G.C.E. (Advanced Level)

PHYSICS

Grade 13

Teachers' Guide

(Implemented from 2018)

Department of Science
Faculty of Science and Technology
National Institute of Education
www.nie.lk

Physics

Teachers' Guide

Grade 13

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Faculty of Science & Technology

National Institute of Education

Message from the Director General…

With the primary objective of realizing the National Educational Goals recommended by the National Education Commission, the prevalent content based curriculum was modernized, and the first phase of the new competency based curriculum was introduced to the eight year curriculum cycle of the primary and secondary education in Sri Lanka in the year 2007.

The second phase of the curriculum cycle thus initiated was introduced to the education system in the year 2015 as a result of a curriculum rationalization process based on research findings and various proposals made by stakeholders.

Within this rationalization process, the concepts of vertical and horizontal integration have been employed in order to build up competencies of students, from foundation level to higher levels, and to avoid repetition of subject content in various subjects respectively and furthermore, to develop a curriculum that is implementable and student friendly.

The new Teacher's Guides have been introduced with the aim of providing the teachers with necessary guidance for planning lessons, engaging students effectively in the learning teaching process, and to make Teachers' Guides help teachers to be more effective within the classroom. Further, the present Teachers' Guides have given the necessary freedom for the teachers to select quality inputs and activities in order to improve student competencies. Since the Teachers' Guides to not place greater emphasis on the subject content prescribed for the relevant grades, it is very much necessary to use these guides along with the textbooks complied by the Educational Publications Department if, Guides are to be made more effective.

The primary objective of this rationalized new curriculum, the new Teachers' Guides, and the new prescribed texts is to transform the student population into a human resource replete with the skills and competencies required for the world of work, through embarking upon a pattern of education which is more student centered and activity based.

I wish to make use of this opportunity to thank and express my appreciation to the members of the Council and the Academic Affairs Board of the NIE, the resource persons who contributed to the compiling of these Teachers' Guides and other parties for their dedication in this matter.

Dr.(Mrs.) T.A.R.J. Gunasekara
Director General
National Institute of Education
Maharagama.

Guidelines to use the Teachers' Guide

In the G.C.E (A/L) classes new education reforms were introduced from the year 2017 in accordance with the new education reforms implemented in the interim classes in the year 2015. According to the reforms, Teachers' Guide for Physics for grade 13 has been prepared.

The grade 13 Teachers' Guide has been organized under the titles, competencies and competency levels, content, learning outcomes and number of periods. The proposed lesson sequence is given for the leaning teaching process. Further it is expected that this teachers' guide will help the teachers to prepare their lessons and lessons plans for the purpose of classroom learning teaching process. Also it is expected that this Guide will help the teachers to take the responsibility to explain the subject matter more confidently. This Teachers' Guide is divided into three parts each for a term.

To attain the learning outcomes mentioned in the teachers' Guide, Teachers should consider the subject matter with extra attention. Further it is expected to refer supplementary curricular materials and reference materials to improve their quality of teaching.

Total number of periods to teach this physics syllabus is 600. Teachers can be flexible to change the number of periods according to their necessity. Teachers can use school based assessment to assess the students.

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Content

Unit 5: Gravitational Field

Competency 5.0: Uses laws and principles of gravitation to be productive in daily pursuits and scientific work.

Competency level 5.1: Analyses the effect of gravitational force on objects using Newton's law of gravitation.

Number of periods: 08

Learning outcomes:

- states that the attractive force between masses is named as gravitational force.
- expresses Newton's law of universal gravitation.
- uses Newton's law to calculate the gravitational force between two masses.
- explains the concept of force field.
- states that all masses create a gravitational field.
- understands that gravitational field is a field of force.
- explains the concept of gravitational field as action at a distance'.
- states that the gravitational forces are directly proportional to the mass of the object.
- uses the concept of gravitational field to calculate the force exerted on a mass in a gravitational field.
- defines gravitational field intensity.
- uses Newton's law of gravitation to find gravitational field intensity at a point due to a point mass and spherical mass (away from the sphere).
- represents graphically the variation of gravitational field intensity with the distance from a point mass.
- defines gravitational potential at a point.
- states that a mass possesses potential energy when it is in a gravitational field.
- calculates gravitational potential at a point in a gravitational field.
- uses the expression for the potential energy of a mass in a gravitational field.
- represents graphically the variation of gravitational potential with the distance from a point mass and outside a spherical mass.

Suggested learning/teaching process:

- State Newton's law of universal gravitation and give the expression $F = \frac{Gm_1m_2}{r^2}$ for mutual attractive force between two masses.
- States that "G" is a universal constant.
- Introduce the concept of gravitational force field as a result of action at a distance.
- State that any mass can create a gravitational field.
- Explain that the force exerted on a mass in a gravitational field is directly proportional to the mass.
- Define gravitational field intensity and give unit.

- Use Newton's law of gravitation to derive expressions for the field intensity at a point due to a point mass and outside a spherical mass.
- Graphically interpret the variation of gravitational field intensity with the distance.
- Define gravitational potential at a point in a gravitational field and give units.
- Explain that the gravitational potential at a point has minus sign.
- Give expressions for the gravitational potential at a point due to a point mass and away from a spherical mass $V = -\frac{Gm}{r}$.
- Graphically interpret the variation of potential with distance due to a point mass and outside a spherical mass.
- Explain that the field intensity and the potential at infinity is zero.
- Explain that the potential energy of a mass at a point is the product of the mass and the gravitational potential at that point.
- Guide students to obtain an expression for the total energy of an object moving with constant speed around a spherical mass.
- Guide students to solve problems related to gravitational field.
- Guide students to understand that the concept of gravitational field can be used to explain the structure and the existence of the universe.

Competency level 5.2: Inquires about the instances of using the knowledge on the Earth's gravitational field to fulfill human activities.

Number of periods: 12

Learning outcomes:

- uses knowledge obtained regarding gravitational fields to deduce corresponding relationships in the Earth's gravitational field.
- explains the variation of gravitational field intensity from the earth surface.
- deduces an expression for the gravitational field intensity on the earth surface.
- states that the gravitational field intensity is numerically equal to the gravitational acceleration.
- derives the expression (mgh) for gravitational potential energy.
- explains the condition that is needed to satisfy to orbit a satellite on a circular path around the earth.
- finds physical quantities related to satellite motion, describing conditions for such motions.
- relates tangential speed, angular speed, time period and frequency of a satellite with the radius of the orbit.
- explains the condition for a geostationary satellite.
- carries out calculations related to satellite motion in circular orbits.
- appreciates the uses of satellites.
- derives an expression for the escape velocity.
- gives example which can be explained using the concept of escape velocity.

Suggested learning/teaching process:

- Give an expression for the gravitational field intensity at a point near the earth surface, considering earth as a perfect sphere.
- Show that the gravitational field intensity and gravitational acceleration at a point have the same magnitude.
- Stating the conditions needed, *g*uide students to derive the expression for the potential energy as $P.E=mgh$.
- Explain that the centripetal force of the circular motion of a satellite around the earth is supplied by the gravitational force.
- Guide students to obtain relationships between radius of the orbit with the speed, period, angular speed and the frequency of a satellite.
- Explain the conditions for a geostationary satellite.
- Introduce escape velocity and obtain expressions, $v_e = \sqrt{\frac{2GM}{R}}$,
  $v_e = \sqrt{2gR}$.
- Discuss phenomena which can be described by using escape velocity.

Unit 6: Electrostatic Force Field

Competency 6.0: **Uses laws and principles of electrostatic field for scientific work and daily pursuits effectively.**

Competency level 6.1: Uses the laws related to electrostatic force appropriately to find the distribution and magnitude of electrostatic field produced by various charged objects.

Number of periods: 15

Learning outcomes:

- uses Coulomb's law to calculate the electrostatic force between two charges.
- states that all charges create electric fields.
- defines electric field intensity.
- uses the equation $F = EQ$ to find the force on a charge placed in an electrostatic (electric) field.
- uses the concept of electric field lines to illustrate the electric field
- draws electric field lines in various electric fields.
- explains the properties of electric field lines.
- calculates the field intensity at a point in an electric field using Coulomb's law.
- finds resultant electric field intensity at a point due to distribution of point charges.
- graphically represents the variation of electric field intensity with the distance from a point charge.

Suggested learning/teaching process:

- Express Coulomb's law to find the mutual force between two electric charges.
- Introduce permittivity of free space, permittivity of the medium and relative permittivity.
- Explain that any electric charge can create an electric field.
- Explain that the force exerted on a charge in an electric field is directly proportional to the magnitude of the charge.
- Define electric field intensity. Give units.
- Give the expression $F=EQ$.
- Explain that the direction of the field is the direction of the force exerted on a positive test charge.
- Explain that the direction of the force changes according to the type (positive or negative) of the charge.
- Explain that electric field lines are used to represent an electric field.
- Explain the properties of electric field lines.

- Draw electric field lines for the following electric fields.
    - around a point charge
    - around two like point charges and two unlike point charges
    - between two parallel oppositely charged conducting plates
- Use Coulomb's law to find the field intensity at a point away from a point charge, $E = \frac{1}{4\pi\varepsilon}\frac{Q}{r^2}$.
- Graphically interpret the variation of electric field intensity with distance.
- Guide students to find the electric field intensity at a point due to distribution of point charges.
- Assign students to solve problems related to electric fields.

Competency level 6.2: Quantifies the electrostatic field using the flux model.

Number of periods: 15

Learning outcomes:

- explains flux model using suitable examples.
- states Gauss's theorem.
- uses Gauss's theorem to find the electric field intensity due to point charge, charged spherical conductor, near an infinite charged plate and a charged of infinite length thin wire.
- represents graphically the variation of field intensity with distance from the centre of the sphere.
- calculates electric field intensity due to different charged objects using relevant expressions.

Suggested learning/teaching process:

- Introduce the flux model.
- Introduce the flux as $\emptyset_E = EA$.
- Express Gauss's theorem.
- Derive expressions for field intensities of the following fields using Gauss's theorem and the flux model.
    - Near a point charge, $E = \frac{1}{4\pi\varepsilon}\frac{Q}{r^2}$
    - Near a charged conducting thin infinite plate, $E = \frac{\sigma}{\varepsilon}$
    - Inside a charged conducting sphere, $E = 0$
    - On the conducting charged sphere and away from the sphere

      $$E = \frac{1}{4\pi\varepsilon}\frac{Q}{R^2}, E = \frac{1}{4\pi\varepsilon}\frac{Q}{r^2}$$
    - Near charged conducting thin wire of infinite length, $E = \frac{\lambda}{2\pi\varepsilon r}$
- Graphically interpret the variation of field intensity with distance from the centre of the conducting charged sphere.

Competency level 6.3: Quantifies the potential energy of charges placed in an electrostatic field.

Number of periods: 15

Learning outcomes:

- defines electric potential.
- finds the electric potential at a point due to a point charge and distribution of point charges.
- illustrates graphically the variation of electric potential with the distance from the center of a conducting sphere.
- finds electric potential energy of a charge in an electric field.
- defines potential difference between two points in an electric field.
- defines electron volt as a unit of energy.
- expresses the relation between potential gradient and electric field intensity.
- carries out numerical calculations to solve problems related to electric potential and potential energy.
- draws equipotential surfaces in different fields.

Suggested learning/teaching process:

- Define electric potential at a point in an electric field. Give units.
- Express electric potential at a point away from a point charge as $V = \frac{1}{4\pi\epsilon}\frac{Q}{r}$.
- Give expressions for the electric potential due to a charged conducting sphere
  when $r > R, V = \frac{1}{4\pi\varepsilon}\frac{Q}{r}$.

  when $r \leq R, V = \frac{1}{4\pi\varepsilon}\frac{Q}{R}$.
- Graphically interpret the variation of the potential with the distance from the centre.
- Define potential difference between two points in an electric field.
- Give the expression $W=VQ$ for the work done when moving a charge "Q" across a potential difference "V".
- Define 'electron-volt' (eV) as a unit of energy.
- Explain the potential energy of a charge in an electric field.
- Give an expression for the potential energy of a system with two charges.
- Introduce potential gradient at a point as $\frac{dV}{dx}$.
- Express electric field intensity at a point as $E = -\frac{dV}{dx}$ for any electric field.
- Express electric field intensity at any point as $E = -\frac{V}{d}$ for a uniform electric field.
- Introduce equipotential surfaces in an electric field.
- Explain properties of equipotential surfaces.
- Assign students to draw equipotential surfaces for various electric fields.
- Guide students to solve problems related to electric potential.

Competency level 6.4: Uses capacitors appropriately in electrical circuits.

Number of periods: 15

Learning outcomes:

- defines the capacitance of a parallel plate capacitor.
- derives expressions for capacitance of a parallel plate capacitor and a conducting sphere.
- obtains the equivalent capacitance of capacitors in series and capacitors in parallel.
- derives expressions for energy stored in a charged capacitor.
- solves problems related to capacitors.
- interprets the charge distribution of conductors having different shapes using diagrams.

Suggested learning/teaching process:

- Show various types of capacitors in practical use.
- Conduct an activity to demonstrate the charging and discharging of a capacitor.
- Explain the processes of charging and discharging a capacitor.
- Explain that a potential difference is built up between the plates of a capacitor when it is charged.
- Define electric capacitance and give units.
- Derive expression, $c = \frac{k\epsilon_0 A}{d}$ for the capacitance of a parallel plate capacitor.
- Introduce *k* as dielectric constant. State *k*=1 for free space or air and *k*>1 for any other dielectric medium.
- Guide students to derive $c = 4\pi\epsilon_0 r$ for the capacitance of a conducting sphere.
- Guide students to derive expression for equivalent capacitance of parallel and series combinations of capacitors. $c = c_1 + c_2 + \cdots + c_n$, $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n}$
- Guide students to conduct activities to demonstrate that energy is stored in a charged capacitor.
- Derive expressions for stored energy in a capacitor, $W = \frac{1}{2}VQ, = \frac{1}{2}\frac{Q^2}{C}$, and $W = \frac{1}{2}cV^2$.
- Conduct a discussion about the uses of capacitors.
- Describe the distribution of charges on the surface of conductors having various shapes.
- Explain corona discharge (point discharge).

Unit 7: Magnetic Field

Competency 7.0 : Uses the effects of interrelationships between electricity and magnetism for scientific work and daily pursuits.

Competency level 7.1: Manipulates the variables to control the force acting on a current carrying conductor and a moving charge placed in a magnetic field.

Number of periods: 10

Learning outcomes:

- states that moving charges or current carrying conductors create a magnetic fields.
- demonstrates the nature of magnetic force using the current balance.
- defines magnetic flux density.
- expresses the magnetic force in terms of magnetic flux density, current and the length of the conductor.
- uses the expression for force acting on a moving charge in a magnetic field.
- finds the direction of the above magnetic force by Fleming's left hand rule.
- solves problems related to magnetic force and magnetic flux density.
- explains Hall effect.
- derives expression for Hall voltage.
- solves problems related to Hall effect.
- gives examples for the applications of Hall effect.

Suggested learning/teaching process:

- Demonstrate the force acting on a current carrying conductor placed in a magnetic field using the current-balance.
- Obtain the expression $F=BIl$ identifying the symbols.
- Define magnetic flux density and give units.
- State Fleming's left hand rule.
- Assign students to find the direction of the force, changing the direction of the current and the direction of magnetic flux density.
- Explain that the force is given by $F=BIl\sin\theta$ when the conductor is inclined to the field at angle "θ ".
- State that there is no force when the conductor is parallel to the field.
- Give the expression $F=Bqv$ for the force exerted on a charged particle moving perpendicular to a magnetic field.
- Discuss the instances where the particle is moving with an angle to the field and moving parallel to the field.
- Assign students to find the direction of the force on a moving positive charged particles and a moving negative charged particles.
- Explain Hall-effect.
- Guide the students to derive an expression for Hall-voltage.
- Discuss application of Hall-effect and give examples.
- Guide students to solve problems related to magnetic force.

Competency level 7.2: Constructs magnetic fields by manipulating variables for the needs.

Number of periods: 15

Learning outcomes:

- expresses Biot-Savart law.
- derives the expression for magnetic flux density at the center of a current carrying circular coil.
- states the expression for the magnetic flux density outside an infinitely long straight current carrying conductor.
- States the expression for the magnetic flux density along the axis of a current carrying long solenoid.
- derives the expression for the force between two parallel infinitely long current carrying conductors.
- solves problems related to the magnetic flux density of a current carrying infinitely long straight conductor, a circular coil and a long solenoid.
- defines "Ampere".

Suggested learning/teaching process:

- Demonstrate magnetic effect of an electric current using simple activities.
- Show that the direction of the field near a current carrying conductor can be obtained by using Maxwell's coke screw rule.
- Express Bio-Savart law introducing the terms, $\delta B = \frac{\mu_0}{4\pi}\frac{I\ \delta l\ \sin\theta}{r^2}$
- Derive an expression for the magnetic flux density at the centre of a flat current carrying circular loop.
- Give expressions for the magnetic flux density for the following instances.
    - Near a current carrying infinitely long thin straight conductor
    - Along the axis of a current carrying long solenoid
- Assign students to draw the magnetic field patterns of above instances.
- Explain that a mutual force acts on two parallel conductors when current flows in the same direction and in opposite directions.
- Guide students to derive an expression for the mutual force acting on two current carrying parallel conductors.
- Define the unit "Ampere".
- Guide students to solve problems related to the magnetic field.

Competency level 7.3: Inquires into the rotational effect due to the interrelationship of electricity and magnetism.

Number of periods: 15

Learning outcomes:

- derives expressions for torque acting on a current carrying rectangular coil placed in a uniform magnetic field.
- deduces the expression for the torque acting on a current carrying rectangular coil placed in a radial magnetic field..
- explains the structure and the function of the moving coil galvanometer.
- derives an expression for the deflection of the moving coil galvanometer
- describes current sensitivity of the moving coil galvanometer.
- describes the structure and function of a direct current motor with one armature coil.
- solves problems related to torque acting on a current loop

Suggested learning/teaching process:

- Explain how a torque is produced on a current carrying rectangular coil placed in a uniform magnetic field.
- Guide students to derive expressions for the magnitude of the torque when the plane of the coil is parallel, inclined and perpendicular to the magnetic field.
- Explain how a radial magnetic field is obtained.
- Explain that the magnitude of the torque is constant on a rectangular coil placed in a radial magnetic field.
- Guide students to obtain the expression for the magnitude of the torque.
- Explain the structure and the action of a moving coil galvanometer.
- Explain that the coil is in equilibrium when the torque due to the current and the restoring torque in the torsional string (hair spring) are equal in magnitude.
- Obtain $C\theta = BINA$ identifying terms.
- Show that the deflection of the galvanometer is directly proportional to the current through it.
- Explain that the scale of the galvanometer is linear.
- Define the current sensitivity of a moving coil galvanometer
- Discuss the factors affecting current sensitivity.
- Explain the structure and action of a direct current (dc) motor having one armature coil using diagrams.
- Guide students to identify main parts of a dc motor using laboratory motor model.
- Guide students to solve relevant problems.

Unit 8: Current Electricity

Competency 8.0 : Uses laws and principles and effects of current electricity productively and appropriately.

Competency level 8.1: Manipulates the physical quantities related to current electricity wherever appropriate.

Number of periods : 10

Learning outcomes :

- defines electric current as the rate of flow of charges.
- explains the mechanism of conduction of electric current through a metallic conductor.
- derives an expression for the relationship between current and drift velocity.
- deduces an expression for current density.
- defines resistance.
- states factors which affect the resistance.
- defines resistivity.
- explains variation of resistance of conductors and insulators with temperature.
- appreciates the properties and uses of superconductors.
- states Ohm's law.
- explains the behavior of ohmic and non-ohmic conductors using. *I- V* curves.
- uses potential divider circuit to obtain variable voltages.
- finds equivalent resistance of simple networks.
- solves problems using Ohm's law.

Suggested learning/teaching process:

- Define electric current and give the expression $I=Q/t$ for a steady current that can be measured as C s^{-1}.
- State that the SI unit of electric current is ampere (A).
- Explain the existence of free electrons and the random motion of free electrons in a metallic conductor.
- Explain the mechanism of conduction of electric current through a metallic conductor.
- Introduce drift velocity of free electrons.
- Guide students to derive the expression ($I = AvNe$) for the relationship between drift velocity and electric current introducing other relevant terms.
- Define current density and guide students to deduce the expression $J= vNe$.

- Recall the definition of potential difference and explain it in relation to a current carrying conductor.
- Define resistance of a conductor and introduce its units.
- Guide students to investigate the factors affecting the resistance through activities.
- Obtain the expression, $R = \rho \frac{l}{A}$.
- Define the resistivity ρ and guide students to obtain its units.
- Define conductivity σ and guide students to obtain its units.
- Explain how resistance increases in metallic conductors with temperature.
- Define temperature coefficient of resistance for a specified reference temperature.
- Give the relationship $R_\theta = R_0(1 + \alpha\theta)$ introducing terms (α is defined for the above reference temperature).
- Represent graphically the variation of resistance of conductors with temperature.
- Explain how resistance decreases in semiconductors and insulators with temperature.
- Describe the conditions under which a metal behaves as a superconductor.
- Introduce transition temperature of a metal using resistance-temperature curve.
- Explain uses and properties of superconductors.
- Give transition temperatures of several superconductors.
- Assign students to derive expressions for equivalent resistance of series and parallel combinations of resistors.
- Guide students to find equivalent resistance of resistor networks.
- State Ohm's law giving conditions under which it is valid.
- Differentiate between ohmic and non-ohmic conductors using relevant *I*-*V* curves.
- Introduce voltage divider circuits and guide students to derive relevant expressions.
- Guide students to solve problems related to above fundamental concepts of current electricity.

Competency level 8.2: Quantifies the energy and power in direct current (*dc*) circuits.

Number of periods: 06

Learning outcomes:

- conduct simple activities to demonstrate that energy dissipates through any electrical apparatus when a current flows.
- expresses formulae for energy dissipation due to flow of charges.
- expresses formulae for the rate of dissipation of energy.
- applies $W = VI$ and $P = VI$ for any electrical appliance.
- explains passive resistors.
- uses $P=I^2R$, $P = \frac{V^2}{R}$, $W = I^2Rt$ and $W = \frac{V^2}{R}t$ to find the dissipation of heat in passive resistors.

Suggested learning/teaching process:

- Guide students to conduct activities to demonstrate that energy dissipates when a current flows through an electrical apparatus.
- State the expression $W=VQ$ for energy dissipation when a charge Q flows through any electrical load when potential difference "V" is applied.
- Guide students to obtain the expression $W=VIt$ for the energy dissipation in any electrical load when current "I" flows across a potential difference "V" in time "t".
- State that the energy dissipated per second (power) in a device is defined as its power and give the expression $P=VI$.
- Explain that $P=VI$ and $W=VIt$ can be used for any electrical load.
- Guide students to obtain $P=I^2R$, $P=V^2/R$, $W=I^2Rt$, and $W=V^2t/R$ expressions for a resistive load using $V=IR$.
- Explain that energy dissipates as heat only in passive resistors (Joule heating).
- Introduce kWh unit as the practical unit for measuring electrical energy.
- Obtain the relationship between kWh and J.

Competency level 8.3: Inquires into the power supply of an electric circuit quantitatively.

Number of periods: 10

Learning outcomes:

- explains the formation of e.m.f. of a source using the action of a simple cell.
- describes the energy transformation in different types of sources of electromotive force (emf).
- defines electromotive force (e.m.f.) in terms of the energy transformation in a source.
- expresses that rate of energy supply from the source as the product EI.
- expresses the voltage difference across a source of emf with internal resistance in a closed circuit.
- understands the effects of the internal resistance of an electric source on the terminal potential difference.
- expresses the effective emf of a combination cells in series.
- expresses the effective emf of a combination of identical cells in paralled.
- explains the condition for maximum power transfer using a graph of power versus resistance.
- conducts an experiment to determine the electromotive force and internal resistance of a cell.
- carries out calculations to solve problems related to electro motive force

Suggested learning/teaching process:

- Explain how electromotive force is built in a simple cell using electrode potential.
- Show that there is a potential difference between the terminals of any electric source.
- Explain that the potential difference which is needed to apply across any electric circuit to flow current is supplied by an electric source.
- Name several electric sources and conduct a discussion to understand their energy transformations.
- Define electro motive force.
- Explain that the rate of energy supplied from a source is given by the product EI.
- Introduce internal resistance of a source.
- Apply the law of conservation of energy for a circuit having one source and one external resistor to obtain $EI = I^2R + I^2r$.
- Obtain $V = E - Ir$ from the above equation.

- Explain that the potential difference between the terminals of a source is obtained when current flows from the above expression.
- Explain the followings using $V = E - Ir$.
  - The potential difference between the terminals of a source is equal to the electro motive force when there is no current flow.
  - If the internal resistance of the source is zero, the potential difference between the terminals of the source is always equal to the electro motive force; for any value of current.
- Assign students to design an experiment to find the electro motive force and the internal resistance of a dry cell.
- Give expressions for equivalent *emf* and internal resistance of a series combination of sources.
- Give an expression for a parallel combination of identical sources
- Give the graph for the variation of power dissipation with external resistance
- State the condition needed for maximum power dissipation
- Guide students to solve problems related to electromotive force

Laboratory Experiment:

- Determination of electromotive force and internal resistance of a cell (graphical method)

Competency level 8.4 : Uses the laws and principles related to current electricity for designing circuits.

Number of periods : 06

Learning outcomes :

- writes Kirchoff's rules.
- explains Kirchhoff's first rule on the basis of conservation of charge.
- explains Kirchhoff's second rule as one form of conservation of energy.
- applies Kirchhoff's rules to electrical networks to solve problems.

Suggested learning/teaching process:

- State Kirchhoff's 1st rule for a junction of a circuit.
- Explain the charge conservation using 1st rule.
- State Kirchhoff's 2nd rule for a close loop.
- Explain energy conservation using 2nd rule.
- Explain how Kirchhoff's rules are used to solve problems related to electric circuits.

Competency level 8.5: Uses electrical measuring instruments accurately and protectively.

Number of periods: 10

Learning outcomes:

- uses ammeter to measure an electric current.
- uses voltmeter to measure a voltage difference.
- uses multimeter to measure current, voltage difference and resistance.
- explains the importance of ideal ammeter and ideal voltmeter.
- derives relationship among resistances of a balanced Wheatstone bridge.
- uses Wheatstone bridge relationship to find equivalent resistance of simple networks.
- uses meter bridge accurately to find the temperature coefficient of resistance.
- explains the facts to be considered in using the metre bridge.
- carries out numerical calculations to solve problems using the Wheatstone bridge
- explains the facts to be considered in using the potentiometer.
- describes the principle of the potentiometer.
- Uses the potentiometer to compare electromotive forces.
- Uses the potentiometer to determine internal resistance of a cell.
- compares advantages and disadvantage of using the potentiometer.
- solves problems related to the potentiometer.

Suggested learning/teaching process:

- Explain how an ammeter is connected to a circuit to measure an electric current.
- Explain that the current through the circuit decreases when an ammeter is connected.
- Explain that the above error can be minimized by lowering the internal resistance of the ammeter.
- State the property of an ideal ammeter.
- Explain how a voltmeter is connected to a circuit when measuring the potential difference between two points of a circuit.
- Explain that the potential difference decreases when a voltmeter is connected.
- Show that the above error can be minimized by increasing the internal resistance of the voltmeter.
- State the property of an ideal voltmeter.
- State that the ammeter and voltmeter scales are linear and the Ohm meter scale is not linear.
- Introduce multimeter.

- Guide students to use ammeter, voltmeter, and multimeter to take measurements.
- Introduce Wheatstone bridge circuit.
- Guide students to obtain the relationship between resistances of a balance bridge by using Ohm's law and Kirchhoff's rule.
- Introduce metre bridge as an apparatus based on Wheatstone bridge principle and describe it.
- Explain that metre bridge can be used to find the resistance of a resistor.
- State the limits of the uses of the metre bridge.
- Explain how an experiment is designed to find the temperature coefficient of resistance.
- Explain potentiometer principle.
- Describe how a potentiometer circuit is connected practically.
- Explain calibration of the potentiometer.
- Describe the factors that are to be considered in using the potentiometer.
- Describe the following experiments.
    - Comparison of emf.
    - Finding the internal resistance of a cell.
- Guide students to conduct the above experiments.
- State advantages and disadvantages in using the potentiometer.
- Guide students to solve problems related to the potentiometer.

Laboratory experiments:

- Finding the temperature coefficient of resistance using the metre bridge
- Uses of the potentiometer
    - Comparison of electromotive forces
    - Determination of internal resistance of a cell

Competency level 8.6: Uses the laws and rules in electromagnetic induction for technical needs.

Number of periods: 20

Learning outcomes:

- conducts activities to demonstrate the laws of electromagnetic induction.
- expresses Faraday's law and Lenz's law.
- derives an expression for the induced electromotive force of a rod moving in a magnetic field.
- drives an expression for the induced electromotive force of a rod rotating in a magnetic field.
- applies Fleming's right hand rule to find the direction of the induced current.
- writes and expressions for the induced electromotive force of a disc rotating in magnetic field
- explains that the *emf* induced across a rectangular coil rotating in a uniform magnetic field varies with the angle between the plane of the coil and the field.
- derives an expression for the maximum value of the induced electromotive force of a rectangular coil rotating in a magnetic field.
- describes the structure of the alternating current generator.
- expresses graphically the variation of the e. m. f. of an alternating current generator with time.
- states the relationship between the r. m. s. value and the peak value of voltage and current.
- states that the average power of a resistive circuit can be calculated using rms values of voltage and current.
- explains the formation of the back *emf* in a direct current motor.
- explains the purpose of the starter switch.
- explains the structure and function of a transformer.
- writes the relationship between the number of terns and voltage.
- explains transmission of electric power qualitatively.
- carries out numerical calculations to solve related problems.
- states the relationship between input and output power of an ideal transformer in terms of voltage and current.
- introduces step-up and step-down transformer.
- gives examples for the uses of step-up and step-down transformers.
- explains energy loss due to Joule heating of a transformer.
- explains the energy loss due to eddy currents.
- carries out calculations related to transformers.
- explains the uses of step-up and step-down transformers in electric power transmission.

Suggested learning/teaching process:

- Introduce magnetic flux and give units.
- Explain flux linkage of a coil.
- Express Faraday's law and Lenz's law.
- Guide students to conduct activities for the demonstration of those laws.
- Derive an expression for the induced *emf* across a straight conductor moving perpendicularly in a uniform magnetic field.
- State Fleming's right hand rule.
- Guide students to find the direction of the induced *emf* using Fleming's right hand rule.
- Give the expression for the *emf* when the conductor moves inclined to the field.
- Derive an expression for the *emf* induced across a rod rotating in a magnetic field.
- Give the expression for the induced *emf* between the axis and the circumference of a rotating disk in a magnetic field.
- Show that the above three electromotive forces are direct current electro motive forces.
- Explain that an electromotive force is induced across a rectangular coil rotating in a magnetic field.
- Explain that the *emf* varies according to the angle between the plane of the coil and the magnetic field.
- Explain that the magnitude of the induced *emf* is zero when the plane of the coil is perpendicular to the magnetic field.
- Explain that the magnitude of the induced *emf* is maximum when the plane of the coil is parallel to the field and guide students to derive an expression for maximum *emf*.
- Describe the structure of an alternating current generator using diagrams.
- Explain how the direction of the induced *emf* changes when the coil rotates.
- Graphically illustrate the variation of the magnitude and direction of the *emf* with time.
- Introduce alternating current and voltage.
- Introduce the terms peak voltage, peak current, root mean square voltage and root mean square current.
- Give the relationship between peak voltage and root mean square voltage and peak current and root mean square current.
- Explain that the power of an electrical apparatus operating with alternating current is given by $P = V_{\mathrm{rms}} I_{\mathrm{rms}}$
- Explain that the power of a passive resistor can be obtained using the expressions, $= V_{rms}I_{rms}$, $P = I_{rms}^2 R$, $P = \frac{V_{rms}^2}{R}$.

- Introduce eddy currents.
- Give examples for the uses of heating effect and magnetic effect of eddy currents.
- Explain how a back *emf* is generated in a direct current motor.
- Explain how the armature current is controlled due to the back *emf*.
- Explain that the initial current is high and it may be harmful to the armature.
- Explain that the starter switch is used to control the initial current.
- Explain the action of the starter switch using a diagram.
- Introduce the transformer as a device which is used to change the magnitude of an alternating voltage.
- Describe the structure of the transformer using diagram.
- Explain the action of a transformer.
- Give the relationship between the number of the turns of the windings and the voltages.
- State the power of primary and secondary windings.
- Explain that the input power is equal to the output power for an ideal transformer.
- Explain step-up and step-down transformers.
- Give examples for uses of step-up and step-down transformers.
- Describe Joule heat loss and eddy current loss as two energy losses.
- Explain how to minimize the energy losses.
- Discuss power transmission briefly.
- Explain the reason why high voltage is used in power transmission.
- Guide students to solve problems related to electromagnetic induction.

Unit 9: Electronics

Competency 9.0: Uses electronic circuits to fulfil human needs.

Competency level 9.1: Inquires about the principle of action of a semiconductor diode.

Number of periods: 10

Learning outcomes:

- identifies pure silicon and germanium as intrinsic semiconductors.
- describes extrinsic semiconductors.
- explains the formation of the depletion region and the voltage barrier of a *p – n* junction.
- represents graphically the characteristic of a practical diode and an ideal diode.
- explains the action of a diode in the forward biased conditions.
- explains the action of a diode in the reverse biased conditions.
- designs an experiment to obtain the *I – V* curve of a practical diode.
- explains with relevant diagrams the uses of a diode as a half wave rectifier.
- explains the full wave rectification of a bridge rectifier.
- explains the smoothing of full wave rectification.
- explains the action of a diode as a switch.
- conducts simple activities to demonstrate rectification of a diode.
- conducts simple activities to demonstrate diode as a switch.
- explains voltage regulation of a zener diode.
- explains qualitatively the action of a LED.
- explains qualitatively the action of a photo diode.
- solves numerical problems related to diodes.

Suggested learning/teaching process:

- Introduce intrinsic semiconductors explaining the formation of free electrons and holes in a lattice of Si or Ge elements in group IV.
- Explain that the formation of free electrons and holes increases with temperature.
- Explain that extrinsic semiconductors can be produced by doping intrinsic semiconductors with group III or group V elements as impurities.
- Introduce *p*-type and *n*-type extrinsic semiconductors and introduce majority carriers and minority carriers in those types.
- Introduce the terms donor atoms and accepter atoms in both types.
- Introduce the *p-n* junction.
- Describe the nature of the *p-n* junction using suitable diagrams.

- Explain that a depletion layer is formed due to the diffusion and drift of majority carriers.
- Explain that a static potential difference is formed across the junction due to the equilibrium of diffusion and drift of charge carriers and name the equilibrium potential difference as a potential barrier.
- State that the potential barrier for Si is about 0.7 V and for Ge it is about 0.3 V.
- Introduce junction diode as a component with one *p*-*n* junction and give the circuit symbol naming the terminals.
- Explain that the diode can be forward biased or reverse biased by applying a suitable external potential difference across the terminals of the diode.
- Explain using diagrams that current flows from *p* to *n* direction, through the diode when it is forward biased.
- Explain that a depletion layer is widened when reverse biased and therefore no current flows due to majority carriers but there is a leakage current due to minority carriers.
- Guide students to obtain the *I*-*V* characteristic of a diode experimentally.
- Introduce the peak inverse voltage and knee voltage using the *I*-*V* characteristic of a diode.
- State that the junction may damage when the peak inverse voltage exceeds the reverse brakdown voltage of the diode.
- Introduce *I*-*V* curve for an ideal diode.
- Explain half-wave rectification using a suitable circuit diagram.
- Demonstrate wave forms using the cathode ray oscilloscope.
- Explain full-wave rectification using a suitable circuit diagram.
- Demonstrate wave forms using the cathode ray oscilloscope.
- Illustrate input and output voltage wave forms.
- Explain that the output voltage can be smoothed using a capacitor.
- Illustrate graphically the smoothed voltage.
- Explain the formation of ripple voltage.
- Compare *I*-*V* curves of an ideal diode with that of a mechanical switch and explain that the diode can be used as a switch.
- Give simple numerical examples with diodes as a circuit element.
- Introduce Zener diode and explain how its operation differs from that of a normal diode using the *I*-*V* characteristic of a Zener diode.
- Introduce the circuit symbol and the term Zener voltage.
- Explain that the Zener diode can be used to regulate a varying dc voltage.
- Give the voltage regulating circuit.
- Discuss about the safety resistor and the maximum power that can be dissipated by the zener diode and the current through the Zener diode.
- Explain voltage regulation using numerical examples.

- Give the symbol of a light emitting diode (LED) and explain qualitatively the action of an LED.
- Give some examples of the uses of LEDs.
- Describe qualitatively the action of photodiode and solar cells.

Laboratory experiment:

- Obtaining the *I-V* characteristic curve of a practical diode.

Competency level 9.2: Uses the action of the transistor for practical needs.

Number of periods: 12

Learning outcomes:

- explains the structure of *npn* and *pnp* transistors.
- describes the action of an *npn* transistor with respect to electrons and holes.
- describes with appropriate diagrams, the common base, common emitter and common collector configuration of a transistor.
- conducts experiments to interpret graphically the input, output and transfer characteristics of common emitter configuration of a *npn* transistor.
- explains the biasing of npn transistors with suitable diagrams.
- describes the action and uses of a transistor in the the common emitter configuration as a current amplifier.
- describes the action and uses of a transistor in common emitter configuration as a voltage amplifier.
- solves problems related to transistors.
- describes the action of a transistor as a switch.
- explains the structure of n- channel and *p*-channel JFETs.
- Explains the action of n- channel JFET.
- explains voltage amplification of an *n*- channel JFET using the characteristic curve.

Suggested learning/teaching process:

- Introduce bipolar junction transistor (BJT) as a component with two *p-n* junctions.
- Introduce structure, circuit symbol and terminals of *pnp* and *npn* transistors.
- State that the base region is thin and the emitter region in highly doped.
- Explain the action of an *npn* transistor by using the common-base configuration.
- Introduce standard symbols used in a circuit diagram (I_B , I_C , I_E , V_{BE} , V_{CE} , etc.).
- Explain how I_E, I_C and I_B currents flow due to the drift of majority carriers by using diagrams.
- State that usually I_B is in microampere range and I_C and I_E are in milliampere range.
- Give the relationship between I_E , I_C and I_B.
- Introduce circuit configurations of a transistor as common-base, common-emitter and common-collector.

- Introduce the common-emitter configuration circuit of an *npn* transistor giving a circuit with a forward biased B-E junction and a reverse biased B-C junction.
- Introduce the following characteristic curves of the common-emitter configuration of an *npn* transistor. input characteristics, output characteristics and transfer characteristics.
- Explain variation of I_B with V_{BE} using input characteristic.
- Introduce cut-off region, active region (linear region) and saturated region of a transistor using output characteristics and transfer characteristics.
- Show that $I_C \approx 0$ in the cut-off region.
- Show that $I_C \propto I_B$ and $I_C = \beta I_B$ in the active region and state that β is a constant name DC current gain. It is a constant for the transistor.
- Show that $I_C < \beta I_B$ in the saturated region.
- Explain the variation of I_C with V_{CE} for various I_B values using output curves.
- Explain the need of biasing a transistor.
- Introduce base-resistor method and voltage-divider method as biasing methods of a transistor using a single voltage source using diagrams.
- Give the circuit diagram of a common-emitter *npn* transistor amplifier.
- Explain that the transistor is biased to be in active region with $V_{BE} \approx 0.7$ V.
- Explain the need of selecting the collector potential (V_C) as half of V_{CC}.
- Explain that the magnitude of I_B varies according to the input signal, using the graphical representations.
- Show that I_C varies according to the variation of I_B, using the graphical representation.
- Explain that the variation of I_C is greater than the variation of I_B, and therefore, it is considered a current amplification.
- Show that potential drop across R_C varies according to the variation of I_C.
- Show that V_C varies according to the variation of potential drop across R_C.
- Explain that the variation of V_0 (output voltage) is greater than the variation of the input voltage, and therefore, it is considered a voltage amplification.
- Show that there is no phase change in the current amplification while there is a phase change of π rad in the voltage amplification.
- Explain why coupling capacitors are used..
- Represent graphically the variations of the input signal (V_{in}), base current (I_B), collector current (I_C) and output voltage (V_{out}) with time.

- To explain the action of transistor as a switch, recall I_C-V_{CE} characteristics for an *npn* transistor in common emitter configuration at the cut-off region and the saturated region.
- Give practical circuit for a transistor switch and explain the action of it using a circuit diagram.
- Explain that the cut-off state and the saturated state of a transistor is equivalent to the off state and on state of a mechanical switch respectively.
- Explain that the transistor can be used as a switch by varying the value of input voltage between two voltage levels.
- Distinguish between bipolar transistor and unipolar transistor.
- Introduce the junction field effect transistor (JFET) as a unipolar transistor.
- Introduce the structure, circuit symbol and terminals of *n*-channel and *p*-channel JFETs.
- Name the terminals as Gate (G), Source (S), and Drain (D).
- Give the circuit diagram for common source configuration.
- Explain the action of *n* - channel JFET and give the I_D -V_{DS} characteristics.
- Explain amplification of JFET using common-source configuration of JFET.

Laboratory experiment:

- Investigating the characteristics of a common emitter configuration of a transistor
- Explain the switching action of a transistor using a practical circuit.

Competency level 9.3: Investigates the uses of an operational amplifier.

Number of periods: 06

Learning outcomes:

- identifies the pin numbers of an operational amplifier.
- describes the open loop characteristic of an operational amplifier.
- expresses the voltage gain of the open loop state.
- states the properties of an operational amplifier.
- explains the purpose of negative feedback and the effects on the gain of an operational amplifier.
- interprets graphically and with suitable circuit diagrams the action of inverting and non-inverting operational amplifiers.
- states the Golden rules I and II regarding an operational amplifier in operating in the linear region.
- derives an expression for the voltage gain of inverting and non - inverting amplifiers.
- explains the use of operational amplifier as a voltage comparator.
- solves problems related to operational amplifier.

Suggested learning/teaching process:

- Describe what is meant by integrated circuits (ICs).
- Describe how electronic chips are named SSI, MSI, LSI and VLSI.
- State the advantages of the uses of ICs.
- Introduce how to number the pins of an IC.
- Introduce the operational amplifier (Op-Amp) as an IC.
- Introduce the circuit symbol and the terminals of an Op-Amp.
- Express the relationship between input voltages and output voltages of an Op-Amp as $V_O=A\,(V_+ - V_-)$ at the open loop state.
- Give the open loop characteristics.
- Introduce linear region and saturated region.
- Show that there is a very narrow range that can be used for amplification according to the characteristic.
- Show that the high open loop voltage gain gives a narrow linear region.
- Explain that the Op-Amp at open-loop state is used as a switch or a voltage comparator.
- Use voltage characteristics and suitable examples for this.
- Show that the close-loop state is obtained by connecting the output and the inverting input terminals by using an external feedback resistor.
- Show that the voltage gain (G_V) is a finite value at close-loop state.
- State Golden rules I and II for Op-Amps.

- Give circuit diagrams and characteristics for non-inverting amplifier and inverting amplifier.
- Guide students to derive expressions for voltage gains of non-inverting and inverting amplifiers.
- Use suitable examples to solve problems related to Op-Amp.

Competency level 9.4: Uses logic gates to control the action of digital circuits.

Number of periods: 12

Learning outcomes:

- writes Boolean expressions and truth tables for AND, OR, NOT, NAND, NOR, Ex-OR, and Ex-NOR logic gates.
- develops logic expressions for simple digital logic circuits having two or three inputs.
- converts given logic expressions into logic circuits.
- designs simple logic circuits to suit given conditions.
- explains basic feature of memory element using NOR gates
- explains the action of SR flip-flop using a truth table.

Suggested learning/teaching process:

- Distinguish between analogue and digital signals.
- Describes conversion between decimal numbers and binary numbers (up to decimal15).
- Show that '0' and '1' digits in binary number can be represented by two different voltage levels.
- Explain that the voltage waveform of a digital signal can be represented by a binary number.
- Give circuit symbols, truth tables, and Boolean expressions for NOT, AND, OR, NAND, NOR, X-OR and X-NOR gates.
- Introduce the terms bit, byte, least significant bit (LSB), most significant bit (MSB).
- Assign students to do the following activities.
    - Obtain the truth table for a given Boolean expression.
    - Write down the Boolean expression for a given truth table.
    - Design a logic gate circuit for a given truth table.
    - Obtain the truth table for a given logic circuit.
    - Obtain the Boolean expression for a given logic circuit.
    - Design a logic circuit for a given Boolean expression.
    - Design a simple logic circuit for a given problem (maximum three inputs).
- Distinguish between combinational logic circuits and sequential logic circuits.
- Explain SR flip-flop using NAND and NOR logic gates.
- Explain SR flip-flop as a device in which the output depends not only on the present state but also on the previous state.
- Explain the action of an SR flip-flop using a truth table.
- Give timing diagram for an SR flip-flop.
- Explain the uses of SR flip-flop as a memory element.

Laboratory experiments:

- Investigating the truth tables of basic logic gates

Unit 10: Mechanical properties of matter

Competency 10.0: Applies the knowledge on mechanical properties of matter quantitatively in scientific activities and daily pursuits.

Competency level 10.1: Selects relevant materials for day-to-day needs in life using the knowledge about elasticity.

Number of periods: 10

Learning outcomes:

- conducts an experiment to investigate the relationship between tension and extension of a string or a spring.
- states Hooke's law.
- defines the terms tensile stress, tensile strain and Young's modulus.
- explains the behaviour of materials using stress-strain graph.
- identifies proportional limit, elastic limit and breaking point.
- determines experimentally the Young's modulus of a metal wire using the relationship between tension and extension.
- gives an expression for energy stored in a string / a spring under a stress.
- carries out numerical calculations to solve problems related to elasticity.
- writes a report mentioning where the knowledge of elasticity is used in technical purposes.

Suggested learning/teaching process:

- Guide students to obtain the relationship between the tension and extension of an elastic string or a helical spring using a simple activity.
- Express Hooke's law.
- Introduce force constant (spring constant).
- Conduct a discussion to explain the elastic properties of solids as change in length, change in shape and those of a gas as change in volume.
- Introduce tensile stress and tensile strain for a string.
- Define Young's modulus.
- Give the expression $E = \frac{F/A}{e/l}$ introducing the symbols.
- Give the graph of stress vs. strain.
- Explain the following terms using the graphs.
  - proportional limit
  - elastic limit
  - yield point
  - breaking stress
- Distinguish ductility and brittleness.
- Guide students to conduct an experiment to find the Young's modulus of a metal.

- Guide students to conduct an activity to investigate that energy stored in a stretched string or spring.
- Derive an expression for energy stored.
- Explain that a stress is formed in a clamped rod or stretched strings due to the change in temperature.
- Guide students to obtain expressions for above instances.
- Assign students to solve problems related to elasticity.

Laboratory experiment:

- Determination of Young's modulus of a metal using a wire.

Competency level 10.2: Uses the knowledge on viscosity in scientific work and daily pursuits.

Number of periods: 15

Learning outcomes:

- demonstrates the differences of flowing of various liquids using simple activities.
- introduces tangential stress and velocity gradient of a fluid flow.
- defines coefficient of viscosity.
- uses the expression for viscous force to solve problems.
- expresses Poiseuille's equation for a liquid flow.
- states the conditions for the validity of Poiseuille's equation.
- conducts experiment to determine coefficient of viscosity of water by the capillary flow method.
- describes the forces acting on a spherical object moving vertically in a viscous medium.
- explains terminal velocity using $v - t$ graph of a body moving through a viscous medium.
- expresses Stokes' law.
- derives expression for the terminal velocity of a sphere moving upwards and downwards in a viscous medium.
- solves simple numerical problems related to viscosity.

Suggested learning/teaching process:

- Design activities to investigate the difference of the nature of flowing of various liquids.
- Explain the difference between streamline flow and turbulent flow.
- Introduce velocity gradient and shear stress for a laminar flow.
- Give the expression $\frac{F}{A} = \eta \frac{(V_1 - V_2)}{d}$ for a laminar flow.
- Define coefficient of viscosity and give units and dimensions.
- Give Poiseuille's equation for a steady flow.
- Explain the conditions for the validity of the above equation.
- Guide students to verify the equation using dimensions.
- Guide students to conduct an experiment to find the coefficient of viscosity of water using the above equation.
- Describe the forces acting on a spherical object moving through a viscous medium.
- Explain that the magnitude of the viscous force increases with the speed of the object.
- Show that the object reaches a terminal velocity due to that reason.
- State Stokes' law as the expression, $F = 6\pi a\eta v$ and introduce the terms.

- Guide students to derive expressions for the terminal velocities of the objects moving up and down in a viscous medium.
- Give the velocity-time graph for an object moving in a viscous medium.
- Conduct a discussion to identify the practical uses related to viscosity.
- Guide students to solve problems related to viscosity.

Laboratory experiment:

- Determination of coefficient of viscosity by using Poiseuille's formula

Competency level 10.3: Uses the knowledge on surface tension to explain the natural phenomena and to fulfill the daily pursuits.

Number of periods: 15

Learning outcomes:

- demonstrates the behavior of free surface of a liquid using simple activities.
- explains the behavior of free surface of a liquid using inter-molecular forces.
- defines surface tension.
- defines surface energy.
- obtains the relationship between surface energy and surface tension.
- describes the angle of contact with the help of diagrams.
- derives an expression for pressure difference across spherical meniscus in terms of surface tension and the radius of the meniscus.
- explains capillary rise in terms of angle of contact and pressure difference across the meniscus.
- derives an expression for capillary rise in terms of surface tension, angle of contact and radius of the meniscus.
- conducts experiments to determine surface tension by using microscope slide method.
- conducts experiments to determine surface tension by using capillary rise method.
- conducts experiments to determine surface tension by using Jaeger's method.
- solves problems related to surface tension.

Suggested learning/teaching process:

- Demonstrate the nature of free liquid surface using simple activities.
- Explain the nature of free liquid surface using suitable examples.
- Describe the nature of free liquid surface using the inter-molecular forces.
- Define surface tension and give units.
- Introduce free surface energy considering the work done to increase the surface area isothermally.
- Obtain the relationship between surface tension and free surface energy.
- Introduce angle of contact for a liquid meniscus.
- Explain the instances where the angle is less than 90^o, 90^o and greater than 90^o considering cohesive forces and adhesive forces.
- Explain capillary rise using surface tension.
- Guide students to derive the equation, $h\rho g = \frac{2T\cos\theta}{r}$ considering force equilibrium.

- Guide students to obtain the expression, $P_{in} - P_{out} = \frac{2T}{r}$ for a spherical meniscus.
- Show that the pressure difference is large when the radius is small.
- Guide students to obtain the expression considering pressure difference method.
- Show that the pressure difference of an air bubble in a liquid and a liquid drop is given by *2T/r*.
- Show that the pressure difference of a soap bubble is given by *4T/r* because there are two liquid-air interfaces.
- Guide students to conduct the following experiments to find surface tension.
  - Microscope-slide method.
  - Capillary-rise method.
  - Jaeger method.
- Guide students to solve problem related to surface tension.
- Conduct a discussion to describe the uses of surface tension.

Laboratory experiments:

- Determination of surface tension using the microscope slide method
  - capillary rise method
  - Jaeger's method

Unit 11 Matter and Radiation

Competency 11.0: Inquires into the modern theories in physics

Competency level 11.1: Applies the quantum theories to explain the intensity distribution of black body radiation.

Number of periods: 06

Learning outcomes:

- explains thermal radiation of bodies at various temperatures using activities and examples.
- introduces the black body.
- describes the intensity distribution of blackbody radiation using the graph of intensity versus wavelength for various temperatures.
- states Stefan's law.
- relates the temperature and intensity of black body radiation using Stefan's law.
- uses the modification of the Stefan's law.
- states Wien's displacement law.
- uses Wien's displacement law for relevant instances.
- describes the failure of classical physics in explaining the black body radiation.
- explains Plank's hypothesis using the appropriate terms.
- accepts the quantum nature of radiation.
- Accepts that Plank's theory can be used to explain black body radiation.

Suggested learning/teaching process:

- Explain that thermal energy radiates from a hot body using simple activities and suitable examples.
- Give electro-magnetic spectrum.
- State that the radiation of all the wavelengths radiate from a hot body.
- State that the rate of radiation from a hot body depends on the following factors.
  - nature of the surface
  - temperature of the body
  - the surface area
- Explain what is meant by black-body.
- Express Stefan's law.
- Introduce Stefan constant as a universal constant.
- Define surface absorptivity and surface emissivity.

  Show that the above value for a black body is 1 and for any other surface is less than 1.

- Present Stefan’s law for non black bodies.
- Present intensity distribution of black body radiation using relevant graphs.
- Present the information that can be obtained from the above mentioned graphs.
- Present Wien’s displacement law.
- Give examples which can be explained by using Wien’s law.
- Show that the failure of classical physics in explaining those observation.
- State that Rayleigh-Jean’s theory which is based on classical physics explains only the long wavelength region.
- State that Wien’s theory which is based on classical physics explains only short wavelength region.
- Compare the graphs drawn by using the experimental data with the graphs drawn based on the above mentioned two theories.
- State two hypotheses put-forward by Max Plank to explain the observations.
- State that Plank’s theory which is based on these two hypotheses can be used to explain the intensity distribution of black body radiation.
- Show that the graph drawn from the experimental data matches well with the graph drawn based on the Plank’s theory.
- State that the concept of energy quantization, stemmed from those hypotheses is used in many explanations.
- Guide students to carry out calculations to solve problems related to black body radiation. (Stefan's law and Wien's law)

Competency level 11.2: Applies the quantum theories to explain the photoelectric effect.

Number of periods: 06

Learning outcomes:

- explains the phenomenon of photoelectric effect using photoelectric effect experiment.
- identifies the threshold frequency (or cut-off frequency).
- explains the stopping potential.
- draws *I-V* graphs for the photoelectric effect.
- accepts that classical physics cannot be used to explain the results of the photoelectric effect.
- states Einstein's hypotheses.
- explains the photoelectric effect using photon theory.
- explains Einstein's photoelectric equation by introducing its terms.
- relates threshold frequency to the work function.
- relates stopping potential to the maximum kinetic energy.
- solves numerical calculation using the photo electric equation.
- explains why the maximum kinetic energy is independent of intensity.
- explains why the photoelectric current is proportional to intensity.
- States that photoelectric effect gives evidence for the particle the nature of electromagnetic waves.

Suggested learning/teaching process:

- Conduct a discussion about the early experiments about the photo-electric effect.
- Explain briefly the photo-electric effect.
- Describe the photocell that is used in photoelectric experiments.
- Present observations obtained from the experiments done by using a photocell.
- Introduce threshold frequency.
- Present the following graphs drawn based on the experimental data.
    - Keeping the intensity constant, varying the potential difference between cathode and anode; consider the change of the polarity of the source.
    - Introduce stopping potential and explain that there is a maximum kinetic energy for photo electrons.
    - Repeat the experiment by using different intensities.
    - Show that the stopping potential doesn't change though the intensity changes for the same frequency.
    - The experiment for different frequencies shows that the stopping potential is different for different frequencies.
    - The graph between stopping potential vs. frequency.

- Graphs between stopping potential and frequency for various metals.
- State the failure of classical physics to explain those observations and graphical representations.

- Present the hypothesis put forward by Albert Einstein to explain the photoelectric effort.
- Introduce work-function for a metal surface.
- Give Einstein's photoelectric equation.
- Give the relationship between the threshold frequency and work function.
- Give the relationship between the maximum kinetic energy of photo electrons and stopping potential.
- Explain each observation by using Einstein's theory.
- Explain the graph between the stopping potential and the frequency.
- Explain the reason why the graphs are parallel to each other for different metals.
- Show that the photons of electromagnetic waves have a particle nature according to the Einstein's theory.
- Guide students to carry out calculations to solve problems related to photoelectric effect.

Competency level 11.3: Inquires about wave-particle duality

Number of periods: 02

Learning outcomes:

- gives evidence about the wave nature of matter.
- accepts that any particle of a specific momentum has an associated wavelength called the de Broglie wavelength.
- applies de Broglie hypothesis for the determination of the de Broglie wavelength of matter waves associated with a moving particle.
- explains the principle of electron microscope.

Suggested learning/teaching process:

- State that de Broglie has stated the there should be a wave nature moving for matter particles as well as photons have particle nature.
- Give de Broglie relationship between the wavelength of matter waves and the momentum.
- Describe that the wavelength of matter waves has been obtained experimentally by considering the diffraction of electron beam, few years after de Broglie has predicted the idea.
- State that the wave length of matter particles predicted by de Broglie's theory is the same with the calculated wavelength through experiment considering the diffraction of an electron beam.
- State that diffraction pattern can be obtained only from microscopic particles such as electrons, protons, and neutrons.
- Show that it is impossible to observe the wave nature of macroscopic objects using numerical examples.
- Explain that the resolving power of a microscope depends on the wavelength used for it.
- Show that the resolving power increases (higher) when the wave length is smaller.
- Show that there is a limitation in resolving power when visible light is used because the wave length range of visible light is 700 nm - 400 nm.
- Explain that it is possible to obtain very short wave lengths from an accelerated electron beam.
- Explain that the electron microscope has obtained higher resolving power due to the highly accelerated electron beams used in it.
- Compare the action of light microscope and electron microscope using diagrams.

Competency level 11.4: Uses X – rays to fulfill human needs.

Number of periods: 02

Learning outcomes:

- explains the discovery of X-rays.
- describes the method of production of X-rays.
- explains the properties of X-rays.
- explains qualitatively how X-rays can be used in different fields (medical, industrial, etc.).

Suggested learning/teaching process:

- Describe the exploration of X-rays.
- Describe the X-ray machine.
- Explain the necessity of main parts of the X-ray machine.
- Describe how X-rays are produced by the X-ray machine.
- State the wavelength range of X-rays in the electromagnetic spectrum.
- Distinguish soft X-rays and hard X-rays.
- Present the properties of X-rays.
- Conduct a discussion about the uses of X-rays.

Competency level 11.5: Inquires about radioactivity to fulfill human needs.

Number of periods: 08

Learning outcomes:

- defines natural radio activity.
- explains *α, β* and *γ* radiation.
- states the Properties of *α, β* and *γ* radiations.
- states that there are two types of *β* particles.
- writes general equations for *α, β* and *γ* emissions.
- expresses the lac of radioactive disintegration.
- introduces the terms decay constant and half- life.
- describes C^{14} dating.
- gives examples for the uses of radioactivity.
- Introduces the terms with units radiation dose, RBE factor (Q factor) and effective does.
- Describes health hazards of radioactivity and safety precautions.
- Carries out numerical calculations to solve problem related to radioactivity.

Suggested learning/teaching process:

- Conduct a discussion to recall the early discoveries about the radioactivity.
- Present the definition of radioactivity.
- Introduce radioactivity as a nuclear reaction.
- Introduce *α*-particles, *β*-particles and γ-rays as radiation of natural radioactivity.
- Introduce the nature of *α, β* and *γ* rays.
- Present properties of *α, β* and *γ* radiations.
- State that there are two types of *β* particles.
- Give general equation for radiation of *α, β* and *γ* emmission.
- Give an example for each radiation.
- Give a table with properties of *α, β* and *γ* radiation for the comparison of their properties.
- Present the radioactive disintegration law.
- Introduce decay constant (λ).
    - Present the graph between the number of particles in a sample and the time.
    - Introduce "activity" (A) and half life ($T_{1/2}$).
- Give the relationship between the decay constant and half life.
- Conduct a discussion to find examples for the uses of radioactivity.
- Guide the students to pay attention to the following facts about the carbon-dating.
- Neutrons are produced due to the reaction between atoms in the air and cosmic rays.
    - It produces $^{14}_{6}C$ when neutrons reacts with $^{14}_{7}N$ atoms.

- $^{14}_{6}C$ is unstable. Therefore it decays emitting *β* particles and produces $^{14}_{7}N$.
- $^{14}C/^{12}C$ ratio in the atmosphere is a constant for a long time.

- Explain how the age of an ancient object is determined using carbon-dating.
- Conduct a discussion about the health hazards of radiation.
- Present the term dose of radiation and units.
- Introduce Q-factor for radiation.
- Introduce equivalent dose of radiation.
- Give a table for Q-factors of various radiations, *α, β*, *γ* and *n* etc.
- State about Guiger Muller counter.

Competency level 11.6: Inquires about the nuclear energy and its uses.

Number of periods: 06

Learning outcomes:

- identifies the atomic structure, the nucleus, the isotopes, nuclear notation and the atomic mass unit.
- explains stability of nucleus.
- explains mass defect.
- states Einstein's mass - energy equation.
- explains binding energy.
- describes graphical representation between atomic number and binding energy of a nucleon.
- compares the energy released in chemical reactions and nuclear reactions.
- Explains the nuclear fission and the process of chain reaction which may be controlled (nuclear power) or uncontrolled (atomic bomb).
- conducts a survey and prepare a report on the study that can be taken to assure the safeguard during a radiation disaster using information technology.
- explains the nuclear fusion, reaction inside the sun/in other stars, and the production of elements.

Suggested learning/teaching process:

- Conduct a discussion to recall the facts about the atomic structure, nuclear, atomic mass number etc.
- State that the mass of a nucleus is less than the mass of theconstituents of it.
- Explain that there is a mass defect when forming a nucleus.
- Show that this mass defect exist as bond energy.
- Guide students to calculate bond energy using $E=mc^2$ equation.
- Present the graph of bond energy per nucleon with mass number.
- Discuss the stability of a nucleus.
- State that the bond energy is in the order of MeV.
- Show that the element with a lower mass number and element with a higher mass number are unstable according to the graph.
- Show that the atoms with higher mass number such as $^{235}_{92}U$ can undergo nuclear fission reactions.
- Present the nuclear reaction that occurs when slow neutrons attack $^{235}_{92}U$ atoms.
- Show that neutrons are produced as a result of the reaction with two lighter nuclei.
- Explain that a chain reaction occurs when these neutrons attack other nuclei of $^{235}_{92}U$.

- Explain that atomic bomb makes use of uncontrolled fission reactions.
- State how the chain reaction is controlled in a nuclear power plant.
- State that nuclear reaction in power plants makes use of controlled fission reactions.
- Show that the atoms of lower mass numbered elements form more stable elements through nuclear fusion reactions.
- State that a temperature in the order of 10^8 K is required to start a nuclear fusion reaction.
- Show that H nucleus is used to form He nucleus in the core of the sun.
- Present the equation for nuclear fusion reaction in the sun.
- Show that energy in the order of 25MeV is released occurs in one cycle.
- State that this reaction exists for 5 billion years in the sun and there is sufficient hydrogen in the sun for another 5 billion years.
- Compare the amount of energy exchanged in a chemical reaction and a nuclear reaction.
- State that various fusion reactions occur in other stars forming other elements.

Competency level 11.7: Inquires about the fundamental constituents of matter and their interactions.

Number of periods: 04

Learning outcomes:

- accepts that particle physics is the modern version of and age- old – quest to find the smallest entities of matter.
- explains that high momentum particles are required to investigated structure of matter.
- explains that cosmic rays are the natural source of high energy particles.
- explains that particle accelerators are used to produce high energy particles.
- explains that detectors are used to analyze the outcome of particle collisions.
- states that a large number of elementary particles have been discovered.
- states that protons and neutrons are made up by quarks.
- states that electrons belong to lepton group.
- identifies the source and strength of fundamental interactions.

Suggested learning/teaching process:

- Introduce particle physics as the modern science which focuses on the fundamental particles of matter.
- Recall Rutherford's experiment carried out to investigate the structure of atoms.
- Show that it is needed to use high momentum particles to explore the nature of matter.
- State that the cosmic rays as the natural source of high momentum particles.
- Explain that particle accelerators are used to obtain high momentum particles.
- Explain that detectors are used to observe the result of collisions.
- State fundamental particles which form neutrons and protons.
- State that quarks are the electron belongs to the lepton family.
- Name four fundamental forces in the nature.
- Compare the range of magnitude of fundamental forces.