COURSE GUIDE

SED 323
GENERAL PHYSICS FOR INTEGRATED SCIENCE

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CONTENTS

Introduction

SED 323 - General Physics for integrated science exposes you to the rudiments concepts theory/principles, examples, application of physics concepts as components that constitutes the integral part of integrated science. It is expected that participants will acquire both cognitive and psychomotor constituents that will bring a clearer understanding of physics concepts as they relate to life and development. Hence, provides an enhanced exposure to contents in such areas as: magnetic fields, electromagnetic induction and modern physics.

What You Will Learn From This Course.

Participant will learn, be exposed to physics concepts as it relates to magnetic fields, electromagnetic induction and modern physics that form the component of the integrated part of integrated science as a school subject.

Course Aims

The aim of this course is to arm participants by exposing them to a clearer understanding of physics concepts, theories/principles examples, application of these concepts to real life situation as components what the integrated nature of science.

Course Objectives

By the end of this course, participants should be able to:

1. Define Various Concepts such as; Magnetic fields; Magnetic flux of wire; Solenoid; Ampere in terms of force existing between conductors; transformers types of radioactivity and so on.
2. Explain concepts of magnetic field, electromagnet, magnetic field due t o a solenoid, meaning and conditions for electromagnetic induction, working principles of a Dynamo generator, and a transformer of short and long life and what carbon and radio activity is.
3. State the followings:
    - i. Properties of a magnetic line of force
    - ii. Application of electromagnets to man
    - iii. Factors that a magnetic flux depends upon.
    - iv. Working principles of a solenoid
    - v. Factors that affect the magnetic flux B of a long conductor
    - vi. Magnitude of the force existing between parallel conductors.
    - vii. Faraday and lenz's Laws of electromagnetic induction
    - viii. Properties of nucleus and radioactive particles

   ix. The major particles emitted fission and fusion reaction.
4. Describe various situation and conditions such as: magnetic field around a magnet and some magnetic materials; Force acting on a conductor; Behaviour of long current carrying conductors; an elective motor; the structure and content of the atomic nucleus; Radioactivity transformation and Fusion and Fission reaction.
5. Draw the following:
   i. A bar magnetic in non-uniform, Uniform and soft iron.
   ii. Working of an electric bell and Telephone earpiece
   iii. A diagram showing the magnetic field of a solenoid.
   iv. Show the magnetic flux B for a narrow coil.
   v. Sketch, when a bar Magnet in pushed into a coil of wire.
   vi. A transformer
6. Calculate /solve problems involving the concepts such as: on force acting on a conductor; Determine energy involved in simple nuclear reaction; determine the time taken by a sample to decay to half its initial number, calculate B for any shape of conductor and due to a long straight wire and find the rate of decay of a radioactivity sample.
7. Deduce the application of an electric motor to man.

Working Through the Course

In this course you are expected to read the 20 units and other relevant text books, journals, online facilities provided by the National Open University of Nigeria at the end of each unit of the work.

Each unit contains main content, in most cases diagrams providing a clearer view of the concept (s) and self-assessments exercise (SAE) as practice and you are required to work on the assignments, with due diligence, submit the assignments that would be marked and recorded as part of your continuous Assessment. SED 323 in expected to last for one semester, at the end of the course, there is the final examination you will find listed, all the components of the course, what you have to do and how you should allocate your time to each unit so that you can complete the course successfully.

Assignments

There are twenty-one assignments in this course, covering all the 20 units. You are expected to complete and submit these assignments to your facilitators in course of the study. It is important to note that, the marks you will obtain from the assignment will form the continuous assessment which will count towards your final mark you will obtain from this course. You are encouraged to utilize the in text reference to enrich your studies.

The Course Materials

The National Open University of Nigeria will provide you with the following:

The Coursed Guide: This consist of 3 modules, all put together having 20 units. Also at the end of each unit are list of references for further consultation and reading and you will do well by also utilizing the Online facilities.

Study Units

The study unity consist of:

Module 1 Magnetic Fields

Unit 1	Concept and Meaning of Magnetic Fields
Unit 2	Electromagnets and the Applications of Electromagnetic Force
Unit 3	Force on a Conductor
Unit 4	Field Due to Solenoids
Unit 5	Field Due to Long Conductor
Unit 6	Biot-Savert Law
Unit 7	Forces Between Current

Module 2 Electromagnetic Induction

Unit 1	Electromagnetic Induction
Unit 2	Faraday's and Lenz's Law of Electromagnetic Induction
Unit 3	The Dynamo Generator
Unit 4	Transformer
Unit 5	Electric Motor

Module 3 Modern Physics

Unit 1	Concept of Nuclear Atom
Unit 2	Radioactivity
Unit 3	Nuclear Reactions
Unit 4	Nuclear Fission and Fusion
Unit 5	Rate of Radioactive Decay and Half Life
Unit 6	Measurement of Short and Long Half-Life
Unit 7	Dating
Unit 8	Relativity

The Units in module 1: magnetic fields, centered on concept and meaning of magnetic fields; Electromagnetism and application of electromagnetic force, Force on a conductor, field due to Solenoids, fields due to long conductor, Biot-Savert Law and forces between current.

Module 2, content on electromagnetic induction, with detail treatment in the 5 units of electromagnetic induction, Faraday and Lenz's Law of electromagnetic induction, the Dynamo generator, transformer and electric monitor.

Module 3, centered on Modern Physics, where detail explanations to the main contents that deal with concept of modern Atom, Radioactivity Nuclear reactions, Nuclear Fusion and Fission, rate of radioactivity decay and Half life measurement of short and long life, Dating and Relativity.

Assessments

There are three aspect of assessments, First are SAEs, second Tutor Marked Assignments (TMAs) and the third is the final Examination.

Self – Assessment Exercise (SAE)

These self-assessment exercise are there to help enrich you in the content knowledge psychomotor activities, hence you are expected to deploy positive affective domain in attending to the exercises. The exercise must be submitted to your tutor for formal assessments in accordance with the dead line stated in your schedule of presentation/academy calendar.

Tutor-Marked Assignment

In addition to the fourteen unit assignments at the end of each unit, you are going to take three Tutor Marked Assignments(TMAs) in this course, and you are advised to attempt all. The TMA may be a Fill-in the Blank Spaces Question (FBQ) or Multiple Choice Question (MCQ) format and each of them carries 10 marks making a total of 30 marks for the three TMAs.

Aside from your course material provided, you are advised to read and research widely using other references which will give you a broader viewpoint and may provide a deeper understanding of the subject.

Ensure all completed assignments are submitted on schedule before set deadlines. If for any reasons, you cannot complete your work on time, contact your tutor before the assignment is due to discuss the possibility of an extension. Except in exceptional circumstances, extensions may not be granted after the due date.

Final Examination

The final examination for this course will be of two hours duration and have a value of 70% of the total course grade. All areas of the course will be assessed and the examination will consist of questions which reflect the type of self-testing, practice exercise and tutor assignments you have previously encountered. Utilize the time between the conclusion of the last study unit and sitting the examination to revise the entire course. You may find it useful to review your self-assessment exercises, tutor marked assignments comments on them before the examination.

Course Marking Scheme

The work you submit will count for 30% of your total course mark. At the end of the course however, you will be required to sit for a final examination, which will also count for 70% of your total marks. The grand total for the course would remain 100%.

How To Get the Most from This Course?

In distance learning, the study materials are specially developed and designed to replace the lecturer. Hence, you can work through these materials carefully at your pace, and at a time and place that suits you best. The course material is interactive enough and allows you to fill the gap created by the absence of the teacher in a face-to-face encounter. However, the online synchronous facilitation and instructional video supplements are also meant to bridge this gap.

Each of the study unit follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next is a set of learning objectives/outcomes. These objectives let you know what you should be able to do by the time you have completed the unit. Use these objectives to guide your study.

On finishing a unit, go back and check whether you have achieved the objectives. If made a habit, this will further enhance your chances of completing the course successfully.

The following is a practical strategy for working through the course:

- ❖ Read this course guide thoroughly.
- ❖ Organise a study schedule, which you must adhere to religiously. The major reason students fail is that they get behind in their course work. If you encounter difficulties with your schedule, please let your tutor/ facilitator know promptly.
- ❖ Turn to each unit and read the introduction and the objectives for the unit.
- ❖ Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow.
- ❖ Review the objectives of each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult with your tutor.
- ❖ When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through

the course and try to pace your study so that you keep yourself on schedule.

- ❖ After submitting an assignment to your facilitator for grading, do not wait for its return before starting on the next unit. Keep to your schedule. When the assignment is returned, pay particular attention to your facilitator's comments.
- ❖ After completing the last unit, review the course and prepare yourself for final examination. Check that you have achieved the units objectives (listed at the beginning of each unit) and the course objectives listed in this course guide.

Facilitators/Tutor and Tutorials

- ❖ There will be specific time made available for tutorial sessions, in support of this course. You will be notified of the dates, time and location of these tutorials, together with the name and phone number of your tutor, as soon as you are allocated a tutorial group.
- ❖ Your tutor will mark and comment on your assignments, keep a close watch on your progress and on any difficulties you might encounter and provide assistance to you during the course. You must mail your tutor marked assignments to your tutor well before the due date. They will be marked by your tutor and returned to you as soon as possible.
- ❖ Do not hesitate to contact your tutor by telephone, e-mail or your discussion group (board) if you need help.
- ❖ The following might be circumstances in which you would find help necessary. Contact your tutor if:
- ❖ You do not understand any part of the study unit or the assigned readings.
- ❖ You have difficulty with the self – tests or exercises.
- ❖ You have a question or problem with an assignment, with your tutor's comments on an assignment or with the grading of an assignment.

You should try your best to attend the tutorials. This is the only chance to have face-to-face contact with your tutor and to ask questions which are answered instantly. You can raise any problem encountered in the course of your study. To gain the maximum benefit from course tutorials, prepare a question list before attending them. You will learn a lot from participating in discussions actively.

Summary

This course is designed to give to you some insight and knowledge that would help you improve your understanding of physics concepts impeded in the integrated science curriculum. I therefore, sincerely wish you the best and that you enjoy the course.

MAIN COURSE

CONTENTS

MODULE 1 MAGNETIC FIELDS

You are welcome to Module 1 of our course material. In this module you will be exposed to the concepts of magnetic fields, force on a conductor, moving charge fields due to solenoids, long conductor, and Biot-sarvert law.

Unit 1 Concept of Magnetic Fields
Unit 2 Force on a Conductor
Unit 3 Fields due to Solenoid
Unit 4 Fields due to Long Conductors
Unit 5 Biot-Savert Law

UNIT 1 CONCEPT AND MEANING OF MAGNETIC FIELDS

Unit Structure

1.1 Introduction
1.2 Learning Outcomes
1.3 Concept of Magnetic field
  1.3.1 Properties of a magnetic field lines/just highlight
  1.3.2 Direction of Current and Fields: Corkscrew Rule
1.4 Summary
1.6 References/Further Readings/Web Resources
1.7 Possible Answers to Self-Assessment Exercise(s)

1.1 Introduction

In our Integrated Science and Physics at the secondary school level, we learnt and performed simple experiments that involved magnetism. We learned out that a bar magnet has two poles, a north pole and south pole. We also found that unlike poles attract each other and like poles repel each other.

Self-Assessment Exercise 1

1: Spring iron fillings on a glass plate placed above a magnet what do you observe?
2. Define a field?

If a bar magnet is suspended by a delicate fiber, one

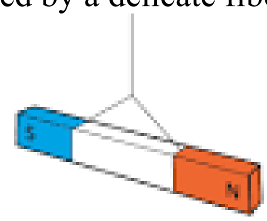


Fig 1: Showing the North Pole of a magnet is defined to the pole that points Northward on the earth when the magnet is freely suspended.

Particular end always points approximately Northward on the earth. This end is called the North pole of the magnet; the other end is the South pole. This device is simply a simple compass.

Also studies with magnet shows that the North poles of two magnets repel each other and that the South pole of one magnet is always attracted to the north pole of another magnet. If one tries to separate the North pole of a bar magnet from the South Pole by breaking the Magnet into two, the effort proves unsuccessful. Because the broken magnet becomes two new bar magnets, each with a North Pole and a South Pole. In this unit leaners are exposed to the concept of magnetic field behaviour of magnets, properties of magnetic field, direction of current and fields (corkscrew Rule).

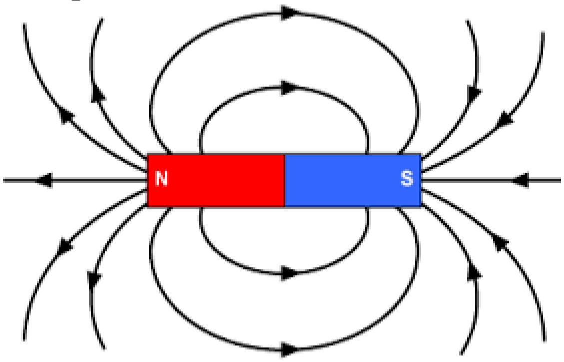
1.2 Learning Outcomes

By the end of this unit, you should be able to:-

- Explain the concepts of a magnetic field.
- Describe magnetic fields around magnet and some magnetic materials
- Draw a bar magnet in a non-uniform, uniform and self iron in earths field
- State the properties of magnetic line of force.

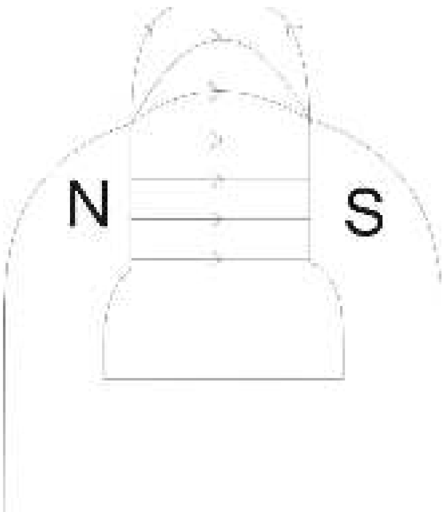
1.3 Concept of Magnetic field

A magnetic field is a region around a magnet; where a magnetic force is experience or the magnetic field of a magnet is also the result of the motion of charges. It can also be seen as a region around a magnet where electric current or charge electric field is experienced. To sketch a magnetic field, we draw a series of lines about the magnet in such a way that the arrows on the lines show the direction of the lines of force that emerge from the North and enter the South.



(a)

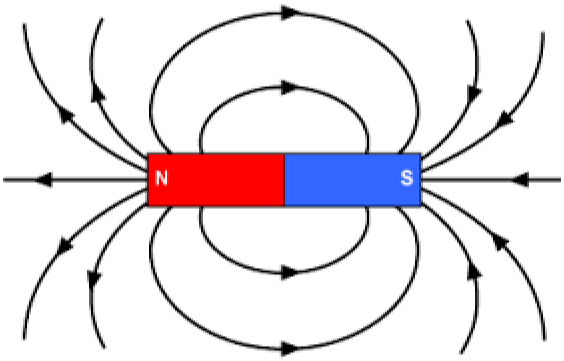
(b)



(c)

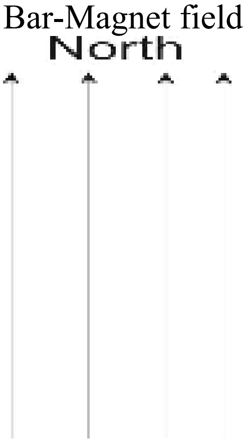
Fig. 2: The Magnetic field points away from the North pole of a magnet and to the south pole.

Now, consider the direction of a magnetic field is taken as the direction of the force on a North pole, if placed in the field. Also lines of force can be drawn to indicate the field on non-uniform (earth's local field), solf iron (earths field and solenoid) imagine the nature of the magnetic field, then draw the sketch.



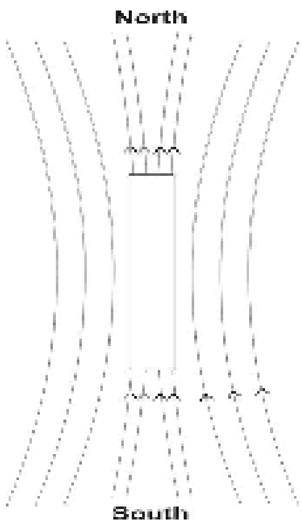
(i)

Bar-Magnet field (non-uniform)



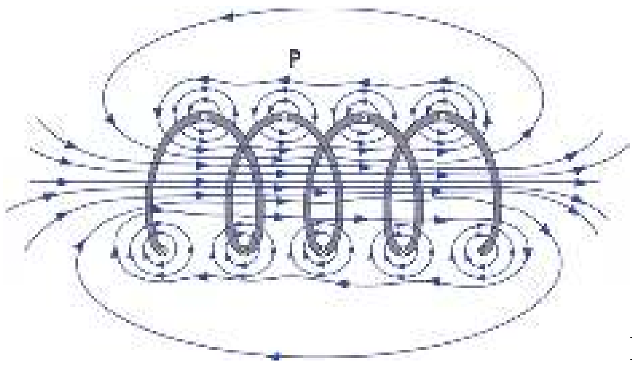
(ii)

Earth's Local Field (Uniform)



(iii)

Soft Iron in Earths Field



Field Row Solenoid

Fig. 3: Magnetism on a non-uniform field, solf iron and solenoid

Fig. 3 (i): shows a field around a bar-magnet is non-uniform that is, its strength and direction vary from place to place.

Fig. 3 (ii) The earth field locally however is uniform. It means it does not change irrespective of place.

Fig. 3 (iii) A bar of solf iron place north-south becomes magnetized by induction by the earth's field and the lines of force become concentrated in the soft iron. The tangent to a line of force at a point gives the direction of the magnetic field at that point.

Fig. 3 (iv) A perspective view of a loosely wound solenoid.

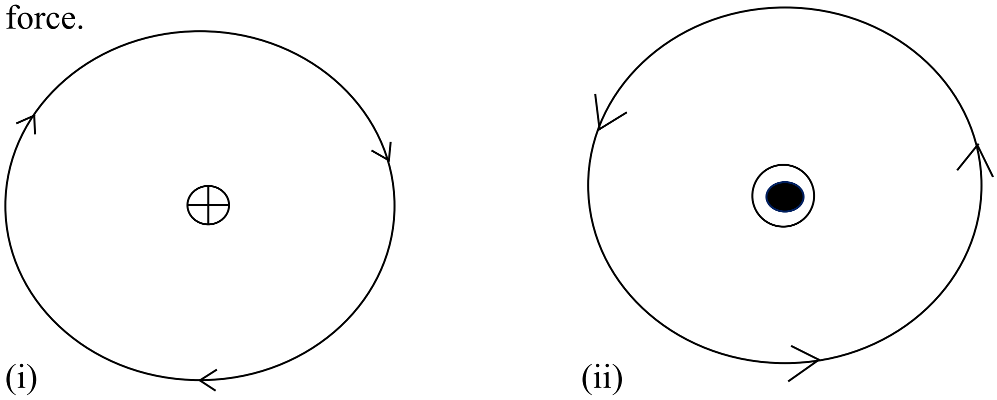
Theappearance of magnetic field can be obtained by using iron fillings and plotted with a small compass around the magnetic materials where the fields is showing the magnetic lines of force becomes dense while the weaker field shows lines of less concentration.

1.3.1 Properties of a magnetic field lines/just highlight

1. The direction of the magnetic field is tangent to the field line at any point in space: A small compass will point in the direction the field line.
2. The strength of the field is proportional to the closeness of the lines. It is exactly proportionate to the number of lines per unit area perpendicular to the lines.
3. Magnetic field of lines can never cross meaning that the field is unique at any point in space.
4. Magnetic field line are continuous, firmly closed loops without beginning or end. They go from North pole to South pole.

1.3.2 Direction of Current and Fields: Corkscrew Rule

The relationship between the direction of the lines of force (field) and of the current is expressed in Maxwell's Corkscrew rule: Imagine you drive a cork screw into and out of the paper in the direction of the current, then the turning motion is in the direction of the field arrow. It then means that the direction of rotation of the corkscrew is the direction of the line of force.



(i) (ii)

Fig. 4: Illustrating Corkscrew rule

The illustration in fig 4 shows that, small, heavy circles representing the wire, and the large light one, a line of force. At (i), the current is flowing into the paper; its direction is indicated by a cross, showing the tail of an arrow moving away from the reader. At (ii) the current is flowing out of the paper; the dot in the center of the wire stands for the points of an approaching arrow. This implies that a wire carrying a current through a region in which a magnetic field exits experiences a force due to the field

Self-Assessment Exercise 2

The North pole of a bar magnet is brought close to an unmagnetic iron nails. What does the field of the magnet do to the nail? Why are nails attracted by the magnet?

1.4 Summary

This unit discussed the meaning and concept of magnetic field, behaviour of magnet in a Non- uniform, uniform and soft Iron on Earths field row solenoid. Also we have been able to learn the properties of a magnetic field lines of forces and the direction of current and fields (Corkscrew rule), Magnetic field is the region where magnetic force is experienced, Lines of force that are drawn on a bar magnet indicates the arrow as they energy from the North pole and enter the South pole, Magnetic fields can be fictionally represented by magnetic field lines, whose properties are as follows:(i.) The field is tangent to the magnetic field line; (ii.) Field strength is proportioned to the line density; (iii) Field lines cannot cross; . (iv) Field lines are continues loops.

A wire carrying a current through a region in which a magnetic field exist experience a force due to the field.

Tutor-Marked Assignment

Place a piece of glass on a bar magnet. Springle iron fillings on the glass, what do you observe? Draw the spread pattern of the action of iron fillings on the bar magnet

1.5 References/Further Readings/Web Resources

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1.6 Possible Answers to Self-Assessment Exercise(s)

1. When a pieces of paper is placed on top of a magnet and the iron fillings are sparingly lightly on to the paper, and the paper is tapped gently the Iron fillings turn and line up in definite directions. Iron fillings behave this way because they become induced magnets in the field of the magnet, and when free, they behave like miniature compass needles and settle along lines of force.
2. A field is a region of space under the influence of some physical agency such as gravitation magnetism and electricity.
3. The iron nails with be given polarity of North and South thus a North pole of the bar magnet mill be attracted to the nails of opposite polarity of South pole. Thus showing that like or similar poles (i.e two N or two S) poles repel and one N and one S alike attract.

UNIT 2 ELECTROMAGNETS AND THE APPLICATIONS OF ELECTROMAGNETIC FORCE

Unit Structure

2.1 Introduction

Application of electromagnetic force is crucial to providing in-depth understanding of electromagnets. How magnets are made, their application to the principle of electric bell, telephone earpiece and their workings. These are common household/office gadgets that help man.

2.2Learning Outcomes

By the end of this unit, you should be able to:

- Explain the concept of electromagnet
- Identify the application of electromagnets to man
- Draw and explain the workings of an electric bell and telephone earpiece

2.3 Electromagnet

The field inside a solenoid can be used for making permanent magnets such as a bar magnet. When you placed an iron core in the solenoid, the magnetic field of the solenoid will exert force on the domains. The magnetic field strength due to such a solenoid is increased by the presence of the soft iron core or rod.

An electromagnet is a tempory magnet. A horse-show type can be made by winding the coils or solenoid in opposite directions around the two points P and Q of a U shaped soft iron core.

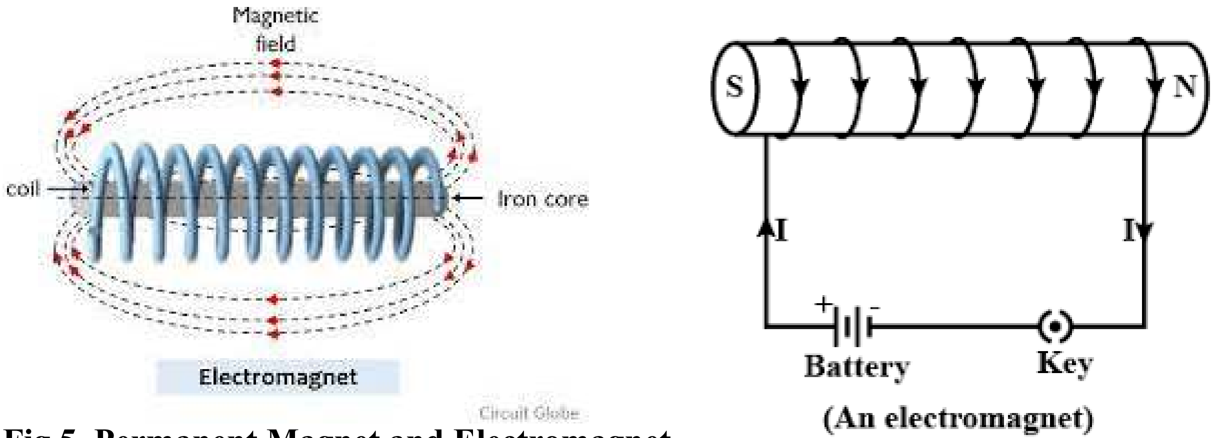

Fig.5 Permanent Magnet and Electromagnet

When the current is switch on and it flows from a battery round the solenoid, it is observed that the end of P acts as an S-pole while the end at Q acts like N-pole. This implies that a strong magnetic field is produced. Hence magnetization occurs rapidly when the current is switch on and off.

2.3.1 Application of electromagnets to industry for the comfort of man

1. For producing strong magnetic fields such as those required in generators (run machines, provide electricity and electric motors)
2. Electromagnets can separate iron from mixtures containing non-magnetic substances.
3. They are used for lifting and transporting heavy pieces of iron and steel for example scrap iron for recycling, steel plates, cargo containers at ports and guiders
4. Are used for the construction of electromagnetic devices as electric bell, telephone earpiece and magnetic relay (passing messages from one parts of an electric circuit to another-magnetic switch)

2.3.2 An Electric Bell

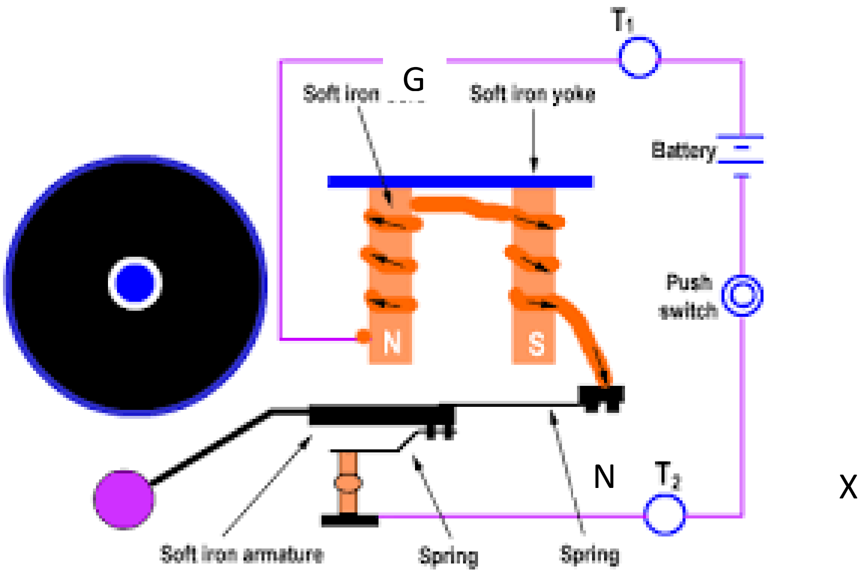

Fig.6. Electric Bell

The electric bell works with the help of an electromagnet. It rings when the electromagnet is energized by the current. When the bell-push is pressed, the circuit of the system is completed and current flows round the electromagnet. The soft iron core X at point of the screw N on which it rest and the iron bar T_1 becomes magnetized and the electricity attracts the solf iron armature attached to a spring. This makes the clapper to strike the gong.

The circuit is broken as soon as the spring moving along with the soft iron armature breaks contact between X and N is now broken and so T_2 is pulled back to make contact again with the screw N. the circuit is thus reestablished and current then flows. The sequence of events is repeated rapidly and the bell continues to ring as long as the bell push is pressed. The instrument works on the principle of make-and-break device.

2.3.3 Telephone Earpiece

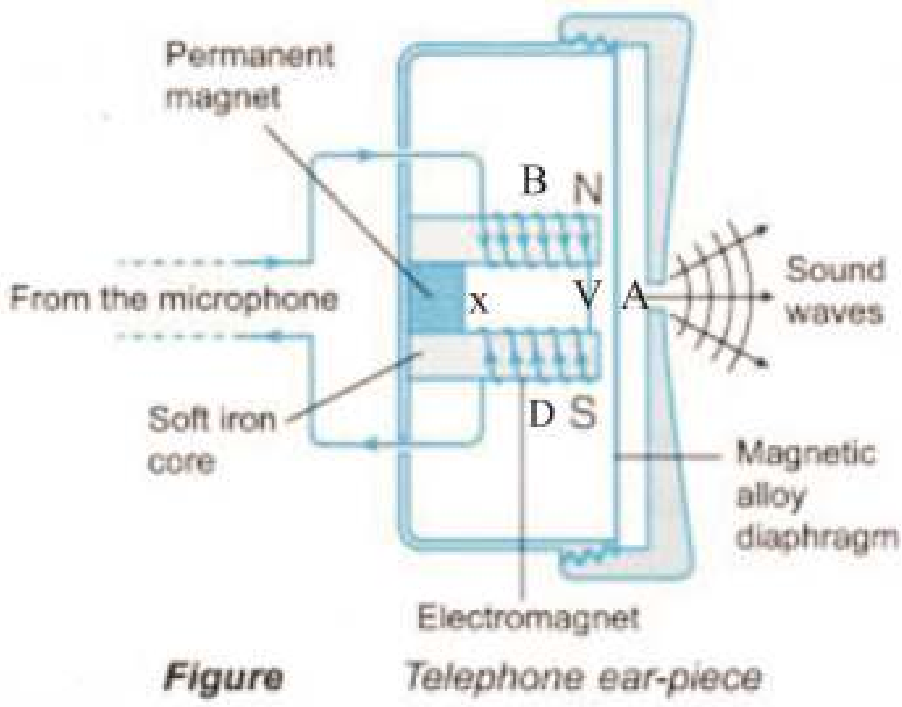

Fig. 7 Telephone Earpiece

The telephone earpiece changes electrical energy to sound energy or speech current along the telephone line to sound waves in the air.

The earpiece has a soft iron pieces B and D at the S and thin soft plate A is fixed near the ends of B and D. Sspeech coils are wound round B and D, which are made of many hundreds of turns of very tiny insulated wire, oppositely wound round B and D. The magnet X induces south (S) and North (N) poles at force ends of B and D. these poles attract the iron plate A, keeping it under tension.

The variation in the electric causes a variation in the magnetism of the electromagnet. This variation of the electromagnet causes variation of the diaphragm placed in front of it. This creates sound waves of the same frequency in the air as the speech current. Hence the speaker is heard.

2.4 Superconducting Electromagnets

In theory, an electromagnet like the solenoid can produce very powerful magnetic fields: all that is required is to increase the coil current I until the flux density B is as large as is required.

In practice, the coil will dissipate power I^2R where R is the coils resistance and eventually this power loss will become unacceptably large and might cause the coil to melt.

For applications where strong magnetic fields are required, superconducting electromagnets are becoming increasingly popular. These magnets have coils made from a material which has zero resistance, so there is no internal power losses. Thus, the coil current can become as large as in necessary to produce the desired field.

The limitation here is that most superconducting materials exhibit their special properties at low temperatures and thus the magnets usually need continuously cooling using liquid nitrogen.

Superconducting magnets are used in high speed levitating train. A strong magnet fields holds the train in suspension above the rails, so there are no frictional forces to overcome, only wind resistance and the inertia of the train.

2.5 Summary

In this unit, we were able to understand that:

Electromagnets are used in the manufacture of electric bells and telephone earpiece; Magnets are made by electrical method and the contact methods; Soft-iron is more easily magnetized than steel. It also loses its magnetism more easily.

Tutor -Marked Assignment

Draw and explain the workings of carbon microphone

2.6 References/Further Readings/Web Resources

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UNIT 3 FORCE ON A CONDUCTOR

Unit Structure

3.1 Introduction

The principle on which moving coil meter, generator and machines are based on the interaction of forces on a conductor in a magnetic field. The study of forces on a conductor is the gate way to indepth insight to related concepts.

3.2 Learning Outcomes

By the end of this unit, you should be able to:

- Describe force acting on a conductor in a magnetic field
- State the conditions on which the magnitude of force is increased
- Define the magnetic flux of a wire
- Solve some problems on force acting on a conductor

3.3 Force on a Conductor

When a conductor carrying a current is placed in a magnetic field due to some source other than itself, the conductor experiences a mechanical force.

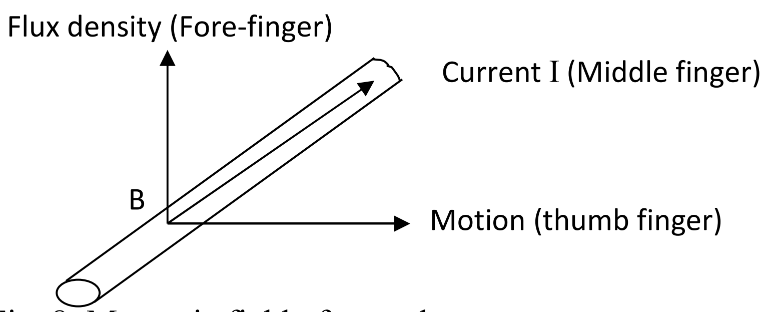

Fig. 8: Magnetic field of a conductor

The relative directions of the current, the applied field, and the motion are determined by the left had rule.Consider the middle finger (showing current I), the force finger (showing flux density B and the thumb (motion) of left hand are stretched perpendicular to each other as shown in Fig. 8.

It is important to note that, the magnitude of the force can be increased by increasing the:

i. Flux density B;
ii. Length, L of the conductor; and
iii. Strength of the current, I through it.

From this therefore, the magnetic flux density B of a magnetic field is equal to the force acting on a conductor or unit length and carrying a unit current at right angles to the field.

The unit for magnetic flux density, tesla (T) can also be re-defined as
The tesla (T) is the magnetic flux density of a magnetic field where a conductor of length 1M carrying a current of 1A at right angles to the field experiences a force of 1N.

3.3.1 Self Evaluation

Consider a current carrying conductor placed in the direction of force is given by

$F \propto \sin\alpha$ ---------- (1)

Where α is the angle between the conductor and the field, it follows that F is zero when the conductor is parallel to the field direction. This defines the direction of the magnetic field, when we apply Fleming's rule, when the conductor is placed at right angles to the field, the direction of the field is the direction of the forefinger.

Showing magnitude of force F depends on current I flowing in conductor of length L is

$F \propto I$ ---------- (2)

When the length l is changed, it can be shown, that with constant current and field

$F \propto L$ ---------- (3)

Since the higher the current in the conductor the higher the force experienced, it was equally observed that the higher the current. The higher the magnetic field generated.

As such $F \propto B$ --------------- (4)

Combination of the above factors gave the magnitude of the force as $F \propto B\, I l\, Sin\propto$

$F \propto B\, I l\, Sin\propto$ --------------- (5)

Where K is constant of proportionality

Self-Assessment Exercise 3

1. A wire carrying a current of 20 A and 4 meters long is placed in a field of flux density 0.30 T. What is the force on the wire if it is placed?

(a) At 65^0 to the field

(b) Perpendicular to the field

(c) Along the field

3. How can the magnetic force be increased?

4. The force on current carry conductor in a magnetic field depends on which factors

3.3.2 Magnetic force due to a Solenoid

The magnetic field due to a solenoid will depend on the current flowing in it. The larger the current in the solenoid, the larger is the force F. this then implies that, the higher the current in the conductor, the higher the force experienced, and also the higher the current the higher the magnetic fields generated.

The magnetic field is represented by a vector quantity which is given by symbol B.

B is the flux density in the field. Let assume that

$F \propto B$ ---------(4)

To find the magnitude of F. consider equations (1) to (4)

Reminder = $F \propto Sin \propto$ -------- (1)
$F \propto I$ ----------- (2)
$F \propto l$ ----------------- (3)
$F \propto B$ ----------------- (4)

A combination of the equations gives that,

$$F \propto B\ I\ l\ Sin \propto$$
$$F = k\ B\ I\ l\ Sin \propto$$

Where K is constant of proportionally, thus

$$F = B\ I\ l\ Sin \propto \text{ ------------------ } (5)$$

When the whole length of the conductor is perpendicular (at right angles) to the field b, and since $Sin \propto = 90^0$

Then $F = B\ Il$

$$B = \frac{F}{Il}$$

4.4 Summary

This unit has been able to expose participants to the fact that:

The force on a conductor is always at right angles to the plane which contains both the conductor and the direction of the field in which it is placed; Magnitude of the force depends on the following: (i). Flux density;(ii) The length of the conductor; (iii) The strength of the current; The unit of the magnetic flux density is tesla (T); The unit force in a conductor carrying wire is given by $F = B\ Il\ Sin \propto$ when situated at and angle and $F = BIl$, when $Sin \propto = 90^0$

Tutor-Marked Assignment

1. Define magnetic flux density B interms of force, current and length of the conductor
2. Show that $F = BIl$
3. If B is a vector, find its component in a direction at an angle Θ to B

3.6 References/Further Readings/Web Resources

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3.7 Possible Answers to Self-Assessment Exercise(s)

1. Things you know: current $I = 20A$
Length $L = 4M$
Flux density $B = 0.30T$

From the equation of $F = BI\,l\,\text{Sin}\propto$

Substituting the known values in the equation for F.

(a) $F = 0.30 \times 20 \times 4 \times \sin 65^0$

(b) $F = 0.30 \times 20 \times 4 \times \sin 90^0$

(c) $F = 0$, since $\text{Sin } 0^0 = 0$

UNIT 4 FIELD DUE TO SOLENOIDS

Unit Structure

4.1 Introduction

A solenoid is a device comprised of a coil of wire, the housing and a moveable plunger (armature), which are widely used in electrical, radio and television industries. The magnetic effect of solenoids, which are long coils of closely wound wire, is widely used in industry.

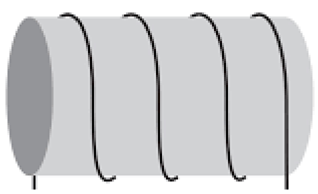
4.2 Learning Outcomes

By the end of this unit, you should be able to:

- Define solenoid
- Explain magnetic field due to solenoid
- Draw a diagram showing the magnetic field of solenoid
- State factors a magnetic flux in a solenoid depends on
- State the working principles of solenoid.

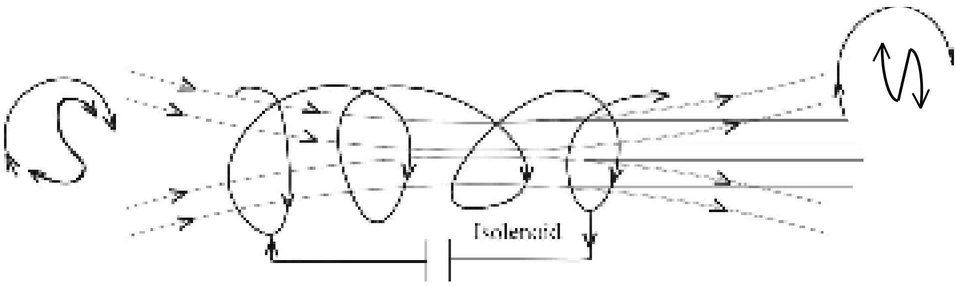
4.3 Magnetic field of long cylindrical of a wire

The magnetic field of long cylindrical coil of wire whose turn are usually wound close together.



(a)

A solenoid



(b)

Fig. 9: Magnetic field of a solenoid

When a current flow in a solenoid (fig. 9 (b)), along the turns, there is a magnetic field inside and around the solenoid, the magnetic field pattern produced is identical to that of a bar magnet. Hence the solenoid has poles like a bar magnet. Considering the direction of the current flow, it can be deduced that the pole.

(i) If the current flows in the anticlockwise direction, the end of the solenoid is N-pole ( )

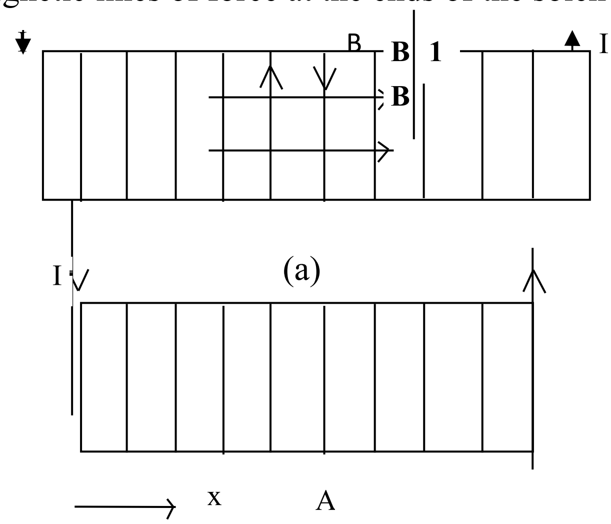
(ii) If the current flows is clockwise, then the end of the solenoid is a S-pole ( )

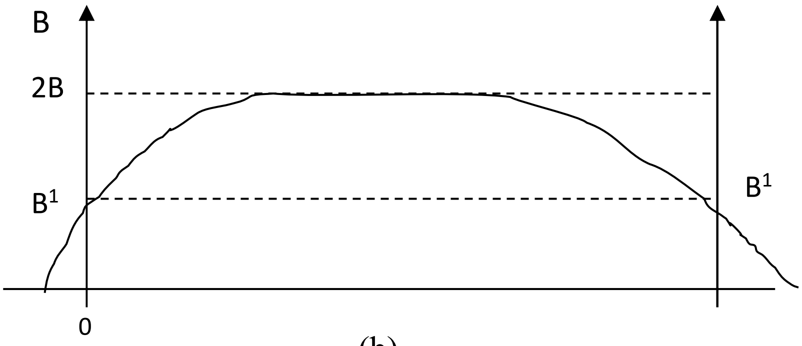
Take note that the magnet lines of force inside the solenoid are parallel. Hence the magnetic field inside the solenoid is uniform.

Consider a solenoid of turns and length L, carrying current I, the magnetic flux density B. within the solenoid depends on the current I, and, n, the number of turns per unit length of the solenoid, it is given by the expression.

$B = \mu_0 n I$ -------------------- (1)

Where, μ_0 is a constant, known as permeability of free space. The magnetic lines of force at the ends of the solenoid spread out.





(b)

Fig. 10 shows (a) the magnetic flux density at the ends of the Solenoid is weaker thus at the end of the solenoid.

Fig.10: show flux density at the ends is weaker. Thus, at the end of the Solenoid, the magnetic flux density in half within the solenoid (decreases).

$\therefore B^1 = \frac{1}{2}$ B since from equation (1)
That $B = \mu_0 n I$
$B^1 = \frac{1}{2} B = \frac{1}{2}\mu_0 n I$ ----------- (2)

From the graph, the flux density within the solenoid is twice that at the ends (maximum) because a long solenoid can be considered as being made up of two sections joined at A.

There the resultant flux density at A is the vector sign of flux density B^1 at the end of the two coils.

Hence flux density at A = $B = B^1 + B^1 = 2B^1$

The solenoid works on the principles of electromagnetism. When current flows through the coil magnetic field is generated in it, if a metal core which increases magnetic lines of flux is concentrated on the core which increases the induction of the coil.

SELF ASSESSMENT Exercise 4

1. What factors does the magnetic flux density B in a solenoid depends on?
2. What is the flux density B, if a soft iron piece is inserted into a solenoid, where μ_1 is the relative permeability of the soft iron?
3. What is the nature of the field lines in the middle and at the end of a solenoid

4.4 SUMMARY

Now we know more behaviour of a magnet in the following areas:

The magnetic fields of a long cylindrical coil, which is closely wound and tightly packed in a helux; When a current flows in solenoid, there is a magnetic field inside and around the solenoid; The magnetic field pattern produced is identical to that of a bar magnet exhibiting the behavior of North and South pole of a bar magnet; Magnetic flux density B within the solenoid depends on (i) the current I (ii) n, the number of turns per unit length; Flux density $B = \mu_0 n I$; μ_0 is the permeability of free space; the magnetic flux density in solenoid of length l ad number of turns is given as; (i). twice the flux = $2 B^1$ at the middle of coil (ii). ½ the flux = ½ B = ½ B = ½ $\mu_0 n I$

4.5 References/Further Readings/Web Resources

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4.6 Possible Answers to Self-Assessment Exercise(s)

1. The magnetic flux density B. depends on
i. Current i
ii. n, the number of turns per unit length of the solenoid

2. Flux density B of a solf Iron inserted into a solenoid where u is the relative permeability
This is given by. the relationship
$B = U_1 Uo \ n I$
Where N, is a constant known as the relative permeability of soft iron and the value of U for soft iron in 370. It is the current, I, n the number of turns.

UNIT 5 FIELD DUE TO LONG CONDUCTOR

Unit Structure

5.1 Introduction
5.2 Learning Outcomes
5.3 Fields Along Straight Current Carrying Conductors.
5.4 Summary
5.5 References/Further Readings/Web Resources
5.6 Answers For Self- Assessment Exercise

5.1 Introduction

Long conductors are important components in electrical and radio equipments.For example, a submarine cable carrying message. All around a straight current-carrying wire, the field pattern consists of circles concentric with the wire.

5.2 Learning Outcomes

By the end of this unit, you should be able to:

- Describe the behaviour of a long current carrying conductor in a magnetic field
- State factors that affect the magnetic flux B of a long current carrying conductor.

5.3 Fields along straight current carrying conductors.

Consider a long straight conductor with the current carrying out of the page of a book,

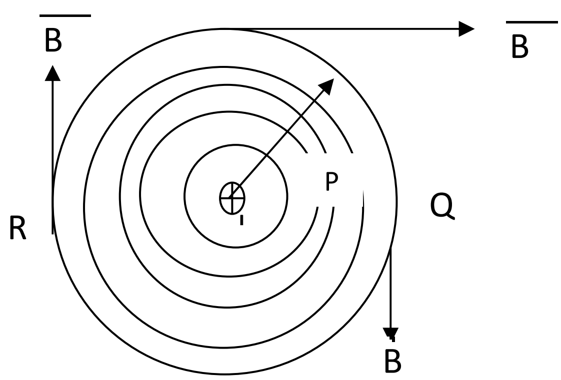

Fig. 11: Field due to a long straight conductor.

Magnetic flux will be generated around the conductor in circular shape. If a right handed corkscrew is turned so that the point moves along the current direction, the field direction is the same as the direction of turning. The direction B is along the tangent to a circle at that point so at P due North of the wire, B points east for a downward current. At a point due east, B points South and at a point due west B point North.

At a distance r from the wire, the magnitude of B is given by

$B = \frac{\mu_0 I}{2\pi r}$

So for a given current $B \propto \frac{1}{r}$

μ_0 is a constant called the permeability of free space with a value of 4 x $10^{-7/1}$ M/A

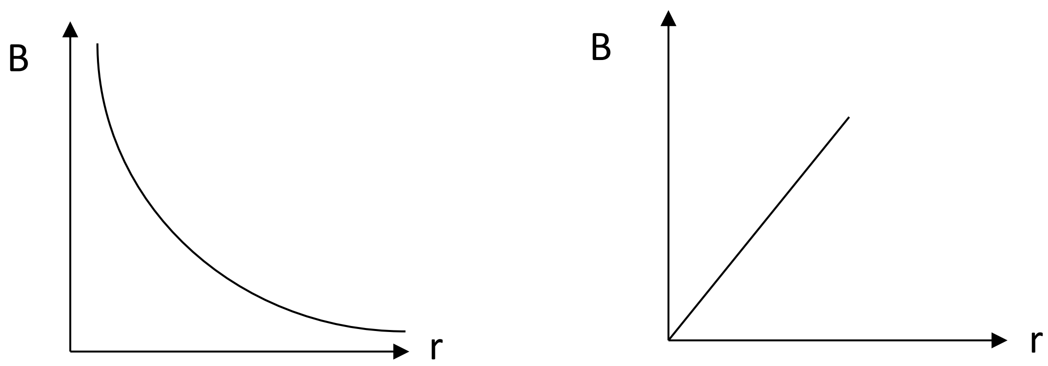

Fig.12: The Variation of flux density with radius r and current I

Self-assessment Exercise 5

What is the relationship between magnetic flux B around a straight conductor and the distance of flux from the conductor?

5.4 Summary

We have been able to learnt that**:** Magnetic flux is generated around the conductor in circular shape; and the magnetic flux B of wire is given by

$B = \frac{\mu_0 I}{2\pi}$

5.5 References/Further Readings/Web Resources

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5.6 Possible Answers to Self-Assessment Exercise

The magnitude of the force is increased by increasing the
i. Flux density B;
ii. Length l, of the conductor and
iii. Strength of the current I , through if, if B is uniform over, and at right angles to the whole length of the conductor, then the relationship of the magnitude of the force F, flux density B and l is given by
$F= B I l$
Generally, if B is uniform and directed at an angles Θ to l, B is resolved into two compounds
i. B cos Θ parallel to l (force = o) and
ii. B Sin Θ at right angles to l, (flux density B perpendicular to the wire
$F=B I l \sin \Theta$

UNIT 6 BIOT- SAVERT LAW

Unit Structure

6.1 Introduction

Magnetic field are experienced in circular coils, a straight conductor of a solenoid

6.2 Learning Outcomes

By the end of this unit, participants shall be able to:

- Calculate B for any shape of conductor
- Show the magnetic flux B for a narrow coil
- Calculate B due to long straight wire

6.3 Law of Biot and Savert

Biot and Savert calculated the magnetic flux density B for any shape of conductor and arrived at a law which stated as follows
The flux density ΔB at a point P due to a small element Δl of a conductor carrying a current is:

$$\Delta B = \frac{I\Delta l Sin\alpha}{r^2} \text{ ----------------- (1)}$$

Where r is the distance from the point P to the element and ∝ is the angle between the element and to P.

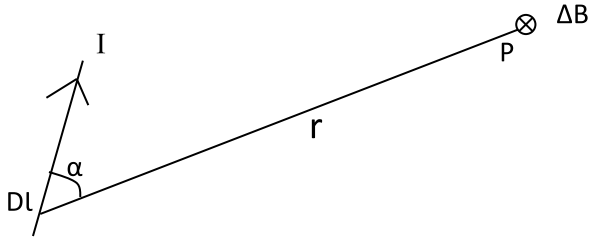

Fig. 13: Blot and Savert Law

The constant of proportionately depends on the medium in which the conductor is situated.

In air or vacuum,

$\Delta B = \frac{\mu_0}{4\pi}\frac{I\Delta l sin\alpha}{r^2}$ ------------(2)

Where $\mu_0 = 4\pi x\ 10^{-7}$ and unit henry per metre (Hm^{-1})

B for narrow coil

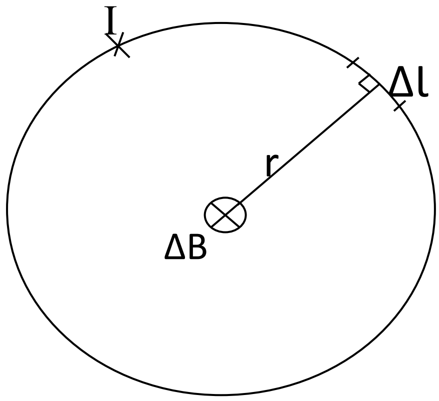

Fig. 14: Field of circular coil

Consider radius r is constant for all the elements Δl, and the angle ∝ is constant, and equal to 90^0 on this coil. The coil has N turns, the length of wire is $2\pi rN$ and the field at its center is

$B\int dB = \frac{\mu_0}{4\pi}\int_0^{2\pi rN}\frac{IdlSin90^0}{r^2}$

$= \frac{\mu_0 I}{4\pi r^2}\int_0^{2\pi rN} dl \ = \frac{\mu_0 I}{4\pi r^2} 2\pi rN$

$B = \frac{\mu_0 NI}{2r}$

B due to long straight wire

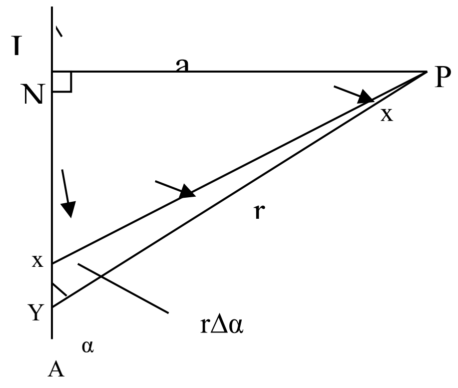

Fig.15: Field of a long straight wire

AC from the fig.12 represents part of a long straight wire P is taken as a point so near it that, from P, the wire looks infinity long. An element XY of the wire of length Δl, makes an angle ∝ with radius vector r, r from P. it therefore contributes to the magnetic field at P given

$\Delta B = \frac{\mu_0 I\Delta l Sin\alpha}{4\pi r^2}$ ------------ (1)

Consider that the wire carries a current I. if a is the perpendicular distance, PN, from P to the wire

PN = PX Sin∝ or ar Sin∝

r = $\frac{a}{Sin\alpha}$ -----------(2)

Also, if we draw an XZ perpendicular to Py, we have

XZ = XY Sin∝ = Δl Sin∝

If Δl has an angle Δ∝ at P, then

XZ = rΔ∝ = Δl Sin∝

From equation (1) ΔB = $\frac{\mu_0 I\Delta l Sin\alpha}{4\pi r^2}$ substitute rΔ∝

= $\frac{\mu_0 Ir\Delta\alpha}{4\pi r^2}$ ΔB = $\frac{\mu_0 I\Delta\alpha}{4\pi r}$

From equation (2) ΔB = $\frac{\mu_0 \, I \, Sin\propto\Delta\propto}{4\pi a}$ substitute the value of r=$\frac{\alpha}{Sin\alpha}$

r=$\frac{\alpha}{Sin\alpha}$

When the point Y is at the bottom end A of the wire, ∝ = 0; and when Y is at the top C of the wire, ∝ = π.

The magnitude of P is

B = $\frac{\mu_0}{\mu\pi}\int_0^{\pi}\frac{I \, Sin\propto\Delta a}{a}\frac{\mu_0 I}{4\pi a}$ [-Cos$\alpha]_0^{\pi}$

=>B = $\frac{\mu_0 I}{2\pi a}$ -----------(3)

This shows that the magnetic field of long straight wire, at a point neat it, is inversely proportional to the distance of the point from the wire.

Self-Assessment Exercise 6

Sketch a graph that best represents the dependence of the magnetic flux density B at the centre of a circular coil on its radius r, if the number of turns and the current remain unchanged?

6.4 Summary

In this unit we have discussed the following that:

Biot and Savert law states that the flux Δl of a conductor carrying a current is given by ΔB = $\frac{I\Delta l \, Sin\propto}{r^2}$; Magnetic flux B of a narrow coil carrying conductor is given by the relationship B = $\frac{\mu_0 \, NI}{2\pi a}$; B for a long straight wire is B = $\frac{\mu_0 \, I}{2\pi a}$; And μ_0 is constant called the permeability of free space and has a value 4 x 10^{-7} MA.

Tutor-Marked Assignment

Show that for a long straight wire, the magnetic flux is given by

B = $\frac{\mu_0 \, I}{2\pi a}$

6.5 References/Further Readings/Web Resources

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UNIT 7 FORCES BETWEEN CURRENTS

Unit Structure

7.1 Introduction

Amperes conducted an experiment and discovered in 1821, that current – carrying conductors exert force on each other.This principles is applied in electrical and radio devices. We have learn that magnetic flux is generated around conductors. Imagine when two or more current carrying conductors are close to each other, how will the magnetic flux interact between these two conductors.

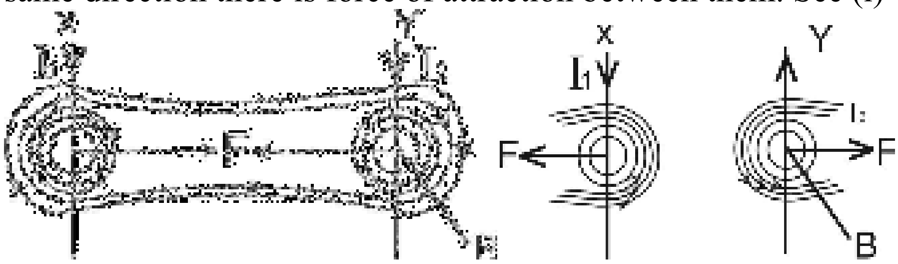
7.2 Learning Outcomes

By the end of this unit, you should be able to:

- Describe forces between current carrying conductors
- State the magnitude of the force existing between parallel conductors.
- Define Ampere in terms of force existing between conductors.

7.3 Current through two long Parallel conductor

Consider two long parallel neighboring straight Conductors X and Y wires separated by a distance r meters carrying currents I_1 and I_2 in the same direction there is force of attraction between them. See (i)



(i) Force between currents (ii)

Fig. 16. Force Between Currents

If the currents flow in opposite directions, there is repulsion force between them.

In (i) the resultant magnetic flux round the two long straights vertical conductors X and Y in a horizontal flame when the currents I_1 and I_2 are both downwards. The line seems to pull the conductors towards each other.

In (ii), the currents I_1 and I_2 are in opposite directions hence the lines tend to push the conductors X and Y apart.

Applying Fleming's left – hand rule to the two situations, is confirms the directions of the force.

At Y, the flux density B due to the conductor X is at right angles (perpendicular) to Y, this implies that the force F and Y in (i) is towards X. from the Law of conservation of energy or action and reaction, the force F on X is towards Y and equal to that on Y. so attraction takes place between the conductors.

Consider (ii), the current I_2 in Y is opposite to that in (i) using Fleming's left hand rule, the force F and Y is away from X and the force is repulsive. The mechanical force between two parallel current-carrying wires is perpendicular to both wires; the force is that of attraction if both currents are in the same direction (sense). It is repulsive, if the currents are opposite direction (sense).

Consider that both wires are very long, and the distance between them is r meters in vacuums, let I_1 and I_2 represent the currents flowing in X and Y respectively let B represents the flux density associated with current I in X, so that Y is in the magnetic field of X is given by $B_1 = \frac{noI}{2\pi r}$

The magnitude of force F on a length L of Y is given by $F = BI_2L = \frac{\mu_0 I_1 I_2 l}{2\pi r}$
Where $u_o = 4\pi \text{ x} 10^{-7}$ henrys per meter and hence the magnitude of the force acting on a unit length of Y due to the whole of X is
$\frac{F}{L} = \frac{\mu_0 I1I2}{2\pi r} = \frac{2x10-7}{r} I_1 I_2$

Similarly, the magnitude of the force acting on a unit length if X due to the whole of Y is

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r} = \frac{2x10^{-7} I_1 I_2}{r}$$

No = 4π x 10^{-7} henrys per meter. These two forces are equal and opposite.

7.3.1 Magnitude of force, The Ampere.

Consider that if two long straight conductors X and Y lie parallel and close together at a distance ʊ apart and currents I_1 I^1
Then the current I is in a magnetic field of flux density

$$ß = \frac{\mu_0 I^1}{2\pi ʊ}$$

due to the current I^1

the force per meter length F, on X is hence given by

$$F = ßI\ell = BIx1 = \frac{\mu_0 I^1}{2\pi ʊ} \text{ x I x 1}$$

$$F = \frac{\mu_0 II^1}{2\pi ʊ}$$

Ampere is defined in terms of the force between conductors. It is that current, which flowing min each of two infinitely long parallel straight wires of negligible cross-sectional are separated by a distance of 1 meter in value, produces a force between the wires of $2x10^{-7}$ Newton $Meter^{-1}$ (NM^{-1})

Self-Assessment Exercise

1. Consider a long straight conductor X carrying a current of 4A is placed parallel to a short conductor Y of length 5cm carrying a current of 6A. the distance between the two conductors are 100cm apart.. Calculate
   a. The flux density due to X at Y
   b. The approximate force on Y
2. Define an Ampere
3. Draw a sketch of two long strength conductors X and Y indicate the following;
   i. Currents in the same direction
   ii. Currents at opposite direction

7.4 Summary

This unit discussed how

One ampere is the value of that steady currently which, when flowing in each of two infinitely long straight, parallel conductors, which have negligible areas of cross-section and are one meter apart in a vacuum, causes each conductor to exert of force of $2 \text{ x } 10^{-7}$N on each meter of the other; **and showed that** The magnitude of force F and a length L of conductor say Y is given by $F = BI_2 l$

Tutor-Marked Assignment

1. State the law of force acting on a conductor carrying an electric current in a magnetic field.
2. Show that the force per unit length, F on a conductor X is given by

$$F = \frac{\mu_0 \, II^1}{2\pi\vartheta}$$

7.5 References/Further Readings/Web Resources

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7.6 Possible Answers to Self-Assessment Exercise(s)

1. Flux density due to X at Y
What do we know?

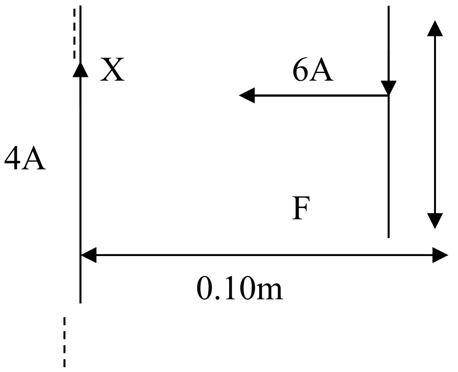
$$ß = \frac{u_0 I^1}{2\pi ȣ}$$

$I = 4A$

$u_o = 4\pi x10^{-7} hm^{-1}$

$ȣ = 100cm \quad \frac{100}{1000} = 0.10m$

Substitute in the equation for $ß = \frac{\frac{2}{4}\pi \, x \, 10{-}7 \, x \, 4}{2\pi \, x \, 0.10m} = \frac{8x10{-}7}{0.10m}$



$= 8 \times 10^{-6}$ T

$5cm = \frac{5}{100} = 0.05m$

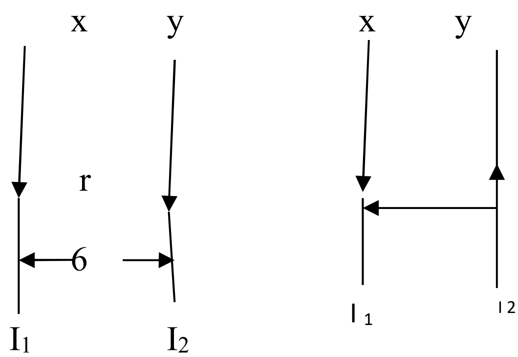
On Y, length L = 0.05m

Force F = BIL = $8 \times 10^{-6} \times 6 \times 0.05$

$= 2.4x10^{-7}$ N

3 An ampere is a unit of measure of the rate of electron flow or current in an electrical conductor. One ampere of current represents one coulomb of electrical charge (6.24×10^{18}) moving past a specific point in one second.

4



They exert equal and opposite attractive force on each other

The will repel each other

MODULE 2 ELECTROMAGNETIC INDUCTION

In this module participants will be exposed to the meaning of electromagnetic induction, Faraday's and Lenz's Laws, the dynamo, transformer and electric motors. The module is divided into five unit as Follows:- Electromagnet Induction, Faraday's and Lenz's Law of Electromagnet Induction, The Dynamo Generator, Transformer, and Electric Motor.

Unit 1 Electromagnetic Induction
Unit 2 Faraday's and Lenz's Law of Electromagnetic Induction
Unit 3 The Dynamo Generator
Unit 4 Transformer
Unit 5 Electric Motor

UNIT 1 ELECTROMAGNETIC INDUCTION

Unit Structure

1.1 Introduction
1.2 Learning Outcomes
1.3 Electromagnetic Induction
1.4 Summary
1.5 References/Further Readings/Web Resources
1.6 Answer For Self-Assessment Exercise

1.1 Introduction

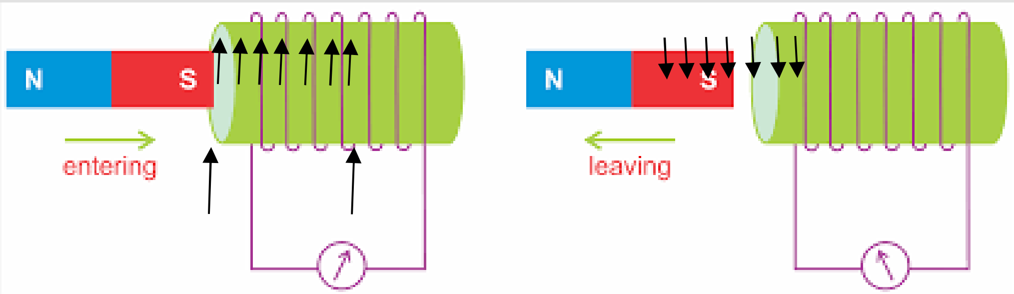
After Ampere and other scientist had investigated and found the magnetic effect of a current, Faraday tried to find the opposite. He tried to produce a current by means of a magnetic field. This lead to studies on the possible effect of magnetic flux on electric current.

1.2 Learning Outcomes

By the end of this unit, you should be able to:

- Explain the meaning and condition for electromagnetic induction.
- Draw a sketch when a bar magnet is pushed into a coil of wire connected to a centre zero galvanometer.

1.3 Electromagnetic induction



(a) Centre Zero Galvonometer (b) Centre Zero Galvonometer

Fig. 17: Electromagnetic Induction

In Michael Faraday's experiment, he discovered that when the North pole of a bar magnet (See Fig 17 (a) and (b)) is pushed into a coil wire connected to a centre zero galvanometer, the pointer of the galvanometer is deflected (kick) suddenly to one side. The sudden movement indicates that an electromagnetic force (emf) is produced in the coil and current flows through the galvanometer. This effect of producing an electric current using magnetism is called electromagnetic induction. Thus the current produced is known as induced current.

The behaviour of the movement of a bar magnet, through a coil wire connected to a galvanometer, indicated that the induced e.m.f was only generated when the magnetic flux was changing by implications by moving the coil to and fro in the electrical coil. It can also be concluded that the speed movement of flux charge increases the induced currents. Thus the deflection is larger if the North pole of the magnet is pushed into the coil when a stronger magnets is used.

Self-Assessment Exercise

1.	Explain the meaning of e.m.f
2.	Draw a sketch showing when the South of a bar magnet is pushed into a coil of wire connected to a zero galvanometer.

We have been able to understand the effect of pushing a bar magnet to and fro through a coil connected to a galvanometer, which produces charges when an e.m.f is induced in the coil and current flows through the galvanometer.

1.4 Summary

This unit exposed participants to the situation: When there is charge in magnetic flux to or fro from a coil, e.m.f is induced which induces electrical current flow;**m**The deflection on the galvanometer is larger if the North pole of the magnet is pushed into the coil or when s stronger magnet issued.

Tutor-Marked Assignment

What is the effect of resistance of the coil in the e.m.f and electrical current induced?

1.5 References/Further Readings/Web Resources

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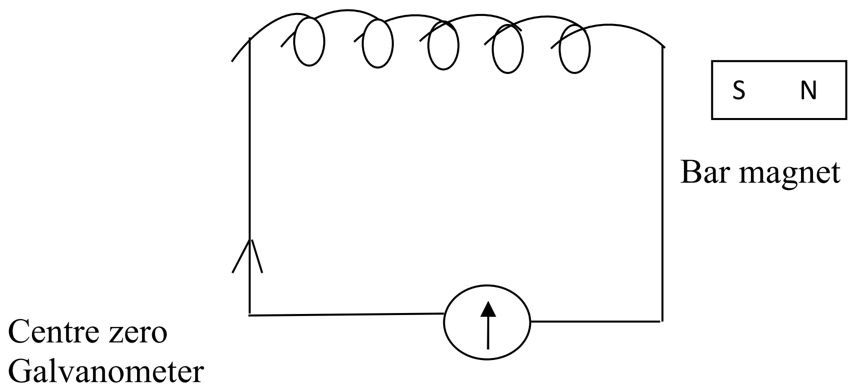
1.6 Possible Answers to Self-Assessment Exercise(s)

1. The electromotive (e.m.f) of a cell is the amount of work done in circulating a unit electric charge in a complete circuit. It is the maximum potential difference made available between its terminals in an open circuit.

2.



When the south pole of a magnet is pushed into a coil of wire connected to a zero galvanometer. The needle of the galvanometer deflects in the opposite direction with regards to the firsts indicating a change in polarity. That is, if deflects slightly to the left

UNIT 2 FARADAY'S AND LENZ'S LAWS OF ELECTROMAGNETIC INDUCTION

Unit Structure

2.1 Introduction

Faraday and Lenz worked on the quantity and direction of flow of induced e.m.f and current which lead to the laws named after them.

2.2 Learning Outcomes

By the end of this unit, you should be able to:

- State Faraday's Law of electromagnetic induction
- Deduce the e.m.f induced in the coil while the flux is changing
- State Lenz's law of electromagnetic induction.

2.3 Faraday's Law

In Faraday's experiment, he conducted that an induced e.m.f exist in a coil only if the flux through the coil is changing

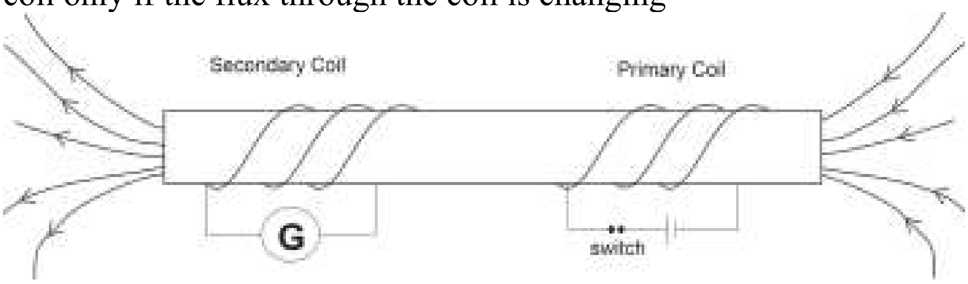


Fig. 18:

A look at fig. 18, when the switch is closed the current in the primary coil generates the magnetic field since the field lines follow the iron rod, so considerable flux passes through the secondary coil. When the switch is pulled open, the flux decreases to zero, in which this change in flux is occurring, an induced e.m.f exist in the secondary coil, but no induced e.m.f exist when the flux is not changing.

Notice the following:

i. The flux through the coil increase as the magnet is brought closer to it
ii. When the magnet is stationary, no flux change is occurring and there is no induced e.m.f in the coil.
iii. When the magnet is being moved from one position to another, the flux through the coil is changing, so there is an induced e.m.f.

The magnitude of induced e.m.f increases with the following:

i. Speed turning induction coil
ii. Area of the coil
iii. Strength of the magnetic fluid
iv. Number of turn in the coil

et us now give a statement of Faraday's quantitative result. Suppose that a coil N loops has the flux through it changed from $\emptyset_1$ to $\emptyset_2$ in a time Δt. Then the change in flux through the coil is

$$\Delta\emptyset = \emptyset_2 - \emptyset_1$$

Faraday found that the e.m.f induced in the coil while the flux is changing is:

e.m.f = $\frac{N\Delta\emptyset}{\Delta t}$

Where = N – number of turns
$\Delta\emptyset$ = Changes in flux
Δt = Changes in time

Thus, Faraday's law states that, when the magnet flux linkage through a circuit changes, an e.m.f which is directly proportion to the rate of change of flux linkage is induced or Faraday's (Neumann's) Law states that the induced e.m.f is directly proportion to the rate of change of magnetic flux linking the circuit or coil.

Lenz's Law

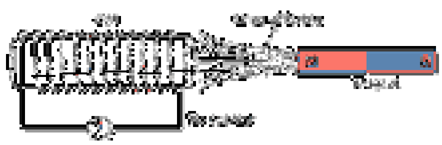
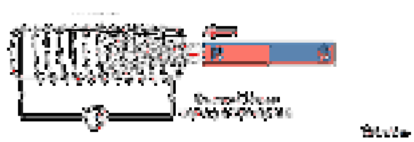
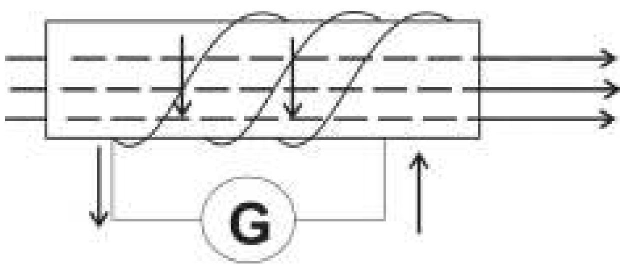


Fig. 19: (a)



(b)



(c)

As the magnet is moved from position in (a) to that in (b), the induced current shown in (c) exists. The lines in (c) show the magnetic field produced on the coil by the induced current. Note that the flux produced in the coil by the coil's own induced current is directed to the right. However, as the magnet was moved from the position in (a) to that in (b), it furnished flux directed to the left through the coil. In other words, the flux due to the induced current tends to cancel the change in the flux that caused the induced current. These results were generalized into simple rule by Lenz that "the induced current flows always in such a direction as the oppose the change causing it", Lenz'S Law.

2. Thus,condition for Lenz's Law an induced e.m.f is obtained when there is a change in the amount of the flux linking a coil. With an open coil, this change produces an induced emf but not an induced current.
3. Lenz's Law follows the principle of the conservation of energy

Faraday's Law and Lenz's law can be summarized by the equation:

Induced e.m.f $E = \frac{-\Delta\emptyset}{\Delta t}$

Where $\emptyset$ is the magnetic flux linkage in webers (Wb) or volt second (Vs) the negative sign (-) in the equation implies that the induced emf E opposes the rate of change of magnetic flux linkage, $\frac{\Delta\emptyset}{\Delta t}$.

Self-Assessment Exercise 9

1. Draw a sketch showing self inductance of a coil and explain its working principles.
2. Identify two conditions of Lenz's Law of electromagnetic induction
3. i. what will happen when a magnet is stationary

ii. a magnet is being moved from one point to another

iii. the magnet is brought closer to the coil

3.4 Summary

We have been able to discussed that:

Faraday's law states that when an induced emf is directly proportional to the rate of change of magnetic flux linking the circuit or coil; Lenz's Law states that the induce current flows always in such a direction as to oppose the change causing it; Faraday's quantitative results shows that $E = \frac{N\Delta\emptyset}{\Delta t}$; Faraday's Law and Lenz's law can be summarized by the equation

emf = $\frac{\Delta\emptyset}{\Delta t}$.

Tutor-Marked Assignment

1. State the law of electromagnetic induction
2. With a well labeled diagram, explain the principles of the Faraday and Lenz laws.

2.5 References/Further Readings/Web Resources

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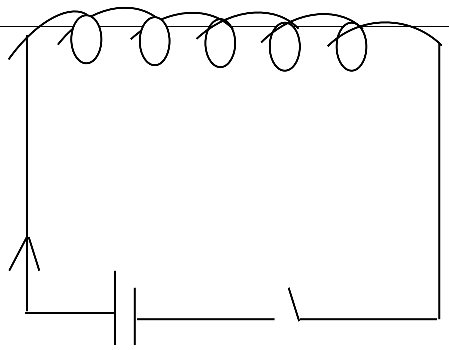
2.6 Possible Answers to Self-Assessment Exercise(s)

1.



Key key
Battery

Self inductance

When a coil of wire is connected to a battery and a switch, initially, before the switch is closed no current flows through the coil, and there is no magnetic flux linked with the coil, and some magnetic flux is now linked to the coil.

The magnetic flux, Q, through the coil, which is proportional to the current in lt, is changing so that there in an induced e.m.f. E in the coil, in a direction tending to oppose the change of magnetic flux Q

Thus a magnetic flux Q ∝ I or Q = l I where 1 is inductance.

So the rate of change of magnetic flux Q with time is proportional to the area of changed current.

$\frac{dQ}{dt} = \frac{d}{dt}$ (LI) L $\frac{dI}{dt}$ => induced emf

E= $\frac{dl}{dt}$ The inductance of coil is 1 Henry if the back emf induced in it is 1 Volt when the current through it is changing at a rate of 1 ampere per second.

2. Thus, the two conditions for Lenz's Law are

i. An induced e.m.f is obtained when there is a change in the amount of the flux linking a coil. With an open coil, this change produces an induced emf but not an induced current.

ii. Lenz's Law follows the principle of the conservation of energy.

3.

i. When a magnet is stationary, near or even inside, the coil, no current will flow through the coil, if the magnet in moved, the galvanometer needle will deflect, showing that current is flowing through the coil. Also the magnetic field is station and referred to as a magnet static field. At any given point its magnitude and direction remain the same.

ii. When a coil of wire and a bar magnet are moved in relation to each other, an electric current is produced. The current is produced is because the strength of the field at the location of the coil changes. The current is an induced current and the emf. that produces it, is an induced emf.. This is called electromagnetic induction. The direction of the induced voltage is reversed when the magnet is moved out of the coil again.

iii. When the magnet in moved towards the coil, then a current is induced in the coil due to the Phenomenon of electromagnetic induction.

UNIT 3 THE DYNAMO GENERATOR

Unit Structure

3.1 Introduction

Faraday's discovery of electromagnetic induction is the foundation of electrical engineering, which leads to the development of electric current generation machines for examples, house hold generator, and industrial generators.

3.2 Learning Outcomes

By the end of this unit, you should be able to:

- Explain the working principles of a Dynamo generator.

3.3 The Dynamo Generator

A generator is a device that converts mechanical energy to electrical energy. It does this by changing the flux through the coil, thereby inducing an e.m.f between the two terminals of the coil.

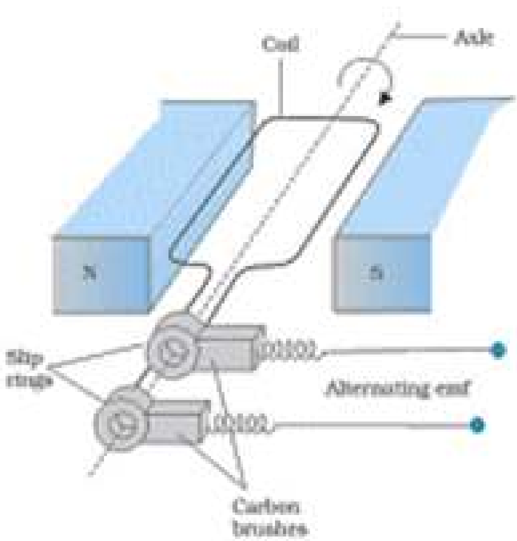
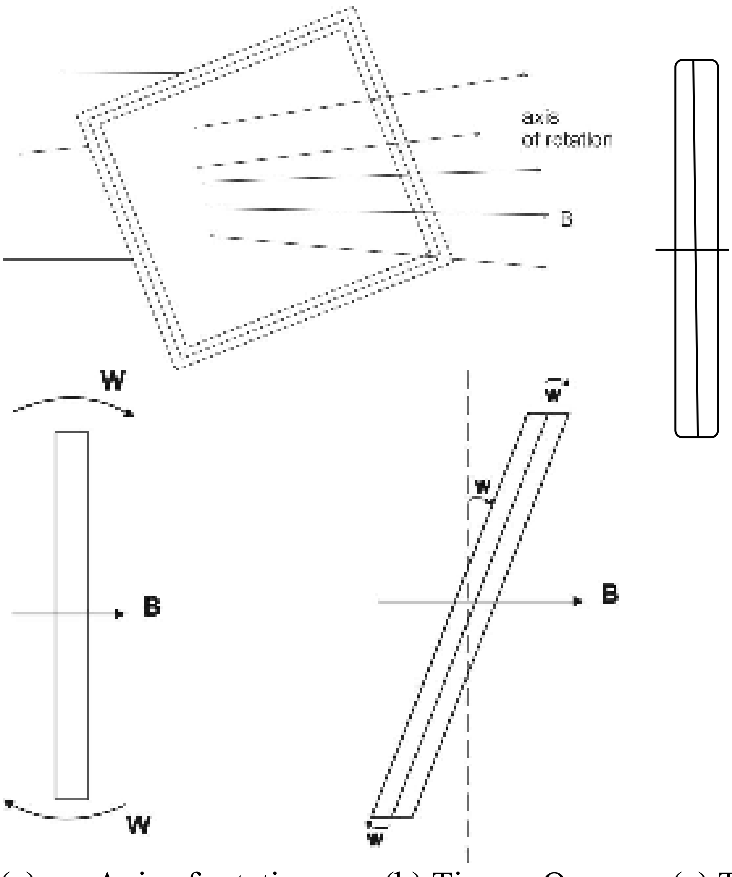


Fig. 20: Dynamo Generator

In theory, the flux could be changed either by moving a magnet with respect to the coil or by moving the coil with respect to a magnet.

As the loop rotates the flux through it changes continually. This changing flux induces an e.m.f in the loop, and the e.m.f causes a current through the loop on the direction indicated. The current can be used to do useful work, perhaps to light a bulb, generate heat, run a simple machine.

A simple generator consists of a flat coil area A and N turns rotating in uniform magnetic fluid of flux density B.



(a) Axis of rotation (b) Time = O (c) Time = T

Fig. 21: A rotating coil in a uniform magnetic foil

Suppose that initially, at time = 0, the plane of the coil is perpendicular to the field. If W is the angular velocity of the coil, after a time t, the coil would have turned an angle of wt.

The magnetic flux linked with the coil is

$$\emptyset = NBA \text{ Cos } wt$$

Applying Faraday's law = The emf in the coil is

$$E = \frac{-d\emptyset}{dt}$$

$= \frac{-dDNBACoswt}{dt}$

= NBA w Sin wt

This equation indicates the e.m.f induced is Siasoidal
With the peak value of E_0 = NBAw
The peak induced e.m.f occurs when wt = 90^0 and wt = 270^0, i.e when the plane of the coil is parallel to the magnetic field. When the place is perpendicular to the field, the emf induced is zero.

Self-Assessment Exercise 10

Explains the working principle of an AC generator

3.4 Summary

We have been exposed to the fact that:

A Dynamo works on the principle of electromagnetic induction; It converts mechanical energy to electric energy; The emf induced in a dynamo is given by E = NBA w Sinwt

Tutor-Marked Assignment

1. What are the difference between a d.c and a.c generator
2. Show that E = NBA w Sin wt.

3.5 References/Further Readings/Web Resources

Anyokoha, M.W. (2016). *New School Physics for Senior Secondary Schools*. Onitsha Nigeria: Africana First Publishers Plc.

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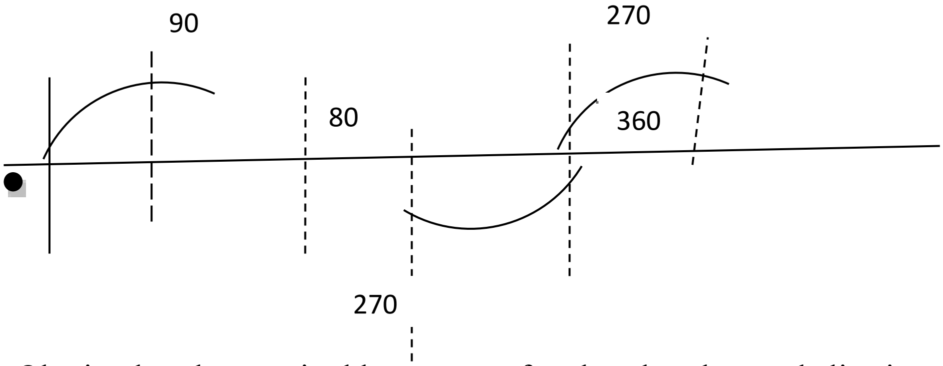
3.6 Possible Answers to Self-Assessment Exercise(s)

1. A simply alternating current generator consist of an armature – a rectangular coil consisting of a large number of turns of insulated wire wound on a laminated soft Iron core.

It has a magnetic field created by the curved poles of a slip – shore magnet or an electromagnet with two copper slip rings to which rotate with the armature. It has two stationary Carbon brushes which are made to press highly against the slip rings.

When the armature (coil) ABCD rotates at a Steady speed about a fixed axis in the magnetic field of the electromagnet. As a result e.m.f is produced in the terminals of the coil by electromagnetic induction. Let us consider a complete rotation of the armature ABCD. In (a) the plane of coil is vertical i.e AB and DC are moving parallel to or along the lines of force. No emf. Is induced at this instant. In (b) the plane of the coil is parallel to the field No line of force link the coil, the rate of change of flux in maximum at this point. Sides AB and DC are moving at right angles, thus EMF in induced. EMF change continuingly from zero (a) to a maximum or peak value at (b) an alternative voltage whose wave form in as in the graph is



Obtained at the terminal by means of carbon brushes and slip rings

UNIT 4 TRANSFORMER

Unit Structure

4.1 Introduction

A transformer is a passive component that transfers electrical energy from one electrical circuit to another circuit, or multiple circuit. Imaging the very high voltage generated at the plant, cannot be used directly in house holds.

4.2Learning Outcomes

By end the of this unit, you should be able to:-

- Define a transformer
- Explain the working principles of a transformer
- Draw a typical transformer

4.3 Transformer

A Transformer is a device that uses mutual induction to change a given (a.c) alternative current Voltage into a larger or smaller a.c voltage in other words, it is a device use for the stepping up or down - an alternative voltage. It consists of a primary coil and a secondary coil wound on a soft iron core.

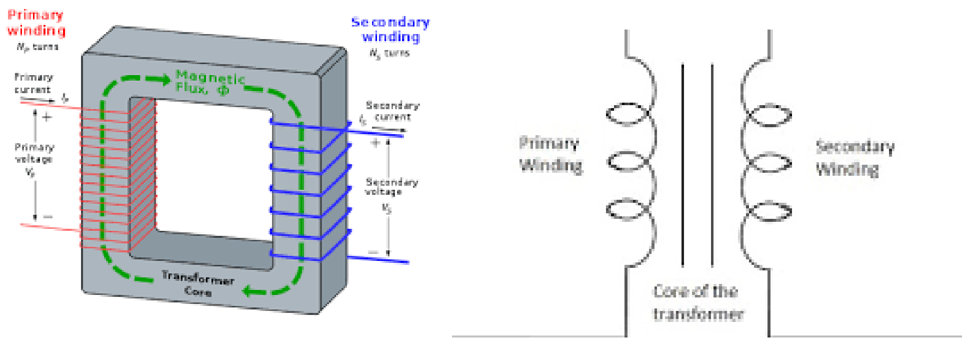


Fig. 22: A transformer

The transformer has an iron core, which is made of thin insulated E-shaped slices of iron lightly bound so that the magnetic flux does not pass through air at all, in this way the maximum flux is obtained with a given current.

When an alternative e.m.f (electromagnetic force) Ep is connected to the primary winding, it sends an alternative current (a.c) through it. This sets up an alternative flux in the core of magnitude BA, where B is the flux density and B is the cross sectional area. This induces an alternative emf in the secondary E_s.

If N_P, N_s are the number of turns in the primary and secondary coils then their linkages with the flux $\emptyset$ are:

$$\emptyset_P = N_p BA \text{ and } \emptyset s = N_s BA \text{ respectively}$$

This flux varies sinusoidal and an e.m.f, is induced in the secondary coil. The magnitude of V, is

$$V_s = \frac{d\emptyset}{dt} = N_s A \frac{dB}{dt} \text{ ------------------------ (1)}$$

Most transformers have very low resistance in their wire. Hence the changing flux also induces a back emf in the primary, whose magnitude is

V_p = back emf

$$V_p = \frac{\emptyset p}{dt}$$

$$= \frac{d}{dt}(N_p BA)$$

$$= N_p A \frac{dB}{dt} \text{ ------------------------------ (2)}$$

From equations (1) and (2)

$$\frac{V_S}{V_p} = \frac{N_S A \frac{dB}{dt}}{N_p A \frac{dB}{dt}} = \frac{N_S}{N_p}$$

The voltage applied to the primary, from the source of current, is used in overcoming the back emf V_p, if we neglect the resistance of the wire, therefore, it is equal in magnitude to V_p – thus action and reaction are equal and opposite. This implies that;

$$\frac{e.m.f induced in secondary}{voltage applied to primary} = \frac{V_S}{V_p} = \frac{N_S}{N_P}$$

So the transformer steps the voltage up or down according to its turns – ratio.

$$\frac{secondary voltage}{Primary voltage} = \frac{number of turns in the secondary coil}{number of turns in the primary coil}$$

$\frac{V_S}{V_p} = \frac{N_S}{N_p}$ is true only when the secondary is an open circuit

Transformers however have energy losses when used due to four main causes.

1. Copper losses – heat is produced in copper cols of the primary and secondary of the current.
2. Eddy Current losses – induced (eddy) currents flow in the soft iron core.
3. Flux leakages – some magnetic flux does not pass through the iron core.
4. Hysteresis losses – the magnetization of the iron does not follow the magnetic field due to the a.c lags behind due to friction

However, in an actual transformer, the efficiency is generally less than 100%.

Transformer efficiency is defined as the ratio:

$$\frac{UsefulPowerdeliveredbyit}{TotalPowerSuppliedtoit} \text{ x } 100\%$$

i.e $\frac{Poweroutput}{TotalPowerInput}$ x 100%

i.e $\frac{I_S V_S}{I_P\ P_P}$ x 100%

Self-Assessment Exercise 11

1. Identify the types of transformer
2. Find the turns ratio in a transformer which delivers a voltages of 160 volts in the secondary coil from a primary voltages of 80 volts
3.
i. Draw a transformer and explain its working which can produce 24 V from a 240 V supply.
ii. Calculate the current in the 240 v supply if the efficiency of the transformer in 90% and the current in the secondary is 10A
iii. Advance three reasons, which can explain why the efficiency of the transformer cannot be 100%
iv. Explain how such inefficiencies can be reduced

4.4 Summary

1. A transformer is a device for stepping up or down an alternative voltage. It has primary and secondary windings but no make-and-break.
2. The flux charge depends on the cross-sectional area A of the coil, the magnitude of flux B and n the number of turns of coil.

$$\frac{secondaryvoltage}{Primaryvoltage} = \frac{numberofturnsinthesecondarycoil}{numberofturnsintheprimarycoil}$$

3. Efficacy of a transformer is given by:-

$$\frac{UsefulPowerdeliveredbyit}{TotalPowerSuppliedit} \text{ x } 100\%$$

=> $\frac{I_S V_S}{I_P\ P_P}$ x 100%

4. Power is lost in actual transformer in the following ways
i. Copper losses
ii. Eddy current
iii. Flux linkage
iv. Hysteresis losses
5. Power loss in a transformer can be minimized by;
i. Using core made of very soft iron
ii. Using coils of very small resistance
iii. Using lamination in the core of the transformer
iv. Efficient coupling between the circuits

Tutor-Marked Assignment
1. If a transformer is used to light a lamp rated at 60w, 220V from a 4400V ac supply calculate the;
v. Ratio of the number of turns of the primary coil to the secondary coil in the transformer.
vi. Current taken from the mains circuit if the efficacy of the transformer is 90%

4.6 References/Further Readings/Web Resources

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Possible Answers to Self-Assessment Exercise(s)

4. The types of transformer are:-

i. Power transformers, A power transformer transfers electricity between a generator and the distribution primary circuits. Power transformer can be-a. step up generator output Voltage to the transmission system voltages level, - step down transmission voltages to safe levels for distribution or step down voltage to the auxiliary power system level in a generating station.

ii. Auto transformer – These are generally used as transmission inter – tie transformer can be used as step-up or step down mode.

iii. Auxiliary transformers supply power to a generating plant's auxiliary hads (thick feed pumps, coo plant pumps, and safety devices that a power plant needs to run)

5. Turns ratio of a transformer = $\frac{number\ of\ turns\ in\ secondary.coil}{number\ of\ turns\ in\ primarr.coil}$

$= \frac{Ns}{Np}$

$\frac{Es}{Ep} = \frac{Ns}{Np}$.

$2\,\frac{1/6\cancel{0}}{8\cancel{0}} = \frac{Ns}{Np} = 2$

Turn ratio = 2.

6.

i. Turns ratio $\frac{Ns}{Np} = \frac{24}{240} = \frac{1}{10}$

This means that there should be more turns in the primary than in secondary coil and the ratio $\frac{Ns}{Np} = 10$

ii. Efficiency is 90 ie. $\frac{power\ in\ the\ Secondary.coils}{power\ in\ the\ Primary.coil} = 90\%$

$\frac{Is\ Es}{Ip\ Ep} = \frac{90}{100}$

But $\frac{Es}{Ep} = \frac{24}{240}$ => $\frac{24}{240}\ \frac{Is}{Ip} = \frac{90}{100}$ but = Is = 10A

⇨ $\frac{24}{240}\ \frac{10}{Ip} = \frac{90}{100} = Ip = \frac{1\cancel{00}}{9\cancel{0}}\ x\ \frac{24}{24\cancel{0}}$ x $10 = \frac{240}{216}$

Ip = 1.11 A

iii.

_ Generation of Joules heat in the coils.

_ Generation of heat in the cores due to eddy currents

_ Inefficient design of the core and windings.

iv.

_ This can be reduced by using copper wire of very low resistance

_ By making the core of iron wires or strips insulated from one another

_ Suitable choice of material

UNIT 5 ELECTRIC MOTOR

Unit Structure

5.1 Introduction

Electric motor is another device developed based on electromagnetic induction.

5.2 Learning Outcomes

By the end of the unit, students should be able to:

- Describe an electric motor
- State and explain working principle of electric motor
- Identify the application of electric motor to life.

5.3 Electric Motor

An electric motor is an electric machine that converts electrical energy into mechanical energy. It is used for driving many machines at home and in the industry.

5.3.1 Electrical Motor Diagram

Simple electric motor consists of;

i. A coil of wire (armature) which can rotate about a fixed axis
ii. A powerful magnetic which the coil turns
iii. A commutator which in its simplest form, is a split copper ring whose two halves A and B are insulated from each other.
iv. Current flaws round the armature coil, and the magnetic field exerts a couple on this, as in a moving coil meter. The commutative reverses the current just as the slides of the coil are changing from upward to downward movement and vice versa.

The applications of electrical motor mainly include: blowers, fans machine tools, pumps, tarbines, alternators compressors, rolling mills, ships, paper mills, drills, washing machines etc.

Self-Assessment Exercise 12

How do we get back emf of a motor

5.4 Summary

The unit discussed that: Electric motor generates mechanical force by rotating conductor carrying current. The coil has two commutator which is made of two halves, and reverses the current in the coil after half revolution so that the coil keeps turning around.

Tutor-Marked Assignment

What are the working principle of an electric motor

5.5 References/Further Readings/Web Resources

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5.6 Possible Answers to Self-Assessment Exercise(s)

The motor moves continuously at a new speed. If the load on the motor is suddenly reduced, the driving tongue on the motor is more than the load tongue. Thus the drawing tongue increases the speed of the motor which also increases their back e.m.f. the high value of back emf decreases the armature current. Also a motor has coil turning inside magnetic field, and a coil turning inside a magnetic field induces an emf.

MODULE 3 MODERN PHYSICS

In this module, participants will be exposed to the meaning of nuclear atom, radio activity, nuclear reactions and relativity.

Unit 1 Nuclear Atom
Unit 2 Radioactivity
Unit 3 Nuclear Reaction
Unit 4 Fission and Fusion Reaction
Unit 5 Relativity

UNIT 1 THE CONCEPT OF NUCLEAR ATOM

Unit Structure

1.1 Introduction
1.2 Learning Outcomes
1.3 The Nuclear Atom
1.4 The concept and properties of Nucleus
1.5 Property of Nucleus
1.6 Summary
1.7 References/Further Readings/Web Resources
1.8 Answer Self-Assessment Exercise 13

1.1 Introduction

Studies in modern or atomic physics centers around the world postulated on what happens in the nucleus of the atom. The proper understanding of this is the gate way to modern physics.

1.2 Learning Outcomes

By the end of this unit, you should be able to:

- Describe the structure and content of the atomic nucleus
- Explain the concept of the nucleus
- State the general properties of nucleus

1.3 The Nuclear Atom

An atom contains a massive, positively charged nucleus, much smaller than the overall dimension of the atom but containing most of the total mass of the atom. The nucleus contains positively charged protons (+e) and Neutral neutrons (that is no charge) the particles inside the nucleus are called nucleons.

The nucleus was discovered in 1909 by Geiger and Marsden after the experiment on scattering of ∝-particles by a thin film of metal of high atomic mass. In the experiment some of the ∝-particles were scattered through very large angles. The scattering was due to the positively charged nucleus.

1.4 The concept and properties of Nucleus

A nucleus is a small, heavy, positively charged portion of the atom and located at the centre of the atom. The radius of the nucleus is found to depend on the number of nucleons in the nucleus. The radii of most nuclei are represented by the equation.
$R = r_0 A^{1/3}$

Exercise
Where r is radius of nuclei, A is the mass number, r_0 is a constant of value $1.2x10^{-15}$m.
For example: Find the radius of ^{56}Fe
What do we know $r = r_o A^{1/3}$ radius of a nucleus

$r_0 = 1.2 \times 10^{-15}$m

A = 56

Substituting the values in the equation for $r = r_0 A^{1/3}$

$r = (1.2\text{fm})(56)^{1/3}$

$= 1.2\text{fm} \times 3.63$

$= 4.6\text{fm}$

1.5 Property of Nucleus

Protons and neutrons have approximately the same mass, but protons carry one unit of positive charge (+e) and neutrons carry no charge.
The number of protons in the nucleus is given by the atomic number, Zthenumber of neutrons in the nucleus is the neutron number N. The total number of nucleus is the mass number A.
These numbers are related by A nucleus and is represented symbolically by

$$= {}^{A}_{Z}X_N$$

Where X represents the chemical element A in the mass number and Z is the atomic number.

For example: ${}^{12}_{6}C$ represents the carbon nucleus with 6 protons and 6 neutrons (or 12 nucleons)
The size nucleus is about 10,000 times smaller than the atom and the charge of the nuclei consist of protons and neutrons. The total number of protons equal in neutral atom to the number of electrons.

Self-Assessment Exercise 13
Determined the radius of the nucleus of ${}^{12}_{6}C$

1.6 Summary

1. A neutral atom is expected to have equal number of protons and electrons
2. The nucleus contains positively charged proton (+e) and neutral neutrons (no charge).
3. The radius of the nucleus depends on the number of nucleus given by the ratio $r = r_0A^{1/3}$
4. r_0 is a constant with value of 1.2×10^{-15}m
5. nucleus of an atom is symbolically represented by $^{A}_{Z}X_N$ where A is mass number, Z, atomic number and N neutron number
6. the total number of protons equal in neutral atom to the number of electrons

Tutor-Marked Assignment

1. The radius of Uranium – 238 nucleus is about 7.4×10^{-15}m, what is the number of nucleus of the atom?
2. State four properties of a nucleus of an atom

1.7 References/Further Readings/Web Resources

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1.7 Answer Self-Assessment Exercise 13

What do we know?, We know that
$r = r_o$ A 1/3 radios of the nucleus
A s the mass number which is = 12
r_o a constant of value = 1.2 x 10m $^{-15}$
we don't know the radius of 12_c
substituting the values in the equation of
$r = r_{o\ A\ 1/3}$
= (1.2 x 10 $^{-15}$ m) ^{9}(12) 1/3
= (1.2 fm) (12) 1/3
= 1.2 fm x 2.29
=2.75fm.

UNIT 2 RADIOACTIVITY

2.1 Introduction

Becquerel in 1896 noticed the same photographic plates placed closed to some uranium salt were blackened. The unit will open participants up to what happens when the emission of radiation from radioactive substance occurs.

2.2 Objectives

By the end of this unit, you should be able to:

- Define and state different types of radioactivity
- State the general properties of radioactive particles
- State the major particles emitted in radioactivity
- Describe radioactivity transformation.

2.3 Radioactivity

It is the spontaneous decay or disintegration of the nucleus of an atom of an element into generation of some energy (heat) and emission of some radioactive particles. The emitted particles are; alpha ∝, Beta particle β and gamma ɤ radiations. The radiated particles are found to have general properties such as high penetration and ionization.

2.4 Radioactive Transmission

There are two classes of radioactivity – the neutral and the artificial. Neutral radioactivity is the spontaneous disintegration of the nucleus of an atom during which ∝- or β- particles or gamma rays or a combination of them and heat is released.

Artificial radioactivity: When radioactivity is induced in an element by irradiation. For example, neutron, meaning when exposed to radiation either by accident or by intent. Also it is a situation were an ordinary atom is made radioactive by bombarding it with radioactive particles.

Table 1: Some general properties of elements in radioactivity

PARTICLES	NATURE	ELECTRICAL CHARGE	MASS	VELOCITY	RELATIVE PENETRATION	ABSORBER
Alpha $\propto$ particle	Helium Nuclei	+2e	4 units	About $\frac{1}{20}$ velocity of light	1	Thin paper
Beta β particle	Electrons	-1e	$\frac{1}{1800}$ unit	3-99% velocity of light	100	Metal plate
Gamma γ – ray	Electromagnetic radiation	No charge	Negligible	Velocity of light	10,000	Large lead blocks

e= numerical value of charge on electron.

2.5 Applications Of Radioactivity

1. Cancer cells can be destroyed by gamma rays from a high activity source of cobalt 60.
2. Deep-lying tumours can be treated by planting radium 226 or cesium 137 inside the body close to the tumor.
3. The thickness of metal sheet can be monitored during manufacture by passing it between a gamma-ray and a detector.
4. The exact position of an underground pipe can be located if a small quantity of radioactive liquid is added to the liquid been carried by the pipe.
5. Radioactive phosphorus is used to assess the different abilities of plants to take up phosphorus from different types of phosphate fertilizer.

The rate of which radioactive materials decays is known as activity, the number of radioactive nuclei in any sample of radioactive material decreases continuously as some of the nuclei disintegrates.

The new elements formed after disintegration can be identified by considering the particles emitted from the nucleus of parent atom;

1. When a nucleus undergoes an alpha decay, it loses four nucleons, two of which are protons, therefore, its mass number, A decreases by 4 and atomic number Z decreases by 2.

Thus for ∝ A – 4

Z – 2

$^{A}_{Z}X \xrightarrow{\alpha} {}^{A}_{Z} + {}^{4}_{2}He$ + Energy

So that $^{238}_{92}U \xrightarrow{\propto} {}^{238-4}_{92-2}Th + {}^{4}_{2}He$ + Energy

The number of nucleons is conserved, (that is 238 = 234+4) and the charge is conserved (that is 92 = 90+2) they are deflected by electric and magnetic fields.

2. When a nucleus undergoes a beta decay its mass number, A does not change and atomic number, Z, increases by 1

Thus for β particle

A – 0 $^{A}_{Z}X \xrightarrow{\beta} {}^{A}Y + {}^{0}_{1}e$ + Energy

Z + 1

So that $^{14}_{6}C \xrightarrow{\beta} {}^{14}_{7}N + {}^{0}_{1}e$ + Energy

The number of nucleons is conserved, (i.e 14 = 14+0) and the charge is conserved (i.e 6 = 7 – 1) Beta particles are less massive than alpha particles and are easily deflected by electric and magnetic fields.

3. Gamma particles have no charge in A, Z or N thus gamma rays cannot be deflected by electric and magnetic fields.

2.6 Health Hazards

2. ∝-particle are stopped by the outer layers of the skin as their penetration power is small. If the penetration into the body, however, they are dangerous and damage organs.
3. B-particles are more penetrating than ∝-particles - are dangerous to the body γ-rays and energetic β-particles destroys cells in tissue and upset the natural chemical reactions. For example x-rays.

3.7 Summary

In this unit have discussed that: Radioactivity is the spontaneous decay or disintegration of the nucleus of an atom of an element into generation of some energy (heat) and emission of some radioactive particles; The emitted particles as a result of radioactivity are alpha (∝), beta (β and gamma rays (γ); When a nucleus undergoes an alpha decay, it loses 4 nucleons, 2 of which are protons, thus the mass number A decrease by 4 and atomic number Z decreased by 2; When a nucleus of a beta particle decay, its mass number A does not change and atomic number Z increases by 1; Gamma rays no change in mass number A, atomic number Z and N.; Alpha is a helium atom, beta an electron and gamma an EM.

Self-Assessment Exercise 14

A uranium nucleus, μ-238, atomic number 92, emits two ∝ particles and two β particles (electrons and forms a thorium (Th) nucleus. Write the symbol of this nucleus.

2.8 References/Further Readings/Web Resources

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1.10 Answer to Self-Assessment Exercise 14

1. From the relationship of $_{Z}^{A}x$ decays by $\propto$ emission, two protons and two neutrons are ejected it as an $\propto$ particle, => $_{Z-2}^{A-4}y$

$_{92}^{238}U \propto {}_{92-2}^{238-4}Th + {}_{2}^{4}He$ + energy

$_{90}^{234}Th + {}_{2}^{4}He$ + energy

Thus when it emits β particles which is given by

$_{Z}^{A}x \xrightarrow{\beta} {}_{2+1} \; {}_{-i}^{o}e$ + energy

$_{90}^{234}th \longrightarrow {}_{91}^{234}P_a + {}_{i}^{o}e$ + Energy.

UNIT 3 NUCLEAR REACTIONS

Unit Structure

3.1 Introduction

In radioactivity, emission of some (particles) and energy are involved. There is the need to know how to determine the energy and nature of particles involved.

3.2 Learning Outcomes

By the end of this unit, you should be able to:

- Determine energy involved in simple nuclear reaction.

3.3 Nuclear Reaction

In any reaction, the law of conservation of mass and charge is always applied. It is stated as follows:

1. Total mass (nucleon) number is constant before and after the reaction
2. Total charge (proton) number is constant before and after the reaction

Let us consider the following reactions

1. An ∝-particle, a helium nucleus, has a charge of +2e and a mass number of 4. Uranium I of atomic number 92 and has mass number 238, emits an ∝-particle from its nucleus of charge +92e so the new nucleus formed has an atomic number 90 and mass number 234 so the nuclear reaction is:

$${}^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{234}_{90}Th$$

2. A β particle is usually an electron of negligible mass and charge – e or -1 in terms of e on rare occasions, however, a β particle is emitted which has a positive charge +e or +1 in terms of e. This particle is called a positron and denoted by β^{+}.

Let us assume a typical β decay reaction is that of thorium decaying to protactinium:

$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e + ^{0-}_{0}V$

The nucleon number obviously balance since 91 + (-1) is 90

Consider the reaction

$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$

To learn more about this reaction, notice the masses of the reactant, nuclei;

Mass of ^{14}N = 14.0031u – 7me

Mass of ^{4}He = 4.0026 – 2me

Total mass before reaction = 18.0057μ – 9me

Examine the masses after reaction:

Mass of ^{17}O = 16.9991μ – 8me

Mass of ^{1}H = 1.0078 – 1me

Total mass after reaction = 18.0069μ – 9me

The product have 1 more than the original reactants, the difference being 0.0012μ. this mass could be created only if additional energy was added to the reaction.

The energy from mass difference is obtained using relation $E = mc^2$ which gives the reaction energy.

Mass difference = 18.0069μ - 18.0057μ = 0.0012μ

$E = mc^2 = 0.0012\mu \times 931\ me\gamma (1\mu = 931 me\gamma)$

$E = 1.1172 \cong 1.1Me\gamma$

This is the energy released after reaction. If energy obtained is +ve, energy released, if energy obtained is –ve, energy is absorbed.

Self Assessment Exercise 15

How does energy release relate to stability of nucleus?

3.4Summary

We have been able to understand that:

Law of Conservation of mass and charge; (i) Total mass (nucleon) number is constant before and after reaction. (ii) Total charge (proton) number is constant before and after reaction; When an uranium I of atomic number 92 and mass number 238. It emits

$^{238}_{92}U \quad ^{4}_{2}He + \rightarrow ^{234}_{90}Th$; When a thorium decay it remits

$^{234}_{90}Th \, ^{234}_{91}Pa + \rightarrow ^{0}_{-1}e + ^{0-}_{0}V$

Tutor-marked Assignment

Radom 222 decays to Polonium 218 by alpha emission. Find the approximate energy of the emitted alpha particle. Pertinent atomic masses are ^{222}Rn = 222.01753, 218_{P0} = 218.00893μ, ^{4}He = 4.00263μ.

3.5 References/Further Readings/Web Resources

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3.6 Answer to Self-Assessment Exercise

1. A Molecules is more stable than its isolated atoms, a nucleus is more stable (lower in energy) than its isolated components. So when isolated nucleons assemble into a stable nucleus, energy is released. Thus the neutron/proton ratio and the total number of nucleons in the nuleus.

2. Consider if the number of $\propto -$ particles emitted is n, then the number of β – particles emitted is (4 – n)

Hence $^{210}_{81}x \rightarrow {}^{A\,Y}_{82} + n\,{}^{4}_{2}He + (4 - n)\,{}^{o}_{i}e$

looking at the atomic numbers

81 = 82 + 2n - 4+ n

= (2n +n)

Collecting like terms

(81 – 82 +4) = (2n + n)

~~3~~ = ~~3~~n

n = 1

$^{210}_{81}x \rightarrow {}^{A}_{82}Y + (1)\,{}^{4}_{2}He + (3)\_\,{}^{o}_{i}e$

Equating the mass number 210 = A+4

$\therefore A = 206$

UNIT 4 NUCLEAR FISSION AND FUSION

Unit Structure

4.1 Introduction

Nuclear reaction goes beyond release of small particles of ∝, β and γ. They also release heavy particles and large amount of energy in a nuclear reaction fission and fusion.

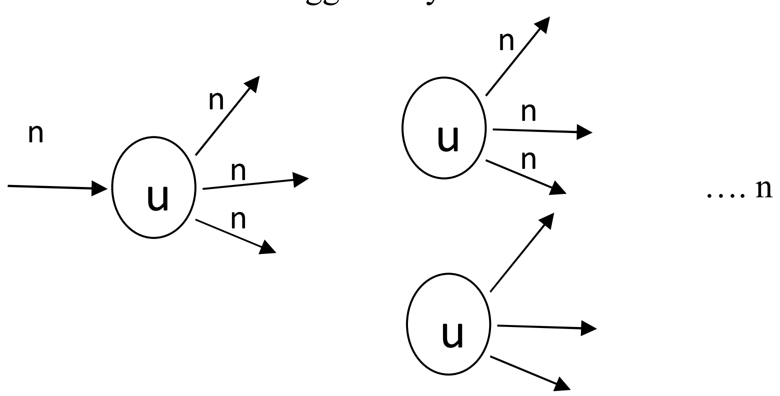
4.2 Learning Outcomes

By the end of the unit, you should be able to:

- Describe fission and fusion reaction
- State some conditions for nuclear fission and fusion reaction

4.3 Nuclear Fission

When the nucleus of heavy radioactive elements is split into smaller nuclei of two or more particles, the nucleus is said to undergo fission when bombarded by neutrons which are fast and large.
Uranium bombarded with fast neutron, gave out barium (Ba), Krypton (Kr) and Neutron (n) among the products. In uranium fission released neutron could cause continuous fission in neighboring nucleus causing chain reaction,
$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{36}Kr + ^{143}_{56}Ba + 3\,^{1}_{0}n$ + energy
Chain reaction could be triggered by the neutron



Both the reaction $^{90}_{36}Kr$ and $^{143}_{56}$ Ba are radioactive, the product of fission is highly reactive and provide strong sources of radiation and the release of large amount of energy. This occurs only in a nuclear reactor, and the energy generated could be tapped and used to generate electricity and other isotopes for other uses. Action of an atomic bomb occurs in the fission manner.

Self-Assessment Exercise 16

1. Explain what is meant by the statement ^{235}U is made to undergo fission by thermal neutrons.
2. Describe fusion reaction

4.4 Fusion Reaction

Fusion involves the combination of two light nuclei to form a nucleus that is heavier and more complex. It occurs with high elements such as hydrogen whose nuclei fuse together and form heavier nuclei such as Helium. Nuclear fusion occurs in the sun and stars where temperature is very high.
For example:

$$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H + ^{0}1$$

$$^{2}_{1}H + ^{1}_{1}H \rightarrow ^{3}_{2}He + \gamma$$

For fusion to occur, the two nuclei must come together with the range of 2×10^{-15}m to overcome electrostatic repulsive forces. The nuclei must be at a temperature of 5×10^{10}k almost the temperature of sun.
The energy released in both fission and fusion reaction can be determined by setting the energy equivalent of the total mass of reactant and that of the mass of the product.

4.5 Summary

In the unit, discussed and explained that:

Nuclear fission is the splitting of a heavy atom, such as Uranium into heavy parts; it is produced when neutrons of suitable speed are fired into a mass of Uranium-235; nuclear energy is released; Nuclear fusion occurs in the sun; hydrogen nuclei fuse to form helium nuclei, with the release of large energy; Condition for

a. Fission (i) A heavy radioactive element, (i). The nucleus is bombarded by neutrons which are fast and large.(i). Isotopes are produced with large amount of energy
b. Fusion' (i). A combination of two light nuclei to form a nucleus that is heavier (ii). The nuclei must fuse together and form heavier nuclei (iii). The two nuclei must come together with a range of 2×10^{-15}M. (iv). Nuclei must be at a temperature of 5×10^{9}k

Tutor-Marked Assignment

1. Describe with an aid of a chain reaction of a neutron
2. What are the differences between fission and fusion reaction

4.6 References/Further Readings/Web Resources

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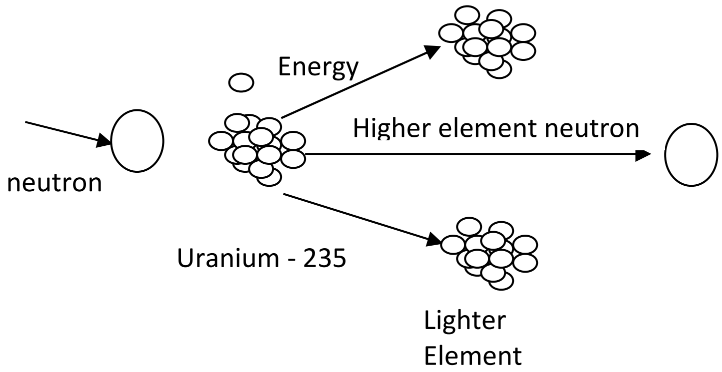
4.7 Answer to Self-Assessment Exercise

1. When a 235 U nucleus absorbs an extra neutron, it quickly breaks into two parts this process is known as fission. Each a U – 235 nucleus splits \, if releases two or three neutrons, Hence creating a chain reaction.



In the nucleus of each atom of uranium – 235 are 92 protons and 143 neutrons for a total of 235. The arrangement of particles within Uranium – 235 is some where unstable and nucleus can disintegrate if it is excited of an outside source.

2. Nuclear is a reaction in which two or more atomic nuclear fusion and subatomic particles. The difference in mass between the reactants and products manifested as either the release or the absorption of energy. Nuclear fusion uses lighter elements, such as hydrogen and helium which are generally more the fusible; while the heavier elements, such as uranium, thorium and plutonium are more fissionable. The joining together of two small nuclear to form a larger nucleus with the release of large amount of energy.

Consider $^{2}H + ^{2}H \rightarrow {}^{3}_{2}H_{2} + {}^{1}_{0}$ n

UNIT 5 RATE OF RADIOACTIVE DECAY AND HALF LIFE

Unit Structure

5.1 Introduction
5.2 Learning Outcomes
5.3 Rate of Radioactive Decay
5.4 Half-life
5.5 Summary
5.6 References/Further Readings/Web Resources
5.7 Answer to Self-Assessment Exercise 17

5.1 Introduction

Radioactivity is the result of unstoppable nuclei disintegrating and in the process emitting particles, it is important for us to know the rate of decay of such particles. Which particular atom will decay and when it will decay cannot be predicted.

5.2 Learning Outcomes

By the end of this unit, you should be able to:

- Find the rate of decay of a radioactive sample
- Determine the time taken by the sample to decay to half its initial number

5.3 Rate of Radioactive Decay

Radioactive decay is a random and spontaneous process due to the disintegration of nuclei of atom. The disintegration obey the statistical law of chance. It is important to note that, which particular atom will decay and when it will decay cannot be predicted nor can we predict how many atoms in a sample would decay at any particular instant. The rate of decay is not affected by the following external conditions:

i. High or low pressures;
ii. High or low temperatures;
iii. Strong or weak magnetic or electric fields; and
iv. Chemical combinations or reactions

The number of atoms disintegrating per second, $-\frac{dN}{dt}$, is directly proportional to the number of atoms N, present that instant.

Rate of radioactive decay, $-\frac{dN}{dt} \propto N$

$$= -\frac{dN}{dt} = -\lambda N \text{ ----------(1)}$$

Where λ is a constant, known as the decay constant, of the radioactive nuclide. Different radioactive nuclides have different values of λ

Hence $\lambda = \frac{(\frac{-dN}{dt})}{N} = \frac{\text{rate of decays}}{\text{number of radioactive nuclei in the sample}}$

The decay constant λ of a radioactive isotope can be define as the probability that a radioactive nucleus of the isotope in the sample would decay in one second.

From equation (1) $\frac{dN}{dt} = -\lambda N$

$$\frac{dN}{N} = -\lambda dt$$

Integrating from t = 0, when $N=N_0$, to t=t when N=N

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt$$

$$[\text{InN}]_{N_0}^{N} = -\lambda\, [t]_0^t$$

$$\frac{in}{N_0} = -\lambda t$$

$$\therefore \frac{N}{N_0} = e^{-\lambda t} \text{ ---------------- (2)}$$

So that the number N of undecayed atoms left decreases exponentially with time t,

From equation (1), $\lambda = \frac{1}{N}\frac{dN}{dt} = \frac{Number of disintegrating atoms per second}{Total number of atoms}$

A graph of N, the number of radioactive nuclei present in a sample, against the time t is shown below

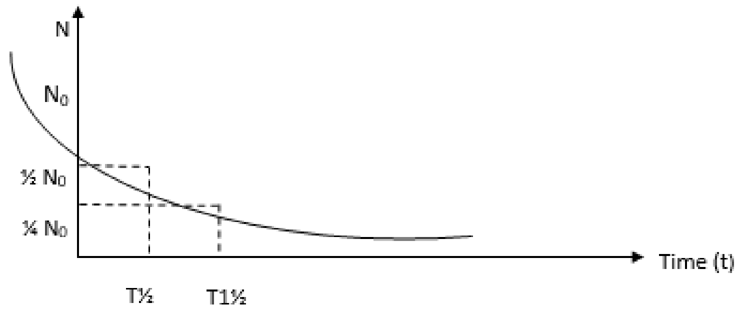


Fig. 23

Radioactive decay with time

From the graph, when t= T ½ N= ½ N_0

5.4 Half-life

The half-life T ½ of a radioactive nuclide (element) is defined as the time taken for the atoms to disintegrate to half their initial number. This means that in a time T½ the radioactivity of the element diminishes to half its value.

So if N_0 is the initial number of atoms from the equation (2)

$\frac{N_0}{2} = N_0\, e^{-\lambda T1/2}$

$½ = 2^{-1} = e^{-\lambda T1/2}$

Taking logs to the base e on both sides of the equations

-1 In 2 = $-\lambda T½$

∴half life $T½ = \frac{1}{\lambda}$ In 2 = $\frac{0.693}{\lambda}$

The unit of radioactive activity is Becquerel (Bq) 1 Bq rate of decay of 1 nucleus per second.

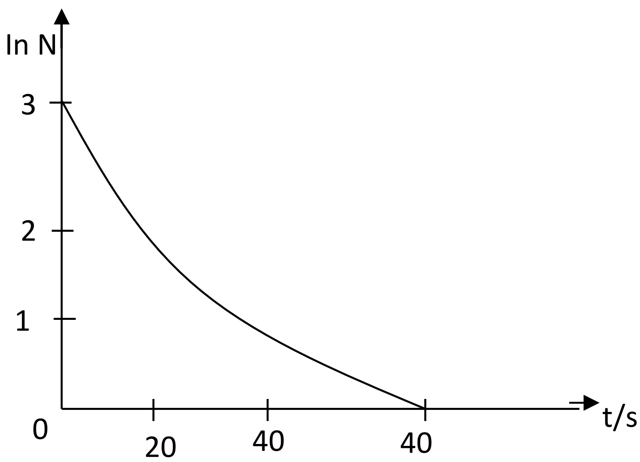
Self-Assessment Exercise

1. Define rate of decay of an atom
2. Write down the relation between the decay constant λ and the half-life T½ of a radioactive isotope.

5.5 Summary

In this unit, we discussed that: Decay constant λ of a radioactive isotope can be defined as the probability that a radioactive nucleus in the sample would decay in one second; The time taken by a sample of radioactive nuclide to decay to half its initial number of radioactive nuclei is the half-life of the radioactive nuclide; Half-life is given by the relation $T½ = \frac{In\ 2}{\lambda}$; Unit for radioactive activity in Bq international while curie (Ci) US unit; $T½ = \frac{0.693}{\lambda}$

Tutor-Marked Assignment



The graph shows the relation between the number of radioactive particle emitted per second N_1 from a source and time t.

Deduce from the graph;

i. The initial activity
ii. The decay constant λ

5.6 References/Further Readings/Web Resources

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5.7 Answer to Self-Assessment Exercise

1. The rate decay or activity, of a sample of a reactive substance is the decrease in the number of radioactive nucleus per unit time. This is measured in terms of half lives. The half – life is the amount of time it takes for a given isotope to lose half of its radioactivity.

2. Rate of decay, -$\frac{dN}{dt}$ of a radioactive sample, is directly proportional to N,

Rate of radioactive decay, - $\frac{dN}{dt} = \propto N$

$$\text{Or } \frac{dN}{dt} = -\lambda N$$

Where λ is a constant – decay constant

hence $\lambda = \left(\frac{dN}{dt}\right) = \frac{rate\ of\ decay}{number\ of\ radioactive\ nuclei}$
N

$\frac{dN}{dt} = -\lambda N \Rightarrow \frac{dN}{N} = -\lambda\, dt$

Integrating from t = o when N=No to t = t when N = N,

$$\int_{No}^{N} \frac{dN}{N} = \lambda \int_{o}^{t} dt \quad -$$

$$[In\ N]\ \frac{N}{No} = -\lambda\ [t]\ \frac{t}{o}$$

in $\frac{N}{No} = -\lambda t$

when t = t ½ N = ½ No ∴ $\frac{N}{No} = e^{-\lambda t}$

taken logs to the base e on both sde – 11n2 = - y T ½ ⇛T ½ = 1n2 = $\frac{0.693}{\lambda}$

Therefore t = $\frac{0.693}{\lambda}$

UNIT 6 MEASUREMENT OF SHORT AND LONG HALF-LIFE

Unit Structure

6.3 Introduction

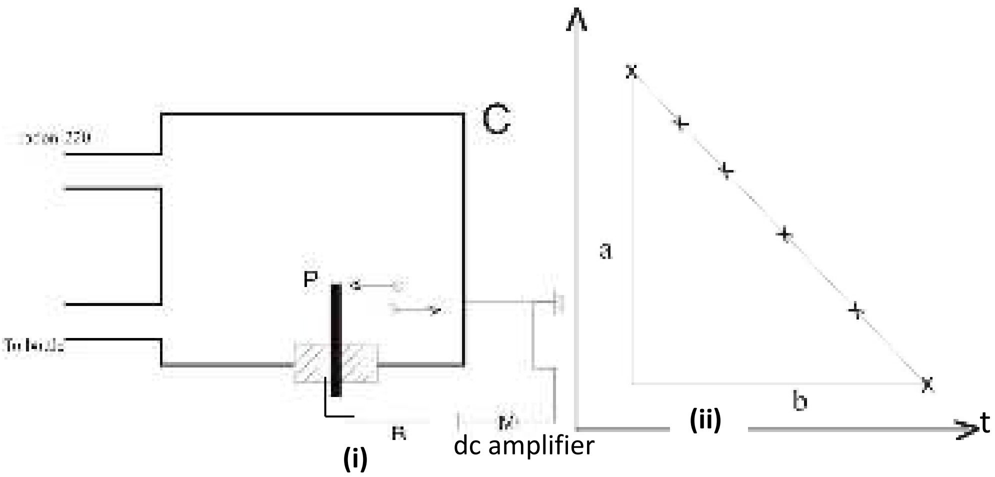
The half-life varies considerably for different-radioactive atoms such as Uranium has a half-life of the order of 4500 million years, Radium has one about 1600 years, Polonium about 138 days. It is important for us to understand how to measure their rate of decay.

6.4 Learning Outcomes

By the end of this Unit, participant should be able to;
Explain the measurement of short and long life.

6.3 Measurement of short and long Half-Life of radioactive atom.

The half-life of radon – 220, a radioactive gas with a short half-life.



C is a metal Can or ionization chamber containing a metal rod P insulated from C. B is a suitable dc supply such as 100V connected between P and C, with a dc amplifier M formed in series. This meter can measure very small currents.

A plastic bottle containing the gas radon-220 is connected to the chamber C. the radioactive gas is passed into C by squeezing the bottle and when the atoms decay the α-particles produced ionize the air in C.

The negative and positive ions produced more between P and C due to the supply voltage B and a small current is registered on the meter M. starting with an appreciable deflection in M, the falling current I is noted at equal intervals of time t such as 15 seconds. A graph of In I against t is then plotted.

We know that $I = Ioe^{-\lambda t}$
Since the number of disintegration per second is proportional to the number of ions produced per second and hence to the current I
Taking logs to the base e
In I = In Io - λt

The gradiant a/b of the straight line AB is λ numerically and this can be found.

The half-life $T_{1/2}$ is given by T/2 = 0.693/λ
For a substance with a half-life such as days, weeks or years we can proceed as follows;
1st weigh a small mass of the specimen S, m say if the relative molecular mass of S is M and S is monatomic, the number of atoms N is given by
$N = \frac{m}{M} \times 6.03 \times 10^{23}$

Using Avogadro constant
2nd determine the rate of emussion, $\frac{dN}{dt}$ all round the specimen S by placing S at a distance r from the end face, area A of GM tube connected to a scaler.

Suppose the measured count rate through the area A, is $\frac{dN1}{dt}$ then the count rate all round S, in a sphere of area $4\lambda r^2$ is given by

$$\frac{dN}{dt} = \frac{4\pi r2}{A} \times \frac{dN1}{dt}$$

Since $dN/dt = -\lambda N^1$
the decay constant λ can be calculated as N and $\frac{dN}{dt}$ are known
The half life is then obtained from

$$T_{1/2} = 0.693/\lambda$$

Self-Assessment Exercise

For a substance with half life of days, how can you proceed to measure its half life.

6.4 SUMMARY

In this unit, participants have learnt that:

$I = Ioe^{-\lambda t}$ number of disintegrations per second is proportioned to the number of ions produces per second; Weigh a small mass of the specimens S, m, say, if the relative molecular mass of S is M and S is monatomic the number of atoms N is $N = \frac{m}{M}$ x $6.03x10^{23;}$ Determine the rate of emission, dN/dt all round S and placing S at a distance r from Area A

$\frac{dN}{dt} = \frac{4\pi r2}{A}$ x $\frac{dN1}{dt}$.

Tutor-Marked Assignment
Explain the measurement of short and long half-life of radioactive gas atoms.

6.5 References/Further Readings/Web Resources

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6.6 Answer to Self-Assessment Exercise 18

Suppose you start with No Nuclei that have a half life days after a time $T^{1/2}$ only ½ No un-decayed Nuclei remain. If you wait another time $T^{1/2}$ then another half of those nuclei will have decayed leaving ½ . ½ No un-decayed this will continue and leaving remaining nuclei be $½^{n}$ No.

UNIT 7 DATING

Unit Structure

7.1 Introduction
7.2 Learning Outcomes
7.3 Carbon Dating
7.4 Radioactive Dating
7.5 Summary
7.6 References/Further Readings/Web Resources
7.7 Possible Answers to Self-Assessment Exercise(S)

7.1 Introduction

This is a mechanism to find out the age of living organism using carbon dating or ages of rocks using uranium dating.

7.2 Learning Outcomes

By the end of this unit, you should be able to:

- Explain what carbon and radio activity is.
- State an estimated period/time that a wood has been part of a living tree.

7.3 Carbon Dating

CARBON – 14 (${}^{14}_{6}C$) is a radioactive Isolope of carbon, and has a half-life of 5,700 years. It is formed when neutrons react with nitrogen (${}^{14}_{7}N$) in the atmosphere with cosmic rays.

$$ {}^{14}_{7}N + {}^{1}_{0}N \longrightarrow {}^{14}_{6}C + {}^{1}_{1}H $$

The radioactive Isolope 14_C is absorbed by living material such as plants or vegetation in form of carbon dioxide, through respiration and photosynthesis. Hence the ratio of 14_C to 12_C in living things is equal to that in the atmosphere.

When a plant/living things dies, the exchange of carbon between it and the atmosphere stops since the process of respiration and photosynthesis ceases. For example wood formed from dead or decaying plants or vegetation, which were alive thousands of years ago, their ages can be determined by measuring the activity of carbon from archaeological specimen, the archaeological age of the specimen can be estimated. Carbon rating is measuring the activity of the Isolope in ancient wood or similar carbon materials can provide information about its age.

Self-Assessment Exercise 19

One gram of carbon from an archaeological specimen gives a count rate of 700 per hour whereas 1.00g of carbon from a living tree gives a count rate of 900 per hour. Calculate the archaeological age of the specimen if the half-life of carbon – 14 is 5600 years.

7.4 Radioactive Dating

Radioactive elements of long half-lives are used to estimate the geological age of a piece of rock.

For example Uranium – 238 (^{238}u) which has a half life of 4.5 x 10^9 years. If ^{238}u decays to ^{234th}, decays to $^{234}p_a$ until a stable Isolope, ^{206}pb is formed.

$$\frac{238}{92}u \quad \propto \frac{234}{90}\text{th} \quad ß \quad \frac{234}{91}p_a \quad ß \quad \frac{234}{92}u \propto \frac{230}{90}\text{th}\ldots$$

$$\frac{206}{82}\text{pb}$$

After a long time a steady state is achieved, where the rate at which an Isolope in the series in formed is equal to that rate of decay.
It can then be deduced that, the amount of 238_u in a piece of ore decreases, and the about of ^{206}pb increases while the amount of other nuclides remain unchanged.

Hence by assuming that there is no ^{206}pb in the Uranium ore, the measurement of the ratio of ^{206}pb to ^{238}u in the ore allows its geological age to be estimated.

Self-Assessment Exercise 20

1. Define carbon dating
2. What do you understand by the ratio ^{206}pb to ^{238}u in an ore?

7.5 Summary

This unit discussed that:

Carbon dating is measuring the activity of the Isolope min ancient wood or similar materials can provide information about its age; Radioactive dating is a situation when a Radioactive element of long half lives are used to estimate the geological age of a piece of rock.

Tutor-Marked Assignment

1. Explain how you can use carbon dating to estimate the age of a dead plant.
2. Using ^{238}u, show how it will decay to an element of a stable nuclide.
3. How can you estimate the age of ore?

7.6 References/Further Readings/Web Resources

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7.8 Possible Answers to Self-Assessment Exercise(s)

1. Activity of 1.00g of living carbon is

$(\frac{dN}{dt})_0 = 700h^{-1}$ 1.00g of carbon living tree count rate 900 per hours

——— 1

Activity of 1.00g of dead carbon from sample is decay rate $= \frac{dN}{dt} =$ N

$(\frac{dN}{dt}) = 700h^{-1}$

——— 2

Relating equations 1 x 2

$(\frac{dN}{dt}) = \frac{1}{2x}(\frac{dN}{dt})_0$

$700 = \frac{1}{2x}$x 900 – cross-multiple by 2^x

Make 2^x the subject

$700 \times 2^x = \frac{1}{2x} \times 900 \times 2^x$

Take log of both sides $2^x = \frac{900}{700} = 1.286$

$x = \frac{\log 1.286}{\log 2} = 0.3628$

Hence, archaeological age of specimen

$t = X \times T_{/2}$

$= 0.3628 \times 5600$ years

$= 2030$ years

Answer to Self-Assessment Exercise

2. Carbon dating is a method ∝ determing the age of an object containing organic material by using the properties of radiocarbon , a radioactive isolope of carbon. The activity of a given mass of carbon from an ancient pieces of wood can be compared with an equal mass of carbon form a living plant.

3. Uranium – 238 decays to lead – 206. The half life for 238 U is 4.5×10^{9}. Thus, the ratio of lead – 206 to uranium – 238 in a uranium – containing mineral is a measure of the time since mineral was formed.

UNIT 8 RELATIVITY

Unit Structure

8.1 Introduction
8.2 Learning Outcomes
8.3 Meaning of Relativity
8.4 Special Relativity
8.5 General Relativity
8.6 Summary
8.7 References/Further Readings/Web Resources
8.8 Answer to Self-Assessment Exercise 21

8.1 Introduction

Several laws of physics have been developed. Are these laws true everywhere and at anytime? This is one of subject of discussion in present unit.

8.2 Learning Outcomes

By the end of this unit, you should be able to:

- State the meaning of Relatively
- State the different kinds of Relatively.

8.3 Meaning of Relativity

It is the notion or believes that the laws of physics are the same everywhere. We here on Earth obey the same laws of light and gravity as someone in a far off corner of the universe. The theory explains the behaviour of objects in space and time.

The universality of physics means that history is provincial. Different viewers will see the timing and spacing of events differently. What is for us is a million years may just be a blink of an eye for someone flying in a high speed rocket of falling into a black hole.

The theory of relativity, or simply relativity in physics, usually encompasses two theories by Albert Einstein: special relativity and general relativity.

8.4 Special Relativity

Special relativity came first and is based on the speed of light being constant for everyone. That may seem simple enough, but it has far-reaching consequences.

Einstein came to this conclusion in 1905 after experimental evidence showed that the speed of light didn't change as the Earth swung around the Sun.

This result was surprising to physicists because the speed of most other things does depends on what direction the observer is moving. If you drive your car alongside a railroad track, a train coming at you will seem to be moving much faster than if you turned around and followed it in the same direction.

Einstein said that all observers will measure the speed of light to be 186,000 miles per second, no matter how fast and what direction they are moving.

Mass, too, depends on speed. The faster an object moves, the more massive it becomes. In fact, no spaceship can ever reach 100 percent of the speed of light because its mass would grow to infinity.

This relationship between mass and speed is often expressed as a relationship between mass and energy: $E=mc^2$, where E is energy, M is mass and C is the speed of light.

8.5 General Relativity

Einstein wasn't done upsetting our understanding of time and space. He went on to generalize his theory by including acceleration and found that this distorted the shape of time and space.

To stick with the above example: imagine the spaceship speeds up by firing its thrusters. Those onboard will stick to the ground just as if they were on Earth. Einstein claimed that the force we call gravity is indistinguishable from being in an accelerating ship.

This by itself was not so revolutionary, but when Einstein worked out the complex math (it took him 10 years), he discovered that space and time are curved near a massive object, and this curvature is what we experience as the force of gravity.

The equations of general relativity predict a number of phenomena, many of which have been confirmed:

i. Bending of light around massive objects (diffraction)
ii. Weakening of light escaping gravity's pull (gravitational red shift)
iii. The existence of black holes that trap everything including light
iv. The behaviour of the planet mercury in its orbit
v. Any object in a big gravity field in accelerating, so it will also experience time dilation

Self-Assessment Exercise 21

What is relativity?

8.6 Summary

This unit discussed that:

Einstein's Relativity theory is divided into special and general relativity; Special relativity came first and is based on the speed of light being constant for everyone; Einstein generalized his theory by including acceleration and found that this distorted the shape of time and space; The relationship between mass and energy: $E=MC^2$ where E is energy, M is mass and C speed of light

Tutor-Marked Assignment

1. Identify some of the concepts introduced by Einstein' relativity theory
2. What are some of the predictions of the special relativity theory?

8.7 References/Further Readings/Web Resources

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8.8 Possible Answers to Self-Assessment Exercise(s)

Relativity is a theory of gravity. The basic idea is that instead of being an invisible force that attracts objects to one another, gravity is a curving or warping of space. The more massive an object the more it warps the space around it. This also means that, the measurement of motion depended on the relative velocity and portion of the observer.