dr B V Sadashivamurthy<br>Professor of Physics (Rtd)<br>No. 29A, "Swayambhu", 5th Main Road,<br>Aravindanagar, Mysore 570 023 | 9448463982<br>bvsm500@gmail.com |
| 9 | Wave Optics | | |
| 10 | Thermodynamic processes | Dr Pramod Tadapatri<br>Assistant Professor (Contractual)<br>DESM, RIE, Mysuru | itsmepramod@gmail.com |
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|---|---|---|---|
| | | | |
| 13 | System of Particles and Rotational Motion | Dr Raman Namboodiri C K<br>Assistant Professor<br>DESM, RIE, Mysuru | 8050490458<br>physics.raman@gmail.com |
| 14 | Lab Activities | Mr Santosh Kumar<br>Assistant Professor<br>DESM, RIE, Mysuru | 7406102055<br>santoshkumar.ncert@gmail.com |
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# 1. Pedagogical Approaches for Teaching Physics at Higher Secondary Level

## 1.1 Learning objectives

After completing this module, the teachers will be able to

- ✓ Describe various pedagogical approaches suitable for teaching of Physical Science
- ✓ Identify the appropriate approaches suitable to the teaching of Physical Science.
- ✓ Differentiate various approaches from each other depending on the transaction of content.
- ✓ Demonstrate with suitable examples corresponding to each pedagogical approach.

## 1.2 Introduction

According to NCF 2005, aim of science education at senior secondary level is science should be introduced as separate disciplines, with emphasis on experiments/technology and problem solving. At this stage, the core topics of a discipline, taking into account recent advances in the field, should be identified carefully and treated with appropriate rigour and depth. In order to accomplish the 21st century learning skills the students should be got the opportunity to experience the possible learning experiences. For that it is the duty of the teacher to include different pedagogical approaches in the normal classroom.

The NCF-2005 emphasizes learner-centred approach to achieve the objective of the curriculum. The curricular content and its transaction must be relevant to the learners and should help them to become constructors of new knowledge and lifelong learners. Therefore, a pedagogical shift is required from teacher-centred to learner-centred teaching-learning process.

Approach is used in the broader sense. It means a way of thinking and working in a set direction so as to accomplish certain goals. It is a general plan of action, on the basis of which, various methods and models are evolved. However, a method is an orderly and logical arrangement of ideas based on a particular approach. It is a procedural illustration of systematic and clearly defined steps of accomplishing particular objectives. An approach can be called as a premise or precursor on which a method is designed.

For example, a teacher can use constructivist approach in teaching learning. This implies that whatever strategies the teacher plans to apply will be guided by the constructivist paradigm. They may adopt any of those innovative teaching-learning strategies and techniques that are guided by this approach.

In order to facilitate at the higher secondary level, the teacher should use different pedagogical approaches. Some of such pedagogical approaches are described below.

-Problem Solving Approach

-Collaborative Learning Approach

-STS Approach

- Laboratory Method

- Project Method

-Discussion Method

## 1.3 Major concepts

Problem Solving Approach, Laboratory Method, Collaborative Learning Approach, STS Approach, Discussion Method Project Method.

## 1.4 Learning Resources

Power point, Worksheet, Physics Resource books

## 1.5 Content Descriptions and Activities

### 1.5.1 Problem Solving Approach

Problem Solving Approach is based on the idea of involvement of students in real life problems. It gives students opportunity to actively construct their learning by thinking, questioning, visualizing the situation, searching for solution, doing activities and experiments and arriving at conclusion on their own. Teacher facilitates them in identifying the problem. For this, teacher may create a situation, pose a question, perform activity or experiment, elicit inquiry from students to make students realize that a problem exists and help them to identify the problem. Teacher will sets up the stage for solving the problem and helps the students to pose questions to initiate thinking, listens to their thinking, facilitate them to recall their existing knowledge and reconstruct them as and when it is required, and to use that knowledge to solve problems.

Problems related to numerical ability

Problems related to process development

Problems related to modification of alternative conceptions

#### 1.5.1.1 Steps in problem solving approach

Problem solving Approach of teaching science is a technique which provides children an opportunity to solve scientific problems quite independently or through guided approach by following some systematic steps.

- Students realise that problem exists. They conceive the situation as problem and provide rationale of the problem. They identify various issues related with problem and separate known and unknown things.

Students think, make decision—how, when and where, they can find the unknown issue by applying their existing knowledge and understanding who else can facilitate them in this process; what experiment/activity/ calculation need to be done; what learning resources to be utilised.

- Students visualise the situation of the problem, process of the problem solving and expected solution of the problem. For this he may draw diagram/graph/flowchart/concept map.
- Students attempt to solve the problem. They make observation and collect data to explore the solution. In this process they apply their understanding to construct their knowledge.
- Students draw conclusion.
- Students present the record.
- Students generalise the conclusion.

Different problems may require different sequence of steps. Studies show that if same problem is presented to different groups of students in the class, they tackle the problem in different ways connecting their prior understanding.

**Example**: When the discussion on the Bernoulli's equation was over, the teacher brought a large metal can to the classroom, she filled 3/4 of the can with water. Students observed that there was a hole in a large *can* slightly above the bottom. Stopper was fitted in the hole and *can* was filled with water. As soon as stopper from the hole was removed, water started flowing from it. After that the Teacher asked "can we find speed of water flowing out from the hole?"(Define the problem)

Teacher relates the same problem with the daily life situation as she observed leakage of water from the overhead tank of her house in the similar situation. Can she find the speed of flowing water by using same relation ($v=2g\Delta h$)

**Activity1:**

Identify a topic from Physics suitable to apply the problem-solving approach with detailed description by including all the necessary steps in the problem-solving approach.

**Self-Check Questions:**

i. Write the Advantages and disadvantages of using Problem Solving Approach in the normal classroom

ii. What are the different types of problems in science that usually we will take in the normal classroom

### 1.5.1.2 Laboratory method

In laboratory method students perform laboratory experiments by their own hands individually or in small groups, under the supervision and guidance of their science (Physics, Chemistry, Biology) teacher. So here students are more active and involved as compared to lecture – demonstration method, where teacher was performing experiments and most of the students in the class were just passive observers. The role of the teacher when using this method in teaching science is that of a facilitator. The teacher goes to different individuals or small groups, observes them what they are doing, corrects them if they are doing something wrong, and he is always available to students when they really need him for any guidance.

Unless students perform experiments themselves, they will never get to know what science really is.

Most laboratory approaches can be classified into one of the following

1. Verification and deduction (Experiments to illustrate scientific principles)
2. Induction
3. Science process oriented
4. Technical Skills oriented (Focussing a telescope, measuring angles, etc.)
5. Exploratory

Example: To establish current-voltage relationship for a given resistance by using an ammeter and a voltmeter, and to find out the unknown value of resistance.

**Activity2:**

Teachers will identify certain topics from Physics content at +1 and +2 and discuss the implementation of the topic through laboratory method.

**Self-Check Questions:**

i. What is the role of the Science teacher in implementing Laboratory method in the classroom?

ii. When will we adopt laboratory method in the classroom?

### 1.5.1.3 Collaborative learning Approach

In Collaborative Learning Approach, learners take responsibility of their own learning. It promotes self-learning skills in them. They have to discuss their ideas with their group members, relating it to their previous experiences.

Teacher facilitates situations for active participation in teaching-learning process by encouraging collaboration among the learners. She communicates the goal to be achieved within a limited time frame realizing and respecting diverse needs of the learners and their different styles of learning. Collaborative learning approach develops both academic and social skills in learner in an integrated manner.

In the collaborative set-up, each learner individually and socially constructs meaning as she learns. Collaborative learning enhances motivation to learn and increases depth of understanding. In the group setting, learners develop a positive attitude towards the learning and materials on which they work on, as they contribute to it.

Learning is more effective as students themselves take care to resolve any conflicting observation and opinion. It also gives them opportunity to apply the concepts in real-life situation and to learn to solve a problem through multiple ways.

#### 1.5.1.3.1 Steps of collaborative approach

- Problem, issue or concept is identified to be dealt with in a group situation. It may be small or big, simple or complex, depending upon learning environment and teaching-learning process.
- Formation of groups (say 3 to 6 students) is facilitated by the teacher. Students are also facilitated to take up the task of their choice.
- There is exchange of ideas, discussion on the issue at hand or performance of activities or experiment to clarify the concept in group situation. Sharing of ideas facilitates visiting and revisiting the concepts.
- Teacher facilitates their interactions directed towards the set goal within stipulated time frame.
- Learning evidences are assessed throughout the teaching learning process and feedback is provided to all groups of the learners.

**Example**: After discussing the concept of *Addition and subtraction of vectors by graphical method and analytical method* in Class XI Physics, the teacher decided to solve following problem by collaborative learning approach.

**Problem:** Find the magnitude and direction of the resultant of two vectors A and B in terms of their magnitude and angle between them.

#### 1.5.1.3.2 Ways of applying collaborative learning approach

There are various ways in which collaborative learning approach may be applied such as given below.

**(i) Brainstorming**

- A problem is identified.
- Small groups are formed.
- All members are encouraged to find the solution and express their ideas.
- No idea is criticized. However, ideas can be modified.

Example*:* How can we minimize wastage of water?

Skills developed*:* Generating ideas, creativity.

**(ii) Task group**

- A task is identified.
- Small groups are formed.
- Each group of the class is assigned a specific task to be completed within a time frame.
- Task of each group is evaluated by other group.
- Completion of task is responsibility of all.

Example*:* Prepare models of lever of Classes I, II and III.

Skills developed*:* Taking responsibility, delegation of work, imitativeness, planning skills, accomplishment, evaluation and emotional skills.

**(iii) Inquiry group**

- Teacher creates a situation of some discrepant event during teaching-learning process.

Students are helped to realize that there exists a problem, solution of which is to be inquired.

- Different groups work on the same problem and may come up with different hypothesis, solutions and conclusion.
- In order to get involved in the inquiry, learners may discuss, share their ideas, derive the equations, perform an activity, experiments and solve numerical.

Example*:* How would our life be affected if force of friction suddenly vanishes?

Skills developed*:* Problem solving skill, inquiry skills, analysis, synthesis and evaluation.

**(iv)Tutorial group**

- Teacher facilitates formation of group according to students' ability.
- A concept is identified by the teacher which can be learned in a group setting.
- A student having good understanding of the concept is identified as group leader by the teacher. Opportunity should be provided to various students in turn.
- The group leader is assigned the job of facilitating learning to all members of her group.
- The group leader asks questions with the members and encourages them to discuss their learning difficulties with her.

Example: Determine unknown resistance using a meter bridge.

Skills developed***:*** Basic competencies related to a concept develop in all members.

**Self-Check Questions:**

i. Suggest one topic for conducting Brainstorming in the Physics classroom

ii. Compare the collaborative approach with Problem solving approach

## 1.5.1.4 STS Approach

Science-Technology-Society (STS) is an integrated approach to science teaching where the social application of scientific content and technological knowledge is assigned greater significance. Through the STS approach, the inter linkage between Science Education and Technology Education with respect to Social Implementation can be done. It will provide an insight to the social issues in a scientific manner.STS based modules can be develop by following the module preparation suggested by Yuenyong (2006) consisting of five stages including Identification of social issues, Identification of potential solutions, Need for knowledge, Decision-making, and Socialization stage.

Example: Circular Motion

**Self-Check Questions:**

i. List out few sciences related social issues

ii. What are the benefits for the students while implementing STS approach in the normal classroom

## 1.5.1.5 Discussion Method

Group discussion is an ideal method to inculcate social consciousness, co-operation, democratic attitude, friendliness, open-mindedness and compromising attitude which are the ultimate aims of education. It helps the development of communication skill, hypothesis formulation, designing of experiments and analytical skills. General discussion is a method where discussion proceeds based on the thought-provoking questions raised by the teacher addressing the whole class. Based on the random presentations of the group members teacher and students move ahead with the development of concepts. Finally, teacher consolidates the concepts/ideas discussed in the class.

**Self-Check Questions:**

i. Suggest one topic from Physics that will teach through Discussion method

ii. What is the role of the teacher while conducting Discussion method in the classroom

## 1.5.1.6 Project Method

It is a method of self-instruction using the method of science and useful in the development of a number of process skills. By doing projects the students are given the opportunity to train in the method of science. In doing so, the student acquires problem solving ability which helps to tide over problematic situations in life and progress in life. Projects help to develop scientific temper, scientific attitude and interest in learning science and to ensure active participation of the student in learning activities.

**1.5.1.6.1 Stages of a project**

**Feeling the problem:** The project topic should not be arbitrarily created. It should reflect a felt problem in the learning situation which requires a solution to proceed further. Project topics arise when discussions relating to lessons are held in the class. It is important that the student has an internal urge to find out a solution to the particular problem. When the topic is presented the teacher must ensure this.

**Defining the aim:** If the student is to tackle the problem in a way suitable to his/her abilities, thinking skills and available facilities, the aims of the project need to be defined precisely. To state the aims of the project simply and clearly, the student needs the help of the teacher.

**Hypothesizing:** Drawing temporary conclusions on the basis of information available at the time is known as hypothesizing.

**Methods and instruments:** Study methods and instruments are to be selected based on aims of the project and the hypothesis drawn. The nature of the topic, instruments used and the scientific approach followed should be correlated.

Survey once survey method is selected, where, when and how to conduct the survey must be decided. What will be the sample and who are to be approached for data will also be considered? Questionnaires and survey forms are to be drawn up. During the planning phase all these are to be discussed in detail. Teacher must interact with the students, give suggestions and ensure that the instructions are suitable and effective.

**Experimentation:** When experimental method is to be used, it must be considered whether necessary equipment is available. If not, can these be improvised? How can materials and instruments be made available? These questions must be considered.

**Analysis:** The collected and tabulated data can be analyzed to examine the validity of the hypothesis. The collected data need to be classified and compared. Comparison with standard information may also be required. Graphics and similar representation will make the analysis easier.

**Conclusion:** Based on similarities, differences and relationships evident from analysis of data, the validity of hypothesis may be examined. Those found invalid are rejected and others are accepted as conclusions.

**Self-Check Questions:**

i. Suggest one topic for conducting Project method in science

ii. Compare the project method with problem solving approach

### 1.6 Summary

These are some of the learner centred and innovative pedagogical approaches that can effectively apply in the higher secondary level. By implementing these approaches, the students will get an opportunity to construct the knowledge and they can develop various skills that should be needed for a learner. Apart from this, the teachers can use Information Communication Technology (ICT) in their classroom. Various interactive websites, mobile apps, Computer simulations, multimedia packages, etc. can also use for the effective teaching learning process.

### 1.7 Module End Exercises

i. Compare between STS approach and Problem-solving approach with suitable examples

ii. Explain the steps of project method by using suitable example

iii. What are the benefits of including learner centred approaches in the science classroom?

iv. Explain the precautions to be taken while implementing the laboratory method and discussion method in the Science classroom?

### 1.8 References


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# 2. Reflective Practice in Teaching

## 2.1 Introduction

The module discusses about reflection, reflective practice and who is a reflective practitioner and the different types of reflection and what are the characteristics of reflection. What are the benefits of reflective practice? Dewey (1933) was among the first to identify reflection as a specialized form of thinking. Later Donald Schon (1983) introduced the concept of reflection in practice. He talked of 2 types of reflection: reflection on action and reflection in action.

Reflection includes looking forward (prospective reflection), looking at what we are doing now (prospective reflection), and looking back (retrospective reflection)" Reflective practice enables instructors to apply a systematic approach to improving their learning facilitation practice. Later in Gibb's gave a reflective cycle in 1988 which is a effective tool to reflect after the event on 'critical' incidents. Later Eby and Kujawa (1998) described six characteristics of the reflective practitioner. There are different types of reflection mainly reflection on action and reflection in action and reflection for action. Other types like the Levels of Reflection that is Pre-reflection, surface reflection, pedagogical reflection and critical reflection. The benefits of reflective practice are discussed in detail here.

## 2.2 Learning objectives:

1. To define reflection.
2. To define reflective practice.
3. To explain reflective cycle.
4. To discuss the characteristics of reflection.
5. To classify reflection into different types.
6. To discuss the levels of reflection.

## 2.3 Major Concepts

Reflection, Reflective practice Reflective cycle, Types of Reflection, Levels of reflection, Characteristics of reflection.

**Reflection:** "Reflection involves describing, analyzing and evaluating our thoughts, assumptions, beliefs, theory base, and actions. (Fade, 2005). Reflection is defined as a thought occurring in consideration or meditation. Rowntree (1988) says that "reflection is studying one's own study methods as seriously as one studies the subject "and "thinking about a learning task after you have done it. In any learning situation, he says, you should prepare for it beforehand, participate actively during it, and reflect on it afterward.

**Reflective practice:** Reflective practice enables instructors to apply a systematic approach to improving their learning facilitation practice. It is intentional way of looking at aspects of their practice, hypothesizing about bringing about change, and implementing the change and analyzing its impact in order to determine what they would replicate in the future and what they would change. It encourages them to reflect on the reasons for their decisions.

***Reflective practitioners*** the term *reflective practitioners* usually refer to adults in a professional field who reflect on their strengths, limitations, and areas for growth. In the education profession, reflective practitioners are educators who study their own teaching methods and determining what works best for the students. Many teachers have gone through a teacher preparation program centered on and around reflective practice. Reflection is integral in helping us perfect our lessons and become better educators for the students in our diverse classrooms.

**Reflective cycle:** Gibbs' (1988) is an effective tool to reflect after the event on 'critical' incidents; those events that have had a profound negative or positive impact on you – learning by doing. These can be events that have occurred in learning, practical or personal areas. Gibbs' (1988) cycle is considered useful for students who are new to reflecting as it has clearly defined sections:

Description: what happened?

Feelings: what were you thinking or feeling?

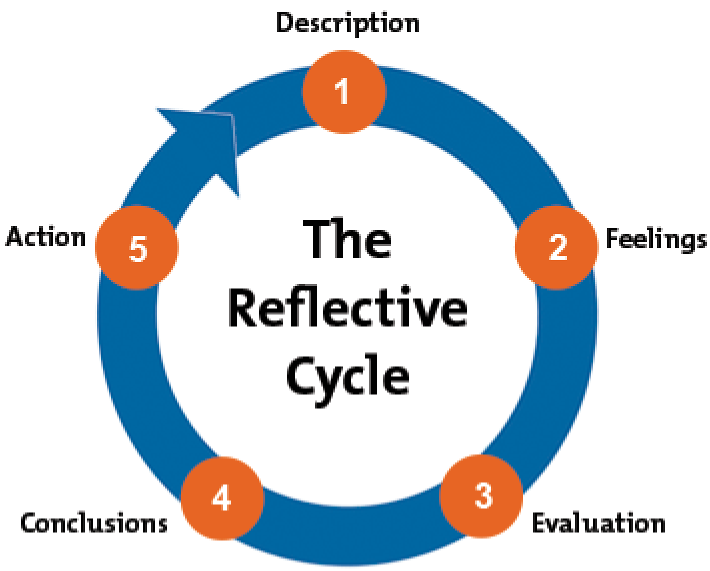
Evaluation: what was good/bad about the situation?

Analysis: what sense can you make of situation

Conclusion: what else could you have done?

Action plan: If situation arose again, what would you do?

**Gibbs' Reflective cycle (1988)**




Reflective practice enables instructors to apply a systematic approach to improving their learning facilitation practice. It is an intentional way of looking at aspects of their practice, hypothesizing about bringing about change, and implementing the change and analyzing its impact in order to determine what they would replicate in the future and what they would change. It encourages them to reflect on the reasons for their decisions.

**Characteristics of the Reflective Practitioner**

Eby and Kujawa (1998) describe six characteristics of the reflective practitioner:

- Reflective practitioners are active—they search energetically for information and solutions to problems that arise in the classroom.

- Reflective practitioners are persistent—they are committed to thinking through difficult issues in depth and continuing to consider matters even though it may be difficult or tiring.
- Reflective practitioners are careful—they are concerned for self and other, respecting students as human beings and trying to create a positive, nurturing classroom.
- Reflective practitioners are skeptical—they realize that there are few absolutes and maintain a healthy skepticism about educational theories and practices.
- Reflective practitioners are rational—they demand evidence and apply criteria in formulating judgments rather than blindly following trends or acting on impulse.
- Reflective practitioners are proactive—they are able to translate reflective thinking into positive action.

Ebby and Kujawa (1998) also came up with six important traits that a reflective practitioner should practice:

- Understand the process of reflection-on-action;
- Go beyond mere description of lessons (the what?);
- Learn about reflection through interaction with teacher educators, cooperating teachers and fellow preservice educators (through journal buddy reading);
- Learn to reflect on learners and the learning processes as well as the content;
- Learn to integrate ideas from others and experiences to improve teaching; and
- Understand that reflective practitioners are active, persistent, careful, skeptical, rational and proactive.

One way these six traits can be accomplished or developed is through the process of reflective journal writing. The literature clearly states that reflective journal writing for teachers/student teachers undertaking their field work experience is a key component to becoming a skillful reflective practitioner. Journal writing needs to go beyond just describing a room setup or talking about the different students in the room. Davis (2006) describes the difference between productive and unproductive reflection. Unproductive reflection is mainly descriptive without very much analysis, usually listing ideas rather than connecting ideas. Productive reflection is likely to promote effective learning and involves questioning assumptions and seeing things in a variety of different ways. A reflective journal needs to address the daily lesson and activities; what happened, what changes could be made, how you could improve the lesson, any questions or issues that occurred in the classroom and how you addressed them or how you could have addressed them.

In essence, one must go beyond just describing the lesson and include an analysis of what could have been done differently, making connections with other experiences and understanding how to interpret a teaching idea. Sweigard (2007) states that teachers gain information about their teaching from their own observations of themselves coupled with their reflections. Therefore, a reflective journal is a logical first step in assisting a teacher in progressing into an exemplary future teacher.

**Types of Reflection:** In general, reflection uses the past to inform our judgment, reflect on our experiences and face new encounters with a broader repertoire of information, skills and techniques (Killion, Joellen, Todnem, & Guy, 1991)**.** When you reflect on what has occurred and consequently change your actions you will hopefully experience a different outcome. There are numerous theorists who address how reflection is used in education. One theorist, Donald Schon, describes two different types of reflection: *Reflection-on-Action* and *Reflection-in-Action*. Reflection-on-Action occurs when a teacher reflects on their daily lessons and classroom actions and uses the information gathered to adjust their lessons/teaching (Killion, Joellen, Todnem, & Guy, 1991). The goal of this form of reflection is for educators to become more effective and conscientious teachers. This type of reflection is reflecting back on lessons that have been taught and is a skill that teachers need to acquire in their early teaching experiences.

The second type of reflection that Schon describes is Reflection-in-Action. This type of reflection occurs during teaching and involves acting immediately to improve or better your teaching. Paulson and Kenneth describe the difference between these two types of reflection; if a teacher thinks reflectively about an episode of teaching after class, he or she engages in reflecting-on-action. In contrast, if they think about the episode while in the midst of teaching, then reflection-in-action takes place (Paulson & Kenneth as cited in Sweigard, 2007). Schon's reflection theory has been used as a foundation for several researchers. Killion, Joellen, Todnem, and Guy (1991) used Schon's two types of reflection (reflection- on-action and reflection-in-action) and added a third type (reflection-for-action). Reflection-for-action is stated as the desired outcome of Schon's reflection-in-action and reflection-on-action. This type of reflection looks at what has occurred in the past and how this can help change our teaching process in the future. Consequently, this will provide students with an enriched learning environment. An example of reflection-for-action in the classroom is when a teacher critiques events from the past and makes a conclusion or judgment that that will impact future teachings/lessons.

Valli (1997) states that there are six components of a teacher's knowledge that guide how they teach: *behavioral, technical, reflection-in-action, reflection-on-action, deliberative, personalistic,* and *critical*. All of these (except behavioral) involve the concept of reflection. The behavioral approach involves skills acquisition and assessment by education faculty and cooperating teachers. The assessment will indicate what behaviour the student needs to address. The five other ways incorporate the concept of reflection which is an expansion of Schon's original concepts. The first, technical reflection involves the teacher candidate's reflection of their own performance and exhibits internal motivation to better them. Reflection-inaction and reflection-on-action are the second ways that Valli identifies and they have previously been described. The third type of reflection, deliberative reflection, involves the consolidation of several sources of information from a variety of perceived experts as the teacher makes decisions about practice (Killion, Joellen, Todnem, & Guy, 1991). Personalistic reflection requires the teacher to draw links between their professional and personal life. In essence, how does being a teacher fulfill their personal life goals (Killion, Joellen, Todnem, & Guy, 1991). The final type of reflection is critical reflection and it goes beyond the person and looks at the institution and political aspects of education and social injustices.

**Levels of Reflection**

Teacher reflection has become increasingly important for both trainees and established classroom practitioners (Pollard, 2008). Teachers in their reflections are encouraged to identify and examine, in context, those things that impact upon their thoughts and actions. The context in which learning takes place can be a very powerful factor. Reflection, in context enables the practitioner to gain a better understanding of their situation and as a consequence explore viable alternatives with the potential to produce positive change. "Reflection is generally assumed to promote understanding and insight and to have transformation or empowerment as its purpose or effect" (Ottesen, 2007).

Increasingly reflective practice is viewed as the hallmark of professional competence for teaching. Indeed, there is a general acceptance of the need to prepare professionals to be reflective practitioners (Larrivee, 2008). Teacher reflection means that individuals will view their own work through the critical lens of another with the anticipated aim of developing their own personal and professional skills (Husu, 2009). According to Shoffner (2008) reflection is worthwhile because it enables classroom practitioners to identify, analyse and manage complex classroom issues. Furthermore, practitioners are forced to question their practice and consequently gain a better understanding of their own beliefs. As a result, those same practitioners will begin to contemplate more fully the relationship between theory and practice and to question those things normally understood to be accepted knowledge. Larrivee (2008) identifies four distinct levels of reflection represented diagrammatically as:

- Level 1 – Pre-reflection: at this level of reflection things are taken for granted and accepted without question. Teachers respond to situations which they believe to be beyond their control; reflections are superficial. Represents the 'zero' level of reflection in which teachers react to students and classroom situations automatically, without conscious consideration of alternatives.
- Level 2 – Surface Reflection: at this level reflections focus on how to achieve specific objectives and standards. Reflections are supported by evidence with an increasing awareness of the need to accommodate different learners.
- Level 3 – Pedagogical Reflection: at this level the teacher evaluates what they do in the classroom and consider show that impacts upon pupil learning.
- Level 4 – Critical Reflection: at this level on-going reflection and critical inquiry into teaching actions and thinking processes are central and significantly important. Teachers reflect on moral and ethical implications and consequences of their classroom practice on students.

At level 1 reflection tends to be rather shallow in nature whereas as at Level 4 it is much more intrusive and searching. At Level 1 reflection is considered to be an obligation that has to be performed or a task to be met but at Level 4 it is central and fundamental to the way in which the practitioner learns. The aim of this unique project was to move the student teacher to Level 4 and encourage them to embrace the full process of 'critical reflection'. The theoretical framework for this study is based on an adoption of Larrivee's model. Level 1 reflection tends to be limited in both breadth and depth; reflection at this level is largely inconsequential and insignificant. However, as the practitioner traverses the levels of reflection from Level 1 to Level 4 their engagement with the reflective process increases and their depth of reflection becomes complex; reflections at this level are profound, sincere and insightful. Level 1 reflection tends to be relatively safe and does not present too much risk to the practitioner whereas Level 4 reflection is more unsafe and there are potentially higher risks attached. All four levels of reflection in this theoretical framework sit along a continuum where low level reflection is at one end, where there is limited or superficial evaluation, and where at the other end there is a high level of reflective practice which is profound and insightful. At one end it focuses on teaching functions, actions and skills, generally considering single teaching episodes or isolated events right through to, at the other end, higher order reflection where the teacher examines the ethical, social and political consequences of their teaching and grapples with the purposes of schooling.

**Use of Reflective Practice**

Reflective practice is a continuous process that involves learners considering critical incidents in their learning or life experiences. Schön argued that the model of professional training that relied on filling up students with knowledge and then sending them out into the world of practice was inappropriate in a fast-changing world. A reflective practice model would enable learners and novices within a discipline to compare their own practices with those of experienced practitioners (Schön, 1987), thus leading to development and improvement.

**Benefits of Reflective Practice**

Roffey-Barentson and Malthouse (2009) in their book *Reflective Practice in the Lifelong Learning Sector*, identify benefits of reflective practice for educators.

**Improvement of teaching practice.** The first, and most important, is the improvement of teaching practice. Educators' performance improves if they take the time to reflect on their teaching, thinking about what worked for students, what limitations that they had, what sort of problems arose, and how to change those for the future. Additionally, their teaching style becomes more grounded.

**Learning from reflective practice.** Teachers learn from reflective practice, and purposeful reflection allows for deeper learning to take place and helps teachers make connections among different aspects of their teaching. This enhances their overall effectiveness as teachers.

Joy Amulya (2003) writes in her paper "What Is Reflective Practice?", "By developing the ability to explore and be curious about our own experiences and actions, we suddenly open up the possibilities of purposeful learning—derived not from books or experts, but from our work and our lives" In the field of education, many of us learn by experience. However, reflecting on that experience deepens our personal growth and makes us more cognizant of that development.

**Enhancing problem-solving skills and critical thinking.** Teachers who reflect on their daily lessons will focus on the problems that arose, what went wrong with each lesson, or what they could have done better or differently. By analyzing these situations, they improve their ability to solve problems. Reflecting on these problems and contemplating how to correct them for the future, weighing the pros and the cons, enhances decision making.

Critical thinking is defined differently based on philosophical ideas, but it generally refers to the complex set of cognitive skills employed in problem solving and intellectual consideration and innovation. Reflective practice helps educators be aware of and revise what they reflect on to embrace changes in situations.

It is easy for us to be stuck in the routine of day-to-day lessons and continue to repeat the same ineffective lessons. Making the time to reflect provides us with the opportunity to critically evaluate our methods and work toward positive changes.

**Benefits of Reflective Practice for Students**

"Reflection on what they know and do not know helps students to appreciate that . . . learning is individual, and that only they can make the connections to existing knowledge" (UK Centre for Legal Education, 2010) to make sense of the content. Students can benefit in a similar way that educators do from engaging in reflective practice.

**Improvement of student practice.** When teachers reflect on their teaching, their practice improves. Students can also experience this benefit when they reflect on their learning experience, especially in a science laboratory setting. Students' performance can improve if they take the time to reflect on their procedures and think about what worked, what limitations they had, what sort of problems arose, and how to change for the future. This validates what worked for them and the different strategies that they chose to use as they approach their assignment.

**Learning from reflective practice.** Reflective learning is defined as "a great or deeper degree of processing of material to be learned" (Herod, 2002). Compared to nonreflective learning, where "material is simply taken in with little or no active thinking or understanding (e.g., memorization), reflective learning engages a large amount of the learner's thinking or cognitive capacities" (Herod, 2002). Reflective learning is engaging in reflection for the goal of producing learning out of the process, and it is the central tool for deriving knowledge formed through the experience.By reflecting on their schoolwork, students make deeper connections to the concepts they are learning. **Improved problem solving and critical thinking.** Students can certainly experience the same kind of improved problem-solving and critical-thinking skills that educators receive from reflection. The act of reflecting is a higher-order process, and by engaging in it, students develop a level of consciousness that they can use to deepen their knowledge of content.

A study conducted by Lerch, Bilics, and Colley (2006) shows that through reflective thinking students are able to develop higher-order thinking skills, develop the ability to analyze their own learning, and start the metacognitive thinking necessary for them to be effective learners. If students focus their reflection on analyzing situations where problems arose, what went wrong or right with the assignment, or what they could have done differently, their problem-solving ability improves.

**Suggestions for Student Reflection Activities**

Designing a practice of reflection means both clarifying the purposes it needs to serve and identifying opportunities for reflection in students' work that are realistic and yet occur at the right intervals with sufficient depth to be meaningful. "Maintaining a practice of reflection, however structured, transforms the possibility of learning from work into a reality," Amulya writes (2003, p. 2).

Reflection activities in the classroom can range from daily to weekly to biweekly, or they can occur at varying intervals, for example at the conclusion of a unit of study. The important piece is that the objective of the reflection assignment is clearly stated for the student and that the activities occur in some regular time frame.

## 2.5 Exercise */Self Check questions*

1. *What is reflection?*
2. What is reflective practice?
3. Explain reflective cycle?
4. What are the six characteristics of reflection?
5. Discuss the different types reflection?
6. What are the different levels of reflection?
7. *What are the uses of reflective practice?*

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# 3. Conception and Misconception/Alternate Conceptions in Physics

## 3.1 Introduction

The way students make sense of the world and their knowledge is an important issue for improving science education. In understanding the scientific concepts, the students do vary in their capabilities and also teachers show variations in convincing the concepts in their complete meaning to the students.

A concept is defined by critical characteristics shared by all examples of the concept. For something to be an example of a concept, it must contain all these critical characteristics. To help students form the concept, the teacher helps them first to see these critical characteristics across different examples and, then to summarize those characteristics in a definition that students themselves write.

Shulman (1987) conceptualized pedagogical content knowledge as the 'amalgam' of content knowledge and general pedagogical knowledge. It includes "an understanding of what makes the learning of specific topics easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons…. knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners…" (Shulman, 1986, p. 9-10), should the preconceptions turn out to be misconceptions.

A concept is the basic unit of all types of learning. Human beings from the infancy to old age, learn new concepts and age-old concepts in new situation of their daily life (Lawson &Renner, 1975). Concept is assumed to be as set of specific objects, symbols or events which share common characteristics (critical attributes) and can be defined by a particular name or symbol. Concept learning thus is regarded as the identification of the concept attributes, which can be generalized to newly encountered examples and to discriminate examples from non-example. Concepts can be thought as information about objects, events and process that allow us to-

1. Differentiate various things or classes.

2. To know relationship between objects.

3. Generalize about events, things and processes.

Flavell (1970) has indicated that a formal definition of concept in terms of its defining attributes is useful in specifying what concepts are and not, and in understanding the great variability among concepts of a variety of objects. Kagan (1966) emphasizing the importance of concepts in life says, "Concepts are fundamental agents to intellectual work." The theoretical significance of cognitive concepts in psychological theory parallels the seminal role of valence in chemistry, gene in biology or energy in physics. According to Pella (1966), a concept may be viewed as 'a summary of essential characteristics of a group of ideas and/or facts that epitomize important common features or factors from a large number of ideas'. (Examples of physics concepts are mass, weight, force, velocity, acceleration, addition of vectors, subtraction of vectors).

## 3.2 Types of Concepts

According to Posner et. al., 1982 there are mainly three types of concepts which are described as follows:

**Conjunctive concepts**

Conjunctive concepts are defined by the presence of two or more features. In other words, an item must have "this feature and this feature and this feature" for example, a motorcycle must have two wheels and an engine and handle bar.

**Disjunctive concepts**

Disjunctive concepts must have at least one of several possible features. These are either for "concept ".to belongs to the category, an item must have "this feature or that feature or another feature". For example, In baseball, a strike is either a swing and a miss or a pitch over the plate or a foul ball. The either/or equality of disjunctive concepts makes them hard to learn.

**Relational concepts**

Relational concepts are based on how an object relates to something else or how its features relate to another. All of the following are relational concepts: Larger, above, north, and upside down.

In science context there are mainly two types of concepts Herron (1977) and they are listed below.

**Concrete concepts**

According to Herron et. al. (1977), concrete concepts are those concepts which name classes of entities for which there are numerous perceptible instances defining attributes which are easily perceived'. Examples of concrete concepts are: table, chair, thermal degree on the thermometer, force when perceived as a pull by a string.

**Formal concepts**

According to Herron, Cantu, Ward and Srinvisan (1977), formal concepts 'are those concepts that do not have perceptible instances, or have defining attributes which are not perceptible', formal concepts are: acceleration, element, density, temperature when defined as the mean kinetic energy of the molecules.

**Concept Formation**

Psychologists use the term *concept formation*, or concept learning, to refer to the development of the ability to respond to common features of categories of objects or events. *Concepts* are mental categories for objects, events, or ideas that have a common set of features. Concepts allow us to classify objects and events. In learning a concept, you must focus on the relevant features and ignore those that are irrelevant (Bourne & colleagues, 1986).

**Concept Formation** is an inductive teaching strategy that helps students form a clear understanding of a **concept** (or idea) through studying a small set of examples of the **concept**.

Concept formation is the process of classifying information into meaningful categories. At its most basic, concept formation is based on experience with positive and negative instances (examples that belong, or do not belong to the concept class).

According to Piaget's theory, scientific knowledge, concepts and conceptual systems are generated through the use of various reasoning strategies which develop continuously through a process of assimilation and accommodation (Inhelder & Piagets, 1958).

Assimilation is commonly used as the process whereby the learner is able to gain new knowledge by fitting new information into existing knowledge structure schema (Tao & Gunstone, 1999). Accommodation however requires changes in structure before the new information can become part of the learner's knowledge or in other words a change in conception (Dykstra, Boyle & Monarch, 1992; Posner, Strike, Hewson & Gertog, 1982).

Conceptual change involves changes in students' assumptions about the world and knowing. One of the most accepted conceptual change theories is posed by Posner et. al. (1982). In order for conceptual change to take place, Posner et. al. (1982) suggested four conditions: (1) students must become dissatisfied with their existing conceptions (dissatisfaction); (2) the new concept must be clear and understandable for students (intelligibility); (3) the current problem should be solved by using the new concept (plausibility); (4) similar future problems can be solved by using the new concept (fruitfulness). Therefore, teachers should develop strategies to create cognitive conflict in students, organize instruction to diagnose errors in students' thinking, and help students translate from one mode of representation to another. Conceptual change is not static but is a dynamic process that occurs over a period of time (Chi, 1992). These conditions can be referred to as conceptual change conditions.

Teacher Preparation

1. *Select a concept*. Choose one that is at the core of your curriculum. It might be one of the five themes of geography (movement, region, human-environmental interaction, location, or place) or a key tool of historical reasoning (thesis, evidence, sourcing, contextualizing, corroborating). It could be a concept used to understand media (advertisement, documentary, home page) or the economy (good, service, production, distribution, money).
2. *List the critical characteristics of the concept*. Check several sources to find the clearest set of characteristics. For example, *Democracy* is (1) a kind of government in which (2) the majority rules (rules and laws are made by all citizens or their representatives), (3) minority rights and individual liberties are protected, and (4) rules and laws are written down. Or, *modernization* involves (1) the use of technology to control nature's resources, (2) the use of inanimate (non-animal) sources of power and energy, and (3) the use of tools to multiply the effects of human energy. Be sure to **list** the critical characteristics. This will help you and your students more easily see which characteristics are present or missing in a particular case.
3. *Assemble a good set of examples*. A good set of examples is small in number (3–4), varied (shows the array of differences allowable within the concept), and developmentally and culturally appropriate (know

your students). Be sure that each example has all the critical characteristics required for the concept. Furthermore, select examples for which plenty of up-to-date information is available.

4. *Make a data-organization chart*. Down the left side, present the 3–4 examples. Across the top, ask 3–5 **focus questions**. These questions help focus your students' data-gathering on the critical information in each example. Each student will need a copy of the chart; also, post a chart on the wall or project it onto a screen.
5. *Assemble a good set of non-examples*. Identify 2–3 non-examples that can be used to help students *classify* after they have formed the concept. A non-example has some, but not all, of the critical characteristics that define the concept. Non-examples make great practice items.

In *The Process of Education*, Jerome Bruner writes: “We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development”. This applies to most concepts. But the teacher needs to find examples that students of a particular age can grasp, and simplify the critical characteristics as needed.

## 3.3 The Functions and Purpose of Concepts

We use concepts for different purposes:

1. For generalizing information.
2. For making associations and discriminations.
3. For speeding up memory.
4. For guiding actions and behaviors.

**Concept Attainment Worksheet**

Write down the positive (Yes) and negative (No) examples below: (to be filled out by teacher)

| **Yes Examples** | **No Examples** |
|---|---|
| • | • |
| • | • |
| • | • |
| • | • |

**Attributes**

1.
2.
3.
4.
5.

Identify the concept using the attributes: …….

Define the concept: ……

**Concept Attainment Glossary**

- Attribute – a major feature or characteristic of something; e.g., robin – red breast.
- Attribute value – the degree or strength to which the attribute is represented in the exemplar.
- Category – a collection of examples that share attributes missing in the other exemplar list.
- Concept – an idea, object, or event that can be given a name or label.
- Data set – a large list of exemplars.
- Essential attribute – the characteristic that is critical to understanding the concept under consideration.
- Exemplars – subset of a collection of data presented as a pair.
- Induction – process of reasoning that proceeds from the specific to the general.

## 3.3 Misconceptions

**Misconceptions** can be referred to as a preconceived notion or a conceptual misunderstanding. These are cases in which something a person knows and believes does not match what is known to be scientifically correct. A lot of people who hold **misconceptions** do not even know that their ideas are false or incorrect.

Misconceptions can be categorized as follows:

- *Preconceived notions* are popular conceptions rooted in everyday experiences. For example, many people believe that water flowing underground must flow in streams because the water they see at the earth's surface flows in streams. Preconceived notions plague students' views of heat, energy, and gravity (Brown and Clement, 1991), among others.
- *Nonscientific beliefs* include views learned by students from sources other than scientific education, such as religious or mythical teachings. For example, some students have learned through religious instruction about an abbreviated history of the earth and its life forms. The disparity between this widely held belief and the scientific evidence for a far more extended pre-history has led to considerable controversy in the teaching of science.
- *Conceptual misunderstandings* arise when students are taught scientific information in a way that does not provoke them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs. To deal with their confusion, students construct faulty models that usually are so weak that the students themselves are insecure about the concepts.
- *Vernacular misconceptions* arise from the use of words that mean one thing in everyday life and another in a scientific context (e.g., "work"). A geology professor noted that students have difficulty with the idea that glaciers retreat, because they picture the glacier stopping, turning around, and moving in the opposite

direction. Substitution of the word "melt" for "retreat" helps reinforce the correct interpretation that the front end of the glacier simply melts faster than the ice advances.

- *Factual misconceptions* are falsities often learned at an early age and retained unchallenged into adulthood. If you think about it, the idea that "lightning never strikes twice in the same place" is clearly nonsense, but that notion may be buried somewhere in your belief system.

(source: https://www.nap.edu/read/5287/chapter/5#28)

**Misconceptions in Physics Exemplars**

**Electricity**

1. Positively charged objects have gained protons, rather than being deficient in electrons.
2. Electrons which are lost by an object are really lost (no conservation of charge).
3. All atoms are charged.
4. A charged object can only attract other charged objects.
5. The electrostatic force between two charged objects is independent of the distance between them.
6. Gravitational forces are stronger than electrostatic forces.
7. Batteries have electricity inside them.

**Forces and Fluids**

1. Objects float in water because they are lighter than water.
2. Objects sink in water because they are heavier than water.
3. Mass/volume/weight/heaviness/size/density may be perceived as equivalent.
4. Wood floats and metal sinks.
5. All objects containing air float.
6. Liquids of high viscosity are also liquids with high density.
7. Adhesion is the same as cohesion
8. Heating air only makes it hotter.
9. Pressure and force are synonymous.
10. Pressure arises from moving fluids.
11. Moving fluids contain higher pressure.
12. Liquids rise in a straw because of "suction".
13. Fluid pressure only acts downward.

Tolerant teachers had a more positive attitude towards pupils' misconceptions and did not reject the idea that a misconception can be considered as an alternative way of looking at a problem situation. Although they advocated, ultimately, the replacing of a misconception with the appropriate scientific conception, they supported promoting multiple perspectives approach towards a problem situation in equal fervour. They did not support 'teaching by confronting' misconceptions in order to resolve them. Tolerant teachers were also not convinced that misconceptions interfere with pupils' learning of scientific conceptions. After all they thought that some misconceptions are helpful for everyday purposes. For example, the idea of 'force causes motion (velocity)' is helpful when you wish to move something around the house. However, this may constitute a misconception since Newtonian conception of motion states that ‘force causes change in motion (acceleration)’ not velocity. In order to address misconceptions in class, tolerant teachers believed that it requires a good balance between teachers’ subject knowledge and pedagogy.

The process of addressing misconcpetions requires that the teacher:

- Identify students' misconceptions.
- Provide a forum for students to confront their misconceptions.
- Help students reconstruct and internalize their knowledge, based on scientific models.

## 3.4 Helping Students Confront Their Misconceptions

It is useful to review and think about possible misconceptions before teaching a class or laboratory in which new material is introduced. Use questions and discussion to probe for additional misconceptions. Students will often surprise you with the variety of their preconceptions, so be careful to listen closely to their answers and explanations. You can help students by asking them to give evidence to support their explanations and by revisiting difficult or misunderstood concepts after a few days or weeks. Misconceptions are often deeply held, largely unexplained, and sometimes strongly defended. To be effective, a science teacher should not underestimate the importance and the persistence of these barriers to true understanding. Confronting them is difficult for the student and the teacher.

Some misconceptions can be uncovered by asking students to sketch or describe some object or phenomenon. For example, one might ask students to sketch an atom before doing so on the board. Even students who have a strong high school background might show a small nucleus surrounded by many electrons circling in discrete orbital paths, much like the solar system. By asking them to draw their own model first and then asking some students to share their answers with the class, a teacher can identify preexisting models and use them to show the need for new models.

## 3.5 Helping Students Overcome Their Misconceptions

Strategies for helping students to overcome their misconceptions are based on research about how we learn (Arons, 1990; Minstrell, 1989). The key to success is ensuring that students are constructing or reconstructing a correct framework for their new knowledge. One way of establishing this framework is to have students create "concept maps," an approach pioneered by Novak and Gowin (1984). With this technique, students learn to visualize a group of concepts and their interrelationships. Boxes containing nouns (and sometimes adjectives) are connected to related terms with a series of lines; prepositions or verbs are superimposed on the connecting lines to help clarify the relationship.

Helping to overcome thier misconception need

- Anticipate the most common misconceptions about the material and be alert for others.
- Encourage students to test their conceptual frameworks in discussion with other students and by thinking about the evidence and possible tests.

- Think about how to address common misconceptions with demonstrations and lab work.
- Revisit common misconceptions as often as you can.
- Assess and reassess the validity of student concepts.

## 3.6 References


- http://www.mhhe.com/cls/psy/ch08/conform.mhtml
- https://k12teacherstaffdevelopment.com/tlb/what-is-the-concept-attainment-model/
- http://www.amasci.com/miscon/opphys.html
- https://www.nap.edu/read/5287/chapter/5#28

# 4. Mechanical Properties of Fluids

## 4.1 Introduction

This module is focusing on the discussion of the content on mechanical properties of fluids, highlighting the concepts of viscosity, surface tension, Reynold’s number, Critical Velocity.

## 4.2 Learning objectives

During /at the end of this session the participants will be able to

- Distinguish laminar and turbulent flow
- Explain viscous force
- Apply the knowledge of viscous force
- Define critical velocity
- Explain the meaning of Reynold’s number
- Analyze the concept of surface tension
- Describe the concept of angle of contact

## 4.3 Major Concepts

- **Viscosity-**Viscosity is a measure of a fluid's resistance to flow. It describes the internal friction of a moving fluid. A fluid with large viscosity resists motion because its molecular makeup gives it a lot of internal friction.
- Critical Velocity: Critical velocity is the speed and direction at which the flow of a liquid through a tube changes from smooth, or "laminar," to turbulent. Calculating critical velocity depends on multiple variables, but it is the Reynolds number that characterizes the flow of the liquid through a tube as either laminar or turbulent.
- Reynold’s number: a dimensionless number used in fluid mechanics to indicate whether fluid flow past a body or in a duct is steady or turbulent.
- Surface Tension: the tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimize surface area.



## 4.4 Learning Resources

- Playing cards (to explain laminar and turbulent flow)
- Different solutions of different viscosity
- Marbles
- Safety pin
- Simulations

## 4.5 Content Descriptions and activities

### Viscosity Explanation

The viscosity of a fluid is the measure of its resistance to gradual deformation by shear stress or tensile stress. Viscosity is the property of a fluid which opposes the relative motion between two surfaces of the fluid that are moving at different velocities. In simple terms, viscosity means friction between the molecules of fluid. When the fluid is forced through a tube, the particles which compose the fluid generally move more quickly near the tube's axis and more slowly near its walls; therefore, some stress (such as a pressure difference between the two ends of the tube) is needed to overcome the friction between particle layers to keep the fluid moving. For a given velocity pattern, the stress required is proportional to the fluid's viscosity.

Figure below shows schematically how laminar and turbulent flow differ. Layers flow without mixing when flow is laminar. When there is turbulence, the layers mix, and there are significant velocities in directions other than the overall direction of flow. The lines that are shown in many illustrations are the paths followed by small volumes of fluids. These are called *streamlines*. Streamlines are smooth and continuous when flow is laminar, but break up and mix when flow is turbulent. Turbulence has two main causes. First, any obstruction or sharp corner, such as in a faucet, creates turbulence by imparting velocities perpendicular to the flow. Second, high speeds cause turbulence. The drag both between adjacent layers of fluid and between the fluid and its surroundings forms swirls and eddies, if the speed is great enough. We shall concentrate on laminar flow for the remainder of this section, leaving certain aspects of turbulence for later sections.

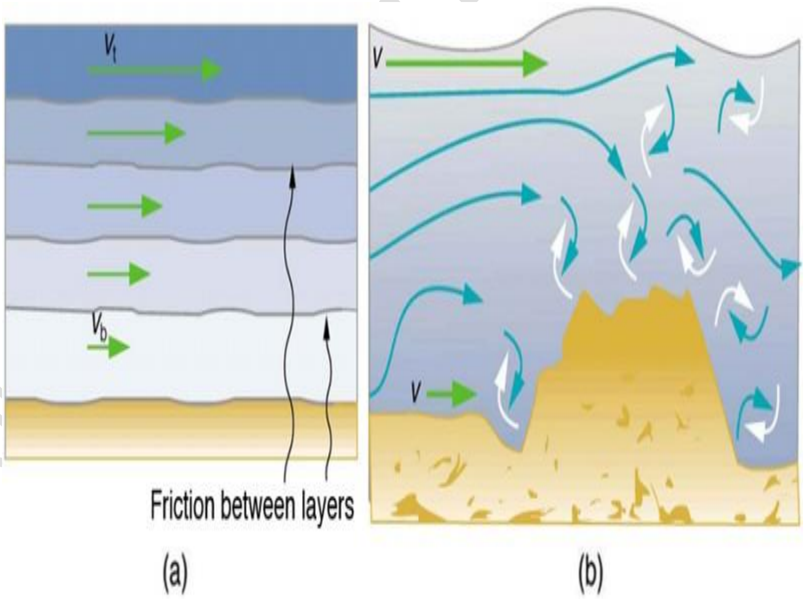



***Figure:*** Laminar flow occurs in layers without mixing. Notice that viscosity causes drag between layers as well as with the fixed surface. (b) An obstruction in the vessel produces turbulence. Turbulent flow mixes the fluid. There is more interaction, greater heating, and more resistance than in laminar flow.

**Focus question:** Try dropping simultaneously two sticks into a flowing river, one near the edge of the river and one near the middle. Which one travels faster? Why?

Figure below shows how viscosity is measured for a fluid. Two parallel plates have the specific fluid between them. The bottom plate is held fixed, while the top plate is moved to the right, dragging fluid with it. The layer (or lamina) of fluid in contact with either plate does not move relative to the plate, and so the top layer moves at *v* while the bottom layer remains at rest. Each successive layer from the top down exerts a force on the one below it, trying to drag it along, producing a continuous variation in speed from *v* to 0 as shown. Care is taken to insure that the flow is laminar; that is, the layers do not mix. The motion in figure below is like a continuous shearing motion. Fluids have zero shear strength, but the *rate* at which they are sheared is related to the same geometrical factors *A* and *L* as is shear deformation for solids.

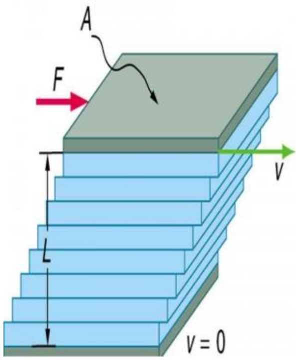


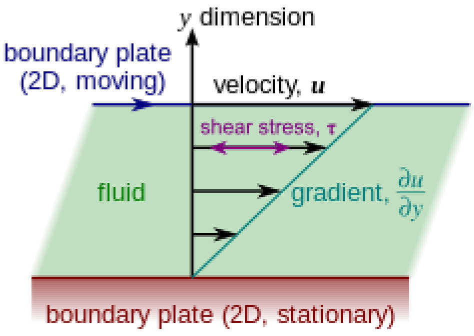

Figure: The graphic shows laminar flow of fluid between two plates of area A. The bottom plate is fixed. When the top plate is pushed to the right, it drags the fluid along with it.

A force *F* is required to keep the top plate in Figure 3 moving at a constant velocity *v*, and experiments have shown that this force depends on four factors. First, *F* is directly proportional to *v* (until the speed is so high that turbulence occurs—then a much larger force is needed, and it has a more complicated dependence on *v*). Second, *F* is proportional to the area *A* of the plate. This relationship seems reasonable, since *A* is directly proportional to the amount of fluid being moved. Third, *F* is inversely proportional to the distance between the plates *L*. This relationship is also reasonable; *L* is like a lever arm, and the greater the lever arm, the less force that is needed. Fourth, *F* is directly proportional to *the coefficient of viscosity*, *η*. The greater the viscosity, the greater the force required. These dependencies are combined into the equation

$F = \boldsymbol{\eta A v / L}$**;** which gives us a working definition of fluid *viscosity η*. Solving for *η* gives$\boldsymbol{\eta = FL/vA}$**;** which defines viscosity in terms of how it is measured. The SI unit of viscosity is N·m/[(m/s)m2] = (N/m2)s or Pa·s. Table 1 lists the coefficients of viscosity for various fluids.

Viscosity varies from one fluid to another by several orders of magnitude. As you might expect, the viscosities of gases are much less than those of liquids, and these viscosities are often temperature dependent.

**Activity:** Taking a bunch of playing cards arranged vertically, then allowing the participants to push the cards and observe the motion of the cards. From the observation, they could discuss and develop analogy to the laminar flow and discuss about the forces and motion.




(https://en.wikipedia.org/wiki/File:Laminar_shear.svg)

- Using PhEt simulation Fluid Pressure and Flow, explain the concept of laminar and turbulent flow.
- Motion of an object in viscus fluid http://physics.bu.edu/~duffy/HTML5/ball_in_viscous_fluid.html
- Motion of balloon and buoyancy file:///C:/Program%20Files%20(x86)/PhET/en/simulation/balloons-and-buoyancy.html

**Critical Velocity**

Explanation and calculation of critical velocity of fluids using the link https://sciencing.com/calculate-critical-velocity-8440253.html

The critical velocity is the velocity of fluid at which turbulence sets in. Osborne Reynolds (1842-1912) showed that the critical velocity *v* for a fluid flowing through a narrow tube is a function of coefficient of viscosity **η**, density of the fluid **ρ**and the radius '*r*' of the tube.

That is,

$$Vc = \frac{Re\eta}{\rho r}$$ ; where Re is the Reynold Number.

**Reynolds Number**

A dimensionless parameter that determines the behavior of viscous flow patterns. In pipe flow a value less than about 2,000 (known as the critical Reynolds number) produces laminar flow, one above about 3,000 produces turbulent flow (intermediate values produce unpredictable behavior).

Reynolds number is the ratio of inertial forces to viscous forces within a fluid which is subjected to relative internal movement due to different fluid velocities, which is known as a boundary layer in the case of a bounding surface such as the interior of a pipe.

With respect to laminar and turbulent flow regimes:

- laminar flow occurs at low Reynolds numbers, where viscous forces are dominant, and is characterized by smooth, constant fluid motion;

- turbulent flow occurs at high Reynolds numbers and is dominated by inertial forces, which tend to produce chaotic eddies, vortices and other flow instabilities.

The Reynolds number is defined as

$$\mathbf{Re} = \frac{\boldsymbol{\rho u L}}{\boldsymbol{\mu}};$$

**ρ**= density of the fluid (kg/m3); u is the velocity of the fluid with respect to the object (m/s); L is the characteristic linear dimension (m); μ is the dynamic viscosity of the fluid (Pa.s or N.s/$m^2$)

The form of the Reynolds number can be derived as follows

$$Re = \frac{inertial\ forces}{Viscous\ forces} = \frac{mass.acceleration}{dynamic\ viscosity.\left(\frac{velcoity}{distance}\right).area}$$

**Activity:** Explanation using the PhET simulation of dynamic fluid flow

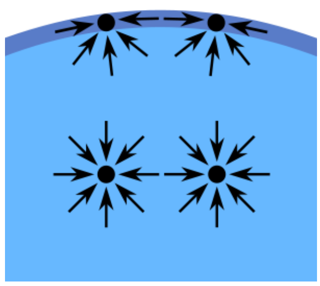
- Using PhEt simulation Fluid Pressure and Flow, explain the concept of laminar and turbulent flow.

**Cohesive Forces Result in Surface Tension**

The molecules in a sample of a liquid that find themselves fully in the interior volume are surrounded by other molecules and interact with them based on the attractive intermolecular forces that are present for molecules of this type. However, the molecules at the interface with another medium (usually air) do not have other like molecules on all of their sides (namely, on top of them), so they cohere more strongly to the molecules on the surface and immediately below them. The result is a surface film which makes it more difficult for an object to pierce through the surface than for it to move once submerged in the sample of liquid. Therefore, the cohesive forces result in the phenomenon of *surface tension*.

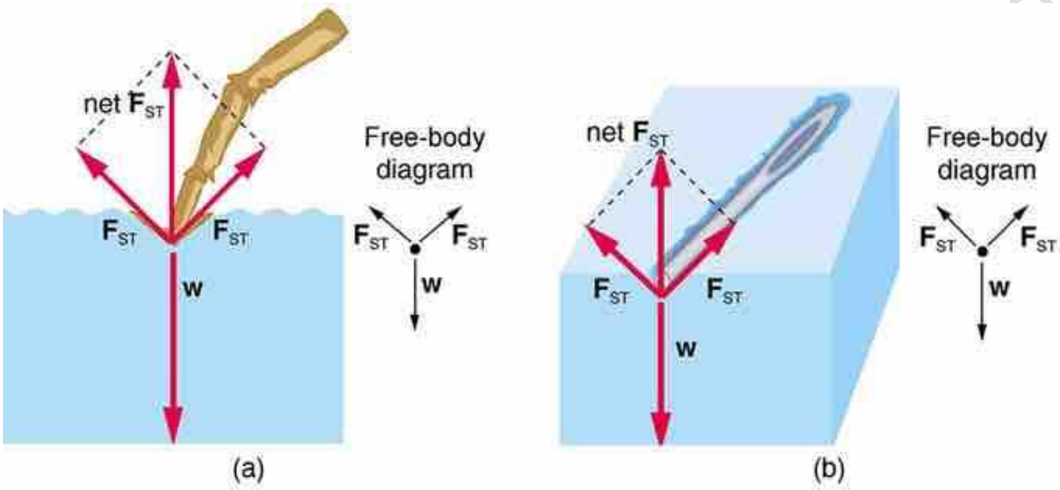
**Surface tension**

The tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk ofthe liquid, which tends to minimize surface area.



Surface tension happens because the water molecules at the surface of the water are strongly attracted to each other more than they are to the air molecules above them. The water molecules make an invisible skin on the water's surface that allows things like the needle to float on top of the water.

Surface tension is the tendency of a liquid surface to resist forces applied to it. This effect is a result of cohesion of the molecules of the liquid causing the surface of the liquid to contract to the smallest area possible. This effect is visible in nature with water strider insects that are able to walk on water. Also, a paper clip or pin can be supported by the surface tension at a water air interface




In the bulk of the liquid, the molecules are pulled equally in all directions. The molecules at the surface feel a greater attractive force toward the bulk material than the interface material.

The surface of a liquid is an interface between another fluid, a solid body, or both. Therefore, the surface tension will be a property of the interface rather than simply the liquid. Adhesion describes the attractive force between molecules of different types. The surface of a liquid in a container is an interface between the liquid, the air, and the container. Where the surfaces meet, forces must be in equilibrium. This results in a contact angle at the interface. The contact angle is measured in the liquid and depends on the relative strength of cohesive forces in the liquid and adhesive forces between the liquid and interface materials. If liquid molecules are strongly attracted to the molecules of the solid surface (adhesive forces > cohesive forces), the drop will tend to spread out and the contact angle will be close to zero degrees. If the cohesive forces are greater than the adhesive forces, the resulting contact angles will be large and will form a more circular drop.

**Activity:**

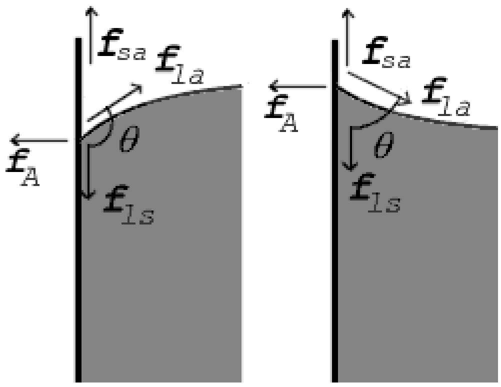
Video clip :Cutting a water droplet using a superhydrophobic knife on superhydrophobicsurfaces.ogv Author: Yanashima R, García AA, Aldridge J, Weiss N, Hayes MA, et al. (2012) Cutting a Drop of Water Pinned by Wire Loops Using a Superhydrophobic Surface and Knife. PLoS ONE 7(9): e45893. doi: 10.1371/journal.pone.0045893; Date: 26 September 2012, 06:28:24

Surface tension experimental demonstration.ogv; Author: Jubobroff; Date: 24 June 2014, 09:05:50

Using the web page http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html

**Angle of Contact**

Where the two surfaces meet, they form a contact angle, θ, which is the angle the tangent to the surface makes with the solid surface.




Forces at contact point shown for contact angle greater than 90° (left) and less than 90° (right) (Taken from https://simple.wikipedia.org/wiki/File:SurfTensionContactAngle.png)

Wetting is the ability of a liquid to form an interface with a solid surface and the degree of wetting is evaluated as the contact angle θ formed between the liquid and the solid substrate surface.

The contact angle is the angle, conventionally measured through the liquid, where a liquid–vaporinterface meets a solid surface. It quantifies the wettability of a solid surface by a liquid via the Young equation. A given system of solid, liquid, and vapor at a given temperature and pressure has a unique equilibrium contact angle.

## 4.5 Misconceptions

1. Objects float in water because they're "lighter" than water.
2. Objects sink in water because they're "heavier" than water.
3. Mass, volume, weight, heaviness, size, and density may be perceived as equivalent.
4. Wood floats and metal sinks.
5. All objects containing air float.
6. Liquids of high viscosity are also liquids with high density.
7. Adhesion is the same as cohesion.
8. Heating air only makes it hotter.
9. Pressure and force are synonymous.
10. Pressure arises from moving fluids.
11. Moving fluids contain higher pressure.
12. Liquids rise in a straw because of "suction."
13. Fluid pressure only acts downward.

## 4.6 Self-Check questions

1. What is viscosity?
2. Explain the reasons for viscous nature of a fluid
3. Distinguish between laminar and turbulent flow

4. What are the application of Reynold’s number?
5. Discuss the importance of critical velocity in fluid flow
6. Explain the concept of surface tension

## 4.7 Module end exercise

- Find out resources that could help to explain the basic concepts related to Mechanical Properties of Fluids
- Discuss the application of Reynold’s number
- Discuss the application of surface tension
- Analyze the wetting nature of fluids as the application of angle of contact

## 4.8 References


1. https://courses.lumenlearning.com/physics/chapter/12-4-viscosity-and-laminar-flow-poiseuilles-law/
2. https://commons.wikimedia.org/wiki/Surface_tension_diagrams
3. http://oer2go.org/mods/en-boundless/www.boundless.com/physics/textbooks/boundless-physics-textbook/fluid-dynamics-and-its-applications-11/bernoulli-s-equation-99/surface-tension-359-352/index.html
4. https://en.wikiversity.org/wiki/Fluid_Mechanics_for_Mechanical_Engineers/Introduction
5. https://nptel.ac.in/courses/122103011/28
6. https://sites.google.com/site/scienceinanutshell/common-misconceptions-about-fluids
7. https://en.wikipedia.org/wiki/Contact_angle

# 5. ELECTRO MAGNETIC INDUCTION

## 5.1 Introduction

In 1820, Oersted discovered the magnetic effect of electric current i.e. when a steady current flow through a conductor, a magnetic field is produced around it. In 1831, Michael Faraday discovered the effect, called *electromagnetic induction,* just converse to the magnetic effect of electric current.

When a coil made of copper wire is placed inside a magnetic field, magnetic flux is linked with the coil. Faraday found that when the magnetic flux linked with the coil is changed, an electric current start flowing in the coil, provided the coil is a closed one. In case the coil is open, an E.M.F. is set up across the two ends of the coil. The current and the E.M.F. so produced are called *induced current* and *induced E.M.F.* respectively. The induced current and the E.M.F. in the coil last only so long as the magnetic flux linked with the coil keeps on changing.

Thus, electromagnetic induction is the phenomenon of production of electric current (or E.M.F.) in a coil, when the magnetic flux linked with the coil is changed.

## 5.2 Learning Objectives

To acquire the knowledge of change in magnetic flux produces induced emf or Induced current

To understand the means of change in magnetic flux

To understand on what factors induced current depends

Able to solve the problems related to motional emf and AC currents

Able to apply the knowledge of rate of change in magnetic flux in practical situations (Generators)

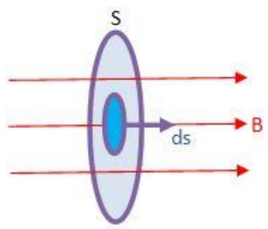
## 5.3 Major Concepts

Magnetic Flux

A number of Magnetic Field lines passing normally through unit area of the surface

Let S = closed surface

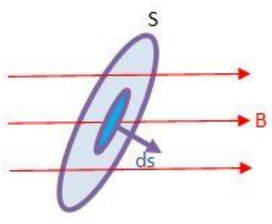
B = magnetic field




Then flux over area element is given by, $\varphi = Bds$

Total flux $\varphi = BA$

If θ = angle between 'B' and 'ds'




Total flux $\varphi = BA\ Cos\theta$

Means of change in Magnetic Field

- By changing Magnetic Field

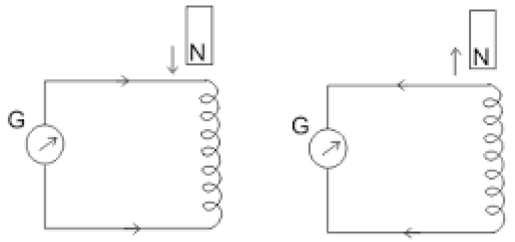
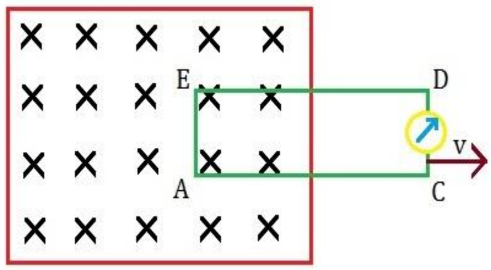
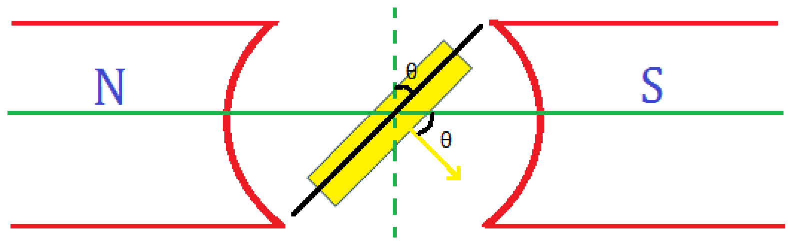



Figure 1. North pole of the magnet moving towards and away from closed circuit containing galvanometer in Faraday's experiment

- By changing Area




- By changing Angle



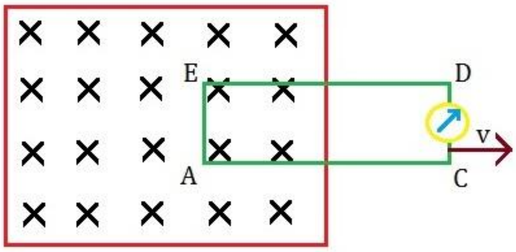

$$\theta = \omega t$$

## 5.4 Learning Resources

Enameled copper wire, Disc magnet, cylindrical magnets. Two identical toys,Inextinguishable thread, Aluminum plates or copper plates ( for activities)

## 5.5 Content Descriptions and Activities

Motional EMF




B = Uniform Magnetic Field Perpendicular to the plane of the paper and directed inverse

ACDE = Rectangular Coil, moving with the velocity 'v'

Change in Magnetic Flux linked with the Closed Loop in time 'dt'

$d\varphi = B\ (l\ X\ dx)$

Rate of Change in Magnetic Flux linked with the Loop

$\xi = -\frac{d\varphi}{dt} = Bl\frac{dx}{dt} = Blv$

Let R = Resistance of Loop

$I = \frac{\xi}{R} = \frac{BVl}{R}$

Note:

If the coil makes an angle θ wrt to the direction of magnetic field

Change in magnetic Flux, $d\varphi = B\ (l\ X\ dx)cos\theta$

Rate of change in magnetic flux is

$\frac{d\Phi}{dt} = -Blvsin\theta$

$\xi\ =\ Blvsin\theta$

AC GENERATOR

Definition: A device which converts mechanical energy into electrical energy

Principle: Based on the principle of electromagnetic induction

Construction:

It has four main parts:

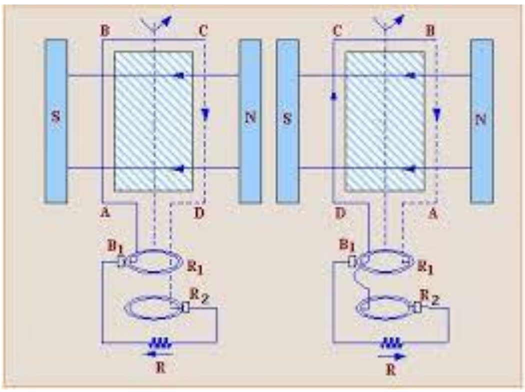
(i) field magnet

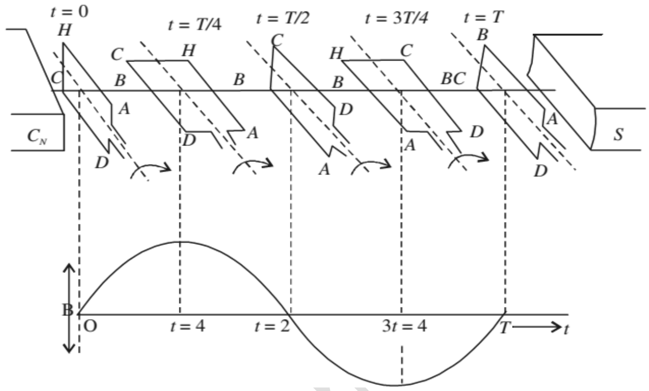
(ii) armature ( shaft and the coil)

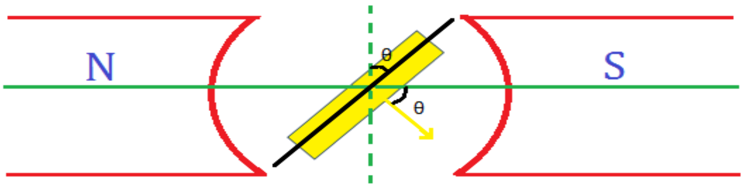
(iii) slip rings or spilt rings

(iv) Brushes

Working




θ = ωt

Initially, say at time t = 0, the coil is vertical and the flux linked with the coil is Φ = BA which is maximum, (but the rate of change in magnetic flux is zero) since there is no change in magnetic flux linked with the coil the induced emf produced is zero.

As the coil rotates there is change in magnetic flux linked with the coil causes the production of induced emf. This induced emf goes on increases and becomes maximum when the coil is horizontal position. At this position the magnetic field lines cuts or intercept the coil to maximum extent that is the rate of change in magnetic flux is maximum and induced emf is maximum. (t= T/4 or one-fourth of rotation)

Further the coil rotates the change in magnetic field decreases and induced emf is also goes on decreases and becomes zero when the coil comes to vertical position as shown in the figure. (t = T/2)

When the coil further rotates again there is increase in magnetic flux in turn increase in induced emf but in the opposite direction and becomes maximum when the coil is horizontal position (t = 3T/4)

As a result of inertia of motion when the coils move further causes change in magnetic flux in turn induced emf goes on decreases and becomes zero (t = T)

Thus, the rotation of the coil inside the magnetic field causes continuous change in magnetic flux linked with the coil and produces induced emf continuously as shown in the figure.

Theory

Let at any instant of time the coil makes an angle ‘θ’

Magnetic flux linked with the coil, $\varphi = nBAcos\theta$ , (n= number of turns of the coil)

If ‘ω’ = angular velocity

$\varphi = nBAcos\omega t$

Rate of change in magnetic flux, $\frac{d\Phi}{dt} = - nBA\omega sin\omega t$

$$- \xi = - (nBA\omega) sin\omega t$$

$$\xi = (nBA\omega) sin\omega t$$

$$\xi = \xi o sin\omega t$$

The above equation represents instantaneous value of emf of ac current.

Activities

Activity 1

Take a simple pendulum stand (preferably wooden).

Suspend an object in the place of pendulum with a powerful magnet attached to its base

Allow the pendulum to oscillate and note down the time taken to come to rest

Now keep an aluminum or copper plate at the base of simple pendulum stand and repeat the activity with the same amplitude

It is observed that pendulum comes to rest quickly than earlier. Why?

Increase the thickness of aluminum plates and repeat the activity. what do you observe?

Ponder the situations and comes to conclusion

Activity 2

(a) Maintaining amplitude of oscillations same

Previous knowledge: Time period of simple pendulum is independent of amplitude (for small angular displacement) and depends upon its length and acceleration due to gravity.

Prepare a stand preferably that accommodate two pendulums side by side,

Take two identical toys one with magnet attached and other without magnet

Place aluminum places at the base of both pendulums

Allow the pendulum to oscillate.

What do you observe?

The pendulum which is attached with magnet comes to rest than the other.  Why?

(b) Increasing amplitude of oscillation

Previous knowledge: Time period of simple pendulum is independent of amplitude (for small angular displacement) and depends upon its length and acceleration due to gravity

Now increase the amplitude of oscillations of pendulum slightly

Repeat the activity.

It is observed that the pendulum attached with the magnet comes to more quickly than earlier.

Infer the situation and justify

Key Points

- Magnetic Flux: The Magnetic flux through any surface placed in a magnetic field is number of magnetic field lines passing perpendicularly through that surface.
- It is measured by the dot product of magnetic field vector B and area vector A.
- Magnetic flux is scalar quantity.
- The phenomenon of production of an emf due to change in magnetic flux linked with acoil is called electromagnetic induction.
- If a coil is closed, the induced emf results an induced current in the coil.
- Faraday's laws of EMI
  - (i) Whenever there is change in magnetic flux linked with the coil an induced emf is produced and it exists as long as the flux is changing.
  - (ii) The rate of change of magnetic flux with time through the coil is directly proportional to magnitude of induced emf in that coil.

    $\xi = -\frac{d\varphi}{dt}$

- If the coil has N turns, then the total emf in that coil

  $\xi = -N\frac{d\varphi}{dt}$

- If the coil is closed and its resistance is R, then the induced current in that coil

  $I = \frac{\xi}{R}$

  $I = -\frac{N}{R}\frac{d\varphi}{dt}$

- The direction of induced current in a closed coil are the polarity of the induced emf in a coil is given by Lenz Law.

- Lenz's Law : the direction of induced current/ emf in a coil is always opposes its own cause ( the change in magnetic flux) due to which it is produced.
- Lenz's Law is in accordance with the Law of conservation of Energy.
- Motional emf: when a conductor of length l moves in perpendicular magnetic field B with velocity v. then the induced emf is produced in the conductor. This induced emf is called motional emf. It is given by,

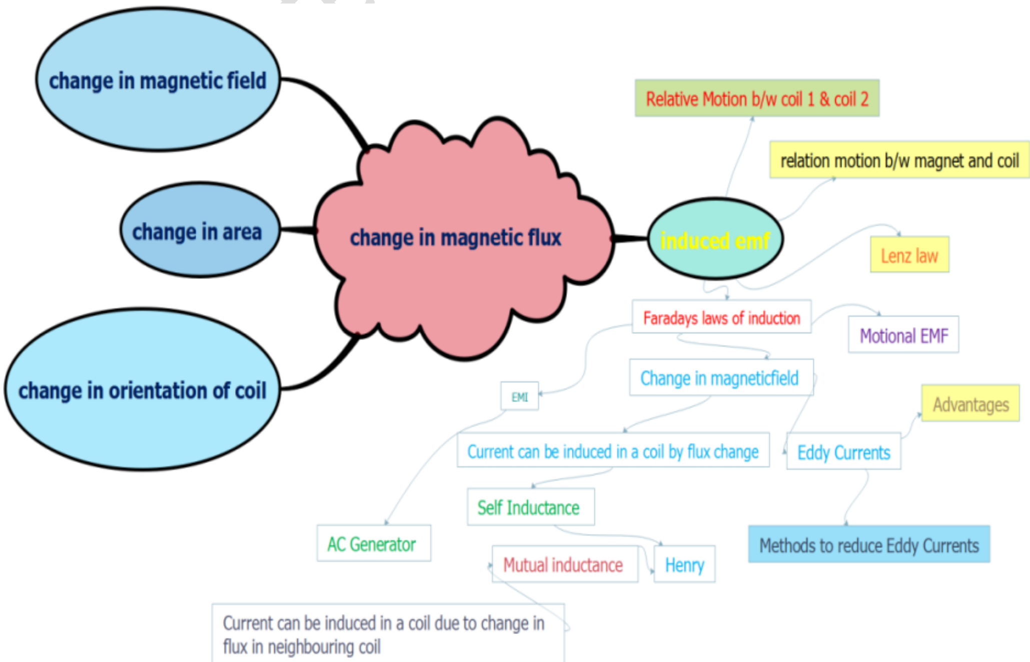
$$E_{motional} = Blv$$

- Eddy Currents: when a conductor or a metal plate is placed in changing magnetic field, the induced current is setup in that conductor, which are in the form of Eddies. Such currents are called Eddy's Currents.
- In such type of cases eddy currents are undesirable and they can never be zero. They can only be minimized by increasing the resistance of the conductor.
- Due to induced Eddy current a large amount of energy is dissipated in the form of heat.
- Eddy currents are sometimes very advantages such as to make dead beat galvanometer, induction furnace, magnetic breaks in trains.
- An AC generator, works on the principle of electromagnetic induction. It converts mechanical energy into electrical energy.
- In an AC generator, when a coil having N turns and area A, is rotated in an uniform magnetic field B with an angular speed Ω, then the produced emf,

$$\xi = (NBA\omega)sin\omega t$$

$$\xi = \xi o sin\omega t$$

where, $\xi_0 = (NBA\omega)sin\omega t$



EXERCISES/PROBLEMS FOR PRACTICE

1. A wire of length 0.1m moves with the speed of 10m/sec perpendicular a magnetic field 1 Wb/m$^2$. What is the value of induced emf?
2. A square copper coil of each side 8cm consists of 100 turns the coil is initially in vertical plane such that the plane of the coil is normal to uniform magnetic field of induction 0.4 Wb/m $^2$. The coil is turn through 180 degree about a horizontal axis in 0.2 sec. Find the induced emf.
3. A circular coil of radius 8 cm and 20 turns is rotated about its vertical diameter with the angular speed of 50 rad/sec in uniform horizontal magnetic field of a magnitude 3 x 10$^{-2}$ T. Obtain maximum emf induced in the coil, if the coil forms a closed loop of resistance 10Ω, calculate the maximum value of current in the coil. Also calculate the average power loss due to joule heating.
4. A jet plane is travelling is travelling towards west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wings having span of 25m, if the earth magnetic field at the location has a magnitude of 5 x 10$^{-4}$ T and the dip angle is 30$^o$.
5. A metallic rod of a 1m length is rotated with a frequency of 50rev/s, with one end hinged at the centre and the other end at the circumference of a circle metallic ring of radius '1m', about amn axis passing through a centre and perpendicular to the plane of the ring. A constant and uniform magnetic field of 1T parallel to the axis present everywhere. What is the emf between centre and the metallic ring

Multiple Choice Questions

1. Two circular loops of same area one is of copper and the other is aluminum are allowed to rotate with same angular speed in a given magnetic field of strength 5T. What is the ratio of EMF's produced in the coils? ($R_{cu} = 1.5\ R_{al}$) (Application Based)
   a. 1 : 1.5
   b. 1.5 : 1
   c. 1 : 1
   d. None of these
2. Two circular loops of same area one is of copper and the other is aluminum are allowed to rotate with same angular speed in a given magnetic field of strength 5T. What is the ratio of Induced current produced in the coils? ($R_{cu} = 1.5\ R_{al}$) (Application Based)
   a. 1 : 1.5
   b. 1.5 : 1
   c. 1 : 1
   d. None of these
3. Lenz's law is consequence of the law of conservation of (Knowledge Based)
   a. Charge
   b. Momentum
   c. Mass
   d. Energy
4. Eddy currents are produced when ( Knowledge Based)
   a. When a metal is kept in varying magnetic field
   b. When a metal is kept in steady magnetic field
   c. A circular coil is placed in a magnetic field

d. Through a circular coil, current is passed

5. If rotational velocity of a dynamo is doubled, then induced EMF will be (Understanding Based)
    a. Half
    b. Two times
    c. Four times
    d. Unchanged
6. An AC generator of 220V having internal resistance r=10Ω and external resistance R=100Ω. What is the power developed in the external circuit (Understanding Based)
    a. 484W
    b. 400W
    c. 441W
    d. 369W
7. A copper rod of length $l$ is rotated about one end perpendicular to the magnetic field $B$ with constant angular velocity $\omega$. The induced E.M.F. between the two ends is (Application Based)
    a. $\frac{1}{2} B\omega l^2$
    b. $\frac{3}{4} B\omega l^2$
    c. $B\omega l^2$
    d. $2\ B\omega l^2$
8. A circular coil of radius 8cm and 20 turns is rotated about its vertical diameter with an angular speed of 50 radians per second in an uniform horizontal magnetic field of magnitude $3 \text{ X } 10^{-2}$ T. Maximum E.M.F. produced in the coil is (Understanding Based)
    a. 0.50 V
    b. 0.60 V
    c. 0.40 V
    d. 0.70 V
9. In an AC generator, when the plane of the armature is perpendicular to the magnetic field (Skilled Based)
    a. Both magnetic flux and emf are maximum
    b. Both magnetic flux and emf are zero
    c. Magnetic flux is zero and emf is maximum
    d. Magnetic flux is maximum and emf is zero
10. Two identical circular loops of metal wire are lying on a table without touching each other. Loop-A carries a current which increase with the time. In response, the Loop-B (Skilled Based)
    a. Remains stationary
    b. Is attracted by the Loop-A
    c. Is repelled by the Loop-A
    d. Rotates about its CM, with CM fixed

Answers to MCQs

1. c
2. a
3. d
4. a
5. b
6. b
7. a
8. b
9. d
10. c

# 6. Gauss's Law and Applications

## 6.1 Introduction

Gauss's law is an important law in classical electromagnetism; and is one of the four Maxwell's equations which describe the relations between three apparently different fields viz. Electricity, Magnetism and Optics which were treated separately. To study and transact Gauss's Law, we need to have a firm understanding of Electric field and Electric flux. The successful applications of Gauss's theorem underlie in the proper selection of Gaussian surface.

## 6.2 Learning objectives

After the completion of this session, the learner will be able to

1. describe Electric flux

2. define Gauss's law and

3. apply Gauss's law to find the electric field due to different charge distributions

4. solve problems in finding Electric flux, electric fields and related topics

## 6.3 Major Concepts

1. Electric field

2. Electric field lines

3. Surface vector

4. Electric flux

5. Gauss's law

6. Relationship between Gauss's law and electric field

## 6.4 Learning Resources

1. Power point presentation slides

2. Small experiment on electrostatic shielding

3. Small experiment on direction of electric field

4. Videos

5. Problem set

6. Hand-out on content descriptions and activities

## 6.5 Content Descriptions and Activities

The concept of electric field was put forward by Michael Faraday. The main aim of the concept was to give a physical representation for the strength of an electrical charge's presence as experienced by another charge and the direction in which this influence acts. Representing the magnitude and direction at each point in the vicinity of the electric charge in consideration makes electric field, a vector field.

**Vector field**

If each point in space is assigned with a vector, it is called a vector field. Mathematically, it is a function of space whose value at each point is a vector quantity.

**Necessity of Electric field**

The Electric vector field associates a force with each point in space; this force is named the Coulombic force. The coulombic force is the force experienced by an infinitesimally small charge (test charge) per unit charge. Action-at-a-distance forces are sometimes referred to as field forces. The concept of a**field force** is utilized to explain this rather unusual force phenomenon that occurs in the absence of physical contact. Gravitational and Electric force and magnetic forces are action - at - a distance forces. While all masses attract when held some distance apart, charges can either repel or attract when held some distance apart. An alternative to describing this action-at-a-distance effect is to simply suggest that there is something rather strange about the space surrounding a charged object. Any other charged object that is in that space feels the effect of the charge. This *special strangeness* created by the charged object is electric field - an alteration of the space in the region that surrounds it. Other charges in that field would feel the unusual alteration of the space. Whether a charged object enters that space or not, the electric field exists. Space is altered by the presence of a charged object. Other objects in that space experience the strange and mysterious qualities of the space.

The presence of a charge or charge distribution creates an electric field in the space around the charge. Similarly a time-varying magnetic field will also create an electric field which is effectively utilized (perhaps unknowingly) by Michael Faraday.

The electric field lines or electric flux lines are used to represent the electric field both in magnitude and in direction and magnitude. Electric flux lines are mental constructs which represent the electric field in a region.



**Experiment No: 1 Action at a distance**

Balloon and paper pieces - A rubber balloon is rubbed with cotton attracts small pieces of paper - action at a distance

**Experiment No. 2 Direction of Electric field**

LED and Electric field in water created by a 30 V power supply. Orientation of LED changes the its brightness.

**Electric flux**

From the above experiment it is clear that the direction of electric field and the direction of orientation of the receiver of the field, matters. The amount of electric field that passed perpendicular to an area is the useful electric field. This is given by E cosθ at any point on the surface of concern. The collection of all these electric field lines over the whole surface is the Electric flux associated with the surface.

**Gauss Law-** The net electric flux through any hypothetical closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net electric charge within that closed surface.

$$\Phi_E = \frac{\sum q}{\varepsilon_0}$$ Here $\varepsilon_0$ is the permittivity of free space

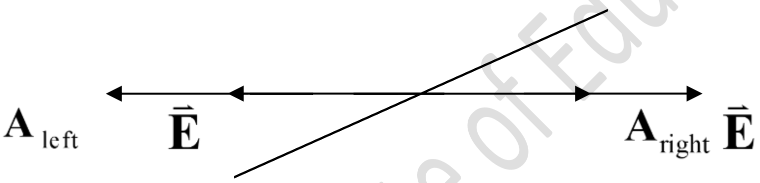
**Applications of Gauss Law**

Gauss law is used extensively to calculate the electric field due to different charge distributions.

Gauss' Law is a powerful technique to calculate the electric field for situations exhibiting a high degree of symmetry.

**Infinite Sheet of Charge**

Let's calculate the electric field from an infinite sheet of charge, with a charge density of σ (measured in C/m$^2$).




By symmetry, we expect **E** to point perpendicular to the surface for a very large sheet (and far from the edges). We would not expect any other angle, because why would any particular direction be preferred over any other for such a symmetric situation?

Now consider a closed surface (which we will call a Gaussian surface) that extends through the sheet of charge. The sides, here assumed cylindrical, are chosen to be perpendicular to the sheet. So $\mathbf{E}\cdot\mathbf{A}_{\text{side}} = 0$. The caps are parallel to the sheet, so $\mathbf{E}\cdot\mathbf{A}_{\text{left}} = \mathbf{E}\cdot\mathbf{A}_{\text{right}}$ since both vectors always point in the same direction. The total flux through the surface is thus:

$$\Phi = \mathbf{E}\cdot\mathbf{A}_{\text{left}} + \mathbf{E}\cdot\mathbf{A}_{\text{right}} = 2EA$$

By Gauss' Law, $\Phi = \frac{q_{\text{enc}}}{\varepsilon_0}$, where $q_{\text{enc}} = \sigma A$. So:

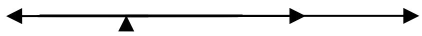
$$\Phi = 2EA = \frac{\sigma A}{\varepsilon_0}$$

$$\Rightarrow \boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

This is exactly the same solution for the magnitude of the electric field from an infinite sheet that we obtained by painstaking integration of rings of charge! And as noted before, the electric field is a constant and does not depend on the distance from the sheet.

**Infinite Line of Charge**

Let's calculate the electric field a distance *r* from a line of electric charge infinite in extent with charge density λ (measured in C/m).



By symmetry, we expect that *E* points in the radial direction (no preferred direction):

$$\mathbf{E} = E(r)\hat{\mathbf{r}}$$

Choose a Gaussian surface with cylindrical geometry, with top and bottom caps aligned such that their area vectors point in the same direction as the line of charge (and perpendicular to the electric field):

$\mathbf{E} \cdot \mathbf{A}_{\text{top}} = \mathbf{E} \cdot \mathbf{A}_{\text{bottom}} = 0$.

So the total flux leaves through the sides:

$$\Phi = \oiint_S \mathbf{E} \cdot d\mathbf{A} = E(r) \oiint_S |d\mathbf{A}| = E(r) 2\pi r h$$

since $|\mathbf{E}|$ is constant at a fixed radius. Thus,

$$\Phi = E(r) 2\pi r h = \frac{q_{\text{enc}}}{\varepsilon_0} = \frac{\lambda h}{\varepsilon_0}$$

$$\Rightarrow \boxed{E(r) = \frac{\lambda}{2\pi\varepsilon_0 r} = \frac{2K\lambda}{r}}$$

**Spheres of Charge**

Let's calculate the electric field outside a spherically charged shell.

The radius of the sphere is *R*. A total charge Q is spread uniformly on the surface, so the charge density per unit area is $\sigma = \frac{Q}{4\pi r^2}$

By symmetry we expect that the electric field points radially: $\mathbf{E} = E(r)\hat{\mathbf{r}}$

For our Gaussian surface choose another sphere with radius $r > R$, centered on the charged sphere.

$$\Phi = \oiint_S \mathbf{E} \cdot d\mathbf{A} = E(r) \oiint_S |d\mathbf{A}|$$

since $|\mathbf{E}|$ is constant at a fixed radius. The surface integral is just the integral of the surface area of a sphere, so:

$$\Phi = \frac{Q}{\varepsilon_0} = E(r) 4\pi r^2$$

$$\Rightarrow E(r) = \frac{Q}{4\pi\varepsilon_0 r^2} = K\frac{Q}{r^2}$$

Exactly the same field strength as if all the charge on the sphere were placed at the center of the sphere as a point charge! This result applies to a solid sphere of total charge *Q* as well.

The situation changes for the electric field *inside* a spherical shell.

For $r < R$, then there is no net enclosed charge, and $E(r) = 0$. No force acts on any point charge placed anywhere inside a charged shell (forces from all infinitesimal charges in the shell balances).

For the electric field *inside* a solid sphere of total charge *Q*, then there is a net enclosed charge. First assume that the total charge of a solid sphere is spread uniformly throughout its volume. The volume charge density is therefore:

$$\rho = \frac{Q}{\frac{4}{3}\pi R^3}$$ (measured in C/m$^3$).

The charge enclosed for $r < R$ is:

$$q_{\text{enc}} = \rho \frac{4}{3}\pi r^3 = \frac{Q}{\frac{4}{3}\pi R^3}\frac{4}{3}\pi r^3 = Q\frac{r^3}{R^3}$$

So Gauss' Law tells us:

$$\Phi = \oint_S \mathbf{E} \cdot d\mathbf{A} = E(r) 4\pi r^2 = \frac{Q \dfrac{r^3}{R^3}}{\varepsilon_0}$$

$$\Rightarrow E(r) = \frac{Q}{4\pi\varepsilon_0 R^3} r$$

That is, the electric field rises linearly from 0 at the center of the sphere to the magnitude obtained at the surface of the sphere (which is the same as that from a point charge at a distance *R*).

# 7. Phasor representations and LCR circuits

## 7.1 Introduction

A phasor is an acronym for Phase vector. A phasor can be envisaged as a rotating vector. Just like a vector having magnitude and direction, a phasor has a *magnitude (say V for voltage representation and I for current representation)* and an *angular displacement* $\phi$. The angular displacement is measured in the counterclockwise direction from the positive X-axis. Phasors are largely used to analyse complex electrical circuits involving resistors, inductors and capacitors.In this module, we will see the phasor representation of different circuit voltages and currents and the use of this phasors in the analysis of LCR circuit.

## 7.2 Learning objectives

After the completion of this session, the learner will be able to

Identify the circuit specialties from a phasor diagram,

Construct Phasor diagrams,

Analyse the phasor diagrams,

Construct and analyse an LCR circuit using Phaosor diagram,

Solve problems connected with phasor diagrams

## 7.3 Major Concepts

Phasors, Voltage and current phasors, Phasor diagram for different circuit elements , Combined Phasors, LCR circuit, Resonance, Band width, Quality factor

## 7.4 Learning Resources

Power point presentation slides, Small experiment on LCR resonance, Problem sets, Videos, Hand-out on content descriptions and activities

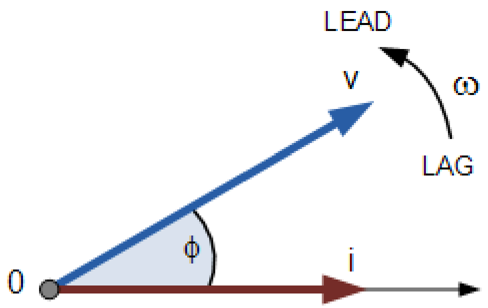
## 7.5 Content Descriptions and Activities

When capacitors or inductors are involved in an AC circuit, the current and voltage do not peak at the same time. The fraction of a period difference between the peaks expressed in degrees is said to be the phase difference. The phase difference is less than or equal to 90 degrees. It is customary to use the angle by which the voltage leads the current. This leads to a positive phase for inductive circuits since current lags the voltage in an inductive circuit. The phase is negative for a capacitive circuit since the current leads the voltage. The phase relation is often depicted graphically in a phasor diagram.

**Phasor diagram**

It is sometimes helpful to treat the phase as if it defined a vector in a plane. The usual reference for zero phase is taken to be the positive X-axis and is associated with the resistor since the voltage and current associated with the resistor are in phase. The length of the phasor is proportional to the magnitude of the quantity represented, and its angle represents its phase relative to that of the current through the resistor.

**Construction of a phasor diagram**

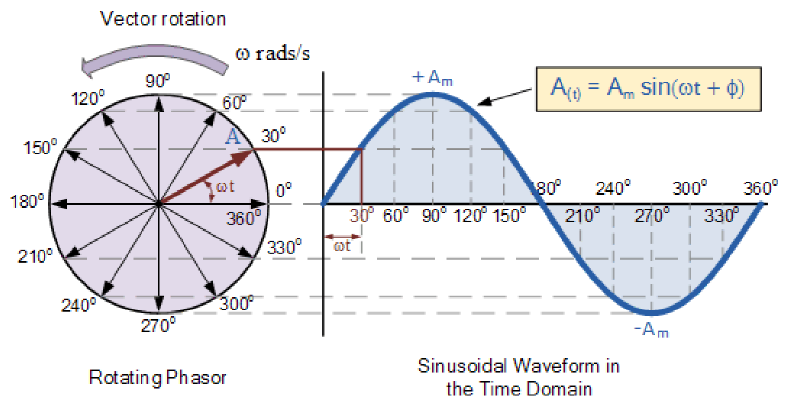



Basically a rotating vector, a **Phasor** is a scaled line whose length represents an AC quantity that has both magnitude (which is the peak amplitude) and direction ( the phase) which is frozen at some point in time.A phasor is a vector that has an arrow head at one end which signifies partly the maximum value of the vector quantity ( V or I ) and partly the end of the vector that rotates.Generally, vectors are assumed to pivot at one end around a fixed zero point known as the point of origin while the arrow end representing the quantity, freely rotates in an anti-clockwise direction at an angular velocity, ( ω ) of one full revolution for every cycle. This anti-clockwise rotation of the vector is considered to be a positive rotation. Likewise, a clockwise rotation is considered to be a negative rotation.

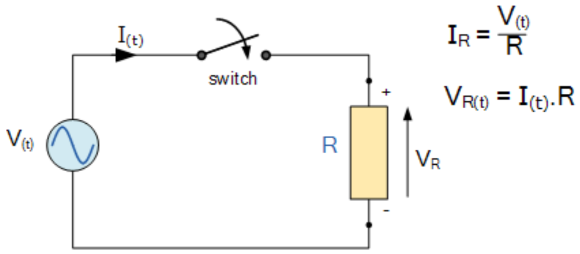
The phase of an alternating quantity at any instant in time can be represented by a phasor diagram, so phasor diagrams can be thought of as functions of time. A complete sine wave can be constructed by a single vector rotating at an angular velocity of $\omega = 2\pi f$, where $f$ is the frequency of the waveform. Then a **Phasor** is a quantity that has both Magnitude and Direction.Generally, when constructing a phasor diagram, angular velocity of a sine wave is always assumed to be: ω in rad/s. The phasor diagram drawn above shows the voltage leading current by a phase angle φ.

**Video1 :Phasor diagram**

Video shows the phasor diagram of a sinusoidal wave

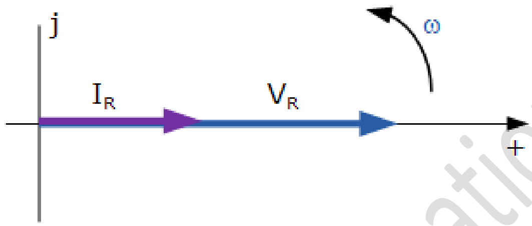



**Phasor diagram of a resistive circuit**

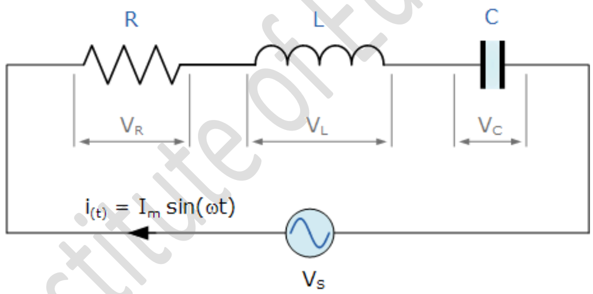



When the switch is closed, an AC voltage, V will be applied to resistor, R. This voltage will cause a current to flow which in turn will rise and fall as the applied voltage rises and falls sinusoidally. As the load is a resistance, the current and voltage will both reach their maximum or peak values and fall through zero at exactly the same time, i.e. they rise and fall simultaneously and are therefore said to be *in-phase.*

*The phasor diagram of ac applied to a resistor is show below:*

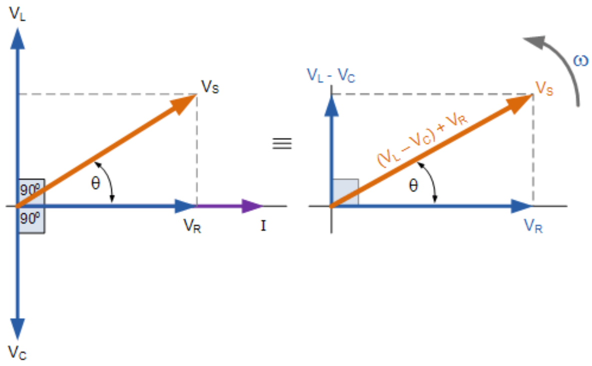



**LCR analysis of an LCR circuit**



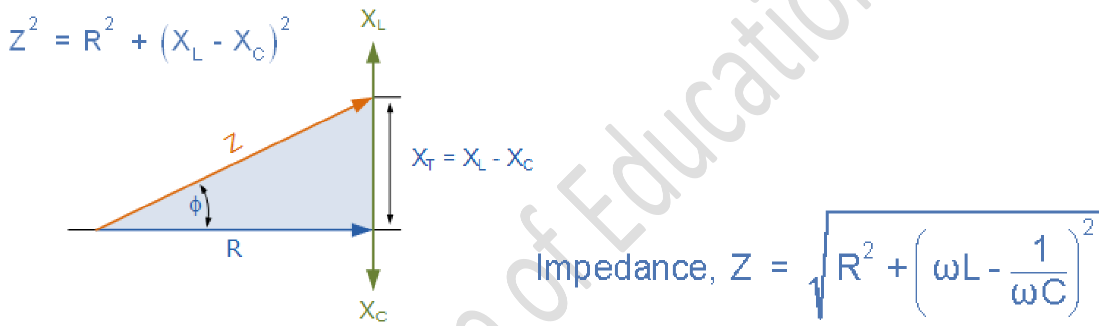

The series RLC circuit above has a single loop with the instantaneous current flowing through the loop being the same for each circuit element. Since the inductive and capacitive reactances $X_L$ and $X_C$ are a function of the supply frequency, the sinusoidal response of a series RLC circuit will therefore vary with frequency, $f$. Then the individual voltage drops across each circuit element of R, L and C element will be "out-of-phase" with each other as defined by:

- $i_{(t)} = I_{max} \sin(\omega t)$
- The instantaneous voltage across a pure resistor, $V_R$ is "in-phase" with current
- The instantaneous voltage across a pure inductor, $V_L$ "leads" the current by $90^o$
- The instantaneous voltage across a pure capacitor, $V_C$ "lags" the current by $90^o$
- Therefore, $V_L$ and $V_C$ are $180^o$ "out-of-phase" and in opposition to each other.




As the three vector voltages are out-of-phase with each other, $X_L$, $X_C$ and R must also be "out-of-phase" with each other with the relationship between R, $X_L$ and $X_C$ being the vector sum of these three components. This will give us the RLC circuits overall impedance, Z. These circuit impedance's can be drawn and represented by an **Impedance Triangle** as shown below.

The Impedance Triangle for a Series RLC Circuit




Series Circuit Current at Resonance

The frequency response curve of a series resonance circuit shows that the magnitude of the current is a function of frequency and plotting this onto a graph shows us that the response starts at near to zero, reaches maximum value at the resonance frequency when $I_{MAX} = I_R$ and then drops again to nearly zero as $f$ becomes infinite. The result of this is that the magnitudes of the voltages across the inductor, L and the capacitor, C can become many times larger than the supply voltage, even at resonance but as they are equal and at opposition they cancel each other out.As a series resonance circuit only functions on resonant frequency, this type of circuit is also known as an Acceptor Circuit because at resonance, the impedance of the circuit is at its minimum so easily accepts the current whose frequency is equal to its resonant frequency.

# 8. Semiconductor Electronics

## 8.1 Introduction

Modern world is filled with electronic devices. There is no place where electronics is not used. Communication is almost at its peak with lots of electronic devices and the internet facilities. Mobiles, computers, radios, televisions robots. what not. Now a day's robots are used by surgeons to carry out even simple operations. Electronic equipment's are largely used in Medicine, Technical fields, Agriculture, Teaching, Studies and every one in general. Even the common men are behind the electronic equipment's. A large variety of equipment's are used in the kitchen and the house hold applications also.

With these, all pervasive electronic equipment's and devices, being used by everyone in the world, it is quite essential, especially for the students, to know what these devices are? how to use them? what they are made off? and other relevant information on these devices. Attempt is made, in the present chapter, to offer a very basic information on these electronic devices.

## 8.2 Essential Previous Knowledge

The electronics devices presently used, are made of impure semi-conductors. Then, semi-conductors are the foundation materials for the making of electronic devices.

(a) It is essential to know the kind of electronics (vacuum tube) used before the use of semi-conductor devise. With which one can appreciate the superiority of semi-conductor devices.

(b) Naturally available semi-conductors, their properties and structure. Different other semi-conducting materials available for electronic devices.

(c) Necessity to convert the pure semi-conductors into a known class of impure semi-conductors.

## 8.3 Learning objectives

1. Get a fair knowledge of physics of semiconductor materials.
2. Know their structure and structure related properties.
3. Describe the properties of semiconductor materials using mathematical equations.
4. Know the reason for the preparation of impure semi-conductor materials.
5. Know the energy band picture of the materials in general.
6. Distinguish between the conductors, semi-conductors and insulators in terms of energy band picture.
7. Explain the properties of n-type and p-type semiconductors.
8. Comprehend the physical characteristics such as electronic structure, optical and transport properties, and current-voltage characteristics of semi-conductors.
9. Know the importance of forbidden energy gap and its role in changing the properties of the materials.
10. Get the knowledge of Fermi energy level and its importance in computing the carrier density in n-type and p-type semiconductors.

## 8.4 Major Concepts

(i) Valence electrons
(ii) Bond formation and structure of pure and impure semi-conductors
(iii) Energy band structure and distinction amongst the materials.
(iv) Energy band picture in intrinsic and extrinsic semi-conductors.
(v) Role of energy gap in finding the concentration of charges and estimation of elelctrical conductivity of materials.
(vi) Formation of n and p junction and consequences.
(vii) Use of junction materials for the manufacturing of electronic devices.'
(viii) Types of electronic devices, their workin and applications

## 8.5 Teaching Methodology

Normally, teachers should have a deep knowledge about the subject and must restrict to deliver only such parts of it which are relevant to the learner, through proper

(i) Presentations
(ii) Demonstrations
(iii) Visual aids and viable assignments (to spare the rod is to spoil the child, rod is not a stick to beat, but a regular return of work from the learner, without which, the learners becomes mute listeners, with no development in skills)

## 8.6 Materials required

The following materials will enable the learners to be active and highly productive:

(i) Encourage to collect relevant connected material from other reference sources and develop the habit of searching for proper and better reading material.
(ii) Demo of the working diodes, transistors and ICs.
(iii) If possible, a few circuits made using diodes, transistors and ICs.
(iv) Visual aids in most of the topics, where comprehension is difficult.
(v) Adventurous assignments and proper follow up.



## 8.7 Content Description and Activities

(i) A few concepts must be explained in the class, asking the students to listen carefully, without noting down any thing and later ask them to write up the details of what they have received.
(ii) Ask them to find the alternate description or explanation in other useful references.
(iii) Ask the learners to make demo-packages for a few topics.
(iv) Encourage them to collect suitable material available in nature and around to illustrate the learnt topics.
(v) Explain the procedure to make a power supply using diodes and assign them to make one.
(vi) Explain the method of wiring an amplifier with a transistor and ask the learners to wire one.

## 8.8 Key Points

Topics on semi-conductors, devices and applications could be accessed using the following key words:

(i) elemental semi-conductors, (ii) intrinsic semi-conductors, (iii) extrinsic semi-conductors, Energy bands in semiconductors, (iv) Energy band picture of semi-conductors, (v) Band gap in semi-conductors, (vi) Junction diode, (vii) Diode characteristics, (viii) Diode applications, (ix) Transistor, (x) Transistor characteristics (xi) Applications of semiconductor devices.

## 8.9 Exercise Questions

A few possible questions to motivate the learners to master the subject.

1. The resistance of a semiconductor …………with increasing temperature

1. When an n and p junction is established, . . . . . . . . .will form at the junction.
2. Diodes are used in . . . . . ... circuits
3. Diodes are always used in the . . . . . .. region.
4. When a transistor is used as an amplifier, the input voltage is applied on the . . . . . ..

## 8.10 MCQs

**1.** A silicon diode measures a low value of resistance with the meter leads in both positions. The trouble, if any, is

(a) the diode is open. (b) the diode is shorted to ground.

(c) the diode is internally shorted. (d) the diode is working correctly.

**2.** Single-element semiconductors are characterized by atoms with ____ valence electrons.

(a) 3 (b) 4

(c) 5 (d) 2

**3.** Normally, a diode conducts current when

(a) no votage is applied (b) large voltage is applied

(c ) Forward biased condition (d) reverse biased condition

**4.** The forbidden energy gap in a diode is equal to

(a) maximum forward voltage (b) Minimum reverse voltage

(c) Threshold voltage (d) none of these

**5.** Essential condition for the working of a transistor is

(a) when there is a high voltage on the collector
(b) when circuit is complete
(c) when there is a voltage on the base

(d) all the above

**6.** A transistor can be used as a

(a) amplifier

(b) Oscillator

(c) Switch

(d) All the above

**7.** An IC is

(a) complex circuit

(b) consists of number of resistors, transistors and other devices

(c) comfortable and more efficient device compared to transistors

(d) all the above

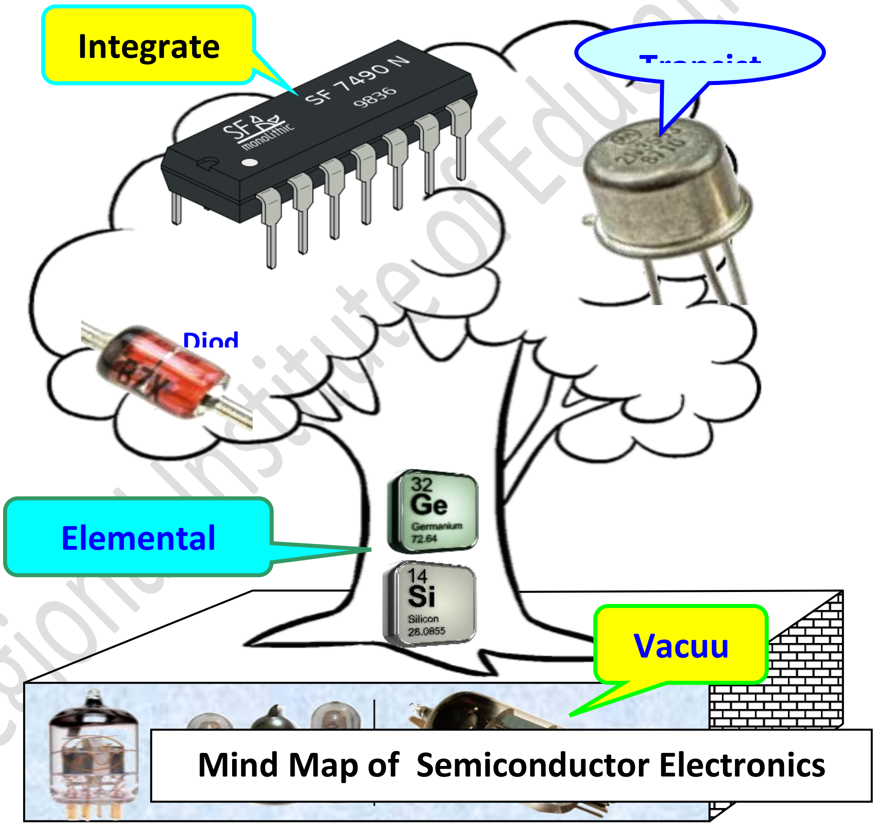
**8.** ICs are used in

(a) linear circuits

(b) Digital circuits

(c) Both linear and digital circuits

(d) None of the above



# 9. Wave Optics

## 9.1 Introduction

Study of properties of optical energy, paves the way to the understanding of the modern and potential Physics. Such a class of Physics took birth in 1990 with Max Planck's announcement of Quantum nature of energy. The modern Physics, based on the concept of Quantum nature of energy, is named *Quantum Physics* or Quantum *Mechanics*.

In order to appreciate and accept the quantum nature of the basic entity called **photon** in optics, it is necessary to look to the developments in this area. Wave nature of light stands as a mile stone during the study of failure of classical Physics and the success of Quantum Physics.

Thomas Young's double slit experiment is the basic experiment which stood in support of the wave nature of light proposed by Huygen.

## 9.2 Essential Previous Knowledge

It is essential to know the step by step development of the theories on the properties of optical energy. Wave theory stands as a better theory to explain most of the properties but, fails to explain the propagation of optical energy through vacuum, Wave nature successfully explains (i) Rectilinear, (ii) Reflection, (iii) Refraction, (iv) Interference, (v) Diffraction and Polarization properties., Wave theory failed to explain the results of the following experiments, Blackbody radiation spectra, Photo-electric experiment, Compton experiment

The success of the wave theory specially lies in the explanation of

(i) Interference of monochromatic light
(ii) Diffraction of light and
(iii) Polarization

This can be considered to be the limitation of Wave theory

## 9.3 Learning objectives

Study of wave theory should satisfy the following objectives:

(i) Should provide a comprehensive picture of waves
(ii) Should provide knowledge on the parameters of the waves, like: frequency, period, wavelength, phase, wave front and other information.
(iii) Should provide knowledge on shapes of wave fronts in case of different sources like (a) point source, (b) extended source, (c) linear source or cylindrical source
(iv) Should inform the reason for dark and bright fringes in interference fringes, colors of thin films.
(v) Should provide information on diverging beams and non-diverging beams.
(vi) Should impart information on the essential condition required for the observation of interference fringes, that the obstacle dimension should be of the order of the wavelength of light given by the equation

$$2d\sin\theta = n\lambda \qquad \text{or} \qquad d\sin(\theta/2) = n\lambda$$

and the difference between the two equations in diffraction.

(vii) Should Comprehensively explain the meaning of polarization, how it can be practically produced and some important applications

## 9.4 Major Concepts

Study of nature and properties of waves is a fundamental physics, which will appear often in the higher studies. Therefore, the clear knowledge about the relation between the parameters involved in explaining the waves in the form of a conventional equation like

$$y = a\sin\frac{2\pi}{\lambda}(vt - x)$$

must be explained very clearly.

## 9.5 Teaching Methodology

Normally, teachers should have a deep knowledge about the subject and must restrict to deliver only such parts which are relevant to the learner, through proper

(iv) Presentations

(v) Demonstrations

(vi) Visual aids and viable assignments (to spare the rod is to spoil the child, rod is not a stick to beat, but a regular return of work from the learner, without which, the learners becomes mute listeners, with no development in skills)

## 9.6 Materials required

The following materials will enable the learners to be active and highly productive:

(vi) Encourage to collect relevant connected material from other reference sources and develop the habit of searching for proper and better reading material.

(vii) Demos wherever possible

(viii) Visual aids in most of the topics, where comprehension is difficult.

(ix) Adventurous assignments and proper follow up.

## 9.7 Content Description and Activities

(vii) A few concepts must be explained in the class, asking the students to listen carefully, without noting down any thing and later ask them to write up the details of what they have received.

(viii) Ask them to find the alternate description or explanation in other useful references.

(ix) Ask the learners to make demo-packages for a few topics.

(x) Encourage them to collect suitable material available in nature and around to illustrate the learnt topics.

## 9.8 Key Points

Topic of waves could be accessed using the following key words:

(i) amplitude, (ii) Phase, (iii) velocity, Reflection, (iv) Refraction, (v) Interference (vi) Monochromatic, (vii) Polychromatic, (viii) Diffraction, (ix) Polarization, (x) Wave front (xi) Secondary source (xii) Huygen's principle etc.

## 9.9 Exercise Questions

A few possible questions to motivate the learners to master the subject.

The Wave Theory Of Light 12th (MCQ With Answers) are:

1. The light waves consisting of vibration of electric field vectors in all possible planes are called ______
2. A wave front originating from a point source of light at finite distance is called ________ wave front
3. In double refraction, out of the two rays, the ray which obeys the laws of refraction is called _________
4. The apparent change in frequency or wavelength of light due to relative motion between the source and the observer is called ________
5. The direction in the crystal along which, both O-ray and E-ray do not separate and they travel with same speed is called _____________
6. __________ are large size sheets which are used to produce plane polarised light of large cross section.
7. Certain double refracting crystals absorb one of the two refracted rays (either O-Ray or E-Ray) and transmit the other rays. This property is called ______
8. A normal or perpendicular drawn to the surface of wave front at any point of a wave front, in the direction of propagation of light, is called a _______
9. When two polaroids are _________ to each other, then the light transmitted by first Polaroid is completely blocked by the second polaroids. Such combination is called Crossed polaroids
10. Restricting the vibrations of an un-polarized light only in one plane and removing the vibrations in other planes is called ______

## 9.10 MCQs

1. In Young's double slit experiment, two slits separated by a distance of 0.1 mm are illuminated by a monochromatic light source of wavelength $5 \times 10^{-7}$ m. If the distance between slit and screen is 2 meters, then separation of bright lines in the interference pattern will be

   (a) 0.5 mm (b) 1.0 mm (c) 1.5 mm (d) 1.75 mm

2. A slit 5 cm wide when irradiated by light waves of wavelength 10 mm results in the angular spread of the central maxima on either side of incident light by about

(a) 1/2 radian (b) 1/4 radian (c) 3 radian (d) 1/5 radian.

3. Light of wavelength 600nm is normally incident on a slit. Angular position of second minimum from central maximum us $30^0$. Width of the slit should be

(a) 12 x 10–5 cm (b) 18 x 10–5 cm (c) 24 x 10–5 cm (d) 36 x 10–5 cm

4. Two waves of same intensity produce interference. If intensity at maximum is 4I, then intensity at the minimum will be

(a) 0 (b) 2I (c) 3I (d) 4I.

5. A ray of un-polarized light is incident on a glass plate of refractive index 1.54 at polarizing angle, then angle of refraction is

(a) $33^0$ (b) $44^0$ (c) $57^0$ (d) $90^0$

6. When light of wavelength 5320Å is incident on a soap film of thickness $5 \times 10^{-5}$ cm, the film appears bright. Then, the refractive index of the film is

(a) 1.22 (b) 1.33 (c) 1.51 (d) 1.83

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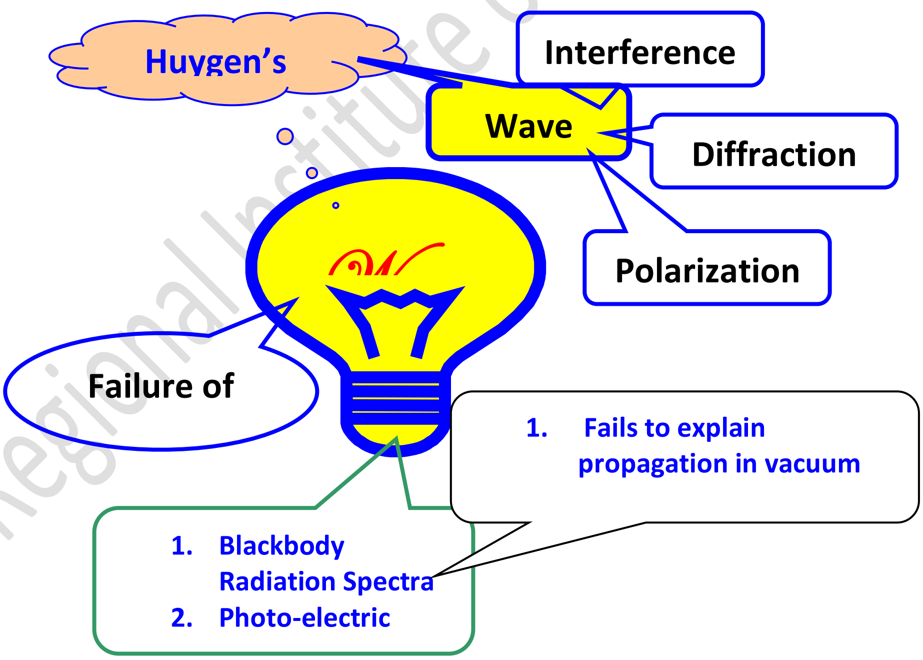
## Concept Map of Wave Optics



# 10. Thermodynamic processes

**Introduction**

Thermodynamics is the branch of physics that deals with the concepts of heat and temperature and the inter-conversion of heat and other forms of energy. Thermodynamics is a macroscopic science. It deals with bulk systems and does not go into the molecular constitution of matter. In fact, its concepts and laws were formulated in the nineteenth century before the molecular picture of matter was firmly established. Thermodynamic description involves relatively few macroscopic variables of the system, which are suggested by common sense and can be usually measured directly. A microscopic description of a gas, for example, would involve specifying the co-ordinates and velocities of the huge number of molecules constituting the gas. The description in kinetic theory of gases is not so detailed but it does involve molecular distribution of velocities. Thermodynamic description of a gas, on the other hand, avoids the molecular description altogether. Instead, the state of a gas in thermodynamics is specified by macroscopic variables such as pressure, volume, temperature, mass and composition that are felt by our sense perceptions and are measurable.

**Learning objectives**

1] Quasi-static process

2] Isothermal process

3] Heat engines

4] Refrigerator

5] Law of equipartition of energy

**Major Concepts**

1] Heat transfer

2] Carnot's engine

3] Kinetic theory of gases

**Learning Resources**

1] Diagrams and videos

**Content Descriptions and activities**

***Quasi-static process:*** Consider a gas in thermal and mechanical equilibrium with its surroundings. The pressure of the gas in that case equals the external pressure and its temperature is the same as that of its surroundings. Suppose that the external pressure is suddenly reduced. The piston will accelerate outward. During the process, the gas passes through states that are not equilibrium states. The nonequilibrium states do not have well-defined pressure and temperature. In the same way, if a finite temperature difference exists between the gas and its surroundings, there will be a rapid exchange of heat during which the gas will pass through non-equilibrium states.

In due course, the gas will settle to an equilibrium state with well-defined temperature and pressure equal to those of the surroundings. Non-equilibrium states of a system are difficult to deal with. It is, therefore, convenient to imagine an idealised process in which at every stage the system is an equilibrium state. Such a process is, in principle, infinitely slow, hence the name quasi-static.

***Isothermal process:*** A quasi-static process is obviously a hypothetical construct. In practice, processes that are sufficiently slow and do not involve accelerated motion of the piston, large temperature gradient, etc., are reasonably approximation to an ideal quasi-static process. We shall from now on deal with quasi-static processes only, except when stated otherwise. A process in which the temperature of the system is kept fixed throughout is called an ***isothermal process***. The expansion of a gas in a metallic cylinder placed in a large reservoir of fixed temperature is an example of an isothermal process. (Heat transferred from the reservoir to the system does not materially affect the temperature of the reservoir, because of its very large heat capacity.) In ***isobaric*** processes the pressure is constant while in ***isochoric*** processes the volume is constant. Finally, if the system is insulated from the surroundings and no heat flows between the system and the surroundings, the process is ***adiabatic***.

***Cyclic process:*** In a cyclic process, the system returns to its initial state. The internal energy of the system will be zero in a cyclic process.

***Heat engine:*** Heat engine is a device by which a system is made to undergo a cyclic process that results in conversion of heat to work. The mechanism of conversion of heat into work varies for different heat engines. Basically, there are two ways: the system (say a gas or a mixture of gases) is heated by an external furnace, as in a steam engine; or it is heated internally by an exothermic chemical reaction as in an internal combustion engine. The various steps involved in a cycle also differ from one engine to another.

***Carnot's engine:*** A reversible heat engine operating between two temperatures is called a Carnot engine. It is the only reversible engine possible that works between two reservoirs at different temperatures. Each step of the Carnot cycle can be reversed. This will amount to taking heat $Q_2$ from the cold reservoir at $T_2$, doing work $W$ on the system, and transferring heat $Q_1$ to the hot reservoir. This will be a reversible refrigerator.

***Refrigerator and Heat pumps:*** A refrigerator is the reverse of a heat engine. Here the working substance extracts heat $Q_2$ from the cold reservoir at temperature $T_2$, some external work $W$ is done on it and heat $Q_1$ is released to the hot reservoir at temperature $T_1$.

A heat pump is the same as a refrigerator. What term we use depends on the purpose of the device. If the purpose is to cool a portion of space, like the inside of a chamber, and higher temperature reservoir is surrounding, we call the device a refrigerator; if the idea is to pump heat into a portion of space (the room in a building when the outside environment is cold), the device is called a heat pump.

In a heat engine, heat cannot be fully converted to work; likewise, a refrigerator cannot work without some external work done on the system.

***Kinetic theory of gases:*** Kinetic theory explains the behaviour of gases based on the idea that the gas consists of rapidly moving atoms or molecules. This is possible as the inter-atomic forces, which are short range forces that are important for solids and liquids, can be neglected for gases. We begin with the idea that molecules of a gas are in incessant random motion, colliding against one another and with the walls of the container. All collisions between molecules among themselves or between molecules and the walls are elastic. This implies that total kinetic energy is conserved. The total momentum is conserved as usual.

***Law of equipartition of energy:*** A molecule free to move in space needs three coordinates to specify its location. If it is constrained to move in a plane it needs two; and if constrained to move along a line, it needs just one coordinate to locate it. This can also be expressed in another way. We say that it has one degree of freedom for motion in a line, two for motion in a plane and three for motion in space. Motion of a body as a whole from one point to another is called translation. Thus, a molecule free to move in space has three translational degrees of freedom.

In equilibrium, the total energy is equally distributed in all possible energy modes, with each mode having an average energy equal to ½ $k_BT$. This is known as the law of equipartition of energy. Accordingly, each translational and rotational degree of freedom of a molecule contributes ½ $k_BT$ to the energy, while each vibrational frequency contributes 2 × ½ $k_BT = k_BT$, since a vibrational mode has both kinetic and potential energy modes.

*Misconceptions*

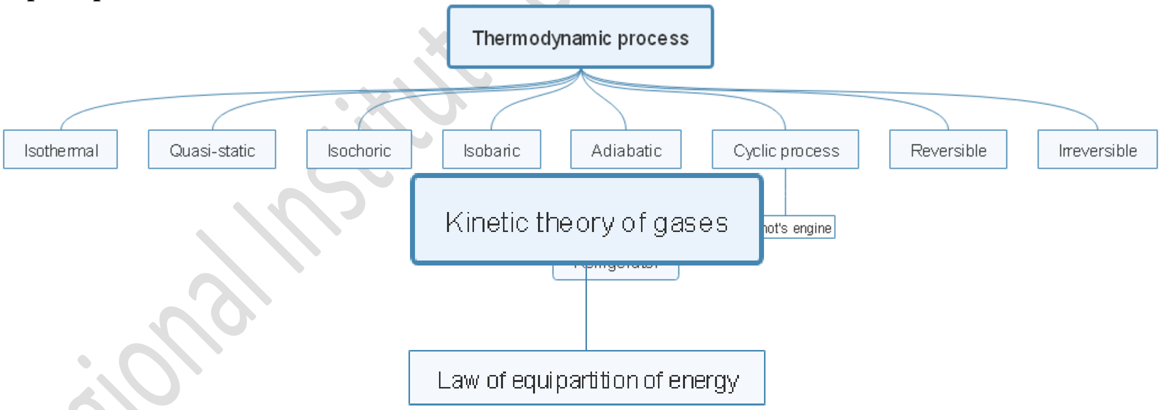
1] Non-equilibrium states have well-defined pressure, temperature and volume.

2] Heat pumps and heat engines are the same.

*Self Check questions*

**Module end exercise**

**Concept map**




**References**

Class XI, NCERT textbook.

**MCQ**

**Q1. Heat and work are**

A) Path functions

B) Inexact differentials

C) Depend upon the path followed

D) all of the mentioned above

Ans: D)

**Q2. Heat transfer and work transfer are**

A) Boundary phenomena

B) Energy interactions

C) Energy in the transit

D) all of the mentioned above

Ans: D)

**Q3. Turbines and engines _____ positive power output, and compressors and pumps _____ power input.**

A) Require, give

B) Give, require

C) Give, give

D) Require, require

Ans: B)

# 11. Gravitation

**11.1 Introduction-**Gravitation is one of the fundamental forces of nature. Gravity is what binds us to earth and it is what keeps the Earth in orbit. It was first discovered by Sir Issac Newton. Legend says, in reasoning why apple fall towards ground, Newton realized gravity. Of course, gravity can be traced back in Kepler's laws and his works way before Newton. But Kepler couldn't realize the concept of force which binds the planets to the Sun.

As we know of today, the gravity is universal. It acts between all the matter in the universe. Even two pens kept on table exerts gravitational force between each other. But the masses of pens are small to have an observable effect of attraction between them. But however small, the force exists.

Stated Mathematically, Newton's gravitationlaw reads: The force **F** on a point mass $m_2$ due to another points mass $m_1$, which are separated by a distance$r$, has the magnitude,

$$F = G\frac{m_1 m_2}{r^2}$$

In vector form,

$$\vec{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$$

Apart from this, the force obeys the law of superposition, that is, the force due to a collection of particles is the vector sum of the forces exerted by the particles individually. Which is to say, when we are talking of the earth's gravity on moon, which keeps it in orbit, you are also contributing a small portion of force in the net force. That is the force between you and the moon, however small. All small contributions gathered together makes a big effect.

**11.2. Shell Theory:**

*Introduction:*

The shell theory states,

- The force of attraction between a hollow spherical shell of uniform density and a point mass situated outside is just as if the entire mass of the shell is concentrated at the center of the shell.
- The force of attraction due to a hollow spherical shell of uniform density, on a point mass situated inside it is zero.

This can be explained by the law of superposition, which is stated above.

*Learning objectives:*

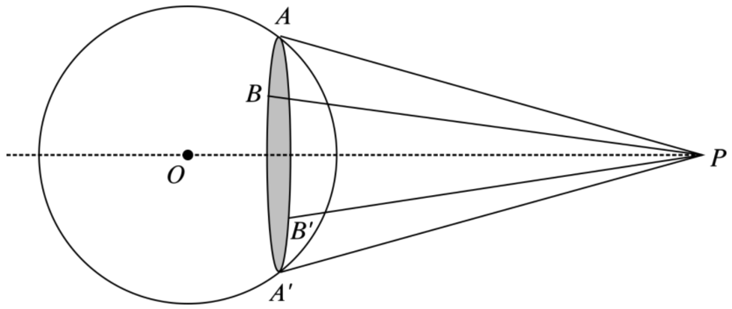
To understand shell theory in gravitation and try to prove it without going much into calculus. Also learning to apply it to find out gravity inside and outside the earth.

*Major Concepts:*

Gravitation, principle of superposition, vector addition

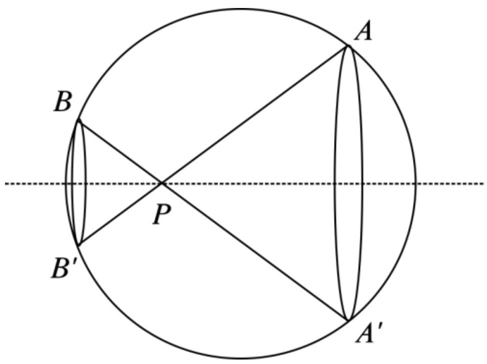
*Content Descriptions:*

1. The force of attraction on a particle outside a spherical shell:




Consider a spherical shell and a fine circular strip of mass in the shell. Let A, A', B, B' are few of the particles on this strip. They are chosen in such a way that they are on the exact opposite side of the circular strip. Remember that the gravitational force on $P$ by the shell is due to addition of forces due to all the particles composing the shell. Consider force on $P$ due to $A$. It will be along the line $AP$. Let us resolve this force, one along horizontal direction and another along vertical direction. The vertical component will be canceled by that of the particle $A'$and only horizontal component remains. Since $A$ and $A'$are on opposite in the circle, the resultant of their horizontal component will be along the dotted line. Similarly, for $B$ and $B'$ pair. And we can imagine for all the particles on the circle and for all of the the resultant will be along the dotted line which joins the center of the shell to the particle $P$. As the spherical shell can be thought up as composed of such circular strips, the net force due to all these circles will be along the dotted line. As if the whole mass of the shell is concentrated at its center. It is true for a solid sphere also. It is because, a solid sphere can be thought to be made up of concentric spherical shells. To prove its magnitude, we need help of integral calculus. Of course, Sir Issac Newton invented integral calculus to tackle this exact problem. See the reference for the proof.

2. The force of attraction on a particle inside a spherical shell:



The gravitational force on any particle inside the shell due to the shell will be zero. The reason why gravitational force vanishes inside a spherical shell can be seen by a simple argument due to Newton. Consider the two small mass elements marked out by a conical surface with its apex at *P*. The amount of mass in each element is proportional to its surface area. The area increases as $(\text{distance})^2$ . However, the strength of the force varies as $l/(\text{distance})^2$, where the distance is measured from the apex to the shell. Thus the forces of the two mass elements are equal and opposite, and cancel. We can pair up all the elements of the shell this way and so the total force on *P* is zero.

*References:*

1. Daniel Kleppner and Robert Kolenkow, *An Introduction to Mechanics,* McGraw-Hill publications.

*MCQ:*

Q1. If a particle of mass *m* is inside a spherical shell of mass *M*, and radius *R*, what is the force on the particle?

a) $GmM/R^2$ b) $GmM/R$c) 0 d) $mg$

Q2. If a particle of mass *m* is outside at a distance *r* from the center of a spherical shell of mass *M*, and radius *R*, what is the force on the particle?

a) $GmM/R^2$ b) $GmM/r^2$c) 0 d) $mg$

Q3. If a particle of mass *m* is outside at a distance *r* from the center of a solid sphere of mass *M*, and radius *R*, what is the force on the particle?

a) $GmM/R^2$ b) $GmM/r^2$c) 0 d) $mg$

**11.3. Shifting a satellite from one orbit to another orbit and related problems:**

*Introduction:*

When they launch rockets to put satellites into orbits, fine tuning of the orbits are done. For example to achieve geostationary orbits, they first put them in geosynchronous orbits and then shift them into geostationary orbits. It is done by firing a propulsion engine attached to the satellite. This gives the thrust and the required energy to shift its obit. As the total energy (kinetic + potential energy) of the satellite increases its orbit size also increases.

*Learning objectives:*

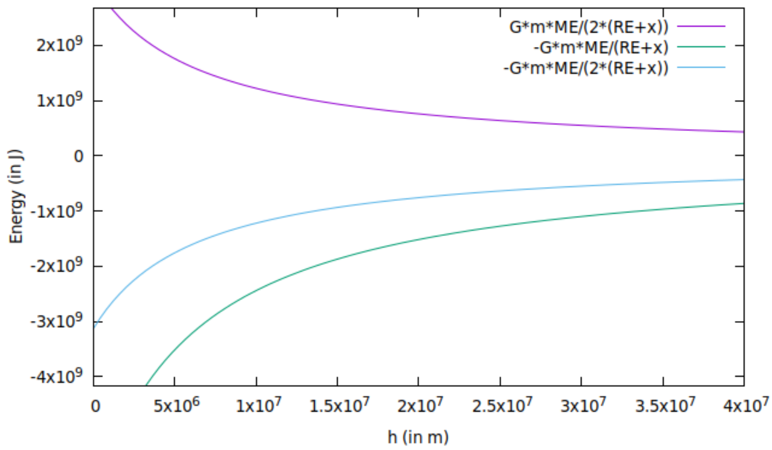
To understand how the satellite can be shifted from one orbit to another.

*Major Concepts:*

Kinetic energy and gravitational potential energy of a satellite.

*Content Descriptions:*

It can be shown that the kinetic energy of a satellite of mass *m* which is orbiting the earth at an height *h* above the ground will be $KE = GmM_E/2(R_E+h)$, where $M_E$ is mass of the earth and $R_E$ is radius of the earth. And its potential energy will be $PE = -GmM_E/(R_E+h)$, the negative sign is because the satellite is part of a bound system with attractive force. It will have zero potential energy at infinity where it is free from the influence of earth's gravitation. The total energy will be (by adding KE and PE), $E = KE+PE = -GmM_E/2(R_E+h)$. For a satellite of 100kg the plot of these energies will be as shown in the graph,




Hence, as energy increase, the orbit size also increases. Interestingly, the kinetic energy decreases and potential energy along with total energy increases. In satellites the energy will be supplied by a thrust engine attached to it which can be remotely turned on or off.

*Activity:*

Take a stone or any small mass tied to an elastic thread. Start rotating the stone by holding one end of the thread. The stone revolves around. If you give more thrust on the stone you can observe that the thread elongates more and the stone revolves with larges radius.

*Module end exercise:*

1. What will be kinetic energy, potential energy and total energy of a 50kg satellite at about 3000km above ground.

2. A 400 kg satellite is in a circular orbit of radius $2R_E$ about the Earth. How much energy is required to transfer it to a circular orbit of radius $4R_E$? What are the changes in the kinetic and potential energies?

*References:*

1. Daniel Kleppner and Robert Kolenkow, *An Introduction to Mechanics*, McGraw-Hill publications.

2. https://youtu.be/COCAIPtVA2M

3. http://www.planetary.org/blogs/jason-davis/20140116-how-to-get-a-satellite-to-gto.html

4. https://earthobservatory.nasa.gov/Features/OrbitsCatalog

MCQ:

Q1. What happens to a satellite if its total energy is positive?

a) It escapes earth's gravity b) It falls into earth c) It assumes circular orbit d) None of the above

Q2. If you give energy to a satellite by giving a thrust. What happens to its speed?

a) Increases b) Decreases c) Remains same d) None

# 12. LAWS OF MOTION

## 12.1 Introduction

This module is focusing on the discussion of the content on frames of reference and laws of motions.

## 12.2 Learning objectives

During /at the end of this session, the participants will be able to

- Explain the frame of reference
- Define inertial and non-inertial frames
- Apply the knowledge of different frame of reference
- Analyze the laws of motion under the inertial and non-inertial frame of reference
- Solve numerical on laws of motion

## 12.3 Major Concepts

- **The frame of reference**- a frame of reference (or reference frame) consists of an abstract coordinate system and the set of physical reference points that uniquely fix (locate and orient) the coordinate system and standardize measurements.
- Inertial Frames: All frames of reference, in which the Law of Inertia is correct, are called inertial frames.
- Non-Inertial Frames: Frames of reference in which the Law of Inertia is not correct, are called non-inertial frames.
- Newton's First Law: If no force acts on a body, the body's velocity cannot change; that is, the body cannot accelerate.
- Newton's Second Law: The net force on a body is equal to the product of the body's mass and its acceleration.
- Newton's Third Law: When two bodies interact, the forces on the masses from each other are always equal in magnitude and opposite in direction.
- **Pseudo Forces:** A physically apparent but nonexistent force felt by an observer in a noninertial frame. Newton's laws hold true within such a reference frame only if the existence of such a force is presumed. The centrifugal force is an example of a pseudo force.

## 12.4 Learning Resources

- Ball
- Bangles, clipboard, white sheet pen
- Ball, plastic jar
- Thread, ball, rigid support
- Simulations

## 12.5 Content Descriptions and activities

By motion, Aristotle (384-322 B.C.E.) understands any change. He defines motion as the actuality of a potentiality. Initially, Aristotle's definition seems to involve a contradiction. However, commentators on the works of Aristotle, such as St. Thomas Aquinas, maintain that this is the only way to define motion.

To adequately understand Aristotle's definition of motion it is necessary to understand what he means by actuality and potentiality. Aristotle uses the words *energeia* and *entelechia* interchangeably to describe a kind of action. Linguistic analysis shows that, by reality, Aristotle means both *energeia*, which means being-at-work, and *entelechia*, which means being-at-an-end. These two words, although they have different meanings, function as synonyms in Aristotle's scheme. For Aristotle, to be a thing in the world is to be at work, to belong to a particular species, to act for an end and to form the material into enduring organized wholes. Actuality, for Aristotle, is therefore close in meaning to what it is to be alive, except it does not imply mortality.

From the Middle Ages to modern times, commentators disagreed on the interpretation of Aristotle's account of motion. An accurate rendering of Aristotle's definition must include inconsistent propositions: (a) that motion is rest, and (b) that a potentiality, which must be, if anything, a privation of actuality, is at the same time that actuality of which it is the lack. St. Thomas Aquinas was prepared to take these propositions seriously. St. Thomas observes that to say that something is in motion is to say that it is both what it is already and something else that it is not yet. Accordingly, motion is the mode in which the future belongs to the present; it is the present absence of just those particular absent things which are about to be. St. Thomas thus resolves the apparent contradiction between potentiality and actuality in Aristotle's definition of motion by arguing that in every motion actuality and potentiality are mixed or blended.

St. Thomas' interpretation of Aristotle's definition of motion, however, is not free of difficulties. His interpretation seems to trivialize the meaning of *entelechia*. One impliation of this interpretation is that whatever happens to be the case right now is an *entelechia*, as though something which is intrinsically unstable as the instantaneous position of an arrow in flight deserved to be described by the word which Aristotle everywhere else reserves for complex organized states which persist, which hold out in being against internal and external causes tending to destroy them.

In the *Metaphysics*, however, Aristotle draws a distinction between two kinds of potentiality. On the one hand, there are latent or inactive potentialities. On the other hand, there are active or at-work potentialities. Accordingly, every motion is a complex whole, an enduring unity which organizes distinct parts. Things have been to the extent that they are or are part of determinate wholes so that to be meant to be something, and change has been because it always is or is part of some determinate potentiality, at work and manifest in the world as change.

**The Physics of Aristotle versus The Physics of Galileo**

Aristotle taught that the substances making up the Earth were different from the substance making up the heavens. He also explained that dynamics (the branch of physics that deals with motion) was primarily determined by the nature of the substance that was moving.

**The Dynamics of Aristotle**

For example, stripped to its essentials, Aristotle believed that a stone fell to the ground because the stone and the ground were similar in substance (in terms of the 4 essential elements, they were mostly "earth"). Likewise, smoke rose away from the Earth because in terms of the four basic elements it was primarily air (and some fire), and therefore the smoke wished to be closer to air and further away from earth and water. Aristotle held that the perfect substance (the "quintessence") that made up the heavens had as its nature to execute perfect (that is, uniform circular) motion. He also believed that objects only moved as long as they were pushed. Thus, objects on the Earth stopped moving once applied forces were removed, and the heavenly spheres just moved because of the action of the Prime Mover, who continually applied the force to the outer spheres that turned the entire heavens. (A notorious problem for the Aristotelian view was why arrows shot from a bow continued to fly through the air after they had left the bow and the string was no longer applying force to them. Elaborate explanations were hatched; for example, it was proposed that the arrow creating a vacuum behind it into which air rushed and applied a force to the back of the arrow!)

**Galileo vs. Aristotle**

Thus, Aristotle believed that the laws governing the motion of the heavens were a different set of laws than those that governed motion on the earth. As we have seen, Galileo's concept of inertia was quite contrary to Aristotle's ideas of motion: in Galileo's dynamics the arrow (with very small frictional forces) continued to fly through the air because of the law of inertia, while a block of wood on a table stopped sliding once the applied force was removed because of frictional forces that Aristotle had failed to analyze correctly.

In addition, Galileo's extensive telescopic observations of the heavens made it more and more plausible that they were not made from a perfect, unchanging substance. In particular, Galileo's observational confirmation of the Copernican hypothesis suggested that the Earth was just another planet, so maybe it was made from the same material as the other planets.

Thus, the groundwork was laid by Galileo (and to a lesser extent by others like Kepler and Copernicus) to overthrow the physics of Aristotle, in addition to his astronomy. It fell to Isaac Newton to bring these threads together and to demonstrate that the laws that governed the heavens were the same laws that governed motion on the surface of the Earth.

Let's review certain basic concepts of motion, namely Newton's first two Laws of Motion, which are presumably as basic and fundamental as any natural law can be:

(1) The Law of Inertia: A body which has no force acting on it will move with uniform motion (that is, with constant speed and direction).

(2) The Force Law: If a force acts on a body, it will not move uniformly, but will be accelerated in the direction of the force at a rate proportional to the force, and inversely proportional to its inertia, or mass.

Now, these two laws seem very simple and obvious, and perfectly reasonable and correct. So much so, that if we see an object which is moving uniformly, we presume that it must not have any force (or at least, any net force) acting on it; whereas if we see an object which is accelerating, we presume it must have some force acting on it, in the direction of its acceleration. The strange thing is, that it is not only very easy but more normal than not, for Newton's Laws of Motion to be wrong. For we often find ourselves in a situation in which bodies appear to be accelerating under the influence of some force, even though no such force is acting on them.

**Inertial Frames of Reference**

To understand how such a statement could be true, we need to discuss frames of reference. A frame of reference is merely that portion of the world around us, which we use to measure the motion of moving bodies. For all practical purposes, the world around us appears to be at rest, and insofar as that statement is true, then any motion we measure relative to our surroundings is correctly observed, and if a motion appears uniform, it must genuinely be uniform, and if the motion appears nonuniform, then it must genuinely be nonuniform.

But suppose that instead of using the world around us, we use some particular portion of the world, such as a railway car, which is moving relative to the rest of the world. As the car moves along its tracks, the motion of whatever object we are observing will not be measured correctly but will have an error equal to the motion of the railway car. So, wouldn't that affect our observations of the moving object? Of course it would; but as long as the motion of the railway car is absolutely uniform and unchanging, whatever error we make in observing the moving object will be absolutely constant and unchanging, as well; so if the object has uniform motion in the everyday world that is our normal frame of reference, then it will appear to have a different but still absolutely uniform motion in the frame of reference represented by the railway car. And if the moving object is moving nonuniformly, because there is a force acting on it, in the everyday world, then it will also be moving nonuniformly, by exactly the same amount, in the frame of reference of the moving railway car.

This concept, that a uniformly moving frame of reference, such as the railway car, should not change the laws of motion, was actually first proposed, albeit in a slightly different form, decades prior to Newton's stating his Laws, by Galileo Galilei. Galileo suggested that in all frames of reference which are moving uniformly relative to each other, the laws of nature must be the same. This statement encompasses not only Newton's Laws, but all the laws of nature, and is the basis of what we call Galilean relativity.

Now, let's suppose that in the everyday world, Newton's Laws of Motion are correct, and most notably, that the Law of Inertia is right. If so, then in any frame of reference that is moving entirely uniformly relative to the everyday world, the Law of Inertia will still be correct. All frames of reference, in which the Law of Inertia is right, are called inertial frames. Frames of reference in which the Law of Inertia is not correct, are called non-inertial frames.

**Non-Inertial Reference Frames**

But how in the world could you possibly find yourself in such a situation that the Law of Inertia would appear to be wrong? Very easily; for remember, in discussing the uniformly moving railway car, it was stated to be moving uniformly, so that any observations of a moving object would have an error, relative to the everyday world, but an error that was as constant as the motion of the railway car, so that uniform motion still appeared uniform, and nonuniform motion still appeared nonuniform.

But what if the motion of the railway car is not constant? Then the error introduced into measurements of the moving object would be changing with time, which would make a constant motion look nonuniform, and therefore accelerated, which would suggest that a force is acting on the moving object, which is incorrect if it is moving with constant motion. In other words, if your frame of reference has a non-uniform, or accelerated motion, then the Law of Inertia will appear to be wrong, and you must be in a non-inertial frame of reference. So, although all frames of reference which are moving uniformly relative to an inertial reference frame are also inertial reference frames, all frames of reference which are moving non-uniformly (are accelerated) corresponding to an inertial reference frame are non-inertial reference frames.

**Pseudo Force**

A Pseudo force (also known as fictitious force, D'Alembert force or inertial force) is a visible force which works on all masses whose motion can explained by using a non-inertial frame of the reference frame, like the rotating reference frame. When the frame of reference starts the acceleration as compared to a non-accelerating frame, the Pseudo force starts coming into effect. Please note that the force F does not get produced from any physical interaction between two objects. It comes from the acceleration 'a' of the non-inertial reference frame itself. This is because the frame gets accelerated in any arbitrary way, so even pseudo forces can be as arbitrary (but it only happens in direct response to the acceleration of the frame). Nevertheless, four pseudo forces can be defined for frames accelerated in commonly occurring ways: one can be defined by relative acceleration of the origin in a straight line (rectilinear acceleration); the second involves rotation: Coriolis force, Centrifugal force and fourth is known as Euler force, which happens by a variable rate of rotation.

**Fictitious Forces on Earth**

The surface of the Earth is nothing but a rotating reference frame. When we have to solve a classical mechanics problem accurately as per the Earth-bound reference frame, then the introduction of three fictitious forces is needed: the Coriolis force, the Euler force, and the centrifugal force. More often than not, the Euler force gets ignored as the variations in the angular velocity of the rotating Earth surface are typically unimportant. And the other fictitious forces are weak in comparison to most conventional forces in everyday life, but they can be spotted under particular conditions. For instance, the time when Léon Foucault used his Foucault pendulum for proving that a Coriolis force results from the Earth's rotation. If the Earth happened to rotate around twenty times faster (making each day only ~72 minutes long), most people could think that such fictitious forces were pulling on them, like on a spinning carousel. Also, people in temperate and tropical latitudes would have to hold on to avoid being launched into orbit by the centrifugal force.

**Examples of Pseudo Force**

For example, let's consider a person who's standing at a bus stop and is looking at an accelerating car. In this situation, he concludes that a force is exerted on the car and it is indeed accelerating. This example is simple, and the pseudo force theory isn't required. But, let's say that the person sitting inside the accelerating car is staring at the person who is standing at the bus stop. So, he will find that the person is accelerating concerning the car, although there is no force acting on it. In this case, we would need the concept of pseudo force for converting the non-inertial frame of reference to an equivalent inertial frame of reference. One more example: Think of a ball that is hanging from the roof of a train using an inextensible string. If the train is at one place or is moving with a uniform speed in a straight line, then the string will seem to be vertical. A passenger would conclude that the net force acting on the ball is zero.

What if the train begins to accelerate? Then, here the string would be making an angle concerning the vertical. When it comes to the passenger, there are only two forces, and they are not collinear. Although, note that the ball remains in a state of equilibrium (as long as the train's acceleration is constant).

**Fictitious Forces and Work**

Even fictitious forces can do work, but only when they start moving an object on a trajectory, which changes its energy from potential to kinetic. For instance, assume that a person is sitting on a rotating chair and is holding a weight in their outstretched hand. From the perspective of the rotating reference frame, if they move their hand toward their body inwards, then they have done work against the centrifugal force. But when the weight is released, it instantly gets thrown outwards relative to the rotating reference frame. This happens because the centrifugal force doesn't work on the object, which is converting its potential energy into kinetic. Of course, when you look at it from an inertial viewpoint, the object flies away from them as it is suddenly allowed to move in a straight line. This signifies that the work done can also be different in a non-inertial frame than an inertial one, just like the total potential and kinetic energy of an object.

**How to Use Pseudo Force for Problem-Solving in Mechanics**

1. Displacement, kinetic energy, velocity, acceleration, and work have done dependent on the frame.
2. Individual forces and time are frame independent.
3. Newton's 1st law and 2nd law is applicable only in the inertial frame. For applying these laws in a non-inertial frame, one needs to introduce a new force, i.e. Pseudo force.
4. 

**Important Things about Pseudo Forces**

1. The direction of Pseudo force is always opposite to the direction of acceleration of frame (it has nothing to do with the direction of motion of frame)
2. The magnitude of Pseudo force is equal to the body which we are analyzing multiplied by the acceleration of the frame (it is not related to the acceleration of the body at all)
3. Point of applicable Pseudo force is at the center of mass of the body.

## 12.6 Module end exercise

- In the earth's frame of reference, the sun moves across the sky each day from east to west. Explain what forces cause this observed motion.
- In a lift that is going up with uniform speed, a boy can jump up to a maximum height of one metre above the floor of the lift. If, instead, the lift was moving down with uniform speed, to what maximum height above the floor of the lift could the boy jump?
- An experiment with a conical pendulum is set up in the laboratory. The motion of the bob is observed by three persons. o 1, viewing the motion from a point directly above the point of suspension, observes the bob to move along a circle. 02, viewing it in the plane of motion of the bob, sees it moving along a

straight line. 03, viewing the motion obliquely, finds the trajectory to be somewhat oval-shaped. What is the correct description of the trajectory relative to the laboratory frame of reference?

## 12.7 References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# 13. System of Particles and Rotational Motion

### 13.1 Introduction

When we deal with the mechanics of small particles, whose internal structure does not matter to us, it is so simple. But applying Newton's laws to more complicated things is interesting and is the subject of the present chapter. There can be several types of complicated objects and the 'simplest complicated' object is a rigid body. A rigid body may be considered as a collection of many particles and the types of motion a rigid body can have will be discussed in the present chapter.

### 13.2Essential Previous Knowledge

Mechanics of single particle, Newton's Laws of motion

### 13.3 Learning Objectives

(i) Define a rigid body

(ii) Define centre of mass

(iii) Apply the conservation of linear momentum principle to a given system of particles

(iv) Define angular velocity and angular acceleration

(v) Define torque

(vi) Apply the conservation of angular momentum principle to the given situation

(vii) Solve the given problems based on the concept of the rotational motion

### 13.4 Major Concepts

Rigid body and non-rigid body, Types of motion of a rigid body, Centre of mass, Motion of centre of mass, Linear momentum of system of particles, Vector product of two vectors, Angular velocity and its relation with linear velocity, Angular Acceleration, Torque and angular momentum, Moment of force, Angular momentum of a particle, Conservation of angular momentum, Equilibrium of a rigid body, Principle of moments, Centre of gravity, Moment of Inertia, Theorems of Perpendicular and Parallel axes, Kinematics of Rotational Motion about a fixed axis, Dynamics of rotational motion about a fixed axis, Angular momentum in case of rotation about a fixed axis, Conservation of angular momentum, Rolling motion.

### 13.5 Teaching Methodology

Lecture cum Discussion Method

### 13.6 Materials Required

A ball, a spinning top, PhET software

### 13.7 Content Description and Activities

**Rigid body and non-rigid body**

A rigid body is a system of particles. The distance between two particles of a rigid body remains the same whereas in non rigid body the distance changes with time. Ideally a rigid body is a body with a perfectly definite and unchanging shape.

**Centre of mass**

Consider two objects connected by a string thrown into air. The motion of the individual particles may be complicated. However the entire system moves along a parabolic path. What actually moves along a parabola? Let us try to answer this.

Consider an n particle system, the total force acting on it is,

$$\sum_i \vec{F}_i = \vec{F} = M\left(\frac{d^2\left(\sum_i m_i r_i\right)\Big/M}{dt^2}\right) = M\left(\frac{d^2R}{dt^2}\right)$$

Where R is the centre of mass of the system. The centre of mass is the point at which all the mass can be considered to be 'concentrated'. In symmetric bodies the centre of mass is the geometric centre whereas it need not be the case with asymmetric objects. Also the centre of mass may or may not lie within the body. It is to be noted that in the case of continuous distribution of mass the summation changes into integration.

It is the centre of mass which moves in a parabolic path in the case of two blocks connected by a string thrown into air.

**Angular Velocity**

Angular velocity ( $\vec{\omega}$ ) is defined as the time rate of change of angle $\theta$.

$$\omega = \frac{d\theta}{dt}$$

where, $\theta$ is the angle of rotation

The relationship between angular velocity $\omega$ and linear velocity $v$ is given by

$$\vec{v} = \vec{\omega} \times \vec{r}$$

where, $\vec{r}$ is the vector from the axis of rotation.

**Angular Acceleration**

Angular acceleration $\vec{a}$ is defined as the rate of change of angular velocity. In equation form, angular acceleration is expressed as follows:

$$\vec{a} = \frac{d\vec{\omega}}{dt}$$

where $d\omega$ is the change in angular velocity and $dt$ is the change in time. The units of angular acceleration is rad/s$^2$ .

**Moment of a force**

It is easier to turn a nut with a long spanner than with a short one. Also the handle on a door is at the outside edge so that it opens and closes easily. A much larger force would be needed if the handle were near the hinge. The turning effect of a force is called the torque or the moment of the force ($\tau$). It depends on both the size of the force and how far it is applied from the pivot or fulcrum. It is measured by multiplying the force by the perpendicular distance of the line of action of the force from the axis of rotation. The unit is the newton metre (Nm).

$$\vec{\tau} = \vec{r} \times \vec{F}$$

Two equal, parallel and opposite forces acting on rigid body known as couple.

**Angular momentum of particle**

Angular momentum is the rotational analogue for linear momentum and is defined as the moment of (linear) momentum.

$$\vec{L} = \vec{r} \times \vec{p}$$

**Conservation of Angular Momentum**

The relation between the torque and the angular momentum is given by,

$$\vec{\tau} = \frac{d\vec{L}}{dt}$$

So, if the net torque is zero, the angular momentum of the object revolving about an axis is conserved, i.e., the product of the mass, the speed, and the distance from the object to the axis of revolution is a constant in time.

**Equilibrium**

**The First Condition for Equilibrium**

The first condition necessary to achieve equilibrium is that the net external force on the system must be zero.

**The Second Condition for Equilibrium**

The second condition necessary to achieve equilibrium is that the net external torque on the system must be zero.

**Centre of gravity**

It is a point where the entire weight of the body is supposed to act. Or, in other words, it is a point about which the total torque is zero.

**Moment of inertia**

For a point mass the moment of inertia is the mass times the square of perpendicular distance to the rotation reference axis and can be expressed as $mr^2$

For a rigid body, $moment\ of\ inertia = \sum_i m_i r_i^2$

The torque ($\tau$) is related with the moment ($I$) of inertia as, $\tau = I\alpha$. Where $\alpha$ is the angular acceleration.

**Conservation of Angular momentum**

When the net external torque is zero ($\tau = 0$) then $I\alpha$ is zero, or $I\omega$ is constant. Hence for systems with zero net external torque on increasing the moment of inertia ($I$), the angular velocity ($\omega$) decreases and on decreasing the moment of inertia ($I$), the angular velocity ($\omega$) increases.

**Kinetic Energy of Rolling Motion**

The kinetic energy of a rolling body is the sum of the kinetic energy of translation and kinetic energy of rotation.

**13.8 Exercise Questions**

1. A girl of mass ‘m’is standing on a platform of mass ‘M’’ kept on smooth frictionless surface. If the girl starts to move on platform with a speed ‘V’’ relative to the platform with what velocity relative to the surface does the platform recoil? (HINT: let $V_g$ ,$V_p$ are the velocities of girl and plank respectively, As there is no force on the system, momentum of system is constant).

Q) Why do tornadoes spin at all? And why do tornados spin so rapidly?

A) The answer is that air masses that produce tornadoes are themselves rotating, and when the radii of the air masses decrease, their rate of rotation increases.

Q) Have you observed the motion of an Ice skater? What is so special in it?

A) Conservation of angular momentum

# Lab Activities

### 1.1. Sonometer

**Introduction**

Sonometer consists of long wire, with uniform cross section, fixed at one end of wooden board and the other end is passes over a pulley, and adjusted such that a known load can be applied it. The wire under tension vibrates with a frequency same as the frequency of an external vibrator kept in contact with wire or the setup. Adjusting two sharp wedges present under the wire, one can obtain stationary wave at which a large resonating sound is observed. This distance between the sharp wedges is called as resonating length. This is dependent on the frequency of the external vibrator and the tension in the wire, and verifying the same is the motto of this experiment.

**Learning Objective**

Learner would be able to

- verify the relation between the frequency and length of a given wire under constant tension using sonometer.
- verify the relation between the length of a given wire and tension in the wire for constant frequency using a sonometer.

**Major Resources**

Sonometer; tuning forks with known frequency; mater scale; paper rider; rubber pad; hanger with known half kilogram weights.

**Content description**

The frequency $n$ of the fundamental node of vibration of a string is given by $n = \frac{1}{2l}\sqrt{\frac{T}{m}}$ where $m$ is mass per init length of the string; $l$ is the resonating length; $T$ is the tension in the wire which is equal to the weight of the load.

**(i) Variation of resonating length with frequency**

- *Set up sonometer on the table and ensure pulley offers minimum friction. Stretch the wire by placing a suitable load on the hanger, and this load is not changed in this section of the experiment.*
- *Strike a known frequency of the tuning fork against the rubber pad and try to compare the sound produce by this with the sound of a plucked wire. Adjust the distance between the sharp wedges till those two sounds appear alike.*
- *For final adjustments, place a small paper rider in the middle of the wire (between those two sharp wedges). Sound the tuning fork and place its shank stem on the sonometer box. Adjust the length till the paper rider vibrates violently and falls off. Note down the length between the sharp wedges and repeat this for different frequencies. Plot the graphs* $\mathrm{l}$ *vs* $\mathrm{n}$*, and* $1/\mathrm{l}$ *vs* $\mathrm{n}$.

*Observation*

| *Frequency* **n** *of the tuning fork (Hz)* | $n_1$ | $n_2$ | $n_3$ | $n_4$ | $n_5$ | $n_6$ |
|---|---|---|---|---|---|---|
| *Resonating length (cm)* | | | | | | |
| $\frac{1}{l}$ *(*$\mathbf{cm^{-1}}$*)* | | | | | | |
| **nl** *(Hz cm)* | | | | | | |

**(i) Variation of resonating length with tension in the wire**

- Choose any tuning fork and don't change it in this section of the experiment. Find the resonating lengths for different tension in the wire.
- Plot graph between $l^2$ and $T$.

*Observation*

| *Tension in the wire* $\boldsymbol{T}$**(N)**. | | | | | | |
|---|---|---|---|---|---|---|
| *Resonating length (cm)* | | | | | | |
| $\mathbf{l^2}$*(*$\mathbf{cm^2}$*)* | | | | | | |
| $\mathbf{T}/\mathbf{l^2}$ *(*$\mathbf{N\ cm^{-2}}$*)* | | | | | | |



**Misconceptions**

1. Wave is not the motion of matter as like in the case of the wind. But it is the propagation of disturbance in the medium.
2. In a harmonic progressive wave, all particles have the same amplitude but different phases at a given instant of time. In a stationary wave, all particles between the nodes have same phase but different amplitude.
3. Amplitude is the maximum displacement from the mean position of the oscillation.

**Self Check Questions**

1. Explain how does the sonometer set up is used to verify dependence of resonating length on tension in the wire and external frequency.
2. How the resonating length does vary with the tension for a constant external frequency?
3. What is resonance? How is this concept used in this experiment?

**Module end Exercise**

1. If we take three wires with different diameters of the same material, how would the resonating length varies for fixed tension and frequency?
2. Is it possible to determine the velocity of waves in the given material medium(wire), from the same experimental setup? Explain.

**References**

1. NCERT lab manual for class XI.

**MCQ**

1. Under a constant tension in wire, velocity of propagation of waves is dependent on
   (a) Total mass of the wire (b) Linear mass density
   (c) Length of wire (d) Total mass and diameter of the wire.

## 1.2 Specific heat capacity

**Introduction**

Specific heat capacity of a substance is the amount of heat required to raise the temperature of unit mass by 1K. For a body of mass m and specific heat s, amount of heat gained or lost by a body when its temperature falls or gains by $\Delta t$ is given by $\Delta Q = ms\Delta t$.

Principle of Calorimeter: If bodies of different temperature are brought in thermal contact the amount of heat lost by the body at higher temperature is equal to amount of heat gained by the body at lower temperature, at thermal equilibrium, provided no heat is lost to the surroundings.

**Learning Objectives**

Learner would be able to

- determine the specific heat capacity of a given solid and a liquid by the method of mixtures.
- differentiate between specific heat capacity and the heat capacity.

**Major Resources**

Calorimeter with stirrer; thermometer; weighing machine; a piece of non-flexible thread; solid (preferably metallic sphere)

**Content description**

- Weigh the empty calorimeter with stirrer and lid. Pour sufficient amount of the given water in the calorimeter so that solid can completely get submerged. Dip the solid in water and take it out. Shake it well to remove water sticking to its surface, before you weigh.
- Tie the solid tightly with a thread and suspend it in a liquid kept for boiling. Keep the solid in this boiling water for at least for 5-10 minutes. After removing the solid, immediately transfer it to the calorimeter containing water. In this step ensure that no hot water is transferred to the calorimeter. Stir the water and measure its temperature when it reaches equilibrium. Do the calculations to determine the specific heat of the solid.
- Repeat above steps by replacing the water kept in the calorimeter by the liquid to determine its specific heat.

**Observations**

**(i) To determine the specific heat of solid**

Mass of the empty calorimeter with stirrer($m_1$) =………g

Mass of the calorimeter with water($m_2$) =………g

Mass of the solid($m_3$) =………g

Initial temperature of the water ($t_1$) =………K

Temperature of the solid in boiling water ($t_2$) = ………K

Temperature of the mixture at equilibrium($t_3$) =………K

Specific heat capacity of the material of calorimeter $s_1$ =………$Jkg^{-1}K^{-1}$

Specific eat of water (s) = ……… $Jkg^{-1}K^{-1}$

**Calculations**

Mass of water in the calorimeter ($m_2$-$m_1$) = ………kg

Change in the temperature of liquid and calorimeter ($t_3$-$t_1$) = ………$K^{-1}$

Change in temperature of the solid($t_2$-$t_3$) =………$K^{-1}$

Heat given by the solid = (Heat gained by liquid in raising its temperature from $t_1$ to $t_3$) +(heat gained by calorimeter in raising its temperature from $t_1$ to $t_3$)

$$s_0 = \frac{(m_2-m_1)s(t_2-t_1)+ m_1s_1(t_3-t_1)}{m_3(t_2-t_3)} = \ldots\ldots\ Jkg^{-1}K^{-1}$$

**(i) To determine the specific heat of liquid by the method of mixture**

Mass of the empty calorimeter with stirrer($m_1$) =………g

Mass of the calorimeter with liquid($m_2$) =………g

Mass of the solid($m_3$) =………g

Initial temperature of the water ($t_1$) =………K

Temperature of the solid in boiling water ($t_2$) = ………K

Temperature of the mixture at equilibrium($t_3$) =………K

Specific heat capacity of the material of calorimeter $s_1$ =………$Jkg^{-1}K^{-1}$

Specific heat capacity of solid ($s_0$) = ……… $Jkg^{-1}K^{-1}$

**Calculations**

Mass of liquid in the calorimeter ($m_2$-$m_1$) = ………kg

Change in the temperature of liquid and calorimeter ($t_3$-$t_1$) = ………$K^{-1}$

Change in temperature of the solid$(t_2$-$t_3)$ =……….$K^{-1}$

Heat given by the solid = (Heat gained by liquid in raising its temperature from $t_1$ to $t_3$) +(heat gained by calorimeter in raising its temperature from $t_1$ to $t_3$)

$$s = \frac{m_3 s_0 (t_2 - t_3) - m_1 s_1 (t_3 - t_1)}{(m_2 - m_1)(t_2 - t_1)} = \ldots\ldots\ \text{Jkg}^{-1}\text{K}^{-1}$$

**Misconceptions**

1. Heat is the form of energy but the temperature is a scale used to measure the degree of hotness or coldness.
2. Specific heat capacity is not same as heat capacity.

**Self-Check Questions**

1. What is thermal equilibrium?
2. Is the specific heat capacity of the substance of 1kg differs from the same substance of the 3kg?
3. Write the S.I. unit of heat capacity.
4. In the evening, water in the pool is little warmer than the sand. Explain.

**Module end Exercise**

1. Why is it important to stir the contents before taking the temperature of the mixture?
2. Is the specific heat capacity of a substance a constant quantity?
3. List all possible sources of errors while performing this experiment.
4. What can we infer if the substance A has the specific heat capacity is twice as of the substance B?

**References**

1. NCERT lab manual for class XI.

**MCQ**

1. Specific heat capacity of a substance is dependent on
   (a) mass of the substance (b) volume of the substance
   (c) nature of the substance (d) all of them.
2. Choose the right statement.
   (a) Heat capacity is dependent only on the amount of the substance.
   (b) If heat capacity of A is greater than B, then A requires large amount energy to raise the temperature by one unit than B.
   (c) If specific heat capacity of A is lesser than B, then A requires large amount energy to raise the temperature by one unit of than B.
   (d) If heat capacity of A is greater than B, then we can't infer that A requires large amount energy to raise the temperature by one unit than B.

## 1.3 Force constant and effective mass of a helical spring

### Introduction

Spring undergoes deformation when an external force acts on it and it regains original structure as external force cease to exists. Restoring force present in the spring helps it to gain its original structure under an elastic limits. This restoring force is directly proportional to the displacement of the spring from its equilibrium position but opposite to the direction of the displacement. The proportionality constant between the restoring force and the displacement is called as force constant, and it describes the elastic nature of the spring. In this experiment we determine the force constant and the effective weight of the given helical spring.

### Learning Objectives

Learner would be able to

- find the force constant and effective mass of a given helical spring.
- appreciate the method involved to reduce the error while collecting the data.
- determine the number of oscillations to be considered, for a given stop-watch to reduce the possible errors while collecting the data

### Major Resources

Helical Spring, measuring scale, load, load hanger, stop-watch.

### Content description

- Fix the spring such a way that its pointer moves freely over scale without touching it. Note down the least count of the stop-watch. Suspend the load gently on hanger; wait until it comes to rest so that it reaches its equilibrium position.
- Pull the load gently so that it set into oscillations in vertical direction. You can neglect the first few oscillations and start the stop-watch to count **n** oscillations when load crosses the mean position.
- The value of the **n** is set such that the associated error in time period becomes less than 1%. Repeat the experiment for different loads, calculate the time period of oscillation and plot the graph $T^2$vs $m$ to determine equivalent mass and force constant of helical spring.

Time period of helical spring under SHM is given by $T = 2\pi\sqrt{\frac{m_0 + m}{K}}$. It is simplified as $T^2 = \frac{4\pi^2}{K}m + \frac{4\pi^2}{K}m_0$. Force constant is determined by equating slope is equal to $\frac{4\pi^2}{K}$ and equivalent mass is determined equating y-intercept to $\frac{4\pi^2}{K}m_0$.

### Observation

Least count of the measuring scale = ………cm

Least count of the stop-watch = ………s

| Sl. No. | Mass of the load (kg) | Mean position of the pointer (cm) | Time for n oscillations (s) | | | | Time period (s) |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | Mean | |
| | | | | | | | |

**Misconceptions**

- In physics, an elastic rubber is less elastic than any metal rod. Because we have quantified the modulus of elasticity as the ratio of stress over strain. An object 'A' is called more elastic compared to 'B' only when 'A' requires more force to deform it than the other.

**Self Check Questions**

1. What is simple harmonic motion?
2. How the time period of oscillation does varies with the increase in load?
3.

**Module end Exercise**

1. Explain the need to start the stop-watch at mean position rather than the extreme positions.
2. If stop-watch has the least count of 0.1s, then how do you set number of oscillations **n**, to get a proper time period?
3. Two springs A(soft) and B(stiff), loaded with the same mass and are suspended from the same rigid support. In which spring will the oscillations be slower when they are set into vertical oscillations?
4. As an add-on to this experiment, what needs to be done to determine the acceleration due to gravity? And how can it be calculated?
5. What is the physical significance of the spring constant $30Nm^{-1}$?

**References**


1. NCERT lab manual for class XI.


**MCQ**

1. A person doing this experiment counts time for 20 oscillations using a stop-watch with least count of 0.3s and if that person finds total time taken is 30s, then what is the percentage error in the measurement?
   (a) 2% (b) 1% (c) 1.5% (d)0.5%
2. What is the nature of the graph drawn $T^2$vs $m$, looks like?
   (a) a parabola starts from origin.
   (b) a straight line starts from origin.
   (c) a parabola with positive y-intercept.
   (d) a straight line with positive y-intercept.

## 1.4 Surface Tension

### Introduction

Surface tension is a force per unit length acting in the plane of the interface between the plane of the liquid and any other substance. It is also the extra energy that molecules at interface have as compared to the molecules in the interior.

Then, if we want to increase the surface of the liquid, we need to do work on it so that molecules get sufficient energy and come to the surface. The value of surface tension of a liquid A is more than B with respect to a given surface, it implies that liquid B can be spread easily than liquid A on that surface. Then we can say that liquid B is more adhesive to that surface than the liquid A. Whenever liquid is adhesive to the surface, it makes an acute angle with the surface and if not it forms an obtuse angle with the surface. For example, water on the lotus leaf forms obtuse angle and on any other leaf it forms acute angle. It tells that, water is adhesive to the any other leaf but not for the lotus leaf.

### Learning Objectives

Learner would be able to

- determine the surface tension of water by capillary rise method.
- explain the physical significance of the value of surface tension.
- estimate about the surface tension of two liquids based on the angle subtended with the surface.

### Major Resources

Capillary tube; travelling microscope; beaker; water.

### Content description

- Capillary tube cleaned thoroughly first with caustic soda then with the water, to be free of contamination and one also ensure that capillary tube sufficiently wet.
- Fill the beaker with water. Clamp the capillary tube near its upper end and ensure that the capillary tube is almost vertical while dipping in water and water level in capillary tube is slightly above the edge of the beaker. Push a pin through the cork, fix this on the other clamp such that tip of the pin just touches the surface of the water.
- First focus the meniscus of the water in the capillary, later the tip of the pin, to note down the corresponding readings of travelling microscope. Cut the capillary tube to determine its inner diameter using travelling microscope(at a point up to which water level is raised).

The weight of the column of the liquid below the meniscus, is supported by the upward force of surface tension acting around the circumference of the points of contact, when liquid raises in a capillary tube. Then,

$$2\pi r T = \pi r^2 h \rho g$$

where, $T$ is the surface tension of the liquid; h is the height of the liquid column and r is the inner radius of the capillary tube.

**Observations**

Least count of the travelling microscope = ………mm

Measurement of the capillary raise

| Sl. No. | Reading of the meniscus $h_1$(cm) | | | Reading of the tip of the pin touching the surface $h_2$(cm) | | | $h_1 - h_2$ (cm) |
|---|---|---|---|---|---|---|---|
| | M.S.R(cm) | V.S.R | TR (cm) | M.S.R(cm) | V.S.R | TR (cm) | |
| | | | | | | | |
| | | | | | | | |

Measurement of the diameter of the capillary tube

| Sl. NO | Reading along a diameter (cm) | | Diameter $d_1(x_2 - x_1)$ (cm) | Reading along perpendicular diameter (cm) | | Diameter $d_1(y_2 - y_1)$ (cm) | Average diameter (cm) |
|---|---|---|---|---|---|---|---|
| | One end $x_1$ | Other end $x_2$ | | One end $y_1$ | Other end $y_2$ | | |
| | | | | | | | |
| | | | | | | | |

**Misconceptions**

1. Surface tension is not the property of the single liquid alone. It depends also on the surface which is in contact with the liquid. As explained earlier, water acts as less adhesive to the lotus leaf compared with other leaf.

**Self Check Questions**

1. Explain surface tension of a liquid with respect to a surface.
2. Surface tension of the liquid A with respect to surface-1 is lesser than liquid B with respect to a surface-2. What can you infer from this statement?
3. What are all the physical quantities on which the value of the surface tension is dependent on?

**Module end Exercise**

1. Why do you require to ensure that the capillary tube is sufficiently wet, before starting the experiment?
2. Why we are very much bothered about the purity of the capillary tube? Explain.
3. If the same experiment is performed at higher temperature, does the capillary rise is same as at lower temperature? Explain.

**MCQ**

1. Choose the physical quantity upon which the surface tension of a liquid in not depend on

   (a) density of the liquid (b) radius of the capillary tube

   (c) mass of the liquid (d) height of the capillary rise

2. If the radius of the capillary tube is reduced to half of its value then what is the value of the surface tension(s) of the liquid?

   (a) 2s (b) s (c) 0.5s (d) 4s

## 1.5 Length Measurements

**Introduction**

Measurement of length may done at various level of accuracy. Take for example a normal scale used in regular class by students. It can be used to measure an object with at most accuracy of 1 mm. This is the least measurement that can be carried out using that instrument and hence it is called "least count" of that instrument. In the present module we are going to study how to make measurement with instruments which can be used to measure length much more precisely i.e., with higher accurate least count. The instrument that will be used in the here are Vernier Callipers, Screw gauge and Spherometer.

**Learning objectives**

- To understand the meaning of least count and zero error.
- To know how to determine the least count and zero error of instrument which contains two scales.
- To measure the different lengths of objects using these instruments.

**Major Concepts**

Main scale, vernier scale, least count, zero error, zero correction

**Learning Resources**

Using the Cardboard to demonstrate how secondary scale can be constructed, Vernier Callipers, Screw gauge, Spherometer.

**Content Description**

**Vernier Callipers**

(i) measure diameter of a small spherical/cylindrical body,

(ii) measure the dimensions of a given regular body of known mass and hence to determine its density and

(iii) measure the internal diameter and depth of the given and hence calculate its volume.

**Screw gauge**

Use screw gauge to

(a) measure diameter of a given wire,

(b) measure thickness of a given sheet; and

(c) determine volume of an irregular lamina.

**Spherometer**

To determine the radius of curvature of a given spherical surface by a spherometer

***Misconceptions***

Zero error and zero

*Self Check questions*

1. **What is meant by 'radius of curvature' of a surface?**
2. **Is there any zero error in a spherometer?**
3. **What will be the effect of:**
   (a) changing the pitch or
   (b) changing the number of circular divisions upon accuracy or least count?
4. **Why main scale is marked on both sides of zero?**
5. **Is paper insertion method for testing the touching position of the screw is correct?**

**Module end exercise**

1. One can undertake an exercise to know the level of skills developed in making measurements sing Vernier Callipers. Objects, such as bangles/kangan, marbles whose dimensions can be measured indirectly using a thread can be used to judge the skill acquired through comparison of results obtained using both the methods.

2. How does a vernier decrease the least count of a scale.

3. How would the precision of the measurement by Vernier Callipers be affected by increasing the number of divisions on its vernier scale?

4. How can you find the value of $\pi$using a given cylinder and a pair of Vernier Callipers?

[Hint : Using the Vernier Callipers, - Measure the diameter Dand find the circumference of the cylinder using a thread. Ratio of circumference to the diameter (D) gives $\pi$.]

**MCQ**

Q1. Which of the following instruments is best suited to measure the diameter of a ball bearing

A) Optical micrometer B) Meter scale
B) Screw gauge D) Range finder

Q2. A spherometer has a least count of 0.005cm . Its head scale is divided into 200 divisions. The distance between consecutive threads on the spherometer should be

A) 0.005cm B) 0.02 cm
B) 0.01cm D) None of these

## 1.6 Newton's second law of motion

### Introduction

We all know the Newton's second law of motion which states that the force is rate of change of momentum i.e., F = dp/dt. This gives the relation F = ma i.e., the net force on a body is equal to the product of the body's mass and its acceleration. If we keep mass m as constant we get a linear relationship between F and a. This can be studied by varying the unbalanced force in a constant mass system.

### Learning objectives

- To study the relation between force and acceleration.

### Major Concepts

Newton's second law of motion, force, acceleration.

### Learning Resources

Dynamic cart, level table, pulleys, weights, stopwatch.

### Content Descriptions and activities

Arrange a cart at a distance of 1:00 m from the bumper. Load the cart with weights from the weight box so that the total mass of the system is nearest hundred. This is the mass m of the system. The mass m of the system is equal to the mass of the cart plus the weights kept on it plus the mass of the scale-pan including the weights put in it. This mass is to be kept constant throughout the experiment. Give a little push to the cart and watch its motion.

Transfer some small weights from the cart to the scale pan so that given a slight push, the cart moves with uniform velocity as judged by our senses. This procedure compensates the frictional force acting on the cart. Now transfer a 20g weight from the cart to the scale pan and then note down the time taken to travel the distance. Using $a = 2S/t^2$ calculate the acceleration for the unbalanced force of 20g. Repeat the experiment for other weights. Then observe how acceleration varies with the unbalanced force.

### Observations

Mass of the cart = ……………… kg

Mass of the system = mass of the cart + mass on the cart + mass of pan + mass on pan

=…………………..

= ………………… kg

| Sl. No. | Unbalanced force (g) | Time taken in (s) | | | | | Mean (best of 3) time | | Acceleration $a = \frac{2S}{t^2}$ m/s$^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | t | $t^2$ | |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **3** | | | | | | | | | |
| **4** | | | | | | | | | |
| **5** | | | | | | | | | |
| **6** | | | | | | | | | |

*Misconceptions*

- Only animate objects can exert a force. Thus, if an object is at rest on a table, no forces are acting upon it.
- Large objects exert a greater force than small objects.
- A force is needed to keep an object moving with a constant speed.

*Self Check questions*

1. How will you compensate for frictional force?
2. What is the net force acting on the system under this condition? How will you make the cart to accelerate?

**Module end exercise**

1. Is the equilibrium of the cart disturbed? Why? How does the cart move now? You have measured the acceleration. How will you do it?

**Test questions**

Q1. Two trains A and B are running in the same direction on parallel tracks such that A is faster than B. If packets of equal weight are exchanged between the two, then

A) A will be retarded but B will be accelerated
B) A will be accelerated but B will be retarded
C) There will not be any change in the velocity of A but B will be accelerated
D) There will be any change in the velocity of B but A will be accelerated

Ans: A)

Q2. A wooden block of mass $M$ resting on a rough horizontal surface, is pulled with a force $F$ at an angle with the horizontal. If μ is the coefficient of kinetic friction between the block and the surface, then acceleration of the block is

A) $\frac{F}{M}\sin\varphi$
B) $\mu\, F\cos\varphi$
C) $\mu F\sin\varphi$
D) $\frac{F}{M}(\cos\varphi + \mu\sin\varphi) - \mu g$

Ans: D)

Q3. A car of mass m starts from rest and acquires a velocity along east $v = v\hat{\imath}$ (v>0) in two seconds. Assuming the car moves with uniform acceleration, the force exerted on the car is

A) $\frac{mv}{2}$ eastwards and is exerted by the car engine

B) $\frac{mv}{2}$ eastward and is due to the friction on the tyres exerted by the road

C) More than $\frac{mv}{2}$ eastward exerted due to the engine and overcomes the friction of the road

D) $\frac{mv}{2}$ exerted by the engine.

Ans B)

Q4. When an object undergoes acceleration

A) Its speed always increases

B) Its velocity always increases.

C) It always falls towards the earth

D) A force always acts on it

Ans: D)

## 1.7 Newton's second law

### Introduction

We all know the Newton's second law of motion which states that the force is rate of change of momentum i.e., F = dp/dt, which gives the relation F = ma, where m is the mass and a is the acceleration. If we keep force F as constant we can find out how acceleration varies with mass.

### Learning objectives

- To study the relationship between mass and acceleration.

### Major Concepts

Newton's second law of motion, force, mass, acceleration.

### Learning Resources

Cart, scale pan, pulley, weights.

### Content Descriptions and activities

Load the cart with some 100g and give the cart a gentle push. Eliminate friction by adding weights in the scale pan so that the cart moves uniformly. Now transfer 20g from the cart to the scale pan. This will be the unbalanced force which is kept constant throughout the experiment. Before taking readings note down the mass of the cart, mass of the scale pan and mass in the scale pan. Compute the total mass of the system. Keep the distance of travel for the cart fixed at 1:00 m throughout the experiment. Release the cart and note down the time taken by the cart to cover the distance of 1:00 m. Repeat the experiment by adding weights on the cart to change the mass of the system.

**Observations**

Mass of the cart = ……………… kg

Mass of the system = mass of the cart + mass on the cart + mass of pan + mass on pan

=…………………..

= ………………… kg

| **Sl. No.** | **Mass of the system (kg)** | **1/m** | **Time taken in (s)** | | | | | **Mean (best of 3) time** | **Acceleration** $a = \frac{2s}{t^2}$ **m/s²** |
|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **t** | |
| **1** | | | | | | | | | |
| **2** | | | | | | | | | |
| **3** | | | | | | | | | |
| **4** | | | | | | | | | |
| **5** | | | | | | | | | |
| **6** | | | | | | | | | |

**Results**

*Self Check questions*

1. How does $a$ vary with the mass of the system when the unbalanced force is constant. What proportionality do you expect? Draw a graph to verify the proportionality so that a linear relation is obtained?
2. What graph will you draw? What is the nature of the graph?
3. Identify the sources of error.
4. Offer explanation for any discrepancies observed.
5. Suggest methods to eliminate/minimize the errors

## 1.8 Conservation of momentum in a mechanical explosion

**Introduction**

Momentum of a moving body is given by p=mv, where m is the mass of the system and v is the velocity. In a mechanical explosion total momentum of the system is conserved.

**Learning objectives**

- To verify the law of conservation of momentum in a mechanical explosion

**Major Concepts**

Conservation of momentum, mechanical explosion

**Learning Resources**

Dynamic carts, bumper, weights.

**Content Descriptions and activities**

Momentum is said to be conserved if the momentum before collision is equal to the momentum after collision. We know that momentum is the product of mass and velocity. If there is no instrument given to measure the time then we would not be able to determine exact value of velocity. This can be overcome by making the time taken to cover a displacement equal. In the present experiment an explosion is initiated using two dynamic carts. This is achieved by leaving the two dynamic carts from a position between two bumpers, such that they hit the bumpers exactly at the same time.

The experiment is carried out by keeping 500g in one of the carts so that there is difference between the weights of the cart. The experiment is repeated for different load combinations. The distances traversed by two carts say $X_A$ and $X_B$ are noted in each trial and the product $m_AX_A$ and $m_BX_B$ are calculated and tabulated. Percentage difference between these two product is determined.

| Sl. No. | Mass of the cart A $M_A$ (g) | Mass of the cart B $M_B$ (g) | $X_A$ (cm) | $X_B$ (cm) | $m_AX_A$ | $m_BX_B$ | Percentage error |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

*Self Check questions*

1. Determine Linear Momentum? What types of physical quantity it is?
2. How do you measure $V_A$ and $V_B$?
3. Can you set $t_A = t_B$ ? How?

**Module end exercise**

1. Discuss the sources of error and suggest methods to minimize/eliminate the same.
2. Write the relation between $X_A$ and $X_B$, $M_A$ and $M_B$.

**Test Questions**

Q1. A bullet in motion hits and gets embedded in a solid block resting on a frictionless table. What is conserved?

A) Momentum and KE

B) Kinetic energy alone

C) Neither KE nor momentum

D) Momentum alone

Ans: D)

Q2. The spacecraft of mass M moves with velocity V in free space at first, then it explodes breaking into two pieces. If after explosion a piece of mass m comes to rest, the other piece of space craft will have a velocity:

(A) $MV/(M - m)$

(B) $MV/(M + m)$

(C) $mV/(M - m)$

(D) $mV/(M + m)$

Ans: A)

Q3. A bomb travelling in a parabolic path under the effect of gravity, explodes in mid air. The centre of mass of fragments will:

A) Move vertically upwards and then downwards

B) Move vertically downwards

C) Move in irregular path

D) Move in the parabolic path the unexploded bomb would have traveled

Ans: D)

## 1.9 Conservation of momentum in a head-on collision

### Introduction

Momentum of a moving body is given by $p=mv$, where m is the mass of the system and v is the velocity.

**Learning objectives**

- To study the law of conservation of momentum in a head on collision.

**Major Concepts**

Conservation of momentum, head on collision

**Learning Resources**

Two steel balls of same mass and same size, grooved ruler, plumb line, drawing board, tracing paper.

**Content Descriptions and activities**

The velocities of the spheres can be measured by making use of the fact that objects projected with different horizontal velocities from the edge of a table take the same time to fall to the floor. Neglecting air resistance the horizontal component of their velocities remain unchanged and the distance they go horizontally before striking the floor is proportional to their horizontal velocity.

To give an initial velocity to one of the spheres, roll it from a height down the grooved ruler. Note the point at which it strikes a drawing board, to which a carbon paper below a tracing paper is pinned. Release the same ball from the same point several times and note the distribution of points on the tracing paper.

Balance the target ball on the set screw and adjust its height such that at the instant of collision the centers of the two spheres are in the same horizontal line. Adjust the position of the screw such that the distance between the two centers of the spheres is twice the radii of either sphere at the time of collision and they are in line with the grooved ruler. Release the bullet ball from the same height as earlier and observe the locations of hit of the balls after collision. Do it 10 to 15 times. Observe the motion of the bullet after collision.

Draw on the paper the vectors representing the velocities of the balls after and before collision. Verify the law of conservation of momentum. Calculate the sum of the squares of the ranges fo the balls before and after collision. Repeat the whole process by releasing the bullet ball from different heights on the grooved ruler.

**Observations:**

Distance of 1$^{st}$ ball from plumb line = …………………….cm

Distance of 1$^{st}$ ball after hitting target = ……………………cm

Distance of 2$^{nd}$ ball after collision = …………………………cm

| Sl. No. | Total momentum before collision ($P_i$) | Total momentum after collision ($P_f$) | $P_i$ -$P_f$ | Angle between $P_i$ and $P_f$ |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

*Misconceptions*

*Self Check questions*

1. To what accuracy the impressions are at the same place?
2. Observe the motion of the bullet after collision. Does it move forward, backward or sideward? Explain why?

## 1.10Newton's law of cooling

### Introduction

The rate at which a hot body loses heat is directly proportional to the difference between the temperature of the hot body and that of its surroundings and depends on the nature of material and the surface area of the body. This is Newton's law of cooling.

### Learning objectives

- To study the relationship between the temperature of a hot body and time by plotting a cooling curve.

### Major Concepts

Newton's law of cooling, cooling curve.

### Learning Resources

a copper calorimeter, two celsius thermometers, a stop clock, a heater, liquid (water), a clamp stand, two rubber stoppers with holes, strong cotton thread and a beaker.

### Content Descriptions and activities

1. Find the least counts of thermometers $T_1$ and $T_2$. Take some water in a beaker and measure its temperature (at room temperature $\theta_o$) with one (say $T_1$) of the thermometers.
2. Examine the working of the stop-watch/clock and find its least count.
3. Pour water into the double- walled container (enclosure) at room temperature. Insert the other thermometer T2 in water contained in it, with the help of the clamp stand.
4. Heat some water separately to a temperature of about 40 $^oC$ above the room temperature $\theta_o$. Pour hot water in calorimeter up to its top.
5. Put the calorimeter, with hot water, back in the enclosure and cover it with the lid having holes. Insert the thermometer T1 and the stirrer in the calorimeter through the holes provided in the lid.
6. Note the initial temperature of the water between enclosure of double wall with the thermometer $T_2$, when the difference of readings of two thermometers $T_1$ and $T_2$ is about 30 $^oC$. Note the initial reading of the thermometer $T_1$.
7. Keep on stirring the water gently and constantly. Note the reading of thermometer $T_1$, first after about every half a minute, then after about one minute and finally after two minutes duration or so.
8. Keep on simultaneously noting the reading of the stop-watch and that of the thermometer $T_1$, while stirring water gently and constantly, till the temperature of water in the calorimeter falls to a temperature of about 5 $^oC$ above that of the enclosure. Note the temperature of the enclosure, by the thermometer T2.

9. Record observations in tabular form. Find the excess of temperature ($\theta - \theta_o$) and also log10($\theta - \theta_o$) for each reading, using logarithmic tables. Record these values in the corresponding columns in the table.
10. Plot a graph between time t, taken along x-axis and log10 ($\theta - \theta_o$) taken along y-axis. Interpret the graph.

**Observations**

Least count of both the identical thermometers = ...............°C

Least count of stop-watch/clock = ................ s

Initial temperature of water in the enclosure $\theta_1$= ................°C

Final temperature of water in the enclosure $\theta_2$=................ °C

Mean temperature of the water in the enclosure $\theta_o = (\theta_1 + \theta_2)/2$ =................°C

Table: Measuring the change in temperature of water with time

| S. No. | Time (t) (s) | Temperature of hot water θ°C | Excess Temperature of hot water ($\theta - \theta_0$) °C | $\log_{10}(\theta - \theta_0)$ |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
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*Self-Check questions*

1. State Newton's law of cooling and express this law mathematically.

2. Does the Newton's law of cooling hold good for all temperature differences?

3. How is Newton's law of cooling different from Stefan's law of heat radiation?

4. What is the shape of cooling curve?

5. Find the specific heat of a solid/liquid using Newton's law of cooling apparatus.

**Module end exercise**

1. Find the slope and intercept on y-axis of the straight-line graph you have drawn. Determine the value of constant k and the constant of integration c from this graph.
2. The cooling experiment is performed with the calorimeter, filled with same volume of water and turpentine oil successively, by maintaining the same temperature difference between the calorimeter and the surrounding enclosure. What ratio of the rates of heat loss would you expect in this case?

**MCQ**

Q1. Equal masses of two liquids are filled in two similar calorimeters. The rate of cooling will

A) Depend on the nature of the liquids

B) Depend on the specific heats of liquids

C) Be same for both the liquids

D) Depend on the mass of the liquids

Ans: B)

Q2. A bucket full of hot water cools from 75˚C to 70˚C in time T1 , from 70˚C to 65˚C in time $T_2$ and from 65˚C to 60˚C in time T3 , then

A) $T_1=T_2=T_3$

B) $T_1>T_2>T_3$

C) $T_1<T_2<T_3$

D) $T_1>T_2<T_3$

Ans: C)

## 1.11 Young's modulus

**Introduction**

The ratio of tensile stress over tensile strain is called the Young's modulus for the material. The apparatus works on the principle of Hookes' Law. If l is the extension in a wire of length Land radius rdue to force F(=Mg), theYoung's modulus of the material of the given wire, Y, is

$$Y = \frac{MgL}{\pi r^2 l}$$

**Learning objectives**

- To determine Young's modulus of the material of a given wire by using Searle's apparatus.

**Major Concepts**

Hooke’s law, Young’s modulus

**Learning Resources**

Searle's apparatus, slotted weights, experimental wire, screw gauge and spirit level.

**Content Descriptions and activities**

1. Suspend weights from both the hooks so that the two wires are stretched and become free from any kinks. Attach only the constant weight *W*on the reference wire to keep it taut.
2. Measure the length of the experimental wire from the point of its support to the point where it is attached to the frame.
3. Find the least count of the screw gauge. Determine the diameter of the experimental wire at about 5 places and at each place in two mutually perpendicular directions. Find the mean diameter and hence the radius of the wire.
4. Find the pitch and the least count of the miocrometer screw attached to the frame. Adjust it such that the bubble in the spirit level is exactly in the centre. Take the reading of the micrometer.
5. Place a load on the hanger attached to the experimental wire and increase it in steps of 0.5 kg. For each load, bring the bubble of the spirit level to the centre by adjusting the micrometer screw and then note its reading. Take precautions to avoid backlash error.
6. Take about 8 observations for increasing load.
7. Decrease the load in steps of 0.5 kg and each time take reading on micrometer screw as in step 5.

**Observations**

Length of the wire (L) = ...

Pitch of the screw gauge = ...

No. of divisions on the circular scale of the screw gauge = ...

Least count (L.C.) of screw gauge = ...

Zero error of screw gauge = ...

Table: Measurement of diameter of wire

| S No. | Reading along any direction | | | Reading along perpendicular direction | | | Mean diameter $d = \frac{d_1 + d_2}{2}$ (cm) |
|---|---|---|---|---|---|---|---|
| | Main scale | Circular scale | Diameter | Main scale | Circular scale | Diameter | |

| | reading S (cm) | reading n | $d_1$= S + n × L.C. | reading S (cm) | reading n | $d_2$= S + n × L.C. | |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

Mean diameter (corrected for zero error) = ………....

Mean radius = .......................

**Measurement of extension 1**

Pitch of the micrometer screw = ……………….

No. of divisions on the circular scale = .....................

Least count (L.C.) of the micrometer screw = .................

Acceleration due to gravity, g = ..........................

Table: Measurement of extension with load

| S. No. | Load on experimental wire M | Micrometer reading | | Mean reading $\frac{x+y}{2}$ (cm) |
|---|---|---|---|---|
| | (kg) | Load increasing x (cm) | Load decreasing y (cm) | |
| 1 | | | | |
| 2 | | | | |

Calculating extension for a given load

| S. No. | Mean extension (cm) | Load (kg) | Mean extension | Extension l′ for 1.5 kg |
|---|---|---|---|---|
| 0.5 | | 2.0 | | d-a |
| 1.0 | | 2.5 | | e-b |
| 1.5 | | 3.0 | | f-c |

Mean $l = \frac{(d-a)+(e-b)+(f-c)}{3}$

= …………..cm for 1.5kg

Young's modulus, Y, of experimental wire $Y = \frac{MgL}{\pi r^2 l}$ = …………N/m$^2$

**Results**

The Young's modulus Y of the material of the wire

(using half table method) = Y ± ΔY N/m$^2$ = ………………….. N/m$^2$

(using graph) = Y± ΔY N/m$^2$ = ………………….. N/m$^2$

*Self Check questions*

1. If the length of the wire used is reduced what will be its effect on

(a) extension on the wire and (b) stress on the wire.

2. Use wire of different radii ($r_1$, $r_2$, $r_3$) but of same material in the above experimental set up. Is there any change in the value of Young's modulus of elasticity of the material? Discuss your result.

**Module end exercise**

1. Repeat the experiment with wires of different materials, if available.
2. Change the length of the experimental wire, of same material and study its effect on the Young's modulus of elasticity of the material.

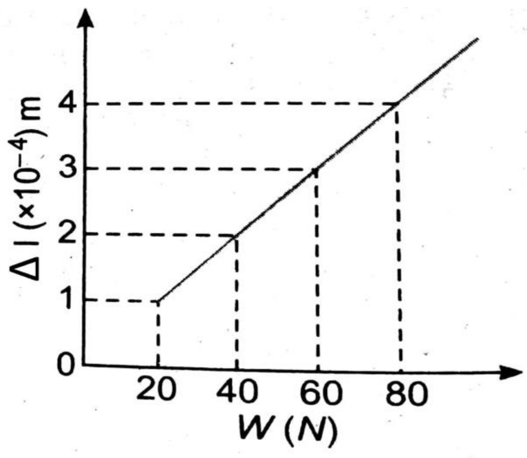
**MCQ**

Q1. The Young's modulus of brass and steel are respective 1.0 x $10^{11}$Nm$^{-2}$ and 2.0 x $10^{11}$ Nm$^{-2}$. A brass wire and a steel wire of the same length extend by 1mm, each under the same force. If radii of brass and steel wires are $R_B$ and $R_S$ respectively, then

A) $R_S = \sqrt{2}R_B$
B) $R_S = \frac{R_B}{\sqrt{2}}$
C) $R_S = 4R_B$
D) $R_S = \frac{R_B}{2}$

Ans: B)

Q2. The graph shows the extension Δl of a wire of length 1m, suspended from the top of a roof at one end and with a load W connected to the other end. If the cross-sectional area of the wire is $10^{-6}$ m$^2$, calculate the Young's modulus of the material of the wire




A) $2 \times 10^{11}$ $Nm^{-2}$

B) $2 \times 10^{-11}$ $Nm^{-2}$

C) $3 \times 10^{12}$ $Nm^{-2}$

D) $2 \times 10^{-13}$ $Nm^{-2}$

**Ans: A)**

## 2.1 Series LCR circuit

**Introduction**

An LCR circuit is a circuit with different combinations of inductors, capacitors and resistors. This kind of circuits has a certain frequency response and thus can be used in many practical applications such as radio transmitters, frequency filters etc.

**Learning objectives**

1] To study the frequency response of a series LCR circuit.

2] To measure the(i) the resonant frequency and (ii) the quality factor of the series LCR circuit.

**Major Concepts**

1] Combinations of different inductors, capacitors and resistor components.

2] Frequency response of series combination of these components.

**Learning Resources**

Inductors, capacitors, resistors, function generator, voltmeter

**Content Descriptions and activities**

**The inductor**

An inductor is a coil wound on a coil of some suitable material. Figure 1 shows the circuit symbol of an inductor. Whenever the current through an inductor changes, a counter emf is

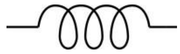


Figure 1: Circuit symbol for inductor

induced in it which tends to oppose this change. This property of the coil due to which to oppose any change of current through it, is called its inductance. For a circuit where current changes in the rate di/dt, suppose a counter emf E is developed. Then the inductance can be mathematically represented as:

$$L = \frac{E}{di/dt}$$

The unit of inductance is henry (H).

An inductor offers a resistance in an electrical circuit. The resistance offered by an induc-tor in an AC circuit is termed as inductive reactance. It is represented by $X_L$. If an alternating current of frequency f is applied across an inductor of inductance L, the inductive reactance is given by:

$$X_L = 2\pi f L$$

So, the inductive reactance is directly proportional to the frequency of the applied AC. The unit of $X_L$ is the same as that of resistance, i.e., ohms (Ω).

**The capacitor**

A capacitor is an electrical component which is capable of storing electrical charge. Basically, a capacitor consists of two conducting plates separated by an insulating medium (dielectric). The circuit symbol of a capacitor is shown in Figure 2.

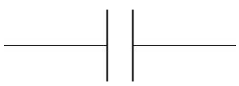


Figure 2: Circuit symbol for capacitor

An important property of a capacitor is that it blocks the passage of direct current and allows only alternating current through it.

The ability of a capacitor to store charge is termed as its capacitance. It may be defined as the amount of charge required to create a unit potential difference between the plates. The mathematical expression of capacitance is:

$$C = \frac{Q}{V}$$

Capacitance is expressed in terms of farads (F).

A capacitor also offers a resistance in an electrical circuit. The resistance offered by a capacitor in AC circuit is called capacitive reactance. It is represented by $X_C$. If an alternating current of frequency f is applied across a capacitor of capacitance C, the capacitive reactance developed is:

$$X_C = \frac{1}{2\,\pi\,f\,C}$$

So, the capacitive reactance is inversely proportional to the frequency of the applied AC. The unit of $X_C$ is also ohms (Ω).

In AC circuit where more than one kind if components (like resistor and capacitor) are present, the overall resistance offered by the circuit is termed as the impedance (Z) of the circuit. In an LCR circuit, the impedance is given by

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

**2.2 The LCR Series Resonant Circuit**

In physics, resonance is a phenomenon in which a vibrating system or external force drives another system to oscillate with greater amplitude at specific frequencies. An electrical circuit is said to be in resonance when an external alternating current drives an oscillatory circuit to oscillate with maximum amplitude, or provide maximum gain.

In the series LCR circuit, an inductor (L), a capacitor (C) and a resistor (R) are connected in series with an AC source.

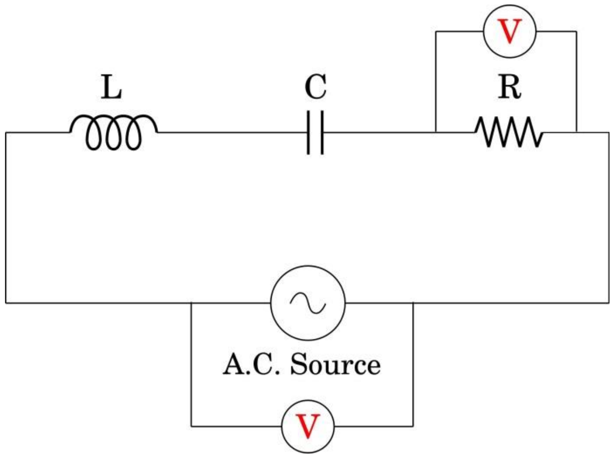



Figure 3: Circuit Diagram

The variation in the amplitude of the output current (measured across the resistor R), in response to a range of input frequencies is studied in this experiment.

The LCR circuit oscillates with maximum amplitude when the circuit offers least resis-tance. In order to achieve this, the reactance of the circuit must be minimum. From the last equation we have,

$$(X_L - X_C)^2 = 0$$

Or $$X_L - X_C = 0$$

which gives,

$$X_L = X_C$$

This is the condition for resonance in the LCR circuit. At this condition, the circuit behaves like a purely resistive circuit, with impedance Z = R. Further,

$$2\pi f L = \frac{1}{2\pi f C}$$

$$4\pi^2 f^2 = \frac{1}{LC}$$

$$f^2 = \frac{1}{4\pi^2 (LC)}$$

$$f_N = \frac{1}{2\pi\ (\sqrt{LC})}$$

This equation gives the natural frequency of the LCR circuit. When the frequency of the applied AC is equal to this natural frequency of the circuit, the voltage across the load resistance will be maximum. Hence, at this frequency, the circuit is said to be in resonance, and the applied frequency at which it happens is termed as resonant frequency.The ratio of output voltage to the input voltage is called the voltage gain of the circuit. It is usually represented by A.

$$A = \frac{V_o}{V_i}$$

where $V_o$ is the output voltage and $V_i$ is the input voltage.

A plot of voltage gain versus frequency of the applied AC gives a graph similar to figure 4. The frequency at which the gain is maximummaximum $(A_o)$ gives the resonant frequency $f_o$.

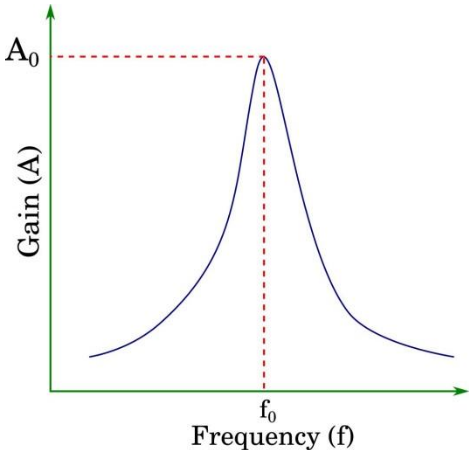



Figure 4: Frequency response

In the above curve, frequencies corresponding to the gain $A_v = \frac{A_o}{\sqrt{2}}$ (where $A_o$ is the maximum gain) is found, say $f_1$ and $f_2$. Then the bandwidth of the series LCR circuit is given by

$$BW = (f_2 - f_1)$$

The quality of the LCR circuit is determined by the quality factor (Q).

$$Q = \frac{f_o}{BW}$$

**Procedure**

1. Make the connections as shown in the circuit diagram.

2. Connect one channel of a CRO to the oscillator (or function generator) and the second channel across the resistor.

3. Calculate the theoretical value (or an approximate) of the natural frequency of the given LCR circuit. For example, if the resistance is 400 W, capacitance 0.05 *m*F and inductance 50 mH, then the natural frequency of the circuit is given by

$$f_N = \frac{1}{2\pi\,(\sqrt{LC})}$$

$$f_N = \frac{1}{2\pi\sqrt{(50 \text{ X } 10^{-3}\text{H})(0.05 \text{ X } 10^{-6}\text{F})}} \approx 3180 \text{ Hz} = 3.18 \text{ kHz}$$

4. Choose an appropriate range of frequencies, with the above calculated frequency in the middle of the range. (This is done so as to get a symmetrical resonance curve. For the above example, choose a range from about 1 kHz to about 5.4 kHz).

5. Choose an appropriate common difference. (For the values above, a difference of 0.1 kHz would be sufficient.)

6. Calculate the corresponding output voltage (across the resistor) for the range of input voltages that is chosen. Tabulate the observations.

7. A graph is plotted with voltage gain ($A_v$) versus external frequency *f*. The bandwidth, and thereby the Q-point is calculated as given in section (6).

8. Another graph is plotted with reactance ($X_L$ or $X_C$) against external frequency *f*. The resonant frequency is identified at the intersection point of $X_L$ and $X_C$.

**Observations and calculations:**

Inductance, L = ………………mH

Capacitance, C = ……………..μF

Resistance, R= ………………Ω

**Tabular column:**

| **Frequency** *f* **(kHz)** | $V_i$ **(volts)** | $V_o$ **(volts)** | **Gain** $A = \frac{V_o}{V_i}$ | $X_L = 2\pi f L$ (Ω) | $X_C = \frac{1}{2\,\pi\,\mathrm{f}\,\mathrm{C}}$ (Ω) |
|---|---|---|---|---|---|
| | | | | | |

**Calculations:**

1) Natural frequency of the circuitNatural frequency of the given LCR circuit is calculated using the relation

$$f_N = \frac{1}{2\pi\,(\sqrt{LC})}$$

*2)* Resonant frequency from reactance curve

At resonance, $X_L = X_C$. From the graph of reactance versus frequency, this condition is obtained at the intersection of the curves $X_L$ and $X_C$, as shown below. The frequency at which $X_L = X_C$ is the resonant frequency ($f_o^{'}$).

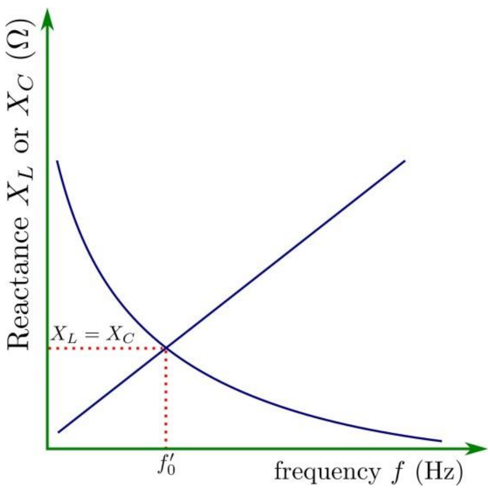



Figure 5: Reactance versus frequency curve

3) Bandwidth and Quality factor

- Plot the $A_v$ versus frequency graph. Locate the resonant frequency ($f_0$) , i.e., the frequency at which the gain is maximum. (Note that $f_o \approx f_o{}'$)
- Construct a horizontal line at $A_v = \frac{A_o}{\sqrt{2}} = 0.707A_o$, where $A_o$ is the maximum gain.
- Find the two frequencies corresponding to $0.707A_o$, say $f_1$ and $f_2$.

The bandwidth of the LCR circuit is given by

$$BW = |f_2 - f_1|$$

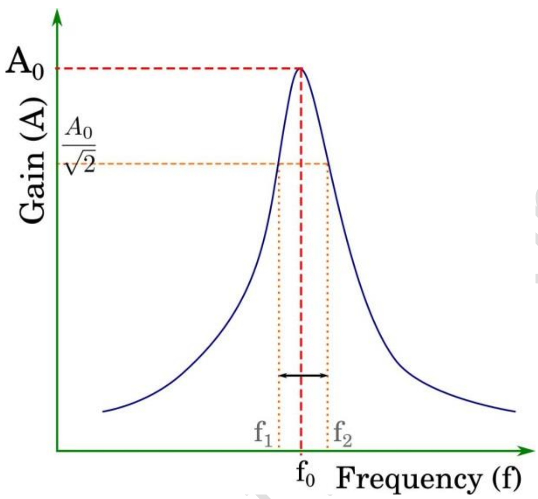



Figure 6: Calculation of bandwidth

Therefore, the quality factor Q of this series LCR circuit can be calculated using

$$Q = \frac{f_o}{BW}$$

**Result:**

The frequency response of the series LCR circuit is studied. The frequency response curve is plotted.

- The Q-point of the series resonant circuit is found to be ………………….
- The resonant frequency of the circuit is identified to be ………………….. Hz

**Misconceptions**

Identifying the inductors, capacitors and resistors values and their proper connection in the circuit is very important.

**Self check questions**

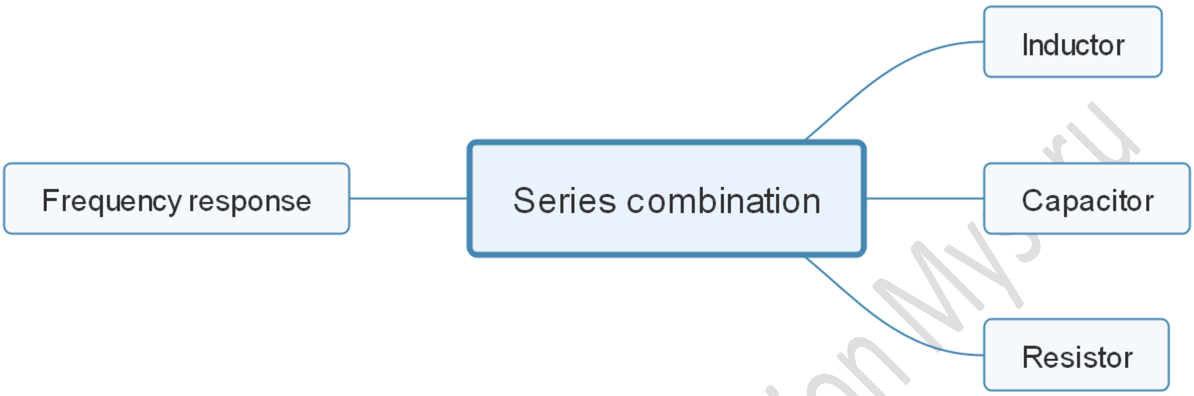
1.What is meant by resonance frequency?

2. What is the bandwidth of series circuit? Will it vary with the different values of circuit components?

**Module end exercise**

1.Change the resistance of $LCR$ series circuit at three different values. In each of the three sets of observations for $I$ as a function of frequency ν, convert values of $I$ to $I'$, where $I'$ is current that would pass keeping $V = Vo$. Then convert values of $I'$ as percentages of its value at resonance in that set. Plot $\frac{I}{I'}$(in percentage) versus frequency graph as shown. Compare values of $Qo$, $Q1$ and $Q2$.

**Concept map**




**MCQ questions:**

**Q1**. If the value of $C$ in a series LCR circuit is decreased, the resonant frequency

A) Is not affected

B) Increases

C) Is reduced to zero

D) Decreases

**Answer: B) Increases**

**Q2.**The impedance at the resonant frequency of a series LCR circuit with $L$ = 20 mH, $C$ = 0.02 µF, and $R_W$ = 90 Ω is

A)0 Ω

B)40 Ω

C)90 Ω

D)20 Ω

**Answer: C) 90 Ω**

## 2.3 Parallel LCR circuit

**Introduction**

An LCR circuit is a circuit with different combinations of inductors, capacitors and resistors. This kind of circuits has a certain frequency response and thus can be used in many practical applications such as radio transmitters, frequency filters etc.

**Learning objectives**

1] To study the frequency response of a parallel LCR circuit.

2] To measure the (i) the resonant frequency and (ii) the quality factor of the parallel LCR circuit.

**Major Concepts**

1] Combinations of different inductors, capacitors and resistor components.

2] Frequency response of parallel combination of these components.

**Learning Resources**

Inductors, capacitors, resistors, function generator, voltmeter

**Content Descriptions and activities**

**The inductor**

An inductor is a coil wound on a coil of some suitable material. Figure 1 shows the circuit symbol of an inductor. Whenever the current through an inductor change, a counter emf is

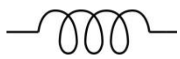


Figure 1: Circuit symbol for inductor

induced in it which tends to oppose this change. This property of the coil due to which to oppose any change of current through it, is called its inductance. For a circuit where current changes in the rate di/dt, suppose a counter emf E is developed. Then the inductance can be mathematically represented as:

$$L = \frac{E}{di/dt}$$

The unit of inductance is henry (H).

An inductor offers a resistance in an electrical circuit. The resistance offered by an inductor in an AC circuit is termed as inductive reactance. It is represented by $X_L$. If an alternating current of frequency f is applied across an inductor of inductance L, the inductive reactance is given by:

$$X_L = 2\pi f L$$

So, the inductive reactance is directly proportional to the frequency of the applied AC. The unit of $X_L$ is the same as that of resistance, i.e., ohms (Ω).

**The capacitor**

A capacitor is an electrical component which is capable of storing electrical charge. Basically, a capacitor consists of two conducting plates separated by an insulating medium (dielectric). The circuit symbol of a capacitor is shown in Figure 2.

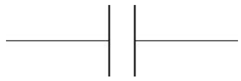


Figure 2: Circuit symbol for capacitor

An important property of a capacitor is that it blocks the passage of direct current and allows only alternating current through it.

The ability of a capacitor to store charge is termed as its capacitance. It may be defined as the amount of charge required to create a unit potential difference between the plates. The mathematical expression of capacitance is:

$$C = \frac{Q}{V}$$

Capacitance is expressed in terms of farads (F).

A capacitor also offers a resistance in an electrical circuit. The resistance offered by a capacitor in AC circuit is called capacitive reactance. It is represented by $X_C$. If an alternating current of frequency f is applied across a capacitor of capacitance C, the capacitive reactance developed is:

$$X_C = \frac{1}{2\,\pi\,f\,C}$$

So, the capacitive reactance is inversely proportional to the frequency of the applied AC. The unit of $X_C$ is also ohms (Ω).

In AC circuit where more than one kind if components (like resistor and capacitor) are present, the overall resistance offered by the circuit is termed as the impedance (Z) of the circuit. In an LCR parallel circuit, the impedance is given by

$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

The quantity $\left(\frac{1}{Z}\right)$ is known as admittance (Y).

In the parallel LCR circuit, resonance happens at $\frac{1}{X_L} = \frac{1}{X_C}$

**The LCR Parallel Resonance Circuit**

In physics, resonance is a phenomenon in which a vibrating system or external force drives another system to oscillate with greater amplitude at specific frequencies. An electrical circuit is said to be in resonance when an external alternating current drives an oscillatory circuit to oscillate with maximum amplitude, or provide maximum gain.

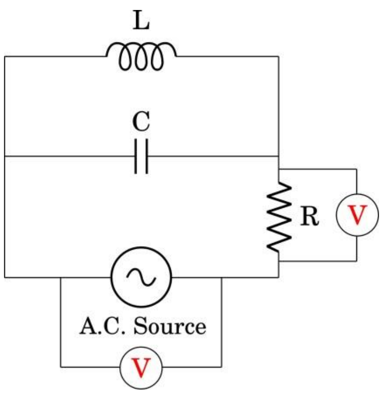



Figure 3: Circuit Diagram

In the parallel LCR circuit, an inductor (L), a capacitor (C) and a resistor (R) are connected in parallel with an AC source. The variation in the amplitude of the output current (measured across the resistor R), in response to a range of input frequencies is studied in this experiment.

The LCR circuit oscillates with maximum amplitude when the circuit offers least resistance. In order to achieve this, the reactance of the circuit must be minimum. We know from the above equation,

$$\frac{1}{X_L} = \frac{1}{X_C}$$

$$\frac{1}{2\pi f L} = \frac{1}{\frac{1}{2\pi f C}}$$

$$\frac{1}{2\pi f L} = 2\pi f C$$

$$f_N = \frac{1}{2\pi\sqrt{LC}}$$

This equation gives the natural frequency of the LCR circuit. When the frequency of the applied AC is equal to this natural frequency of the circuit, the voltage across the load resis-tance will be maximum. Hence, at this frequency, the circuit is said to be in resonance, and the applied frequency at which it happens is termed as resonant frequency.

The ratio of output voltage to the input voltage is called the voltage gain of the circuit. It is usually represented by A.

$$A = \frac{V_o}{V_i}$$

where $V_o$ is the output voltage and $V_i$ is the input voltage.

A plot of voltage gain versus frequency of the applied AC gives a graph similar to figure 4. The frequency at which the gain is maximum ($A_o$) gives the resonant frequency $f_o$.

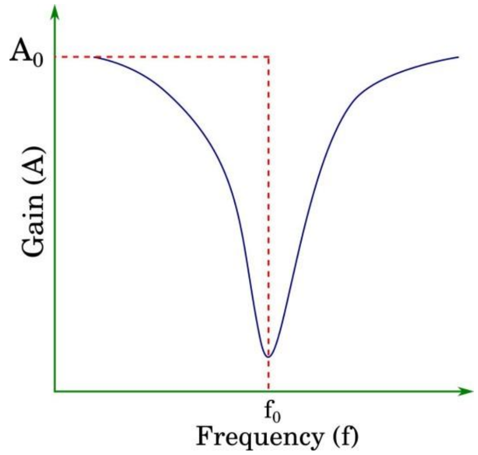



Figure 4: Frequency response

In the above curve, frequencies corresponding to the gain $A_v = 2A_o$ (where $A_o$ is the maximum gain) is found, say $f_1$ and $f_2$. Then the bandwidth of the series LCR circuit is given by

$$BW = (f_2 - f_1)$$

The quality of the LCR circuit is determined by the quality factor (Q).

$$Q = \frac{f_o}{BW}$$

**Procedure**

1. Make the connections as shown in the circuit diagram.

2. Connect one channel of a CRO to the oscillator (or function generator) and the second channel across the resistor.

3. Calculate the theoretical value (or an approximate) of the natural frequency of the given LCR circuit. For example, if the resistance is 400 W, capacitance 0.05 *m*F and inductance 50 mH, then the natural frequency of the circuit is given by

$$f_N = \frac{1}{2\pi\,(\sqrt{LC})}$$

$$f_N = \frac{1}{2\pi\sqrt{(50 \text{ X } 10^{-3}\text{H})(0.05 \text{ X } 10^{-6}\text{F})}} \approx 3180 \text{ Hz} = 3.18 \text{ kHz}$$

4. Choose an appropriate range of frequencies, with the above calculated frequency in the middle of the range. (This is done so as to get a symmetrical resonance curve. For the above example, choose a range from about 1 kHz to about 5.4 kHz).

5. Choose an appropriate common difference. (For the values above, a difference of 0.1 kHz would be sufficient.)

6. Calculate the corresponding output voltage (across the resistor) for the range of input voltages that is chosen. Tabulate the observations.

7. A graph is plotted with voltage gain ($A_v$) versus external frequency *f*. The bandwidth, and thereby the Q-point is calculated as given in section (6).

8. Another graph is plotted with reactance ($X_L$ or $X_C$) against external frequency *f*. The resonant frequency is identified at the intersection point of $X_L$ and $X_C$.

**Observations and calculations:**

Inductance, L = ………………mH

Capacitance, C = ……………..µF

Resistance, R= ………………Ω

**Tabular column:**

| **Frequency** ***f* (kHz)** | $V_i$ **(volts)** | $V_o$ **(volts)** | **Gain** $A = \frac{V_o}{V_i}$ | $X_L = 2\pi f L$ (Ω) | $X_C = \frac{1}{2\pi f C}$ (Ω) |
|---|---|---|---|---|---|
| | | | | | |

**Calculations:**

1) Natural frequency of the circuit

Natural frequency of the given LCR circuit is calculated using the relation

$$f_N = \frac{1}{2\pi\,(\sqrt{LC})}$$

*2)* Resonant frequency from reactance curve

At resonance, $X_L = X_C$. From the graph of reactance versus frequency, this condition is obtained at the intersection of the curves $X_L$ and $X_C$, as shown below. The frequency at which $X_L = X_C$ is the resonant frequency ($f_o'$).

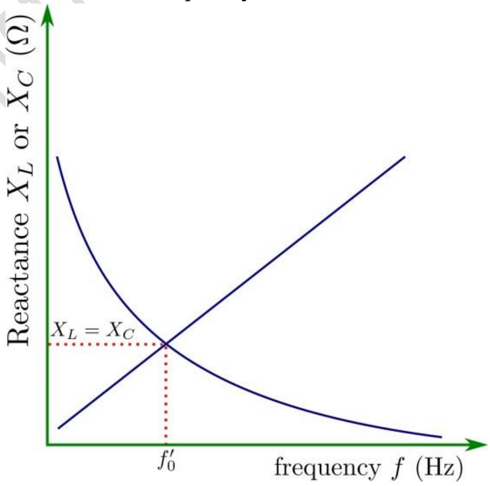


Figure 5: Reactance versus frequency curve

3) Bandwidth and Quality factor

- Plot the $A_v$ versus frequency graph. Locate the resonant frequency ($f_o$) , i.e., the frequency at which the gain is minimum. (Note that $f_o \approx f_o'$)
- Construct a horizontal line at $A_v = \sqrt{2}A_o = 1.414A_o$, where $A_o$ is the maximum gain.
- Find the two frequencies corresponding to $1.414A_o$, say $f_1$ and $f_2$.

The bandwidth of the LCR circuit is given by

$$BW = |f_2 - f_1|$$

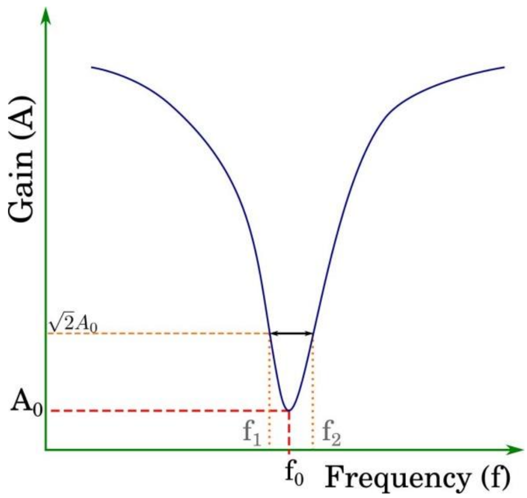



Figure 6: Calculation of bandwidth

**Result:**

The frequency response of the parallel LCR circuit is studied. The frequency response curve is plotted.

- The Q-point of the parallel resonant circuit is found to be ………………….
- The resonant frequency of the circuit is identified to be ………………….. Hz

**Misconceptions**

Identifying the inductors, capacitors and resistors values and their proper connection in the circuit is very important.

**Self check questions**

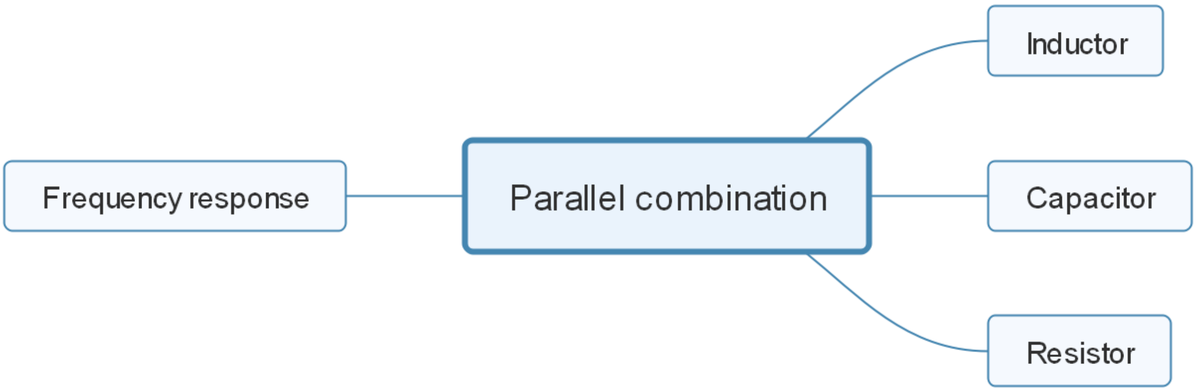
1. Why should the maximum value of current gain be multiply by $\sqrt{2}$ for finding bandwidth?

2. What is the quality factor of parallel LCR circuit?

**Module end exercise**

1.Change the resistance of *LCR* parallel circuit at three different values. In each of the three sets of observations for $I$ as a function of frequency ν, convert values of $I$ to $I'$, where $I'$ is current that would pass keeping $V = Vo$. Then convert values of $I'$ as percentages of its value at resonance in that set. Plot $\frac{I}{I'}$(in percentage) versus frequency graph as shown. Compare values of $Qo$, $Q1$ and $Q2$.

**Concept map**




**MCQ questions:**

**Q1:**For a parallel resonance circuit, the plot of input impedance magnitude v/s frequency:

A) is a peak at the resonant frequency B) is a straight line

C) is a dip at the resonant frequency D) none of the above

**Answer: A) isa peak at the resonant frequency**

**Q2:**A 15 Ω resistor, an inductor with 8 Ω inductive reactance, and a capacitor with 12 Ω capacitive reactance are in parallel across an ac voltage source. The circuit impedance is

A)12.7 Ω B) 127 Ω

C) 4436 Ω D) 6174 Ω

**Answer: A) 12.7 Ω**

## 2.4 Characteristics of p-n junction diode

### Introduction

A p-n junction diode is a two-terminal device formed when n-type and p-type semiconductor crystals are joined together. It is constructed by doping one half of a piece of semiconductor material (Germanium or Silicon) with p-type impurity and the other half by n-type impurity. The plane dividing the two halves or zones is known as a p-n junction.

### Learning objectives

1] To study the current-voltage characteristics of a p-n junction diode under forward bias and reverse bias conditions.

2] To measure the (i) forward resistance, (ii) knee voltage and (iii) breakdown voltage of the p-n junction diode.

### Major Concepts

1] p-type and n-type semiconductors

2] Variation of diode current for variation in diode voltage in forward and reverse biasing

**Learning Resources**

p-n junction diode, variable dc power supply, milliammeter and microammeter, voltmeter.

**Content Descriptions and activities**

If a junction is formed between p-type and n-type semiconductors, without disturbing the crystalline continuity across the junction, holes (majority carrier in p-type) diffuse from the p-region to the n, while electrons (majority carrier in n-type) diffuse from the n-region to the p. This recombination of free electrons and holes produces the narrow region at the junction known as depletion layer. It is called so because this region doesn't contain any mobile charge carriers (though it does contain immobile charges). Due to this charge separation, an electric potential $V_B$ is established across the junction even when the junction is not connected to any external source of emf. This potential difference is known as barrier potential.

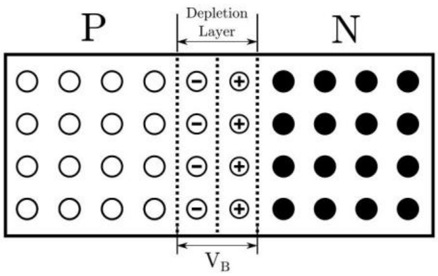



Figure 1: The P-N junction

**Diode under forward bias condition**

A P-N junction diode is said to be in forward bias condition when the positive potential of a battery is applied to the P-side and the negative to the N-side of the diode. As soon as the battery is connected, holes are repelled by the positive terminal and electrons are repelled by the negative terminal of the battery. This drives the electrons and holes towards the junction, reducing the width of the depletion layer. When the external voltage applied reaches the barrier potential, the depletion layer becomes so narrow as to allow the electrons and holesto recombine at the junction, thus allowing a large current flow through the semiconductor. Thus the semiconductor offers a low resistance in the forward-biased mode, so long as the applied voltage exceeds the barrier potential.

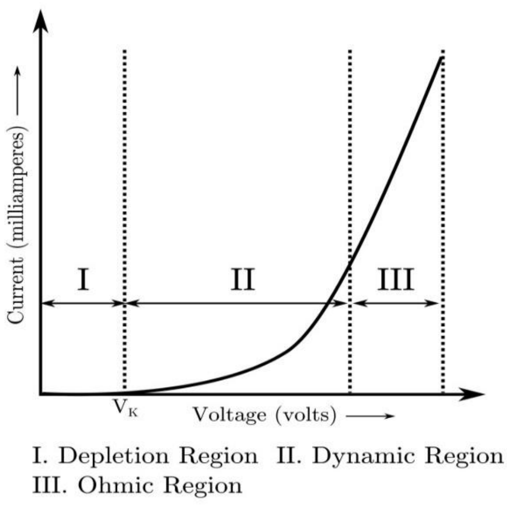



Figure 2: V-I Characteristics of P-N junction diode in forward bias

1. When the diode is forward biased, there will not be any current initially. This region is marked as (I) in the figure 2.

2. As the external voltage exceed the barrier potential, current starts increasing non-linearly. This voltage at which the diode starts conducting is termed as threshold voltage or knee voltage. This non-linear region where current starts flowing is also termed as the dynamic region, marked as (I I) in figure 2. (In this region, the increase in current is not directly proportional to the voltage applied as per Ohm's law.)

3. After a certain point, current starts flowing linearly across the diode, following Ohm's law. This region is known as the ohmic or linear region.

**Diode under Reverse Bias condition**

A P-N junction diode is said to be in reverse bias condition if the P side of the diode is connected to the negative terminal and the N side to the positive terminal of a battery. In this case, the holes in the P region are attracted by the negative terminal of the battery and the electrons in the N region, by the positive. As a result, the electrons and holes move away from each other, increasing the depletion region. Since there is no electron-hole recombination, no current flows through the diode, and hence the junction offers a high resistance in reverse biased mode.

Some minority charge carriers are generated (in both the N and P regions) due to thermal energy. Hence some electrons exist in the P region, and vice-versa. So the applied external voltage acts as a forward bias for these minority carriers, which consitute a very feeble current known as reverse saturation current or leakage current.

If the reverse bias voltage is further increased, a point is reached when the junction breaks down and reverse current rises sharply. This critical value of the external reverse bias voltage is known as breakdown voltage ($V_{br}$).

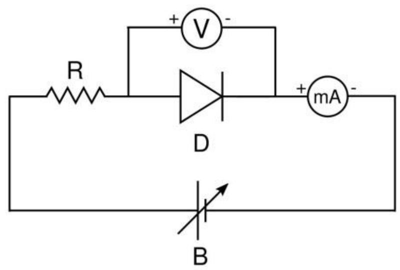


Figure 3: Circuit schematic for diode under under forward bias

The circuit symbol for a P-N junction diode is shown in figure 4. The P and N regions of a diode are referred to as anode and cathode respectively. The symbol indicates the conven-tional direction of current flow when the diode is forward biased. (It is the same direction in which the hole flow takes place.)

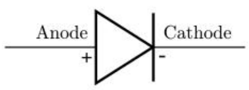


Figure 4: Circuit symbol for a P-N junction diode

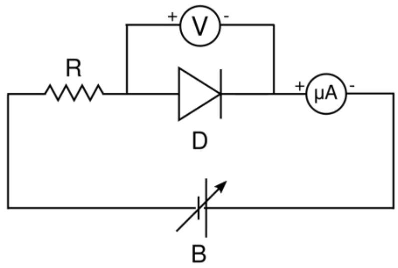



Figure 5: Circuit schematic for diode under reverse bias

**Procedure**

**Forward Bias**

1. Connect the circuit as shown in figure 5. As the P side is connected to the positive terminal of the battery B and the N side to the negative, the diode is said to be forward biased.

2. Gradually increase the external voltage until the milli-ammeter starts to show deflection.

3. Note down the milli-ammeter reading for increase in every 0.2 volts.

4. Plot a graph with the external voltage along the X-axis, and current along the Y-axis.

- **Reverse Bias**

1. Connect the circuit as shown in figure 6. As the P side is connected to the negative terminal of the battery and the N side to the positive, the diode is said to be reverse biased.

2. Increase the reverse voltage, noting down the current in regular intervals, until a large value of current is shown in the micro-ammeter.

3. Plot a graph with the voltage across the X-axis and current (in micro-amperes) along the Y-axis.

**Observation and calculations:**

- **Forward Bias**

| **Voltage V (volts)** | **Current I (mA)** |
|---|---|
| | |

- **Reverse Bias**

| **Voltage V (volts)** | **Current I (μA)** |
|---|---|
| | |

- **Forward Bias**

From the plot of V-I characteristics of the for-ward bias, find out the voltage at which the diode current starts shooting up. This volt-age is the knee voltage.

Identify the linear/ohmic region of the V-I characteristics. Find out the slope of the graph in this region.

$$slope = \frac{\Delta I}{\Delta V} = \frac{1}{R_s}$$

where$R_s$ is the static resistance of the diode.

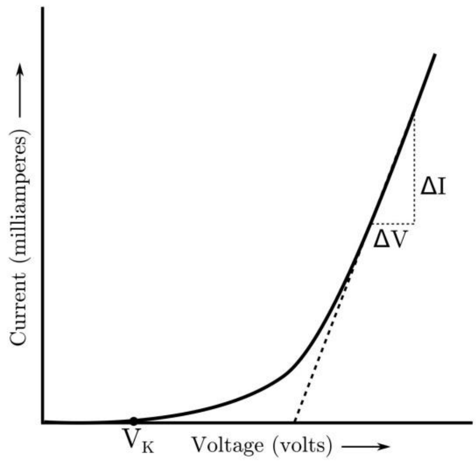



Figure 7: Forward bias V-I characteristics

Therefore, $R_s = \frac{1}{slope}$

- **Reverse Bias**

The constant value of current passing through the diode gives the reverse saturation current I0. The tangent at the point of breakdown of the diode gives the value of the breakdown voltage VB.

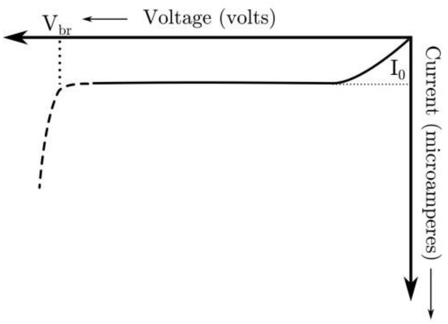



Figure 8: Reverse bias V-I characteristics

**Result:**

- The I-Characteristics of a P-N junction is plotted under forward and reverse bias conditions.
- The forward (static resistance) of the given P-N junction diode is calculated to be ……. Ω
- The knee voltage of the given diode is calculated to be ……………………V.
- The breakdown voltage of the given diode is calculated to be …………………V

**Misconceptions**

Never increase the value of the voltage too much across the diode.Excessive current flow may damage the diode if it exceeds its limit.Maximum permissible current that can pass through the diode canbe known from the technical data as specified by the manufacturer.

**Self Check questions**

1. If we use different diodes (Ge or Si), what change do you observe in the *I - V* characteristics? Does the threshold voltage / cut- in voltage of the diode depend on the material of the diode?

2. What is the difference between a diode and a resistor?

**Module end exercise**

1. Perform the same experiment with a light emitting diode (LED) in place of a diode and plot the *I - V* characteristics. What change do you observe in the threshold voltage when you use different coloured LEDs?

**MCQ questions:**

**Q1:** Avalanche breakdown in a diode occurs when

A) Potential barrier is reduced to zero.
B) Reverse bias exceeds a certain value.
C) Forward current exceeds certain value.
D) None of the above

**Answer: B) Reverse bias exceeds a certain value.**

**Q2:** When a reverse bias is applied to a diode, it will

A) Raise the potential barrier
B) Increases the majority-carrier a current greatly
C) Lower the potential barrier
D) None of these

**Answer: A) Raise the potential barrier**

## 2.5 Characteristics of Zener diode

**Introduction**

Zener diode is a special kind of P-N junction, designed to be operated in the reverse-biased mode. This is achieved by increasing the percentage impurity added to the extrinsic semiconductor (Silicon or Germanium), i.e., the diode is heavily doped.

**Learning objectives**

1] To study the V-I characteristics of a Zener diode under forward bias and reverse bias conditions.

2] To measure the (i) forward resistance, (ii) knee voltage and (iii) Zener voltage of the Zener diode.

**Major Concepts**

1] p-type and n-type semiconductors

2] Variation of diode current for variation in diode voltage in forward and reverse biasing

**Learning Resources**

p-n junction Zener diode, variable dc power supply, milliammeter and microammeter, voltmeter.

**Content Descriptions and activities**

Zener diodes are essentially p-n junction diodes (both p and n regions are more heavily doped as compared to rectifying p-n junction diode) operated in the breakdown region of the reverse oltage characteristic. These diodes are designated with sufficient power dissipation capacities to work in the breakdown region. The following two mechanisms can cause breakdown in a junction diode:

(i) Avalanche breakdown

With increasing reverse bias voltage, the electric field across the junction of p-n diode increases. At a certain reverse bias, the electric field imparts a sufficiently high energy to a thermally generated carrier crossing the junction. This carrier, on colliding with a crystal ion on its way,

disrupts a covalent bond and produces an electron-hole pair. These carriers on gaining sufficient energy from the applied field collide with other crystal ions and generate further electron-hole pairs. This process is cumulative and produces an avalanche of carriers in a very short time. This mechanism is known as avalanche multiplication, causes large reverse current and the diode is said to work in the region of avalanche breakdown.

(ii) Zener breakdown

In a Zener diode, both the p and n-sides are heavily doped. Due to the high dopant densities, the depletion layer junction width is small. Since the junction width is small i.e. less than 10–7 m, even a small voltage across it may create a very high field. This high junction field may strip an electron from the valence band which can tunnel to the n-side through the thin depletion layer. Such a mechanism of emission of electrons after applying certain electric field (~ 106 V/m ) or voltage *VZ* is termed as internal field emission which gives rise to a high reverse current or

breakdown voltage. This breakdown is termed as *Zener breakdown* and the voltage at which it occurs is called *Zener voltage*. The reverse current at Zener voltage is called *Zener current*.

The circuit symbol for a Zener diode is shown in Figure 1.

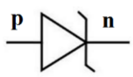



Figure 1: Circuit symbol for Zener diode

**Procedure**

**Forward Bias**

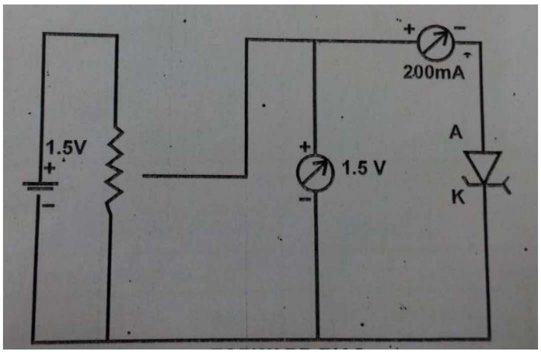



Figure 2: Circuit schematic for diode under forward bias

1. Connect the circuit as shown in figure 2. As the P side is connected to the positive terminal of the battery B and the N side to the negative, the diode is said to be forward biased.

2. Gradually increase the external voltage until the milli-ammeter starts to showdeflection.

3. Note down the milli-ammeter reading for increase in every 0.2 volts.

4. Plot a graph with the external voltage along the X-axis, and current along the Y-axis.

- **Reverse Bias**

1. Connect the circuit as shown in figure 3. As the P side is connected to the negative terminal of the battery and the N side to the positive, the diode is said to be reverse biased.

2. Increase the reverse voltage, noting down the current in regular intervals, until a large value of current is shown in the micro-ammeter.

3. Plot a graph with the voltage across the X-axis and current (in micro-amperes) along the Y-axis.

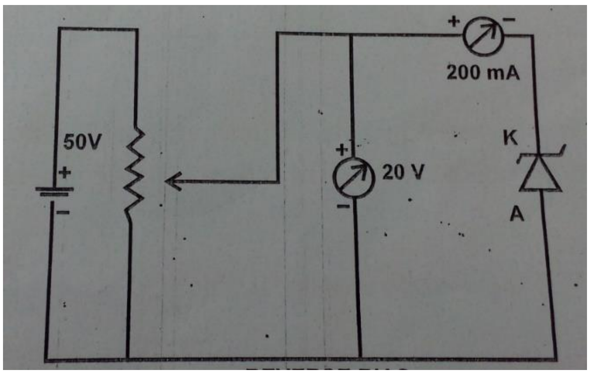



Figure 3: Circuit schematic for diode under reverse bias

**Observation and calculations:**

- **Forward Bias**

| Voltage V (volts) | Current I (mA) |
|---|---|
| | |

- **Reverse Bias**

| Voltage V (volts) | Current I (μA) |
|---|---|
| | |

- **Forward Bias**

From the plot of V-I characteristics of the for-ward bias, find out the voltage at which the diode current starts shooting up. This voltage is the knee voltage.

Identify the linear/ohmic region of the V-I characteristics. Find out the slope of the graph in this region.

$$slope = \frac{\Delta I}{\Delta V} = \frac{1}{R_s}$$

where$R_s$ is the static resistance of the diode.

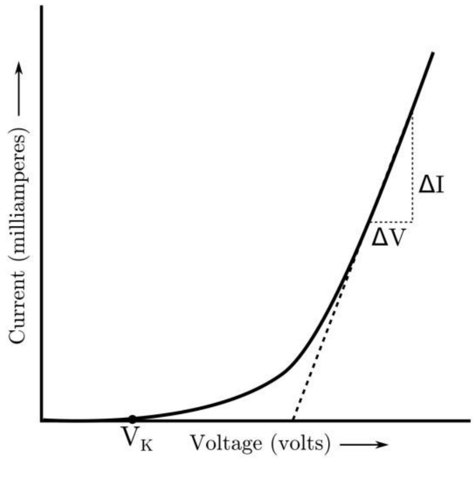



Figure 4: Forward bias V-I characteristics

Therefore, $R_s = \frac{1}{slope}$

- **Reverse Bias**

The constant value of current passing through the diode gives the reverse saturation current I0. The tangent at the point of breakdown of the diode gives the value of the breakdown voltage VB.

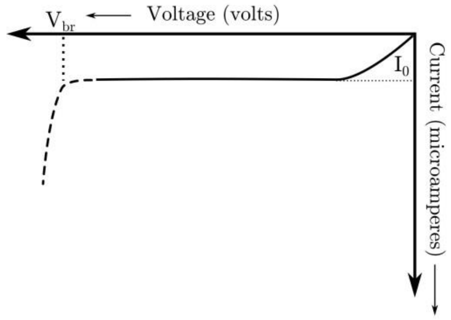



Figure 5: Reverse bias V-I characteristics

**Result:**

- The V-I characteristics of a Zener diode is plotted under forward and reverse bias conditions.
- The forward (static) resistance of the given Zener diode is calculated to be………Ω.
- The knee voltage of the given diode is calculated to be ………………..V
- The breakdown voltage of the given diode is calculated to be ……………V

**Misconceptions**

Positive and negative terminals of the Zener diode should be identify and connect properly to record the diode voltage and the diode current.

**Self Check questions**

1.What happens at Zener breakdown?

2. How can you use a Zener diode as a voltage regulator?

**Module end exercise**

1. Repeat the experiment using Zener diodes of different code numbers. Do youobserve any variation in their reverse breakdown voltages?

**MCQ questions:**

**Q1: A zener diode has**

C) One pn junction C) Two pn junction
D) Three pn junction D) None of the above

**Answer: A) one pn junction**

**Q2: A zener diode is used as**

C) an amplifier C) a voltage regulator
D) a rectifier D) a multivibrator

**Answer: C) a voltage regulator**

## 2.7 i-d curve for a prism

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### Introduction

In optics, a prism is a transparent optical element with flat, polished surfaces that refract light. At least two of the flat surfaces must have an angle between them. The exact angles between the surfaces depend on the application. The traditional geometrical shape is that of a triangular prism with a triangular base and rectangular sides, and in colloquial use prism usually refers to this type. Some types of optical prism are not in fact in the shape of geometric prisms.

### Learning objectives

1] To determine the angle of minimum deviation for a given glass prism.

2] To calculate refractive index of the material of the prism.

### Major Concepts

1] Angle of incidence, angle of minimum deviation

2] Angle of prism and refractive index of the prism

### Learning Resources

Drawing board, triangular glass prism, scale, pins, adhesive tape or drawingpins, protractor, white paper sheets.

### Content Descriptions and activities

Prisms can be made from any material that is transparent to the wavelengths for which they are designed. Typical materials include glass, plastic and fluorite. A dispersive prism can be used to break light up into its constituent spectral colours (the colours of the rainbow). Furthermore, prisms can be used to reflect light, or to split light into components with different polarizations.

As a ray of light enters a transparent material, the ray's direction is deflected, based on both the entrance angle (typically measured relative to the perpendicular to the surface) and the material's refractive index, and according to Snell's Law. A beam passing through an object like a prism or water drop is deflected twice: once entering, and again when exiting. The sum of these two deflections is called the deviation angle.

The deviation angle in a prism depends upon:

1. Refractive index of the prism: The refractive index depends on the material and the wavelength of the light. The larger the refractive index, the larger the deviation angle.

2. Angle of the prism: The larger the prism angle, the larger the deviation angle.

3. Angle of incidence: The deviation angle depends on the angle that the beam enters the object, called angle of incidence. The deviation angle first decreases with increasing incidence angle, and then it increases.

There is an angle of incidence at which the sum of the two deflections is a minimum. The deviation angle at this point is called the minimum deviation angle, or angle of minimum deviation. At the minimum deviation angle, the incidence and exit angles of the ray are identical. This is a consequence of the principle of time reversibility; if the incidence and exit angles were not identical, then reversing the paths (exit becomes entrance, and vice versa) would indicate erroneously that there were two incidence angles resulting in minimum deviation. One of the factors that causes a rainbow is the bunching of light rays at the minimum deviation angle that is close to the rainbow angle.

- Angle of the prism, A

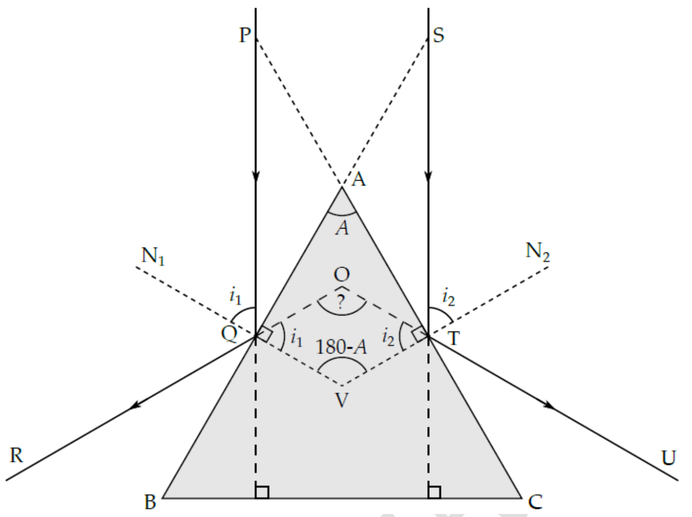



Figure 1: Ray diagram to derive angle of the prism.

Let two rays PQ and ST, which are parallel to each other, incident on the two sides of the prism, gets reflected from the sides AB and AC of the prism respectively. Let $i_1$ and $i_2$ be the respective angle of incidence. See Fig. 1. PQ reflects to QR and ST reflects to TU. Let $N_1Q$ and $N_2T$ be the normals to sides AB and AC. By the laws of reflection, $\angle PQN_1 = \angle RQN_1 = i_1$ and $\angle STN_2 = \angle UTN_2 = i_2$. Extend RQ and UT into the prism to meet at O. Similarly extend $N_1Q$ and $N_2T$ to meet at V. And extend the sides AB and AC to meet at S and P respectively as shown in the figure. The opposite angles are equal and hence $\angle RQN_1 = \angle OQV = i_1$ and $\angle UTN_2 = \angle OTV = i_2$. In the quadrilateral AQVT, the angles at vertices Q and T are 90°and hence the remaining two angles must add to 180°. Hence, $\angle QVT = 180 - A$, where $\angle BAC = A$ is the angle of the prism. Now we have to show a way to determine A by tracing the reflecting light rays.

Since PQ||ST, the alternate interior angles involved must be equal. Hence, $\angle PQA = (90 - i_1) = \angle AST$ and $\angle STA = (90 - i_2) = \angle APQ$. In 4APQ the angles must add to 180°, i.e,

$$\angle QAP + \angle APQ + \angle PQA = 180$$

$$\angle QAP + (90 - i_2) + (90 - i_1) = 180$$

Or,

$$i_1 + i_2 = \angle QAP$$

From the figure,

$$\angle QAP + A = 180$$

Substituting ∠QAP from eqn. 2 into eqn. 1 gives,

$$i_1 + i_2 = 180 - A$$

Now, in the quadrilateral OQVT, the sides must add to 360°. Hence,

$$\angle QOT + \angle OQV + \angle VTO + \angle QVT = 360$$

$$\angle QOT + i_1 + i_2 + 180 - A = 360$$

Substituting $i_1 + i_2$ from eqn. 3 into the above eqn. 4 gives,

$$\boxed{\angle QOT = 2A}$$

Hence, a measure of the angle made between the reflected rays extended into the prism gives twice the angle of the prism.

Angle of minimum deviation of the prism, $\delta_m$:

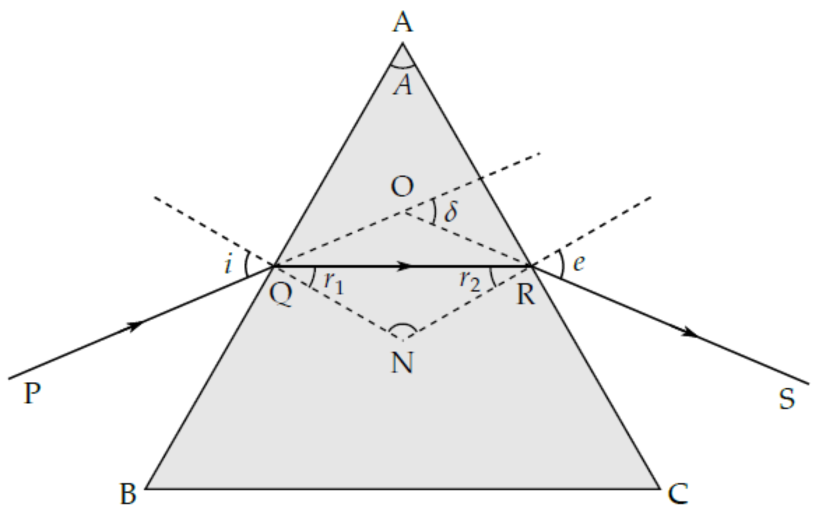



Figure 2: Ray diagram to derive angle of minimum deviation.

A ray of light PQ (from air to glass) incident on the first face AB at an angle i is refracted at an angle $r_1$ along QR and finally, emerges along RS. See Fig. 2. The dotted lines joining at N in the figure represent the normal to the surfaces. The angle of incidence (from glass to air) at the second face AC is $r_2$ and the angle of refraction (or emergence) is e. The angle between the direction of incident ray PQ (produced forward) and the direction of emergent ray RS (produced backward) is the angle of deviation $\delta$.

In the quadrilateral AQNR, two of the angles (at the vertices Q and R) are right angles.

Therefore, the sum of the other angles of the quadrilateral is 180°.

$$A + \angle QNR = 180$$

From the triangle QNR,

$$r_1 + r_2 + \angle QNR = 180$$

Comparing these two equations, we get

$$r_1 + r_2 = A$$

From the figure, $\angle OQN = i$ (opposite angles) and hence $\angle OQR = (i - r_1)$. Similarly $\angle ORN = (e - r_2)$. Hence, in the $\Delta OQR$, the exterior angle $\delta$ is given by the sum of the other two angles, that is,

$$\delta = \angle OQR + \angle ORQ = (i - r_1) + (e - r_2)$$

$$\text{Or, } \delta = i + e - A$$

Thus, the angle of deviation depends on the angle of incidence. A plot between the angle of deviation and angle of incidence is shown in the Fig. 3. You can see that, in general, any for i = e corresponds to two values i and hence of e. This, in fact, is expected from the symmetry of i and e i.e.,$\delta$remains the same if i and e are interchanged. Physically, this is related to the fact that the path of ray can be traced back, resulting in the same angle of deviation. At the minimum deviation $\delta_m$, the refracted ray inside the prism becomes parallel to its base. We have at $\delta = \delta_m$, = e which implies $r_1 = r_2 = r$. With 2r = A, we have

$$r = A/2$$

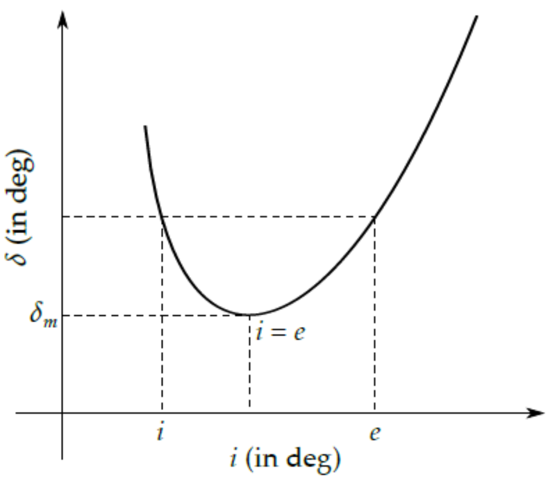



Figure 3: A plot of $\delta$ versus i.

In the same way, with $\delta_m = 2i - A$, we have

$$i = (A + \delta_m)/2$$

The refractive index of the prism is given by,

$$\mu = \frac{\sin i}{\sin r} = \frac{sin\left(\frac{A+\delta_m}{2}\right)}{sin\left(\frac{A}{2}\right)}$$

The angles A and $\delta_m$ can be measured experimentally. The above equation thus provides a method of determining refractive index of the material of the prism. The advantage of putting the prism in minimum deviation position is that the image is brightest in this position.

**Procedure:**

- Determination of angle of prism, A

1. Place a drawing board on the table and fix a drawing sheet on the drawing board using drawing pins. Place the prism on the drawing sheet and holding the prism trace the outer boundary of the prism.

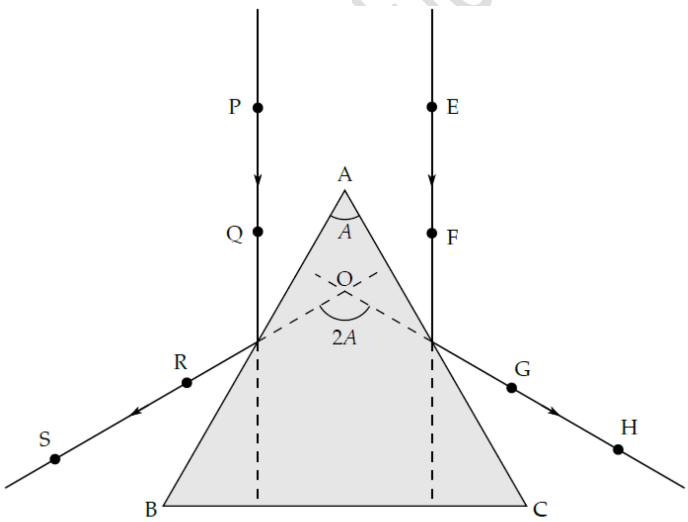



Figure 4: Prism and pins placement to determine A.

2. Mark the 3 vertices of the triangle as A, B and C. Draw two parallel lines so that edge A lies symmetrically between the parallel lines. See Fig. 4.

3. Fix two pins on the just drawn parallel line which intersects the face AB. Let these points be P and Q. Now, looking through the face AB fix two more pins one by one at the points R and S so that the reflected images of the pins at P and Q lie in the same straight line with these two pins without any parallax error.

4. Now join and extend the points R and S using a scale till it touches the face AB. The RS line represents the reflected ray of PQ.

5. In the same way repeat the procedure for the other face AC of the prism to get reflected ray GH of the incident ray EF.

6. Remove the prism and extend the straight lines passing through RS and GH in to triangle ABC so that they meet at a point O. Using a protractor, measure the ∠ROG which will be equal to 2A. Hence A = ∠ROG/2.

- Determination of angle of minimum deviation, $\delta$, of the prism

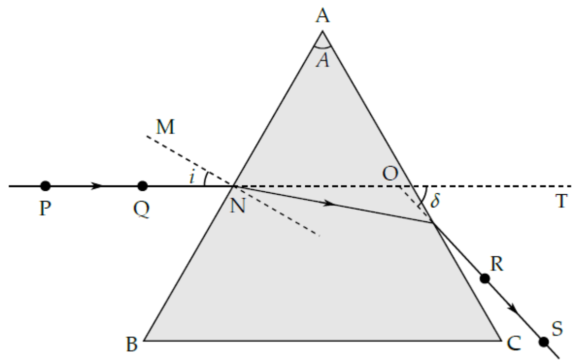



Figure 5: Prism and pins placement to determine $\delta$.

1. Fix the drawing sheet on the drawing board using drawing pins, keep the prism on the paper and trace the prism. The trace will give us a triangle ABC. AB and AC are the refracting surfaces and BC is the base of the prism. See Fig. 5.

2. Draw a normal line MN to the refracting surface AB at N. Using a protractor, draw an incident line PQ making an angle of 30°with the normal line MN. Now place the prism on its trace along ABC.

3. Fix two pins on the incident ray at two points P and Q. All the pins should be fixed vertically to the plane of paper. Now observing through the face AC fix two more pins at R and S so that these two pins will be in the line with the refracted images of P and Q.

4. Remove the prism and join the points R and S with a straight line which meets the line PQ extending into the prism at O.

5. Measure the ∠TOR which will be the angle of deviation $\delta$ corresponding to angle of incidence, i=30°.

6. Repeat the same procedure for various angles of incidences 35, 40, 45, 50, 55, 60, . . and measure the respective angles of deviations. Tabulate the values. As a precaution same angle of prism should be used for all observations.

**Observations and calculations:**

Angle of the prism is, A = ∠ROG/2 =…………………

**Table for the angle of deviation of the prism:**

| Sl No. | Angle of incidence $i$ (in deg) | Angle of deviation $\delta$ (in deg) |
|---|---|---|
| 1 | 30 | |
| 2 | 35 | |
| 3 | 40 | |
| 4 | 45 | |
| 5 | 50 | |
| 6 | 55 | |
| 7 | 60 | |



Plot a graph by taking angle of incidence i along x-axis and angle of deviation $\delta$ along y-axis using the observed values from the table. See Fig. 3. Take care that you draw a free hand smooth curve passing practically through all the plotted points on the graph. Draw a tangent to the lowest point of the graph parallel to x-axis and read the angle of minimum deviation $\delta_m$on they-axis of the graph. Calculate refractive index of the material of the prism by using,

$$\mu = \frac{\sin i}{\sin r} = \frac{sin\left(\frac{A+\delta_m}{2}\right)}{sin\left(\frac{A}{2}\right)}$$

**Result:**

1.The angle of the prism is, A =…………………………

2. The angle of minimum deviation of the given prism is, $\delta_m$ = ………………

3. Refractive index of the material of the given prism is, $\mu$ = ……………………..

**Misconceptions**

1. The i– d curve that is obtained in this experiment is a non-linear curve. In such situations, more readings should be taken in the minimum deviation region to be able to obtain the value of angleof minimum deviation accurately.

2. The graph does not show a sharp minimum. We have same deviation for a range of angle of incidence near minimum deviation. Therefore extra care should be taken in drawing tangential lineto the i – d graph at minimum deviation.

**Self Check questions**

**1.** If the experiment is performed with angle of emergence taken as angle of incidence, will there be any change in the values?

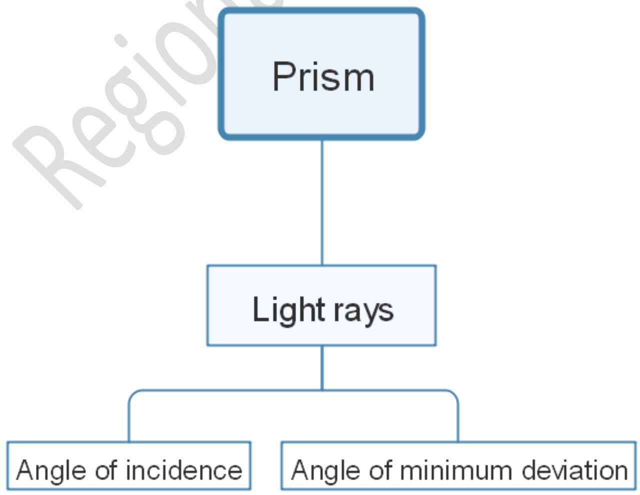
**2.** What will happen if you go on decreasing the angle of incidence? What happens when '*i'* is less than the minimum angle of incidence?

**Module and exercise**

**1.**Measure the angle of emergence *e* corresponding to the value of each angle of incidence *i* and angle of deviation □□you have observed. Compute the values of *(i + e)* and *(A +* □*)* and see how they compare.

**2.** Determine the refractive index of different liquids using a hollow prism by plotting *i* – □□graph.

**Concept map**



**MCQ questions:**

**Q1:** Dispersion can be easily noticed by passing a white light through

E) Prism C) Water

F) Glass D) Mirror

**Answer: A) Prism**

**Q2: Angle of the equilateral prism is**

E) 65 degree C) 60 degree

F) 56 degree D) 45 degree

**Answer: C) 60 degree**

## 2.8 Lens combination

**Introduction**

Two lenses with known focal lengths can be used to obtain the lens combination. A parallel beam of lightparallel to principal axis after refraction through a lens either focus at a point or appears to diverge from a point on the principal axis called the focus point. The distance from the optical centre to the focal point is called the focal length.

**Learning objectives**

1] To use lenses of specified focal lengths to obtain lens combination.

2] To know the focal points of the lens.

**Major Concepts**

1] Learning about the focal length of the lenses.

2] Proper use of lenses and screen on optic bench.

**Learning Resources**

Optic bench, lenses with different focal length, light source, screen

**Content Descriptions and activities**

The ability of a lens to converge or diverge the rays passing through it is called the power of the lens

$$\text{Power} = \frac{1}{\text{focal length}(f)}$$

Its SI unit is Dioptre. Power of a convex lens is taken as positive. Two or more lenses, placed in contact together to have a common principal axis, form a lens combination. If $f1$, $f2$, ...$f$n be the focal length of individual lens and $F$ be the focal length of the combination, then

$$\frac{1}{F} = \frac{1}{f1} + \frac{1}{f2} + \cdots + \frac{1}{fn}$$

$P = P1 + P2 + ... + Pn$, where $P$ is the power of the lens combination and $P1$, $P2$, ...$Pn$ are the powers of the individual lenses.

**Experimental setup:**

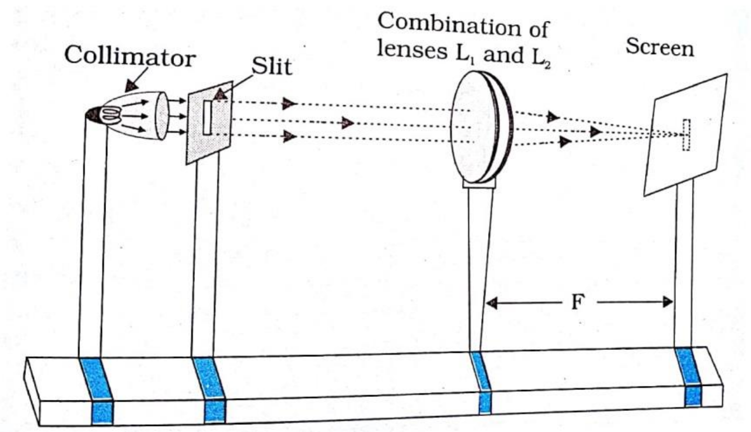



**Figure: Lenses placed on optical bench.**

**Procedure:**

1. Calculate the power of the combination of two lenses corresponding to the required focal length.
2. Select a lens from the given set of lenses whose power is smaller than that of the combination of lenses to be prepared (if only convex lenses are provided).
3. Calculate the power of unknown convex lens to be kept in contact with the lens of known focal length to obtain a combination of lenses of desired focal length. Select the lens whose power is close to the calculated power from the given set of lenses.
4. Set up the optical bench on a horizontal table. Adjust the collimator to direct parallel beam of light along the optical bench. In case collimator is not available, a plane mirror may be used to direct sunlight along the optical bench and illuminate a slit with it.
5. Place the two lenses on the uprights such that they are in contact with each other. An upright that can hold two lenses in contact may also be used or the same may be improvised by fixing the lenses on grooves carved on a thermo cole sheet.
6. Direct a parallel beam of light on the combination of lenses and obtain a sharply focused image of the source of light on a screen placed on the other side of the lenses. This can be done by adjusting the distance between the combination of lenses and screen.
7. Measure the distance of the screen from both the lenses and record it in a table.
8. Repeat the activity at least three times by changing the position of the lens combination on the optical bench. Record your observations in each case.

**Observation and calculations:**

Focal length of lens L1 = *f*1

Focal length of lens L2 = *f*2

Calculated focal length of lens combination $\frac{1}{F} = \frac{1}{f1} + \frac{1}{f2}$

Least count of the scale of the optical bench = ……....mm

**Tabular Column: Focal length of combination of lenses**

| Sl. No | Distance of first lens from the screen *d*1 (cm) | Distance of second lens from the screen *d*2 (cm) | Mean distance ofscreen from lenscombination 2 $2\frac{d1+d2}{2}$= *F* (cm) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |

The mean distance of the screen from the lens combination is a measure of its focal length. Take average of all readings as the focal length of the combination determined by the experiment.

**Result:**

Measured value of focal length of lens combination =....................cm

Calculated value of focal length of lenses =………………cm

Difference between measured value of focal length and the calculated focal length = ………..…..cm

**Misconceptions**

The position of the lenses, screen and their alignment on the optic bench should be carefully observed while measuring the distance.

**Self check questions**

1. A convex lens of focal length 20 cm is put in contact with a concave lens of focal length 10 cm. What will be the

effective focal length of the combination?

2.If a convex lens is dipped completely in water, what will be the effect on its focal length?

3. If two lenses of focal lengths *f1* and *f2* are placed distance *d* apart,is the formula $\frac{1}{F} = \frac{1}{f1} + \frac{1}{f2}$ still valid? If not, give the modified formula. Will the focal length of the combination be (i) <*F* (ii) >*F*?

**Module end exercise**

1.Select a pair of lenses whose combination (i) will act as a converging lens (ii) will not act as a converging lens.

2. Use different lenses to obtain desired combination of focal length.

**MCQ questions:**

**Q1:** Distance between optical center and principle focus is

G) radius C) focal length

H) linear length D) 2 focal length

**Answer: C) focal length**

**Q2:** Lens which diverges light from a single point is

G) concave lens C) convex lens

H) bioconvex D) both B and C

**Answer: A) concave lens**

## 2.9 Transistor characteristics

**Introduction**

An n-p-n transistor is made up of a semiconductor such as Ge or Si in which there is a thin p-type layer between two n-type layers. A p-n-p transistor has a thin n-type layer between two p-type layers.

**Learning objectives**

To study of the following characteristics of a Bi-Junction transistor

1. Input characteristics
2. Output characteristics
3. Transfer characteristics

and calculate its (i) input resistance, (ii) output resistance and (iii) amplification factor.

**Major Concepts**

1] n-p-n and p-n-p transistors

2] Three different terminals of the transistors

3] Measuring the current variation for corresponding variation of voltage

**Learning Resources**

A transistor, resistors, milliammeter, microammeter, voltmeter, dc power supplies.

**Content Descriptions and activities**

Transistor is a semiconductor device which controls the flow of current in a circuit. There are two types of transistors

- Unipolar transistor
- Bipolar transistor

In this experiment we study the working of a Bipolar Junction transistor (BJT).

A BJT is a three terminal solid-state electronic device which consists of two PN Junctions formed by sandwiching either P type or N type semiconductors between a pair of opposite types. Accordingly, there are two types of transistors:

- **n-p-n transistor**: It consists of a thin section of p-type semiconductor sandwiched be-tween two thicker sections of n-type semiconductors. Figure 1 shows the n-p-n transistor and its circuit symbol. The arrowhead in the symbol points outwards.

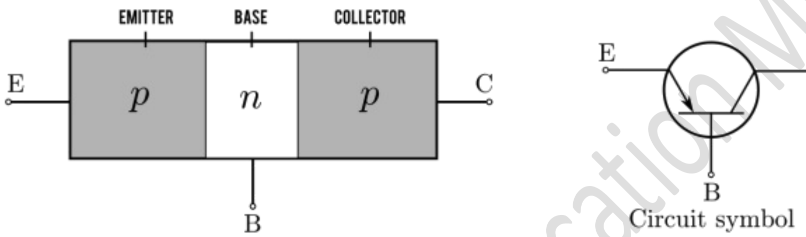



Figure 1: n-p-n transistor and its circuit symbol.

- **p-n-p transistor**: It consists of a thin section of n-type semiconductor sandwitched be-tween two thicker sections of p-type semiconductors. Figure 2 shows the p-n-p transistor and its circuit symbol. The arrowhead in the symbol points inwards.

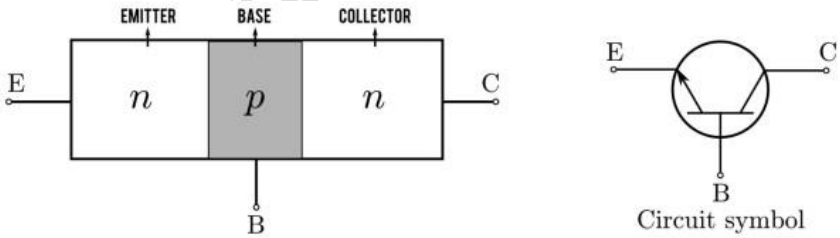



Figure 2: p-n-p transistor and its circuit symbol.

In this experiment, we use an n-p-n transistor. The three parts of any BJT are:

- **Emitter**: It supplies majority charge carriers (electrons or holes) for the flow of currentthrough the transistor. It is of moderate size and heavily doped. It is usually forward biased in a circuit.

7 **Base**: It is the middle section of the BJT which forms two pn-junctions between theemitter and the collector. It is very thin in size and lightly doped. It controls the flow of majority carriers from emitter to collector.

7 **Collector**: It collects the majority charge carriers for the circuit operation. It islargerinsize as compared to the emitter and is moderately doped. It is normally reverse biased with respect to any other part of the transistor.

**Working of n-p-n transistor**

The n type emitter of n-p-n transistor is forward biased by connecting it to the negative terminal of the battery $V_{EB}$ and the n-type collector is reverse biased by connecting it to the positive terminal of the battery $V_{CB}$ as in figure,

The forward bias of the emitter-base circuit repels the electrons of the emitter towards the base, setting up emitter current $I_E$. As the base is very thin and lightly doped, a very few electrons(< 5%) from the emitter combine with the holes of base,giving rise to base current $I_B$ and the remaining electrons(> 95%) are pulled by the collector which is at high positive potential. The electrons are finally collected by the positive terminal of the battery $V_{CB}$, giving rise to collector current $I_C$

As soon as an electron from the emitter combines with a hole in the base region,an electron leaves the negative terminal of the battery, $V_{EB}$ and at the same time the positive terminal of battery, $V_{EB}$receives an electron from the base. This sets a base current, $I_B$. Similarly, corresponding to each electron that goes from collector positive terminal of $V_{CB}$, an electron enters the emitter from negative terminal of $V_{EB}$. Hence

Emitter current = Base current + Collector current

$$I_E = I_B + I_C$$

Here $I_B$ is a small fraction of $I_C$ depending on the shape of transistor, thickness of base, doping levels,bias voltages etc.

**Configurations of a BJT**

As the transistor is a three-terminal device, one terminal has to be always common to the input and output circuits. This terminal is connected to the ground and acts as a reference point for the entire circuit. So a transistor has three configurations.

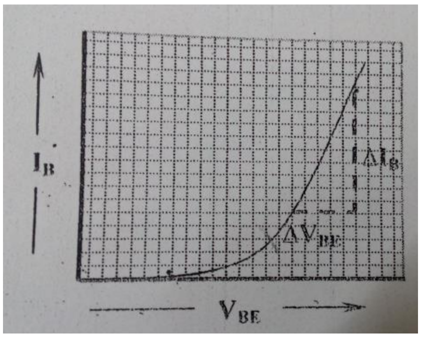
1. Common-base (CB) configuration
2. Common-emitter (CE) configuration
3. Common-collector (CC) configuration

This experiment is conducted in the CE configuration, where the emitter is taken as the common terminal and grounded (zero potential), base is the input terminal and collector is the output terminal.



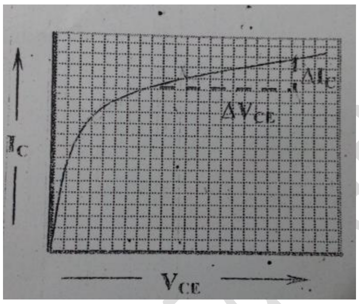
Three types of characteristic curves are studied here.

1. **Input characteristic**-A graph showing the variation of base current $I_B$ with base-emitter voltage $V_{BE}$ at constant collector-emitter voltage $V_{CE.}$



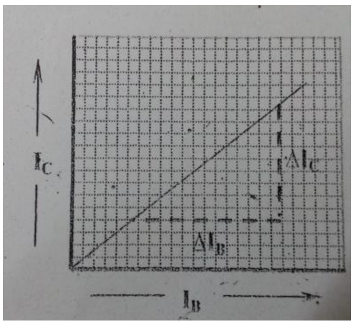

**Input resistance**, ri of the transistor in CE configuration is defined as the ratio of small change in base emitter voltage to the corresponding small change in the base current, when the collector-emitter voltage is kept constant.

2. **Output characteristic**- A graph showing the variation of collector current $I_C$ collector-emitter voltage $V_C$ E at constant base current $I_B$



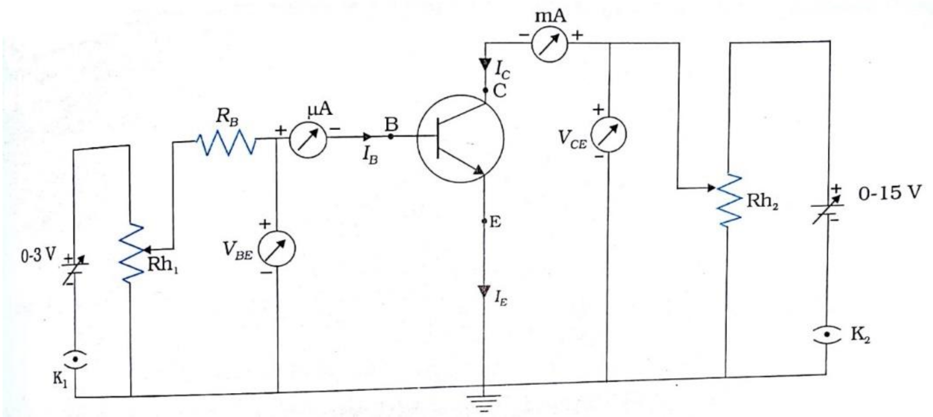

**Output resistance**,$r_o$of a transistor in CE configuration is defined as the ratio of small change in the collector-emitter voltage to the corresponding change in the collector current when the base current is kept constant

3. **Transfer characteristic**-A graph showing the variation of collector current $I_C$ with base current $I_B$ at constant collector-emitter voltage $V_{CE}$




**Current amplification factor**, **β**is defined as the ratio of the change in collector currentwith a small change in base current at constant collector-emitter voltage $V_{CE}$ when the transistor is in the active state.

**Circuit connection:**




**The circuit connection of n-p-n transistor in CE configuration.**

**Procedure:**

Study of input characteristics

1. During this study, the parameters in the output circuit are kept constant. i.e, voltage between collector and emitter, $V_{CE}$ is kept constant (at around 3-4 volts).

2. The base current $I_B$ and the collector current $I_C$ are recorded at different base voltages (Voltage between base and emitter, $V_{BE}$).

3. The readings are tabulated.

4. A graph of $I_B$ versus $V_{BE}$ is plotted. The slope is found in the linear region of the graph. Inverse of the slope gives the input resistance ($r_i$) of the transistor.

Output characteristics

1. During this study, the parameters in the input circuit are kept constant. i.e.,voltage be-tween base and emitter, ($V_{BE}$) or the base current, ($I_B$) (at around 30-40 *m*A)

2. The collector current, $I_C$ is recorded at different collector voltages (voltage between the emitter and the collector, ($V_{CE}$)

3. The readings are tabulated.

4. A graph of $I_C$ verses $V_{CE}$ is plotted. The slope is found in the linear region of the graph.

   Inverse of the slope gives the output resistance ($r_o$) of the transistor.

Study of transfer characteristics

1. A graph of collector current, $I_C$ verses base current, $I_B$ is plotted.

2. The slope of the graph gives the amplification factor, $\beta$ of the transistor.

**Observation and calculation:**

| Input and transfer characteristics | | |
|---|---|---|
| VBE (volts) | IB ($m$A) | IC (mA) |
| | | |

| Output characteristics | |
|---|---|
| VCE (volts) | IC (mA) |
| | |

**From the input characteristics graph**

$$slope = \frac{\Delta I_B}{\Delta V_{BE}}$$

Input resistance of the transistor = $r_i = \frac{\Delta V_{BE}}{\Delta I_B} = \frac{1}{slope}$

**From the output characteristics graph**

$$slope = \frac{\Delta I_C}{\Delta V_{CE}}$$

Output resistance of the transistor = $r_o = \frac{\Delta V_{CE}}{\Delta I_C} = \frac{1}{slope}$

**From the transfer characteristics graph**

$$slope = \frac{\Delta I_C}{\Delta I_B}$$

Amplification factor = $\beta = \frac{\Delta I_C}{\Delta I_B}$ = slope

**Result:**

1. The input, output and the transfer characteristics of a n-p-n transistor is studied.

2. From the input characteristics graph, input resistance ($r_i$) =………………….

3. From the output characteristics graph, output resistance ($r_o$) = ………………….

4. From the transfer characteristics graph, amplification factor (β)= ……………………..

**Misconceptions**

- Biasing of the transistors should be done considering whether the transistor is n-p-n or p-n-p
- Connection should be proper while measuring the voltage and the current.

**Self Check questions**

1. Is there any change in characteristic curves if we use a p-n-p transistor instead of n-p-n transistor?
2. Why is the input circuit forward biased and output circuit reverse biased?
3. You notice the dynamic output resistance $r_o$is different for different regions of the output characteristic curve. What do you infer from this?

**Module end exercise**

1. What do you mean by dynamic input resistance and why is it called dynamic?
2. For CE configuration, $I_C$ is not cut-off even for $I_B$= 0. For determination of the cut-off voltage in CE mode, how will you reduce $I_C$to zero?

**MCQ questions:**

**Q1: A transistor has**

I) One pn junction C) Two pn junction
J) Three pn junction D) Four of the above

**Answer: C) Two pn junction**

**Q2: The input impedance of a transistor is**

I) High C) Very high
J) Low D) almost zero
K) **Answer: B) Low**

**2.10 Comparison of emfs of two cells using a potentiometer**

**Introduction**

With the help of a voltmeter we can measure only the potential difference between the two terminals of a cell, but using a potentiometer we can determine the value of emf of a given cell. The emf is the potential difference across the cell not a force per se. To determine and compare the emf of two cells, one side of the wire is connected to positive terminals of the two cells and the other ends are connected to a galvanometer.

**Learning objectives**

1] Finding the balancing length in the resistance wire corresponding to two cells

2] Calculating the emfs using the two balancing lengths

**Major Concepts**

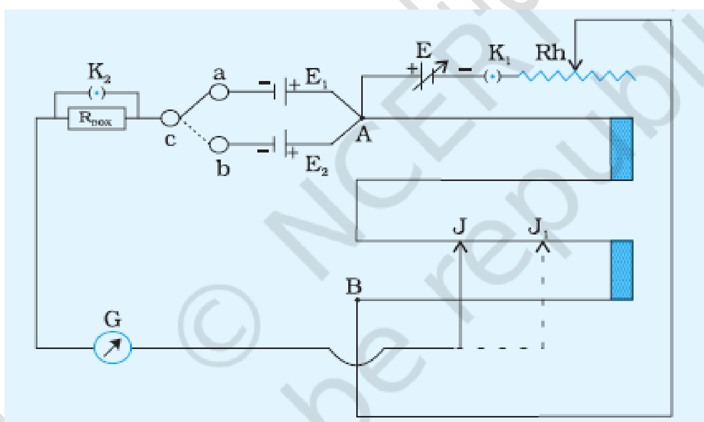
1] Using the potentiometer as a tool to measure the emf of a cell

**Learning Resources**

Potentiometer, a Leclanche cell, a Daniel cell, a two way key, a resistance box plug type (0 to 1000 W), a galvanometer, a voltmeter (0-3 V), a battery eliminator/lead accumulator, a low resistance rheostat (about 20 W), two one-way keys, connecting wires.

**Content Descriptions and activities**

Make the circuit as shown in the Figure.




Plug the key such that Leclanche cell is included. Determine the balancing length $l_L$. Similarly the key is closed such that Daniel cell is included. Determine the balancing length $l_D$. If the emfs of the Daniel and Leclanche cells are $E_D$ and $E_L$ then $E_L/E_D = l_L/l_D$. Different values of $l_L$ and $l_D$ can be obtained by varying the position of rheostat. Tabulate the readings. Find $l_L/l_D$ in each case and verify the given relation.

| Tr. No. | Balancing length for | | $l_L/l_D$ |
|---|---|---|---|
| | Leclanche cell ($l_L$) | Daniel cell ($l_L$) | |
| | | | |

**Module end exercise**

**MCQ**

**Q1. What kind of force is the emf?**

A) Electrostatic

B) Gravitational

C) Nuclear

D) Chemical

**Q2. Two cells having 2 different emfs are in series. How does the combination act like?**

A) 2 individual cells

B) Voltage divider

C) Current divider

D) Effective single cell

## 2.11 Internal resistance of a cell using a potentiometer

**Introduction**

With the help of a voltmeter we can measure only the potential difference between the two terminals of a cell, but using a potentiometer we can determine the value of emf of a given cell. The emf is the potential difference across the cell not a force per se. To determine the internal resistance, one side of the wire is connected to positive terminals of the two cells and the other ends are connected to a galvanometer through a common key.

**Learning objectives**

1] Finding the balancing length in the resistance wire corresponding to two cells

2] To determine the internal resistance of a cell

**Major Concepts**

1] Using the potentiometer as a tool to measure the emf of a cell

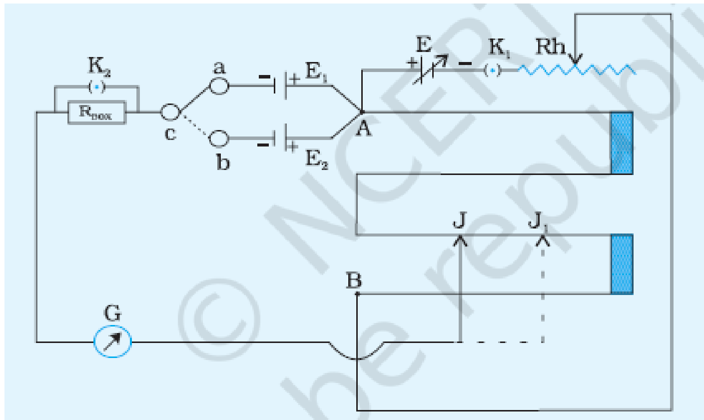
2] According to the principle of potentiometer, when a steady current flows through a wire of uniform thickness and material, potential difference between any two points on it is directly proportional to the length of the wire between the points.

**Learning Resources**

Potentiometer, a Leclanche cell, a Daniel cell, a two way key, a resistance box plug type (0 to 1000 W), a galvanometer, a voltmeter (0-3 V), a battery eliminator/lead accumulator, a low resistance rheostat (about 20 W), two one-way keys, connecting wires.

**Content Descriptions and activities**

Make the circuit as shown in the Figure.




Plug the key such that Daniel cell is included. Determine the balancing length $l_1$. By closing the second key, introduce some resistance R and determine the balancing length $l_2$. Repeat the experiment for different values of R, keeping the position of the rheostat same for $l_1$ and all values of $l_2$. Tabulate the readings as shown in table.

| R | $l_1$ | $l_2$ | $l_1/l_2$ | 1/R |
|---|---|---|---|---|
| | | | | |

The equation to find out the internal resistance of a cell is $r = \left(\frac{l_1 - l_2}{l_2}\right) R$

$$\frac{l_1}{l_2} = r\frac{1}{R} + 1 \qquad \ldots\ldots(1)$$

Plotting the graph of $l_1/l_2$ vs 1/R and keeping the *y*-intercept as 1, the slope gives the internal resistance of a cell.

**References**

Class XII, NCERT Lab manual

**MCQ**

**Q1. What happens when the internal resistance of a cell is same as load resistance in the circuit?**

A) Zero current

B) Maximum current

C) Maximum voltage

D) None of these

**Q2. What is the role of rheostat in this experiment?**

A) Inducing variable resistance

B) Stabilizing the circuit

C) Controls the current in circuit

D) All of the above

## 2.12 Determination of absolute M and H



**Introduction**

Magnetisation of a bar magnet can be found by the deflection magnetometer. The needle deflects away from initial $0^o$-$0^o$ reading when the magnet is brought closer to the magnetometer. Only the deflections less than $45^o$ are considered.

**Learning objectives**

1] To determine M/H for a Bar magnet using a 'MH' deflection magnetometer

2] To determine 'MH' using a vibration magnetometer

3] To calculate the Magnetic moment (M) and the Horizontal component of the Earth's magnetic field (H).

**Major Concepts**

1] Magnetisation

2] Deflection due to bar magnet

**Learning Resources**

Deflection magnetometer, Bar magnet, weighing machine

**Content Descriptions and activities**

(a) **To determine M/H:** The given bar magnet is placed on the scale of the deflection magnetometer, to the east of the magnetometer box. With the N-pole of the Bar magnet pointing to the magnetic needle (as in Figure 1) and the distance 'd' between the centre of the magnetic needle and the centre of the Bar magnet is adjusted to so as to get a deflection of about $45^o$ by the pointer. The distance 'd' and the readings of the pointer $\theta_1$ and $\theta_2$ are noted. Keeping the distance (d) the same, the magnet is reversed pole for pole and the two readings of the pointer $\theta_3$ and $\theta_4$ are noted. Keeping the distance the same, the experiment is repeated keeping the bar magnet to the west of the magnetometer box, and four more readings of the pointer ($\theta_5$ & $\theta_6$ and $\theta_7$ & $\theta_8$) are noted. The average of the 8 readings gives the mean deflection θ for distance ‘d’ between the magnetic needle and the bar magnet. Repeat this at least 3 distances.

The bar magnet is placed on a paper in north-south direction. Using a compass needle the positions of the magnetic poles N and S of the bar magnet are located and magnetic length (2L) of the bar magnet is determined (as in Figure 2). The value of M/H is calculated using the relation $\frac{M}{H} = \frac{(d^2-L^2)^2 tan\theta}{2.d}$.

(b) To determine MH: Using a paper stirrup, the bar magnet is suspended in the Earth’s magnetic field so as to swing freely in a horizontal plane. Using a stop-clock the period of oscillation (T) of the bar magnet is determined. The geometric length (l) and the breadth (b) of the bar magnet are measured. And its mass (m) is determined. The moment of inertia (I) of the bar magnet is calculated using the relation $I = \frac{m(l^2+b^2)}{12}$ gms.cm$^2$.

The value of ‘MH’ is calculated using the relation $H = \frac{4\pi^2 I}{T^2}$.

(c) To determine ‘M’ and ‘H’

The value of M and H can be calculated by using the relations:

$$M = \sqrt{\frac{M}{H}.MH} \text{ CGS units}$$

$$H = \sqrt{\frac{MH}{M/H}} \text{ Gauss}$$

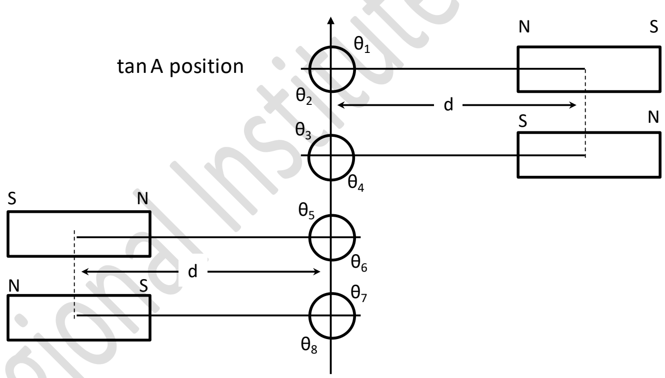



Figure 1

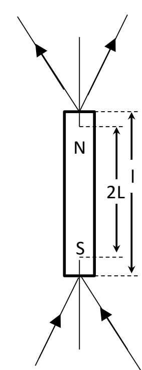



Figure 2



**Tabular columns**

| d (cm) | Magnet East of the needle | | | | Magnet West of the needle | | | | Mean θ (degrees) |
|---|---|---|---|---|---|---|---|---|---|
| | N pole facing needle | | S pole facing needle | | N pole facing needle | | S pole facing needle | | |
| | $\theta_1$ | $\theta_2$ | $\theta_3$ | $\theta_4$ | $\theta_5$ | $\theta_6$ | $\theta_7$ | $\theta_8$ | |
| | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

To determine time period of oscillation (T):

| Trial | No. of oscillations | Time | | Time for 1 oscillation | |
|---|---|---|---|---|---|
| 1 | | Minutes | Seconds | | Seconds |
| 2 | | | | | |
| 3 | | | | | |
| | | | | | |

*Misconceptions*

1] The magnetic length and geometric length are same.

2] Distance from magnetometer upto one edge of the magnet should be taken.

*Self Check questions*

**Module end exercise**

Exercise: Use the bar magnet of different weight and length.

**Concept map**

**References**

Class XII textbook, NCERT.

**MCQ**

**Q1. Why the deflections (θ) are taken to be less than 45º?**

A) To reduce errors

B) For convenience

C) tan θ ≤1

D) None of these

**Q2. This way deflection magnetometer can be made almost independent of errors.**

A) Taking the deflections both sides

B) By taking readings between 45º -10º

C) Aligning the magnetometer correctly D) A and B

## 2.13 Mapping of the magnetic field due to a current carrying solenoid

**Introduction**

A current carrying Solenoid can be used to construct a bar magnet at any time. Depending on the current direction the north and south poles of the bar magnet can be changed.

**Learning objectives**

1] To use a solenoid to construct a bar magnet

2] To know the neutral points

3] To find the neutral points when the direction of current is reversed

**Major Concepts**

1] Learning about the artificial bar magnet

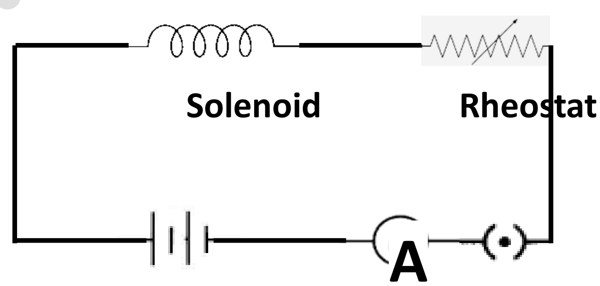
2] Field of lines of a current carrying solenoid

**Learning Resources**

Solenoid, Rheostat, Battery, Ammeter, key

**Content Descriptions and activities**

Make the connections as shown in the circuit diagram.



Keep the solenoid axis parallel to the N-S direction of earth's magnetic field. Place the compass needle very near the solenoid axis and switch on the current. Note down the direction of its defection. Now keep the drawing board on the same line but at the edge of the drawing board. When the needle reverses its direction, that point is known as a neutral point. There will be one more neutral point on the other side. These neutral points are due to the combined field of the current carrying solenoid and the earth.

Starting from one end of the solenoid, using a compass needle, plot the line of force of the combined field. Whole board should be filled with lines of force by checking the direction of the compass needle at various positions.

*Misconceptions*

1] Neutral points can be obtained whichever way the board is kept.

**MCQ**

**Q1. Which way the neutral points are obtained when the current is reversed?**

A) Along N-S direction

B) Along E-W direction

C) Along NE direction

D) Along NW direction

**Q2. What happens to the number of field of lines if the current is increased?**

A) Increases

B) Decreases

C) Remains the same

D) Becomes opposite

### 2.14 Verifying the law of combination of resistances (series) using meter bridge

**Introduction**

The meter bridge consists of a wire of length 1m and of uniform cross sectional area stretched taut and clamped between two thick metallic strips bent at right angles, as shown. The metallic strip has two gaps across which resistors can be connected. The end points where the wire is clamped are connected to a cell through a key. One end of a galvanometer is connected to the metallic strip midway between the two gaps. The other end of the galvanometer is connected to a 'jockey'. The jockey is essentially a metallic rod whose one end has a knife-edge which can slide over the wire to make electrical connection.

**Learning objectives**

1] Finding the balancing length for two unknown resistances

2] Verify the series combination of resistances

**Major Concepts**

1] Wheatstone bridge

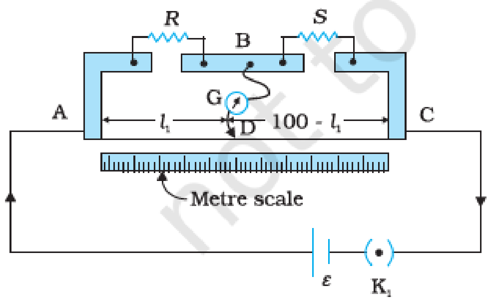
2] Law of combination of resistances (series)

**Learning Resources**

A metre bridge, a sensitive galvanometer, two different resistances (carbon or wire-wound resistors), a resistance box, a jockey, a rheostat, a plug key, a cell or battery eliminator, thick connecting wires.

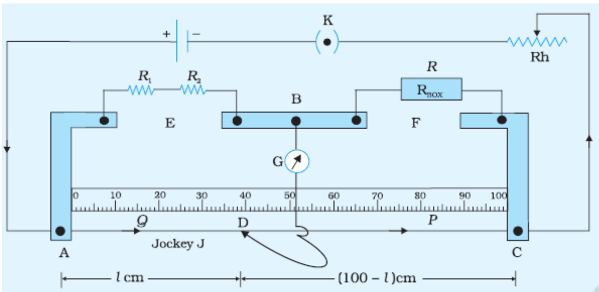
**Content Descriptions and activities**

Make the circuit as shown in the Figure.




The four arms AB, BC, DA and CD [with resistances $R$, $S$, $R_{cm}$ $l$ and $R_{cm}(100\text{-}l)$] obviously form a Wheatstone bridge with AC as the battery arm and BD the galvanometer arm. If the jockey is moved along the wire, then there will be one position where the galvanometer will show no current. Let the distance of the jockey from the end A at the balance point be $l=l_1$. The four resistances of the bridge at the balance point then are $R$, $S$, $R_{cm}$ $l_1$ and $R_{cm}(100–l_1)$. Thus, once we have found l1, the unknown resistance R is known in terms of the standard known resistance S by, $R = S\frac{l_1}{100-l_1}$

Make the circuits as shown below for series combination of resistances. First, find out the individual unknown resistances. When two resistances $R_1$ and $R_2$ are connected in series, the resistance of the combination $R_S$ is given by $R_S = R_1 + R_2$.



Remove some plug(s) from the resistance box to get suitable value of resistance $R$. Obtain the null point D on the metre bridge wire by sliding the jockey between ends A and C as was done earlier. Note resistance $R$ and lengths AD and DC in the observation table. Calculate the unknown resistances and combination of resistances as shown in Table.

| | Sl No. | Resistance $R$ (ohm) | Length AD = $l$ (cm) | Length DC, $l' = 100 - l$ (cm) | Unknown resistance $X (R_S \text{ or } R_P) = \frac{R \times l}{l'}$ (ohm) | $\Delta R_s$ or $\Delta R_p$ (ohm) |
|---|---|---|---|---|---|---|
| $R_1$ and $R_2$ in series, $R_s$ | 1<br>2<br>--<br>5 | | | | | |
| | | | | | Mean $R_S$ = | |

**MCQ**

**Q1. How does resistivity change if length of the wire is doubled?**

A) Increases

B) Decreases

C) Remains the same

D) Halved

**Q2. What happens to the resistance of the wire if its thickness is doubled?**

A) Increases

B) No change

C) Decreases

D) Halved

## 2.15 Verifying the law of combination of resistances (parallel) using meter bridge

**Introduction**

The meter bridge consists of a wire of length 1m and of uniform cross sectional area stretched taut and clamped between two thick metallic strips bent at right angles, as shown. The metallic strip has two gaps across which resistors can be connected. The end points where the wire is clamped are connected to a cell through a key. One end of a galvanometer is connected to the metallic strip midway between the two gaps. The other end of the galvanometer is connected to a 'jockey'. The jockey is essentially a metallic rod whose one end has a knife-edge which can slide over the wire to make electrical connection.

**Learning objectives**

1] Finding the balancing length for two unknown resistances

2] Verify the parallel combination of resistances

**Major Concepts**

1] Wheatstone bridge

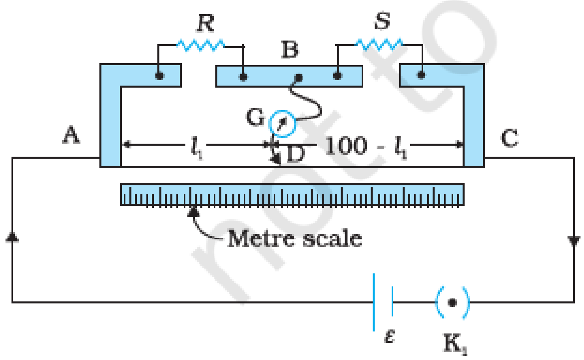
2] Law of combination of resistances (parallel)

**Learning Resources**

A metre bridge, a sensitive galvanometer, two different resistances (carbon or wire-wound resistors), a resistance box, a jockey, a rheostat, a plug key, a cell or battery eliminator, thick connecting wires.

**Content Descriptions and activities**

Make the circuit as sh



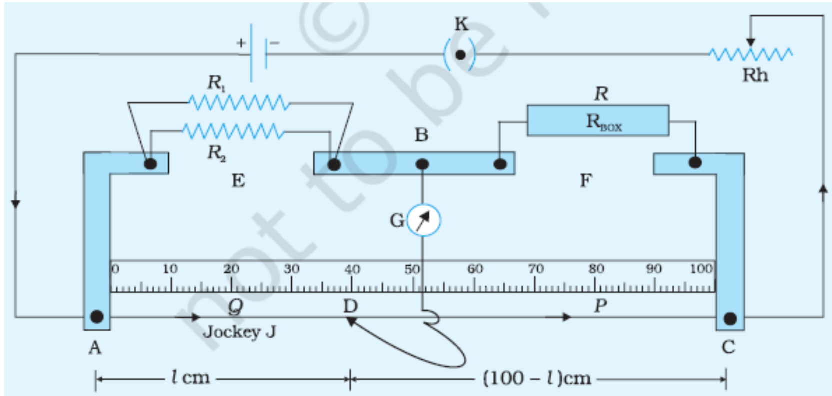

The four arms AB, BC, DA and CD [with resistances $R$, $S$, $R_{cm}\, l$ and $R_{cm}(100\text{-}l)$] obviously form a Wheatstone bridge with AC as the battery arm and BD the galvanometer arm. If the jockey is moved along the wire, then there will be one position where the galvanometer will show no current. Let the distance of the jockey from the end A at the balance point be $l=l_1$. The four resistances of the bridge at the balance point then are $R$, $S$, $R_{cm}\, l_1$ and $R_{cm}(100–l_1)$. Thus, once we have found l1, the unknown resistance R is known in terms of the standard known resistance S by,

$$R = S\frac{l_1}{100 - l_1}$$

Make the circuits as shown below for parallel combination of resistances.

First find out the unknown resistances. When connected in parallel, the resistance $R_P$ of the combination is given by, $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$.

Remove some plug(s) from the resistance box to get suitable value of resistance $R$. Obtain the null point D on the metre bridge wire by sliding the jockey between ends A and C as was done earlier. Note resistance $R$ and lengths AD and DC in the observation table. Calculate the unknown resistances and then combination of resistances as shown in Table.




| | Sl No. | Resistance $R$ (ohm) | Length AD = $l$ (cm) | Length DC, $l'$ = 100 - $l$ (cm) | Unknown resistance $X (R_s \text{ or } R_p) = \frac{R \times l}{l'}$ (ohm) | $\Delta R_s$ or $\Delta R_p$ (ohm) |
|---|---|---|---|---|---|---|
| $R_1$ and $R_2$ in parallel, $R_p$ | 1<br>2<br>--<br>5 | | | | | |
| | | | | | Mean $R_p$ = | |

**MCQ**

**Q1. How does resistivity change if length of the wire is doubled?**

A) Increases B) Decreases

C) Remains the same D) Halved

**Q2. What happens to the resistance of the wire if its thickness is doubled?**

A) Increases B) No change

C) Decreases D) Halved

## 2.16 Charging and Discharging of a Capacitor

**Introduction**

A Capacitor when connected to a d.c. voltage $V_0$ through a resistance R, voltage V across the Capacitor at time t is: $V = V_0 (1 - e^{-\frac{t}{RC}})$. Again, when Capacitor is discharged, the voltage V at time t is: $V = V_0 e^{-\frac{t}{RC}}$. Thus, in case of charging difference $V_0$-V decreases exponentially reducing by a factor of 2.72 in a time interval equal to RC. During discharging the voltage V itself behaves similarly. The time interval is known as the **time constant** of the circuit.

**Learning objectives**

1] To learn the charging characteristics of a Capacitor

2] To learn the discharging characteristics of a Capacitor

**Major Concepts**

1] Charging and discharging of a capacitor in a RC combination

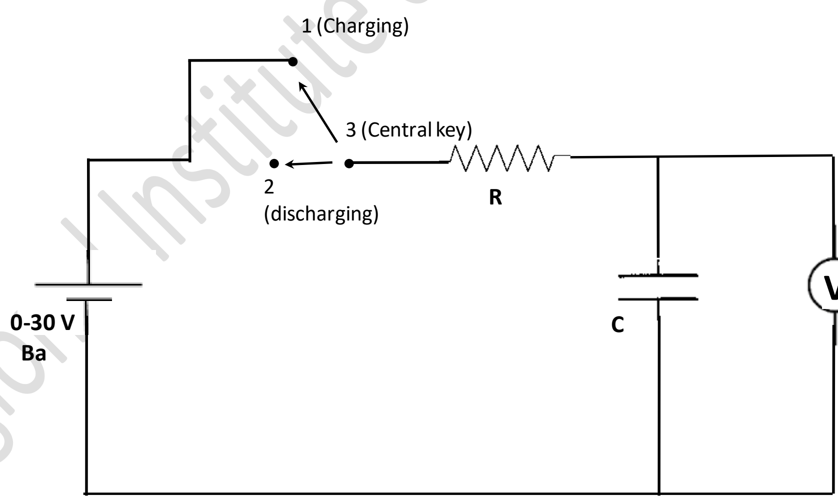
2] Exponential variation of voltage developed in a capacitor

**Learning Resources**

Capacitor, voltmeter, two-way switch, battery, resistor

**Content Descriptions and activities**

Connect the circuit as shown in the Figure. Now, put the switch for charging of the capacitor. Start the timer and take the voltage output every 5 seconds until it reaches the applied voltage. Similarly, record the discharging voltages. Tabulate as shown in the table. Repeat the observations 2 more times and take mean.




| Time t(s) | Voltage during charging V (volt) | | | | Voltage during discharging V (volt) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | Mean | 1 | 2 | 3 | Mean |
| 5 | | | | | | | | |
| 10 | | | | | | | | |
| … | | | | | | | | |

Plot two graphs between V and t for charging and discharging of the capacitor. The graphs show exponential rise and fall of voltages. If $V_0$ is the highest voltage charged, then the value 0.63 $V_0$ is spotted on the charging curve and 0.37 $V_0$ on the discharging curve. The corresponding times are known as $\tau_1$ and $\tau_2$. The average of these two time values is the time constant $\tau$ (=RC) of the circuit. Knowing the resistance R value, Capacitance C value can be calculated.

**MCQ**

**Q1. What is the relation between half time of the RC circuit and time constant?**

A) $\tau = t_h$

B) $\tau \approx t_h$

C) $\tau < t_h$

D) $\tau > t_h$

**Q2. What happens to value of time constant while charging if the value of resistance of the voltmeter is comparable to the resistance (R) of the circuit?**

A) Remains the same

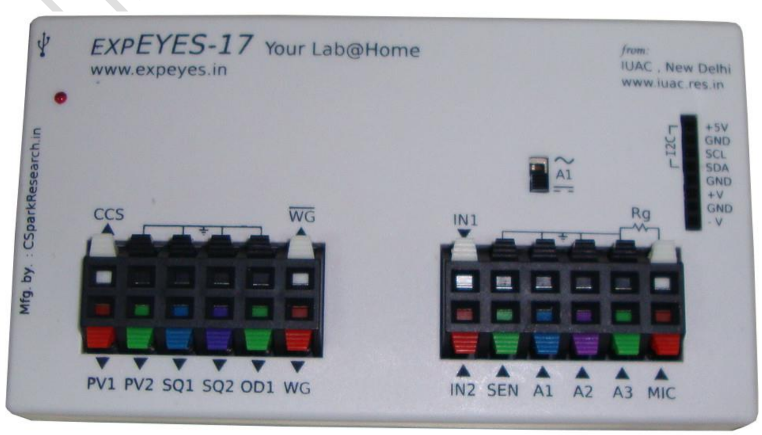
B) Becomes too large

C) Becomes too small

D) Becomes zero

## 2.17 ExpEYES17

ExpEyes-17 is a microcontroller-based device. It can function as a low frequency oscilloscope, function generator, voltage measuring device, programmable voltage source, frequency counter and data logger. It is interfaced with computer through an USB port. A software installed in the computer displays the output and with this software itself the device can be controlled by setting its various parameters. For connecting external signals, it has two spring loaded terminals blocks, one for output signals and another for inputs, as shown in figure. The software can monitor and control the voltages at these terminals. In order to measure other parameters (like temperature, pressure etc.), we need to convert them in to electrical signals by using appropriate sensor elements.



*IMPORTANT:*

The external voltages connected to ExpEYES17 must be within the allowed limits. Inputs A1 and A2must be within±16volts range and Inputs IN1 and IN2 must be in 0 to 3.3V range. Exceeding these limits may result in damage to the equipment. To measure higher voltages, scale them down using resistive potential divider networks.

**Connections:**

The functions of the external connections briefy explained below. All the black colored terminals are at ground potential, all other voltages are measured with respect to it.

**Outputs:**

*1. Constant Current Source (CCS):* The constant current source can be switched ON and OFF under software control. The nominal value is 1.1 mA but may vary from unit to unit, due to component tolerances.

*2. Programmable Voltage (PV1):* Can be set, from software, to any value in the -5V to +5V range. The resolution is 12 bits, implies a minimum voltage stepof around 2.5 millivolts.

*3. Programmable Voltage (PV2):* Can be set, from software, to any value in the -3.3V to +3.3V range. The resolution is 12 bits.

*4. Square Wave SQ1:* Output swings from 0 to 5 volts and frequency can be varied 4Hz to 100kHz. All intermediate values of frequency are not possible. The duty cycle of the output is programmable. SQR1 output has a100Ω series inside so that it can drive LEDs directly.

*5. Square Wave SQ2:* Output swings from 0 to 5 volts and frequency can be varied 4Hz to 100kHz. All intermediate values of frequency are not possible. The duty cycle of the output is programmable. SQR2 is not available when WG is active.

*6. Digital Output (OD1):* The voltage at OD1 can be set to 0 or 5 volts, using software.

*7. Sine/Triangular Wave Equ*i frequency can be varied from 5Hz to 5kHz. The peak value of the amplitude can be set to

3volts, 1.0volt or 80mV. Shape of the output waveform is programmable. Using the GUI sine or triangular can be selected. WG bar is inverted WG.

**Inputs:**

*1. Capacitance meter IN1:* Capacitance connected between IN1 and Ground can be measured. It works better for lower

capacitance values, upto 10 nanoFarads, results may not be very accurate beyond that.

*2. Frequency Counter IN2:* Capable of measuring frequencies up to several MHz.

*3. Resistive Sensor Input (SEN):* This is mainly meant for sensors like Light Dependent Resistor, Thermistor, Phototransistor etc. SEN is internally connected to 3.3 volts through a5.1kΩresistor.

*4. ±16VAnalog Inputs, A1 & A2:* Can measure voltage within the±16volts range. The input voltage range can be selected from .5V to 16V full-scale. Voltage at these terminals can be displayed as a function of time, giving the functionality of a low frequency oscilloscope. The maximum sampling rate is 1 Msps /channel.

*5. ±3.3V Analog Input A3:* Can measure voltage within the ±3.3 volts range. The input can be amplified by connecting a resistor from *Rg* to Ground, gain = 1 + *Rg*/10000. This enables displaying very small amplitude signals.

*6. Microphone input MIC:* A condenser microphone can be connected to this terminal and the output can be captured.

*7. ±6V /10mAPower supply:* The VR+ and VR- are regulated power outputs. They can supply very little current, but good enough to power an Op-Amp.

**The main GUI program:**

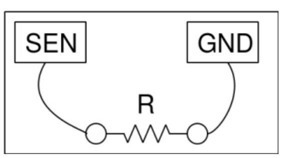
A four-channel oscilloscope screen with several extra features will open as shown in figure. Various experiments can be selected from the menu. The main window looks like a low frequency four channel oscilloscope, with some extra features, on the right-side panel. Applications for various experiments can be selected from the pulldown menu.

**Experiments:**

**1. Measuring Voltage:**

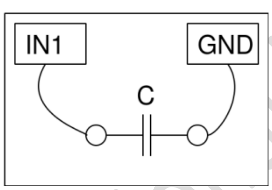

Take a dry-cell and two wires and connect the circuit as shown in the circuit diagram. Observe the voltage displayed at A1. Repeat by reversing the cell connections. We are measuring the potential difference between two points. One of them can be treated as at zero volts, or Ground potential. The voltage measuring points of expEYES measure the voltage with respect to the terminals marked GND. We have connected the negative terminal of the cell to Ground.

**2. Measuring Resistance:**




ExpEYES has a terminal marked SEN, thatcan be used for measuring resistances in the range of 100 Ω to 100kΩ. You can also study the series and parallel combination of resistors. Connect the resistor between SEN and any Ground terminal. Observe the value shown on the right side panel. Try series and parallel combinations.

**3. Measuring Capacitance:**

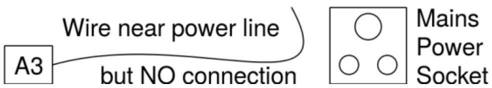



Connect the capacitor between IN1 and Ground. Click on "Capacitance on IN1". Should not touch the capacitor while measuring. Repeat the measurement for Series and parallel combinations. You can make the capacitors by pasting thin metal foils on both sides of insulators like paper, polythene or glass.

**4. Direct and Alternating Currents:**

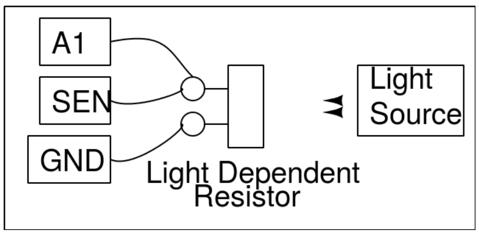

This is to introduce the concept of time dependent voltages, using a V(t) graph, to compare the graph of DC and AC. Set PV1 to 2 volts and Set WG to 200 Hz. Enable analyse on A1, to measure amplitude and frequency. Enable A2. In the plot if voltage is not changing, it is pure DC. If the voltage is changing with time, it has an AC component.

**5. AC mains pickup:**



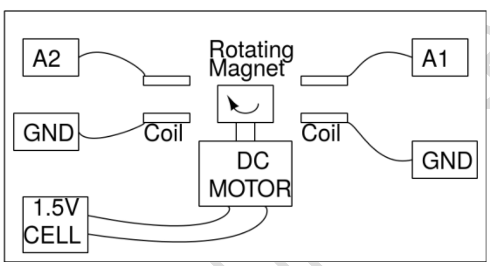

To learn about the AC mains supply and to explore the phenomenon of propagation of AC through free space. Connect a long wire to A3. Take one end of the wire near the AC mains line, without touching any mains supply. Enable A3, and it's analysis. There will be five cycles in 100 milliseconds in the wave form obtained. Without making any connection, how are we getting the AC voltage from the mains supply? Why the voltage increases when you touch the end of the wire connected to A1 by hand.

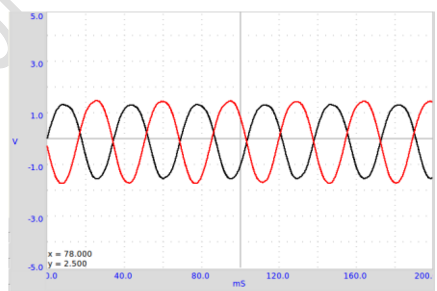
**6. Light dependent resistors:**




To learn about LDR andto measure intensity of light and its variation with distance from the source. Measure the LDR's resistance, for different light intensities. Illuminate LDR using a fluorescent lamp, A1 should show ripples. Put A1 in AC mode and measure ripple frequency. The resistance of the LDR vary from 1kΩ to around 100 kΩ depending on the intensity of light falling on it. The voltage is proportional to the resistance.The resistance decreases with intensity of light.If you use a point source of light, theresistance should increase as the square of the distance between the LDR and the light source.

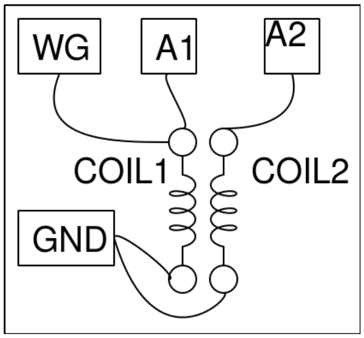
**7. A simple AC generator:**

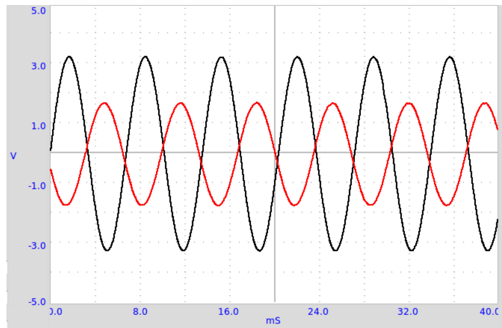


To measure the frequency and amplitude of the voltage induced across a solenoid coil by a rotating magnet. Use the 10 mm x 10 mm magnet and the 3000T coils that comes with the kit. Mount the magnet horizontally and power the DC motor from a 1.5 volts cell. Enable A1 and A2, with analysis option. Set time base to 100 ms full scale. Bring the coil near the magnet (not to touch it), watch the induced voltage. Repeat the experiment using 2 coils. The voltage output is shown in figure. The phase difference between the two voltages depends on the angle between the axes of the two coils.

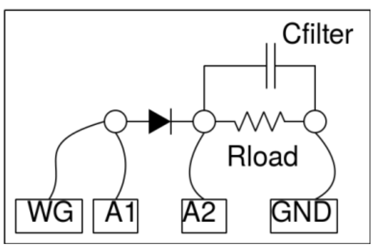
**8. AC Transformer:**




To demonstrate mutual induction using two coils, supplied with ExpEYES. One coil, the primary, is connected between WG and Ground. The axes of the coils are aligned and a ferrite core is inserted. Make connections as shown in the figure. Enable A1 and A2. Set WG to 500 Hz. Bring the coils close and watch the voltage on A2. Try inserting an ion core.

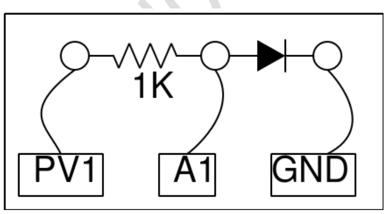
**9. Half wave rectifier using PN junction:**

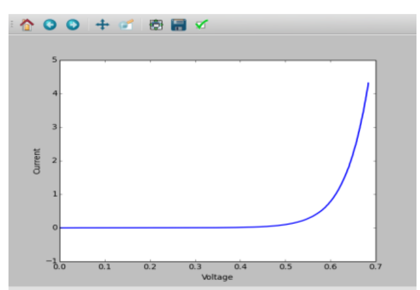



To learn the working of a PN junction diode as a rectifier and RC filtering to reduce the ripple (the AC component). Make connections and observe the output. Connect a 1k load resistor, note the difference in amplitude. Connect a 1uF capacitor, and see the filtering effect. Try different values load resistors and filter capacitors.

The negative half is removed by the diode. Also notice that the voltage in the positive half is reduced by around 0.7 volts, the voltage drop across a silicon diode. A load resistor is required for the proper operation of the circuit, it could be more than 1kΩ but do NOT use very low values since our AC source can drive only up to 5 mA current. We can see that the capacitor charges up and then during the missing cycle it maintains the voltage. The remaining AC component is called the ripple in the DC.

**10. Diode I-V characteristics:**

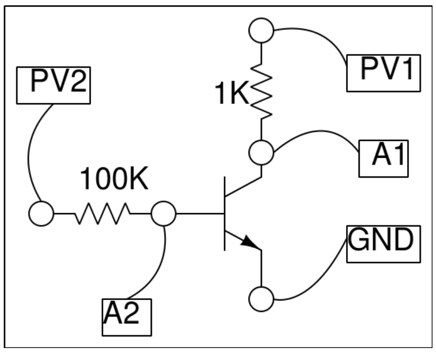


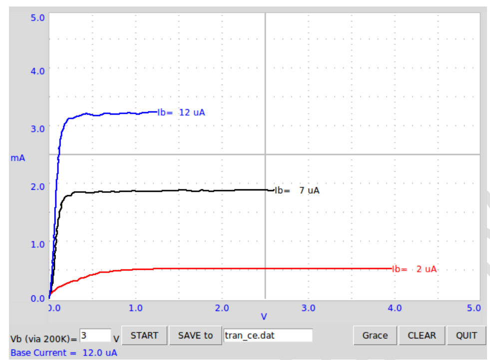




To draw the I-V Characteristic of diode. Make connections as shown in the circuit diagram. Click on START to draw the characteristic curve. Then plot the IV of LEDs by replacing the diode by a LED. The voltage $V_0$at which LED starts emitting light depends on its wavelength and Planck's constant. Energy of a photon is given by $E = h\nu = hc/\lambda$. This energy is equal to the energy of an electron that overcomes the junction barrier and is given by $E = eV_0$. So

Planck's constant $h = eV_0 \lambda/c$, where $\lambda$ is the wavelength of light from the LED, $e$ the charge of electron and $c$ the velocity of light. $V_0$ is the voltage at which the LED just glows.

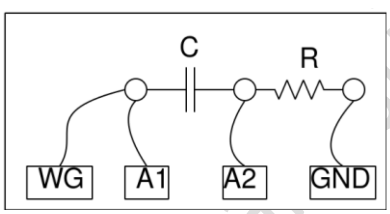
**11. Transistor Output characteristics (CE):**

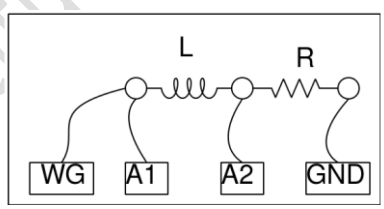


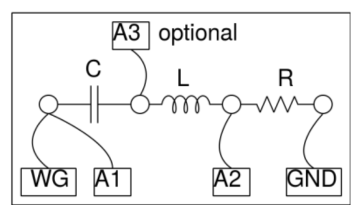




To plot the output characteristic curve of a transistor. Collector is connected to PV1 through a 1K resistor. Set base voltage to the 1 volt and START. Repeat for different base currents. The characteristic curves for different base currents are shown in figure. The collector current is obtained from the voltage difference across the 1k resistor. The base current is set by setting the voltage at one end of the 100 k Ω resistor, the other end is connected to the transistor base.

**12. RLC circuitsin AC:**



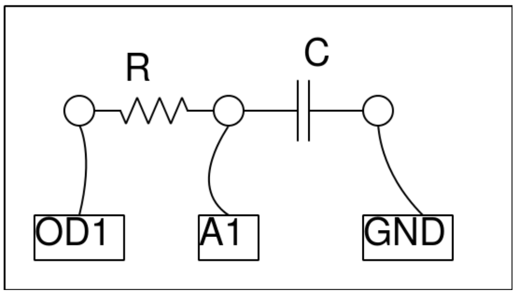

To study the effect of series LCR elements in an AC circuit. Three different combinations can be studied. Make connections one by one, as per the drawing. Note down the amplitude and phase measurements, in each case. Repeat the measurements by changing the frequency. For RLC series circuit, the junction of L and C is monitored by A3. For resonance select C = 1uF, L = 10mH and $f$= 1600 Hz, adjust $f$ to make phase shift zero. The total voltage across L and C together goes almost to zero, the voltage across them are out of phase at resonance.

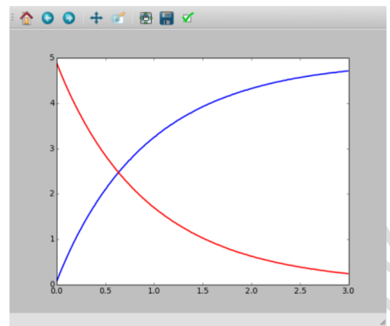
**13. Transient Response of RC circuits:**

To plot the voltage across a capacitor, when it is charged by applying a voltage step through a resistor and to calculate

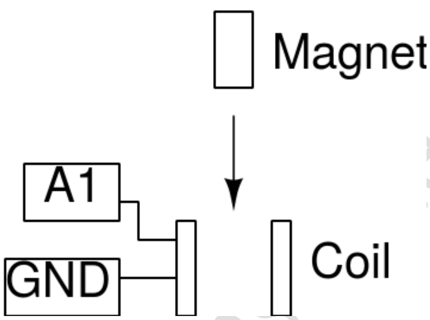
the value of the capacitance from the graph. From "Electrical" menu, select RC Transient response. Click on 0->5V STEP and 5->0V step Buttons to plot the graphs. Adjust the horizontal scale, if required, and repeat. Calculate RC time constant.

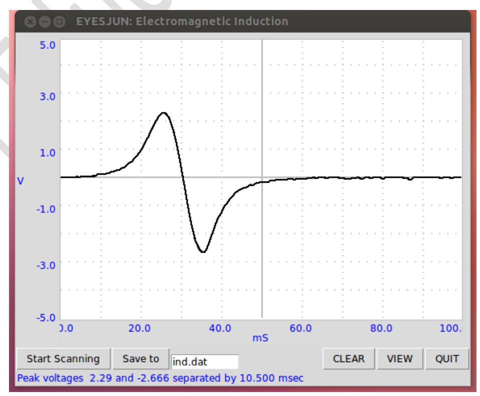
Applying a 0 to 5V step makes the voltage across the capacitor to rise exponentially as shown in the figure. By fitting the discharge curve with $V(t) = V_0 \exp(-t/(RC))$,we can extract the RC time constant and find the values of capacitance from it. The voltage across a capacitor is exponential only when it is charged trough a linear element, a resistor for example. When charged from a constant current source, the voltage shows linear increase, because $Q = It = CV$, and voltage increases linearly with time as $V = (I/C)t$.



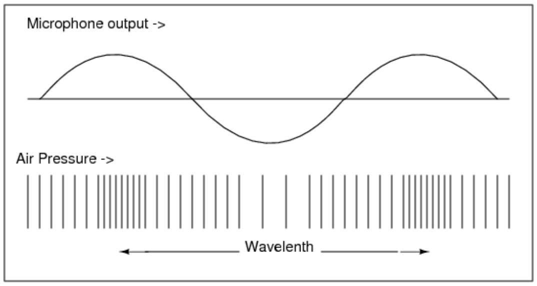
**14. Electromagnetic induction:**

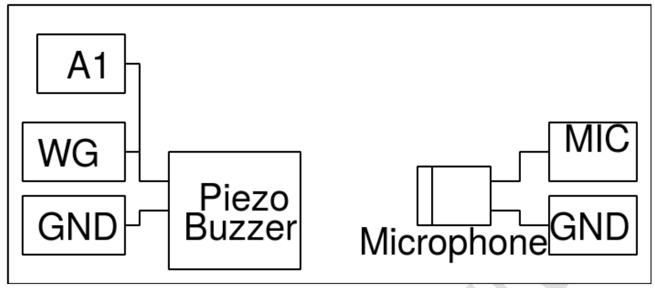



Explore the voltage induced across a coil by a changing magnetic field, by dropping a small cylindrical magnet into a coil. Use a tube to guide the magnet through the coil. Click on Start Scanning. A horizontal trace should appear. Drop the magnet through the coil, until a trace is caught. Repeat the process by changing the parameters like magnet strength, speed etc. The result is shown in figure. The amplitude increases with the speed of the magnet. From the graph, we can find the time taken by the magnet to travel through the coil. The second peak is bigger than the first peak. Why ? Where will be the magnet at the zero crossing of the induced voltage? Drop the magnet from different heights and plot the voltage vs square root of the height.

**15. Velocity of sound:**

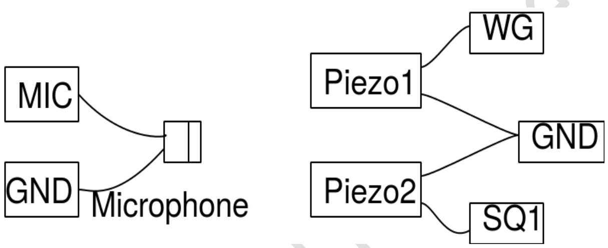



To measure the velocity of sound by measuring the pressure variation with distance. Sound travels as a series of compressions and rarefactions. Figure shows the High- and Low-pressure regions along the direction of travel, along with output of a pressure sensor at corresponding positions. We can display the pressure variation at any point with respect to the variation at the starting point. The phase of the microphone output changes as you change its distance from the Piezo. Moving by one wavelength changes the phase by 360degrees. If the phase changes by$X$degrees for$D$cm change in distance, the wavelength is given by$\lambda = 360D/X$velocity of sound can be calculated by multiplying the frequency with this.

Set frequency to resonant maximum by measuring the frequency response of the piezo. Keep the Piezo facing the microphone, on the same axis. Enable measurement. Adjust the distance to make both the traces in Phase. Change the distance to make them 180 degree out of phase, that distance is half wave length.

**16. Sound beats:**




To study the interference of sound from two individual sources. Two Piezo buzzers are powered by two different sources, and the sound is directed towards the microphone. Set WG to 3500 Hz and SQ1 to 3600 Hz. Enable WG and SQ1 separately to check the MIC output. Adjust positions of Piezo buzzers, from the mic, to get almost same amplitude with both. Select both of them to get the beat pattern.

**Bibliogrphy:**

1. expEYES-17 User's Manual, *Experiments for Young Engineers and Scientists*, http://expeyes.in from PHOENIX Project. expEYES-17 user's manual is distributed under GNU Free Documentation License. The above content is an extraction from this manual and is made for this training program. For more details and some more experiments refer to this manual.

# 3. Training programme

The training programme commenced on the 1st October 2018 as per the schedule. The participants included only the PU lecturers of Telangana state. After the registration of the participants, there pre-test conducted in order to evaluate the programme success. Dr. T. V. Somashekher and Mr. Noufel started the first session by revisiting the pedagogical approaches in teaching of science, which was followed by discussions. After lunch, first session was taken by Dr. Sujatha B H on Reflection- Teaching science followed by discussion. Last session of the day was taken by Dr. Biju K on Conception ans misconceptions in Physics followed by the discussions on alternate concepts. After that presentation and feedback of the day by the KRP's and came to an end of the activities of first day.

The second day activity began with a reflection of the day one. This was followed by a presentation on Wave optics by Dr. B V Sadashivamurthy followed by the second session on Mechanical properties of fluids by Dr Biju K. In the afternoon, KRP's were made in two groups to carry on the lab experiments of PUC-I and PUC-II level. This went on for the rest of the day followed by feedback and presentations by KRP's.

The third day activity began with a reflection of the day two. This was followed by a presentation on Electromagnetic induction by Mr. Mr. V K Manohar K followed by the second session on Semiconductors and communication system by Dr B V Sadashivamurthy. In the afternoon, KRP's were exchanged the groups to carry on the lab experiments of PUC-I and PUC-II level. This went on for the rest of the day followed by feedback and presentations by KRP's.

The fourth day activity began with a reflection of the day three. This was followed by a presentation on System of particles and rotational motion by Dr. C K Raman N followed by the second session on Gravitation by Dr. Niranjana K M. In the afternoon, third session on Electric Charges and fields by Mr. Justin John followed by exposure to RIE studio where KRP's were made aware by the studio team about making of e content. Last session on Thermodynamics by Dr. Pramod T. This went on for the rest of the day followed by feedback and presentations by KRP's.

The fifth day began with the reflections of the fourth day activities and then the fifth day activities began with a presentation on System of particles and rotational motion by Dr. C K Raman N followed by the second session on Newton's Laws of motion by Mr. Santosh Kumar. In the afternoon, third session on Alternating currents by Mr. Justin John followed by the post. The post-tea session was a valedictory session, where the **Principal of the institute, Prof. Y Sreekanth** and **Prof. C G V Murthy, Head, Department of Extension**, addressed the participants and the resource persons. They thanked all the resource persons and congratulated the participants. The views of resource persons and some participants were sought. The valedictory session ended with a formal vote of thanks by the Coordinator.

## Schedule

# Regional Institute of Education Mysuru- 570006

PAC . Programme. Training higher secondary teachers in content and methodology of teaching physics (Telangana)

Venue- Room No. T-4 Tech Block RIE Mysuru

| Date\Time | (0900-0930) Hrs | (0930-1100) Hrs | (1115-1245) Hrs | (1245-1330) Hrs | (1330-1500) Hrs | (1500-1545) Hrs | (1600-1730) Hrs | (1730-1800) Hrs |
|---|---|---|---|---|---|---|---|---|
| 1/10/2018 (Monday) | Registration | Inaugural ( 0930-1000)Hrs, Pre-Test (1000-1100)Hrs | Padegogical Approaches-Teaching of Science ( TVS/Noufel) | Lunch | Reflection - Teaching Science ( SBH) | Presentation by the participants | Conceptions & Misconceptions in Physics ( BK) | Presentation by the participants/ Reflections of the day |
| 2/10/2018 (Tuesday) | Presentation by the participants | Wave Optics ( BVS) | Mechanical Properties of fluids( BK) | | Lab Session PUC 1 ar ( SK, NKM, PT, SBM, KK, ARP) | | | Presentation by the participants/ Reflections of the day |
| 3/10/2018 (Wednesday) | Presentation by the participants | Electromagnetic Induction ( VKMK) | Semiconductors and Communication System (BVS) | | Lab Session PUC 1 ar ( SK, NKM, PT, SBM, KK, ARP) | | | Presentation by the participants/ Reflections of the day |
| 4/10/2018 (Thursday) | Presentation by the participants | System of Particles & Rotational Motion (CKRN) | Gravitation (NKM) | | Electric Charges & fields(JJ) | Presentation by the participants | Thermodynamics (PT) | Presentation by the participants/ Reflections of the day |
| 5/10/2018 (Friday) | Presentation by the participants | System of Particles & Rotational Motion (CKRN) | Newton's Laws of Motion (SK) | | Alternating Currents(JJ) | Post -Test | Valedictory (1630-1700) hrs | |

BVS- Dr.B. V. Sadashivamurthy, TVS- Dr. T . V. Somashekar, SBH- Dr. Sujatha B. H., BK- Dr. Biju K., CKRN- Dr. Raman N.C.K., Sk-Mr. Santosh Kumar, VKMK- Mr. V.K.Manohar K., JJ-Mr. Justin John, NKM- Dr. Niranjan K. M., PT- Dr. Pramod T., SKM- Dr. Sankarshan B. M., KK- Mr. Karthik Kumara, APR- Mr. Ananda R. P., Noufel

Tea Break- (1100-1115) Hrs , (1545-1600) Hrs

Santosh Kumar
Programme Co-ordinator

Copy to-
1. Resource persons,
2. Principal office,
3. Head DESM/ DEE,
4. PAC file

## List of Resource Persons

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| 11 | Justin John<br>Assistant Professor, Department of Physics,<br>St Berchmans College, (Autonomous) Changanacherry, Kerala | 9447803668<br>jusinpjohn@gmail.com |

| | | |
|---|---|---|
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| 13 | Dr Sujata B Hanchinalkar<br>Assistant Professor, DE, RIE, Mysuru | |
| 14 | Mr Noufal P<br>Assistant Professor (Contractual), DE, RIE, Mysuru | 8078119884<br>noufalmrk@gmail.com |

## List of Participants

| Sl.No. | Name, Designation, Address | Phone Number & E-mail ID |
|---|---|---|
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| | | |
|---|---|---|
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# 4. Outcomes of the training programme

Pre-Test and Post Test have been carried out to check the effectiveness of the programme "**Training higher secondary teachers in content and methodology of teaching Physics (Telangana)"** to explore the extent to which learning activities provided by the different resource person during the course of training programme influence the learning outcomes. Further, feedback on session wise-resource person wise and overall feedback of the programme have been taken from the all the participants.

## Results

1. **Pre-Test and Post-Test**
    - The mean score of pre-tests is 28.2 marks.
    - The mean score of post-tests is 34.1 marks.
    - Question wise analysis shows that there is a scope of improvement in the field of topics-rotational motion, laws of motion, alternating currents, Wave optics.

2. **Session-wise/resource person -wise overall feedback (Excellent-5, VERY GOOD-4, GOOD-3, AVERAGE -2, BELOW AVERAGE-1**

| S.No. | Domain | Level |
|---|---|---|
| | | Mean Value |
| 1 | The objectives of the training are clearly defined | 4.9 |
| 2 | Participation and interactions were encouraged | 4.9 |
| 3 | The topics covered relevant to me | 4.8 |
| 4 | The content was organized and easy to follow | 4.9 |
| 5 | The resource person was knowledgeable about the training topic | 4.7 |
| 6 | The usefulness of the information received in session | 4.8 |
| 7 | The structure of the training session. | 4.95 |
| 8 | The pace of the training session. | 4.9 |
| 9 | The usefulness of the training materials | 4.9 |
| 10 | Was this training session appropriate for your level of experience? | 4.9 |
| 11 | Overall rating of the session | 4.9 |

3. **Overall Feedback of the Programme (Excellent-5, VERY GOOD-4, GOOD-3, AVERAGE -2, BELOW AVERAGE-1**

**PART-A**

| S.No. | Domain | Level |
|---|---|---|
| | | Mean Value |
| 1 | The objectives of the training are clearly defined | 4.9 |
| 2 | Participation and interactions were encouraged | 4.8 |
| 3 | The topics covered relevant to me | 4.8 |
| 4 | The content was organized and easy to follow | 4.8 |
| 5 | The resource persons were knowledgeable about the training topics | 4.8 |
| 6 | The usefulness of the information received in training. | 4.9 |
| 7 | The structure of the training sessions. | 4.95 |
| 8 | The pace of the training sessions. | 4.9 |
| 9 | The convenience of the training schedule | 4.9 |
| 10 | The usefulness of the training materials | 4.9 |
| 11 | Was this training appropriate for your level of experience? | 4.95 |
| 12 | Assistance from office staff | 4.9 |
| 13 | Infrastructure facilities | 4.8 |
| 14 | Overall rating of the course | 4.95 |

**PART B (Consolidated views of all participants)**

1. What did you like most about this training?

Interactive sessions with knowledge sharing and demonstrations of concepts.

2. What aspects of the training could be improved?

More time to be given to lab sessions since four lab sessions are not enough.

3. How do you hope to change your practice as a result of this training?

The way of teaching in physics by using demonstrations, ICT, etc.

4. What additional trainings would you like to have in the future?

Training on more hard spots for five days training not sufficient for all hard spots.

5. Please share other comments:

Inclusion of different Methodology and teaching techniques in physics is important that is proved by the programme. Regular training should be conducted once in an academic year.

## Findings

The following are the major findings arrived from the analysis

The level of training is highly influenced by the content and methodology of teaching chosen for the training program.

It is found that medium number of participants (25) in a training program is found to be optimum for an effective training.

It is pinpointed that an interactive capability of the trainee during the training has a good impact on training effectiveness.







*“If you can't explain it simply,
you don't understand it well enough.”*

- Albert Einstein

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