CONTENT STRUCTURE

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II. Newtonian Mechanics	2. Kinematics 3. Dynamics 4. Mass, Weight and Density 5. Turning Effect of Forces 6. Pressure 7. Energy, Work and Power
III. Thermal Physics	8. Kinetic Model of Matter 9. Transfer of Thermal Energy 10. Temperature 11. Thermal Properties of Matter
IV. Waves	12. General Wave Properties 13. Light 14. Electromagnetic Spectrum 15. Sound
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SUBJECT CONTENT

SECTION I: MEASUREMENT

Overview
In order to gain a better understanding of the physical world, scientists use a process of investigation that follows a general cycle of observation, hypothesis, deduction, test and revision, sometimes referred to as the scientific method. Galileo Galilei, one of the earliest architects of this method, believed that the study of science had a strong logical basis that involved precise definitions of terms and physical quantities, and a mathematical structure to express relationships between these physical quantities.

In this section, we study a set of base physical quantities and units that can be used to derive all other physical quantities. These precisely defined quantities and units, with accompanying order-of-ten prefixes (e.g. milli, centi and kilo) can then be used to describe the interactions between objects in systems that range from celestial objects in space to sub-atomic particles.

1. Physical Quantities, Units and Measurement

Content
- Physical quantities
- SI units
- Prefixes
- Scalars and vectors
- Measurement of length and time

Learning Outcomes

Candidates should be able to:

(a) show understanding that all physical quantities consist of a numerical magnitude and a unit

(b) recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol)

(c) use the following prefixes and their symbols to indicate decimal sub-multiples and multiples of the SI units: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G)

(d) show an understanding of the orders of magnitude of the sizes of common objects ranging from a typical atom to the Earth

(e) state what is meant by *scalar* and *vector* quantities and give common examples of each

(f) add two vectors to determine a resultant by a graphical method

(g) describe how to measure a variety of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier scale as necessary

(h) describe how to measure a short interval of time including the period of a simple pendulum with appropriate accuracy using stopwatches or appropriate instruments

SECTION II: NEWTONIAN MECHANICS

Overview
Mechanics is the branch of physics that deals with the study of motion and its causes. Through a careful process of observation and experimentation, Galileo Galilei used experiments to overturn Aristotle's ideas of the motion of objects, for example the flawed idea that heavy objects fall faster than lighter ones, which dominated physics for about 2,000 years.

The greatest contribution to the development of mechanics is by one of the greatest physicist of all time, Isaac Newton. By extending Galileo's methods and understanding of motion and gravitation, Newton developed the three laws of motion and his law of universal gravitation, and successfully applied them to both terrestrial and celestial systems to predict and explain phenomena. He showed that nature is governed by a few special rules or laws that can be expressed in mathematical formulae. Newton's combination of logical experimentation and mathematical analysis shaped the way science has been done ever since.

In this section, we begin by examining kinematics, which is a study of motion without regard for the cause. After which, we study the conditions required for an object to be accelerated and introduce the concept of forces through Newton's Laws. Subsequently, concepts of moments and pressure are introduced as consequences of a force. Finally, this section rounds up by leading the discussion from force to work and energy, and the use of the principle of conservation of energy to explain interactions between bodies.

2. Kinematics

Content
- Speed, velocity and acceleration
- Graphical analysis of motion
- Free-fall
- Effect of air resistance

Learning Outcomes

Candidates should be able to:

(a) state what is meant by speed and velocity

(b) calculate average speed using *distance travelled / time taken*

(c) state what is meant by uniform acceleration and calculate the value of an acceleration using *change in velocity / time taken*

(d) interpret given examples of non-uniform acceleration

(e) plot and interpret a displacement-time graph and a velocity-time graph

(f) deduce from the shape of a displacement-time graph when a body is:
  (i) at rest
  (ii) moving with uniform velocity
  (iii) moving with non-uniform velocity

(g) deduce from the shape of a velocity-time graph when a body is:
  (i) at rest
  (ii) moving with uniform velocity
  (iii) moving with uniform acceleration
  (iv) moving with non-uniform acceleration

(h) calculate the area under a velocity-time graph to determine the displacement travelled for motion with uniform velocity or uniform acceleration

(i) state that the acceleration of free fall for a body near to the Earth is constant and is approximately 10 m/s^2

(j) describe the motion of bodies with constant weight falling with or without air resistance, including reference to terminal velocity

3. Dynamics

Content

- Balanced and unbalanced forces
- Free-body diagram
- Friction

Learning Outcomes

Candidates should be able to:

(a) apply Newton's Laws to:
   (i) describe the effect of balanced and unbalanced forces on a body
   (ii) describe the ways in which a force may change the motion of a body
   (iii) identify action-reaction pairs acting on two interacting bodies
   (stating of Newton's Laws is not required)

(b) identify forces acting on an object and draw free body diagram(s) representing the forces acting on the object (for cases involving forces acting in at most 2 dimensions)

(c) solve problems for a static point mass under the action of 3 forces for 2-dimensional cases (a graphical method would suffice)

(d) recall and apply the relationship *resultant force* = *mass* × *acceleration* to new situations or to solve related problems

(e) explain the effects of friction on the motion of a body

4. Mass, Weight and Density

Content

- Mass and weight
- Gravitational field and field strength
- Density

Learning Outcomes

Candidates should be able to:

(a) state that mass is a measure of the amount of substance in a body

(b) state that mass of a body resists a change in the state of rest or motion of the body (inertia)

(c) state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction

(d) define gravitational field strength, g, as *gravitational force per unit mass*

(e) recall and apply the relationship *weight* = *mass* × *gravitational field strength* to new situations or to solve related problems

(f) distinguish between mass and weight

(g) recall and apply the relationship *density = mass / volume* to new situations or to solve related problems

5. Turning Effect of Forces

Content

- Moments
- Centre of gravity
- Stability

Learning Outcomes

Candidates should be able to:

(a) describe the moment of a force in terms of its turning effect and relate this to everyday examples

(b) recall and apply the relationship *moment of a force (or torque) = force × perpendicular distance from the pivot* to new situations or to solve related problems

(c) state the principle of moments for a body in equilibrium

(d) apply the principle of moments to new situations or to solve related problems

(e) show understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity

(f) describe qualitatively the effect of the position of the centre of gravity on the stability of objects

6. Pressure

Content

- Pressure
- Pressure differences
- Pressure measurement

Learning Outcomes

Candidates should be able to:

(a) define the term pressure in terms of force and area

(b) recall and apply the relationship *pressure = force / area* to new situations or to solve related problems

(c) describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press

(d) recall and apply the relationship *pressure due to a liquid column = height of column × density of the liquid × gravitational field strength* to new situations or to solve related problems

(e) describe how the height of a liquid column may be used to measure the atmospheric pressure

(f) describe the use of a manometer in the measurement of pressure difference

7. Energy, Work and Power

Content

- Energy conversion and conservation
- Work
- Power

Learning Outcomes

Candidates should be able to:

(a) show understanding that kinetic energy, potential energy (chemical, gravitational, elastic), light energy, thermal energy, electrical energy and nuclear energy are examples of different forms of energy

(b) state the principle of the conservation of energy and apply the principle to new situations or to solve related problems

(c) calculate the efficiency of an energy conversion using the formula *efficiency = energy converted to useful output / total energy input*

(d) state that kinetic energy $E_k = \frac{1}{2} mv^2$ and gravitational potential energy $E_p = mgh$ (for potential energy changes near the Earth's surface)

(e) apply the relationships for kinetic energy and potential energy to new situations or to solve related problems

(f) recall and apply the relationship *work done = force* × *distance moved in the direction of the force* to new situations or to solve related problems

(g) recall and apply the relationship *power = work done / time taken* to new situations or to solve related problems

SECTION III: THERMAL PHYSICS

Overview

Amongst the early scientists, heat was thought as some kind of invisible, massless fluid called 'caloric'. Certain objects that released heat upon combustion were thought to be able to 'store' the fluid. However, this explanation failed to explain why friction was able to produce heat. In the 1840s, James Prescott Joule used a falling weight to drive an electrical generator that heated a wire immersed in water. This experiment demonstrated that work done by a falling object could be converted to heat.

In the previous section, we studied about energy and its conversion. Many energy conversion processes which involve friction will have heat as a product. This section begins with the introduction of the kinetic model of matter. This model is then used to explain and predict the physical properties and changes of matter at the molecular level in relation to heat or thermal energy transfer.

8. Kinetic Model of Matter

Content

- States of matter
- Brownian motion
- Kinetic model

Learning Outcomes

Candidates should be able to:

(a) compare the properties of solids, liquids and gases

(b) describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules

(c) infer from a Brownian motion experiment the evidence for the movement of molecules

(d) describe the relationship between the motion of molecules and temperature

(e) explain the pressure of a gas in terms of the motion of its molecules

(f) recall and explain the following relationships using the kinetic model (stating of the corresponding gas laws is not required):
   (i) a change in pressure of a fixed mass of gas at constant volume is caused by a change in temperature of the gas
   (ii) a change in volume occupied by a fixed mass of gas at constant pressure is caused by a change in temperature of the gas
   (iii) a change in pressure of a fixed mass of gas at constant temperature is caused by a change in volume of the gas

(g) use the relationships in (f) in related situations and to solve problems (a qualitative treatment would suffice)

9. Transfer of Thermal Energy

Content

- Conduction
- Convection
- Radiation

Learning Outcomes

Candidates should be able to:

(a) show understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature

(b) describe, in molecular terms, how energy transfer occurs in solids

(c) describe, in terms of density changes, convection in fluids

(d) explain that energy transfer of a body by radiation does not require a material medium and that the rate of energy transfer is affected by:
  (i) colour and texture of the surface
  (ii) surface temperature
  (iii) surface area

(e) apply the concept of thermal energy transfer to everyday applications

10. Temperature

Content

- Principles of thermometry

Learning Outcomes

Candidates should be able to:

(a) explain how a physical property which varies with temperature, such as volume of liquid column, resistance of metal wire and electromotive force (e.m.f.) produced by junctions formed with wires of two different metals, may be used to define temperature scales

(b) describe the process of calibration of a liquid-in-glass thermometer, including the need for fixed points such as the *ice point* and *steam point*

11. Thermal Properties of Matter

Content

- Internal energy
- Specific heat capacity
- Melting, boiling and evaporation
- Specific latent heat

Learning Outcomes

Candidates should be able to:

(a) describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)

(b) define the terms *heat capacity* and *specific heat capacity*

(c) recall and apply the relationship *thermal energy = mass* × *specific heat capacity* × *change in temperature* to new situations or to solve related problems

(d) describe melting/solidification and boiling/condensation as processes of energy transfer without a change in temperature

(e) explain the difference between boiling and evaporation

(f) define the terms *latent heat* and *specific latent heat*

(g) recall and apply the relationship *thermal energy = mass* × *specific latent heat* to new situations or to solve related problems

(h) explain latent heat in terms of molecular behaviour

(i) sketch and interpret a cooling curve

SECTION IV: WAVES

Overview
Waves are inherent in our everyday lives. Much of our understanding of wave phenomena has been accumulated over the centuries through the study of light (optics) and sound (acoustics). The nature of oscillations in light was only understood when James Clerk Maxwell, in his unification of electricity, magnetism and electromagnetic waves, stated that all electromagnetic fields spread in the form of waves. Using a mathematical model (Maxwell's equations), he calculated the speed of electromagnetic waves and found it to be close to the speed of light, leading him to make a bold but correct inference that light consists of propagating electromagnetic disturbances. This gave the very nature of electromagnetic waves, and hence its name.

In this section, we examine the nature of waves in terms of the coordinated movement of particles. The discussion moves on to wave propagation and its uses by studying the properties of light, electromagnetic waves and sound, as well as their applications in wireless communication, home appliances, medicine and industry.

12. General Wave Properties

Content
- Describing wave motion
- Wave terms
- Longitudinal and transverse waves

Learning Outcomes

Candidates should be able to:

(a) describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by waves in a ripple tank

(b) show understanding that waves transfer energy without transferring matter

(c) define *speed, frequency, wavelength*, *period* and *amplitude*

(d) state what is meant by the term *wavefront*

(e) recall and apply the relationship *velocity = frequency* × *wavelength* to new situations or to solve related problems

(f) compare transverse and longitudinal waves and give suitable examples of each

13. Light

Content
- Reflection of light
- Refraction of light
- Thin lenses

Learning Outcomes

Candidates should be able to:

(a) recall and use the terms for reflection, including *normal*, *angle of incidence* and *angle of reflection*

(b) state that, for reflection, the angle of incidence is equal to the angle of reflection and use this principle in constructions, measurements and calculations

(c) recall and use the terms for refraction, including *normal, angle of incidence* and *angle of refraction*

(d) recall and apply the relationship sin i / sin r = constant to new situations or to solve related problems

(e) define *refractive index* of a medium in terms of the ratio of speed of light in vacuum and in the medium

(f) explain the terms *critical angle* and *total internal reflection*

(g) identify the main ideas in total internal reflection and apply them to the use of optical fibres in telecommunication and state the advantages of their use

(h) describe the action of a thin lens (both converging and diverging) on a beam of light

(i) define the term *focal length* for a converging lens

(j) draw ray diagrams to illustrate the formation of real and virtual images of an object by a thin converging lens

14. Electromagnetic Spectrum

Content

- Properties of electromagnetic waves
- Applications of electromagnetic waves
- Effects of electromagnetic waves on cells and tissue

Learning Outcomes

Candidates should be able to:

(a) state that all electromagnetic waves are transverse waves that travel with the same speed in vacuum and state the magnitude of this speed

(b) describe the main components of the electromagnetic spectrum

(c) state examples of the use of the following components:
   (i) radio waves (e.g. radio and television communication)
   (ii) microwaves (e.g. microwave oven and satellite television)
   (iii) infra-red (e.g. infra-red remote controllers and intruder alarms)
   (iv) light (e.g. optical fibres for medical uses and telecommunications)
   (v) ultra-violet (e.g. sunbeds and sterilisation)
   (vi) X-rays (e.g. radiological and engineering applications)
   (vii) gamma rays (e.g. medical treatment)

(d) describe the effects of absorbing electromagnetic waves, e.g. heating, ionisation and damage to living cells and tissue

15. Sound

Content

- Sound waves
- Speed of sound
- Echo
- Ultrasound

Learning Outcomes

Candidates should be able to:

(a) describe the production of sound by vibrating sources

(b) describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction

(c) explain that a medium is required in order to transmit sound waves and that the speed of sound differs in air, liquids and solids

(d) describe a direct method for the determination of the speed of sound in air and make the necessary calculation

(e) relate loudness of a sound wave to its amplitude and pitch to its frequency

(f) describe how the reflection of sound may produce an echo, and how this may be used for measuring distances

(g) define *ultrasound* and describe one use of ultrasound, e.g. quality control and pre-natal scanning

SECTION V: ELECTRICITY AND MAGNETISM

Overview

For a long time, electricity and magnetism were seen as independent phenomena. Hans Christian Oersted, in 1802, discovered that a current carrying conductor deflected a compass needle. This discovery was overlooked by the scientific community until 18 years later. It may be a chance discovery, but it takes an observant scientist to notice. The exact relationship between an electric current and the magnetic field it produced was deduced mainly through the work of Andre Marie Ampere. However, the major discoveries in electromagnetism were made by two of the greatest names in physics, Michael Faraday and James Clerk Maxwell.

The section begins with a discussion of electric charges that are static, i.e. not moving. Next, we study the phenomena associated with moving charges and the concepts of current, voltage and resistance. We also study how these concepts are applied to simple circuits and household electricity. Thereafter, we study the interaction of magnetic fields to pave the way for the study of the interrelationship between electricity and magnetism. The phenomenon in which a current interacts with a magnetic field is studied in electromagnetism, while the phenomenon in which a current or electromotive force is induced in a moving conductor within a magnetic field is studied in electromagnetic induction.

16. Static Electricity

Content

- Laws of electrostatics
- Principles of electrostatics
- Electric field
- Applications of electrostatics

Learning Outcomes

Candidates should be able to:

(a) state that there are positive and negative charges and that charge is measured in coulombs

(b) state that unlike charges attract and like charges repel

(c) describe an electric field as a region in which an electric charge experiences a force

(d) draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge

(e) draw the electric field pattern between two isolated point charges

(f) show understanding that electrostatic charging by rubbing involves a transfer of electrons

(g) describe experiments to show electrostatic charging by induction

(h) describe examples where electrostatic charging may be a potential hazard

(i) describe the use of electrostatic charging in a photocopier, and apply the use of electrostatic charging to new situations

17. Current of Electricity

Content

- Conventional current and electron flow
- Electromotive force
- Potential difference
- Resistance

Learning Outcomes

Candidates should be able to:

(a) state that current is a rate of flow of charge and that it is measured in amperes

(b) distinguish between conventional current and electron flow

(c) recall and apply the relationship *charge* = *current* × *time* to new situations or to solve related problems

(d) define electromotive force (e.m.f.) as the work done by a source in driving unit charge around a complete circuit

(e) calculate the total e.m.f. where several sources are arranged in series

(f) state that the e.m.f. of a source and the potential difference (p.d.) across a circuit component are measured in volts

(g) define the p.d. across a component in a circuit as the work done to drive unit charge through the component

(h) state the definition that *resistance = p.d. / current*

(i) apply the relationship $R = V / I$ to new situations or to solve related problems

(j) describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations

(k) recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems

(l) recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems

(m) state Ohm's Law

(n) describe the effect of temperature increase on the resistance of a metallic conductor

(o) sketch and interpret the I/V characteristic graphs for a metallic conductor at constant temperature, for a filament lamp and for a semiconductor diode

18. D.C. Circuits

Content

- Current and potential difference in circuits
- Series and parallel circuits
- Potential divider circuit
- Thermistor and light-dependent resistor

Learning Outcomes

Candidates should be able to:

(a) draw circuit diagrams with power sources (cell, battery, d.c. supply or a.c. supply), switches, lamps, resistors (fixed and variable), variable potential divider (potentiometer), fuses, ammeters and voltmeters, bells, light-dependent resistors, thermistors and light-emitting diodes

(b) state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems

(c) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems

(d) state that the current from the source is the sum of the currents in the separate branches of a parallel circuit and apply the principle to new situations or to solve related problems

(e) state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems

(f) recall and apply the relevant relationships, including $R = V / I$ and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit

(g) describe the action of a variable potential divider (potentiometer)

(h) describe the action of thermistors and light-dependent resistors and explain their use as input transducers in potential dividers

(i) solve simple circuit problems involving thermistors and light-dependent resistors

19. Practical Electricity

Content

- Electric power and energy
- Dangers of electricity
- Safe use of electricity in the home

Learning Outcomes

Candidates should be able to:

(a) describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters

(b) recall and apply the relationships $P = VI$ and $E = VIt$ to new situations or to solve related problems

(c) calculate the cost of using electrical appliances where the energy unit is the kW h

(d) compare the use of non-renewable and renewable energy sources such as fossil fuels, nuclear energy, solar energy, wind energy and hydroelectric generation to generate electricity in terms of energy conversion efficiency, cost per kW h produced and environmental impact

(e) state the hazards of using electricity in the following situations:
  (i) damaged insulation
  (ii) overheating of cables
  (iii) damp conditions

(f) explain the use of fuses and circuit breakers in electrical circuits and of fuse ratings

(g) explain the need for earthing metal cases and for double insulation

(h) state the meaning of the terms *live, neutral* and *earth*

(i) describe the wiring in a mains plug

(j) explain why switches, fuses, and circuit breakers are wired into the live conductor

20. Magnetism

Content

- Laws of magnetism
- Magnetic properties of matter
- Magnetic field

Learning Outcomes

Candidates should be able to:

(a) state the properties of magnets

(b) describe induced magnetism

(c) describe electrical methods of magnetisation and demagnetisation

(d) draw the magnetic field pattern around a bar magnet and between the poles of two bar magnets

(e) describe the plotting of magnetic field lines with a compass

(f) distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)

21. Electromagnetism

Content

- Magnetic effect of a current
- Applications of the magnetic effect of a current
- Force on a current-carrying conductor
- The d.c. motor

Learning Outcomes

Candidates should be able to:

(a) draw the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and/or direction of the current

(b) describe the application of the magnetic effect of a current in a circuit breaker

(c) describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing
  (i) the current
  (ii) the direction of the field

(d) deduce the relative directions of force, field and current when any two of these quantities are at right angles to each other using Fleming's left-hand rule

(e) describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field)

(f) explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by increasing
  (i) the number of turns on the coil
  (ii) the current

(g) discuss how this turning effect is used in the action of an electric motor

(h) describe the action of a split-ring commutator in a two-pole, single-coil motor and the effect of winding the coil on to a soft-iron cylinder

22. Electromagnetic Induction

Content

- Principles of electromagnetic induction
- The a.c. generator
- Use of cathode-ray oscilloscope
- The transformer

Learning Outcomes

Candidates should be able to:

(a) deduce from Faraday's experiments on electromagnetic induction or other appropriate experiments:
  (i) that a changing magnetic field can induce an e.m.f. in a circuit
  (ii) that the direction of the induced e.m.f. opposes the change producing it
  (iii) the factors affecting the magnitude of the induced e.m.f.

(b) describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings (where needed)

(c) sketch a graph of voltage output against time for a simple a.c. generator

(d) describe the use of a cathode-ray oscilloscope (c.r.o.) to display waveforms and to measure potential differences and short intervals of time (detailed circuits, structure and operation of the c.r.o. are not required)

(e) interpret c.r.o. displays of waveforms, potential differences and time intervals to solve related problems

(f) describe the structure and principle of operation of a simple iron-cored transformer as used for voltage transformations

(g) recall and apply the equations $V_P / V_S = N_P / N_S$ and $V_P I_P = V_S I_S$ to new situations or to solve related problems (for an ideal transformer)

(h) describe the energy loss in cables and deduce the advantages of high voltage transmission