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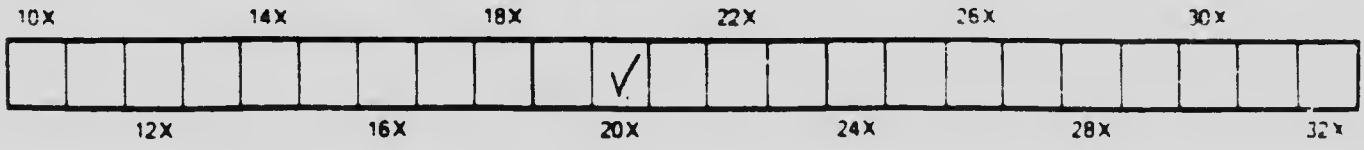

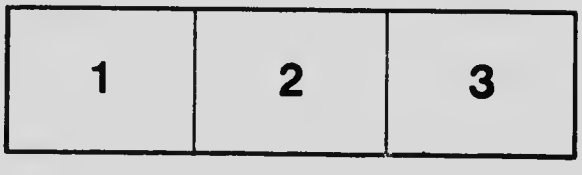

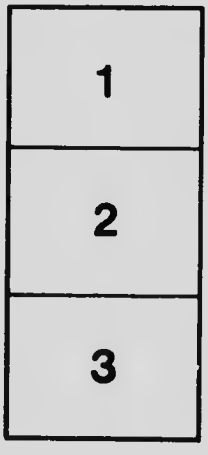

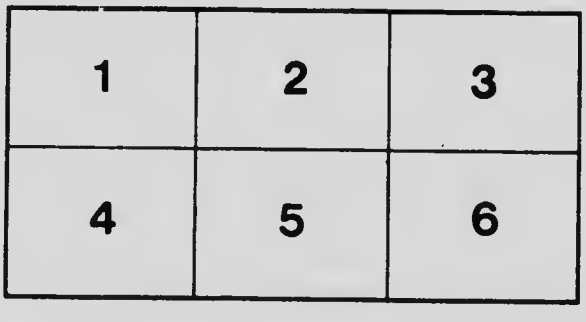

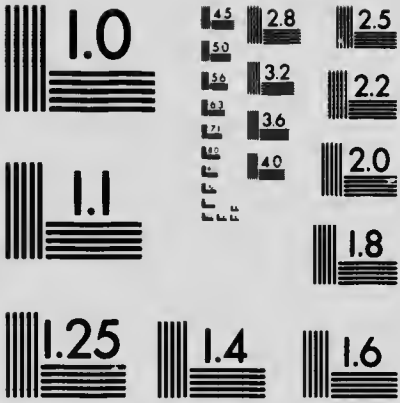

A SYNOPSIS

OF A

COURSE OF LECTURES

IN PHYSICS

UNIVERSITY PRESS:
TORONTO

University of Toronto.

DEPARTMENT OF PHYSICS.

SYLLABUS OF A

COURSE OF LECTURES ON

GENERAL PHYSICS.

This course of Lectures is designated to meet the needs of students of the first year in the Faculties of Arts, Medicine, Forestry, Dentistry and Household Science. The lectures, which are illustrated by experiments, are intended to give in a one year course an outline of the elements of Physics. The first six lectures present in an elementary manner the broad underlying principles more fully developed in detail in the main part of the course.

Revised 1913.

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LECTURE I.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

This lecture consists of a very brief historical sketch of the development of the metric system of weights and measures, a description of its chief features, a presentation of its advantages and illustrations of its use in domestic, industrial and scientific life. Various government standards of length, capacity and mass are exhibited during the lecture.

LECTURE II.

CONSTITUTION OF MATTER.

1. Mechanics: its scope.
   Force and motion.
   Energy and work.
   Centre of gravity.
2. Structure of matter.
   Investigation of the structure of matter suggested by existence of following forces:—statical resistance; friction; fluid pressure; gravitation; electrical and magnetic forces.
3. Matter:—continuous or discontinuous.
   Deductions from expansion under heat; compressibility; diffusibility; dispersion.
   Experiments: heated ball and ring; thermometers; sponge; pumice; wood and mercury; alcohol and water colouring of agates and marble; steel, gold, and platinum films; cathode and beta rays; diffusion of gases through metal and fused quartz.
4. Molecular forces.
   (*a*) Iron block and table; magnet and keeper.
   (*b*) Molecular forces act over small distances.
   Function of glue; adhesion of glass plates; welding of cracks in glass; flour; sandstone.
   (*c*) Molecular forces of different magnitudes.
   Steel, wood, lead, wax, pitch, oil, glycerine, mercury, water, air.
   (*d*) *Perfect solids* and *perfect fluids.*
   (*e*) *Viscous fluids* and *soft solids.*
      1. Marine glue and buoyancy.
      2. Wax bubbles.
5. Comparison of properties of solids and liquids.
   (*a*) Difference in support.
   (*b*) Difference in shape.
   (*c*) Effect of air resistance:—water hammer and spray formation at water falls.
   (*d*) Compressibility.

Mercury loses	.000004	of its volume for increase of one atmosphere or out of 10^6 parts		4 parts
Water "	.000049			49 "
Ether "	.000145			145 "
Glass "	.0000026			$2\frac{3}{5}$ "
Steel "	.0000005			$\frac{1}{2}$ "

   (*e*) Diffusibilities.
6. Fluids; *liquids* and *gases.*
   (*a*) Compressibility; football bladder under receiver.

7. Solids, liquids, and gases.
   (*a*) Solids have definite size and definite shape.
   (*b*) Liquids have definite size and indefinite shape.
   (*c*) Gases have indefinite size and indefinite shape
8. Molecular dimensions.
   (*a*) Comparison of volumes of equal masses of liquid water and gaseous water.
   (*b*) Molecules about 10^{-8} cm. in diameter.
   (*c*) Mean free paths at atmospheric pressure and 0° C:—
   Hydrogen 183×10^{-7} cm.
   Oxygen 10×10^{-7} cm.

LECTURE III.

ENERGY.

1. Idea of energy:—moving bodies, steam engine, trolley cars, dynamite, etc.
2. The capability of doing work.
3. Forms of energy convertible.
4. Examples:
   (*a*) Potential energy:—moving mass on Atwood's machine.
   (*b*) Kinetic energy. Falling mass striking lever carrying masses.
   (*c*) Energy of rotation,—water motor; fly-wheels.
   (*d*) Elastic energy;—spiral spring and ball.
   (*e*) Work and heat.
      1. Compressing air and igniting phosphorus.
      2. Twisting wire.
      3. Stretching rubber.
   (*f*) Heat and work.
      Expansion of rod and lever.
   (*g*) Friction and heat.
      Ether experiment.
   (*h*) Potential energy.
      Compressed air.
   (*i*) Kinetic energy.
      1. Currents of air and water.
      2. Anemometers.
      3. Windmills.
   (*j*) Sound waves a form of energy.
      1. Resonance between wires and wires; forks and forks.
      2. Sound mill.
   (*k*) Electrical energy.
      1. Movement of pith balls, water streams, paper rolls, etc.
      2. Falling weight, water wheels, dynamos and electric current.
   (*l*) Electric current and its transformations.
      1. Heat.
      2. Light and radiometer.
      3. Chemical separation; electrolysis.
      4. Combination of hydrogen and oxygen.
      5. Rotation of magnetic needle and electric motor.

(*m*) Magnetic energy.
1. Permanent magnets.
2. Electromagnets.

(*n*) Energy of electromagnetic radiation.
1. Electrical resonance.
2. Electric waves and wireless telegraphy.

(*o*) Energy of radioactivity.
Alpha, beta, and gamma rays.

(*p*) Matter and energy.
Radium clock.

5. Conservation of energy.
Physical phenomena and energy transformations.

LECTURE IV.

KINETIC THEORY OF MATTER.

1. Review of arguments in favour of discontinuity of matter.

2. Uses of a theory.
(*a*) To group together many physical properties and to offer a possible explanation of them.
(*b*) To suggest the investigation of properties not clearly or completely explained by the theory.

3. The Kinetic Theory assumes that:—
(*a*) Matter is composed of small particles.
(*b*) The particles have two motions, rotational and translational.
(*c*) Forces are exerted between the particles.

4. Confirmatory experiments.
(*a*) Tyndall's experiment; blue colour of sky.
(*b*) The ultramicroscope and what it reveals.

5. Relative importance of molecular forces and molecular motions.
(*a*) Change of state.
(*b*) Experiment on vaporisation of ether, and of liquid carbon dioxide.
(*c*) Production of liquid air by increasing the pressure and lowering the temperature.
(*d*) Production of solid carbon dioxide.

6. Kinetic theory explains:
(*a*) Relation between vapour tension and temperature.
(*b*) Cooling by rapid evaporation.
(*c*) Velocity of propagation of sound.
(*d*) Effusion of gases.
(*e*) Viscosity of gases.

7. Properties of matter apparently at variance with kinetic theory.
(*a*) Expansion of matter on change to a lower state, e.g., ice.
(*b*) Decrease of electrical resistance of carbon with increase of temperature.
(*c*) Solubility of substances in cold water greater than in hot water, e.g., calcium acetate and calcium citrate.

8. Ether and Matter.
   (*a*) Properties of molecules and motions in ether discussed.
   (*b*) Chain, ring and rod experiment.
   (*c*) Rigidity; revolving chain.
   (*d*) Elasticity,
         Motion. of mechanical governor.
   (*e*) Polarisation and gyroscope:
         The top.
         The mono-rail train.
   (*f*) Vortex motion.

LECTURE V.

THE ELECTRON THEORY OF MATTER.

1. Electrification and electroscopes.
   (*a*) Gold and aluminium leaf electroscopes.
   (*b*) Paper hoops.
   (*c*) Water sprays.
   (*d*) Bar electroscopes.
2. Laws of electrical action.
3. Electrical machines, induction coils, and electric cells means for producing positive and negative electrification.
4. Conduction of electricity through gases.
   (*a*) Electrical discharge in gases at different pressures.
   (*b*) Cathode rays or electrons.
      (1) Fluorescent action.
      (2) Photographic action.
      (3) Magnetic deflection.
      (4) Velocities about 3×10^9 cm. per sec.
      (5) Mass of electrons about 1/1900 of mass of Hydrogen atom.
      (6) Electrons present in all matter.
5. Electrons emitted by metals at ordinary temperatures.
   Photoelectric effect.
6. Electrons emitted by substances at high temperatures.
   Vacuum tubes with Wehnelt cathodes of calcium oxide, etc.
7. Electrons emitted by uranium, thorium, actinium and radium.
   Beta rays.
   Illustrated by
      1. Discharging electroscopes.
      2. Production of electric sparks in air.
      3. Their photographic action.
8. Electrons and conduction of heat and electricity through matter.
9. Constitution of atoms.
   Cathode rays and anode or canal rays.
10. Models of atomic structure.
    Meyer's magnets.
11. Electrons and the ether.
    (*a*) Rontgen rays, light and heat waves.
    (*b*) Radioactivity of ordinary matter discussed.
12. Matter; energy; ether.

LECTURE VI.

WAVE MOTION.

1. Wave motion constitutes the most important agency in nature for the transmission of energy.
2. Examples of wave motion.
   (*a*) Water waves, gravitational and surface tension.
   (*b*) Wave motion in strings.
   (*c*) Wave motions in air; sound waves.
   (*d*) Wave motions in the ether, electromagnetic waves, including,
   Light waves from ultra violet to infra red.
   Heat waves.
   Electric waves (wireless telegraphy).
   Rontgen rays.
3. Characteristics of harmonic motion.
   (*a*) Vibrations double and single, amplitude, period, frequency.
4. Characteristics of wave motion.
   (*a*) Origin of waves.
   Water, light and electric waves.
   (*b*) Self-propagating motion.
   Illustrated with different kinds of waves.
   (*c*) Wave length, $\lambda = \frac{V}{n}$
   (*d*) Velocity of wave form.
   (1) Velocity and wave length.
   (2) Velocity and other factors, including depth of water; reflection; refraction; dispersion.
   (*e*) Motions of particles taking part in wave.
   Illustrated with water waves, sound waves, and light waves.
5. Combinations of wave motions.
   (*a*) Interference phenomena.
   (*b*) Beats.
   (*c*) Stationary waves.
6. Polarisation of waves.
   (*a*) Illustrated with strings.
   (*b*) Illustrated with light waves.
   (*c*) Illustrated with electromagnetic waves.
7. Diffraction phenomena.
   (*a*) Illustrated with sound and light waves.
8. Interference and polarisation as tests for wave motion.

LECTURE VII.

MECHANICS.

Use of graphs in illustrating results of experiments:

1. Representation of phenomena involving two variable quantities.
   Axes: x and y.
   Abscissae and ordinates.
   Collections of points make curves.
   From curves natural laws may be determined.
2. Direct proportion between the two variables gives a straight line.
   Ex.—Salary and time.

3. Other relations between the variables give other curves.

4. Applications to physics:

   (1) Straight line—(*a*) body moving uniformly; time—distance.
   (*b*) Current from lamps arranged in parallel order.
   Current—No. of lamps.

   (2) Case of current from lamps arranged in series.
   Current—No. of lamps
   Algebraic expression.

   (3) Falling body: distance—time.
   Algebraic expression.

   (4) Special case of motion of a pendulum.
   Distance of swing—time.
   Harmonic motion.

LECTURE VIII.

1. Velocity: uniform, non-uniform, average.

$$v = \frac{s}{t}.$$

2. Acceleration: a = rate of gain of velocity.
   Uniform, non-uniform.

$$a = \frac{v}{t}.$$

3. Momentum: proportional to mass in motion and velocity possessed by it. Momentum = mv.

4. Force: proportional to mass acted on and acceleration produced. $F = ma$.

5. Work (energy): proportional to force acting and distance through which it acts. $W = Fs$.

6. Power: rate at which work is done

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

   Power of man, horse-power, power of engine.

7. All these ideas are compounded of the three fundamental conceptions: space, time, mass.

LECTURE IX.

1. Relation between V, a, s, and t:

   (1) Body starting from rest. At time t velocity is V.

$$V = at.$$

$$\text{Average velocity} = \frac{V}{2}$$

$$\therefore \quad s = \frac{V}{2} \cdot t$$

$$= \frac{at}{2} \cdot t = \tfrac{1}{2} a t^2$$

$$V^2 = 2as.$$

(2) Body beginning with velocity u, and attaining velocity V at time t.

$$V = u + a\,t$$

Average velocity $= \frac{u+V}{2}$

$$s = \frac{u+V}{2} \cdot t$$

$$= \frac{u+u+a\,t}{2} \cdot t = (u + \tfrac{1}{2}\,a\,t)\,t$$

$$= u\,t + \tfrac{1}{2}\,a\,t^2$$

Also $V^2 - u^2 = 2\,a\,s$.

2. Acceleration due to earth:.
   Same for all bodies.
   Determination—(1) pendulum and falling weight.
   (2) tuning fork falling.

LECTURE X.

1. Review of relations between u, V, a, s, t, in case where a body starts with an initial velocity u and attains a velocity V in time t under a uniform acceleration a.
2. Review of determination of the acceleration given to a body by the earth.
   Value in English system: 32.2 feet per sec. per sec.
   Value in C.G.S. system: 980.5 cms. per sec. per sec.
3. Relation between mass and weight.
4. Outline of problems on falling bodies.
   A body is allowed to fall from rest a height of 1600 feet. Find
   (1) how long it will take to reach the ground,
   (2) its velocity at the end of the 6th second,
   (3) how far it falls in the 7th second,
   (4) the distance traversed in 4 seconds,
   (5) its velocity when passing a point 1000 feet from the ground.
5. Problems on bodies projected vertically upward from the earth.

LECTURE XI.

1. Work done by gravity on a body of weight w, falling from a height h.

   Work $= wh$.

2. $wh = \frac{wv^2}{2g}$

   where v = velocity attained when body reaches the earth.
   Kinetic and potential energy.
3. The sum of the kinetic and potential energies of a falling body is a constant.
4. Application of this principle to the pendulum

$$t = 2\,\pi\sqrt{\frac{l}{g}}$$

Another method of determining "g".

5. Practical units of work in engineering.
   English—foot-pound
   C. G. S.—gram-centimetre
   kilogram-metre.

6. Measurement of power—units.
   English—Horse-power = 550 foot-pounds per sec.
   C.G.S.—1 erg per sec.
   1 watt = 10^7 ergs per sec.
   1 horse-power = 746×10^7 ergs per sec.
   = 746 watts.

LECTURE XII.

1. Graphical representation by vectors.
   Displacements, velocities and accelerations.
2. Graphical representation of a force.
   Resolution of a force along different directions.
3. Special case of a right angle. Falling bodies.
4. Addition of forces
   (1) Along same line.
   (2) Along different lines.
5. Parallelogram of forces and triangle of forces.
6. Resultant of a number of forces acting at a point.

LECTURE XIII.

1. Forces can also cause rotation.
   (1) Drive wheel of engine; (2) the teeter.
2. The moment of a force about a point is the product of the force into the perpendicular distance from the point on the direction of the force.
3. Conditions of equilibrium.
   (1) Algebraic sum of the forces resolved along any direction equals zero.
   (2) Algebraic sum of the moments of the forces about any point equals zero.
4. When a body is rotating about a centre forces are called into play.
   Centrifugal and centripetal

$$F = \frac{M v^2}{r}$$

   F = centrifugal force v = speed about the circle
   M = mass of body r = radius of circle.

5. Examples of these forces:
   Flying of mud from a wheel.
   Bursting of emery wheel.
   Centrifugal machines about 4000 rev. per min.
   Banking on race courses and curves on railways.
   Motor and ring, etc., etc. Rotating chain wheel.

LECTURE XIV.

1. Composition of parallel forces acting on a body.
2. Centre of gravity defined.
3. Experimental determination of the centre of gravity of a slab of any shape, *e.g.*, triangular.
4. Machines in general.

   A contrivance by means of which a force applied at one point gives rise to a force at some other point is called a machine.
5. Application of principle of the conservation of energy.

LECTURE XV.

1. The *lever*.
   Fulcrum, Effort arm, Resistance arm.
2. Three Classes.
   Class 1: Fulcrum between E and R.
   Crowbar, pump handle, scissors, beam of balance.
   Class 2: R between E and Fulcrum.
   Nutcrackers, oar.
   Class 3: E between Fulcrum and R.
   Tongs, the forearm.
3. Wheel and axle.
   Windlass, capstan, bicycle crank.
4. Pulleys.
   Stationary, movable, compound.
5. Friction.
   Friction[illegible]amometer.
   Friction[illegible]ple $(R-E)r$
   Work $= (R-E)r \cdot 2\pi n$
   $= 2\pi rn\,(R-E)$.

LECTURE XVI.

ACOUSTICS.

1. Review waves and wave motion.
2. Sound waves propagated in solids, liquids and gases:—self-propagating disturbances.
3. Sound as a sensation and as a mode of motion.
4. Harmonic motion; vibrations double and single; amplitude, period, frequency.
5. Different modes of producing sound vibrations:
   (1) Plucking; (2) bowing; (3) striking; (4) rubbing; (5) tapping; (6) miscellaneous methods, including the musical sling, siren, singing flames, Rijke's tubes, magnetisation.

LECTURE XVII.

1. Characteristics of motion in propagation of sound disturbances.
   (*a*) Wheatstone's model.
   (*b*) Crova's discs.

2. Methods of detecting and recording sound vibrations.
   (*a*) The barometer.
   (*b*) The graphical method.
   (*c*) The Marey drum.
   (*d*) The manometric capsule and flame.
   (*e*) Sand figures.
   (*f*) The ear.
3. Audition.
   (*a*) Reflection of sound waves; echoes.
   (*b*) Absorption of sound waves.
   (*c*) Absorbing powers of different media.

LECTURE XVIII.

1. Velocity of sound in air.
   (*a*) Koenig's conduit experiment.
2. Velocity and wave length, etc., etc.

$$\lambda = \frac{V}{n}$$

3. Loudness, pitch, and quality corresponding respectively to intensity, frequency and wave-form.
   (*a*) Sound and music.
4. Resonance phenomena.
   (*a*) Forks; strings; air columns; plates.
   (*b*) Resonators.
   (*c*) $\lambda = V\,t, \frac{\lambda}{4} = \frac{V\,t}{4} \therefore l$, the length for first resonance,
   $= \frac{V\,t}{4} = \frac{V}{4\,n}$
   (*d*) Problems.
5. Velocity of sound in liquids and gases.
   Kundt's method.
6. Velocities of sound waves in various substances.

Hydrogen	1290	metres per sec.		Glass	5000	metres per sec.	
Oxygen	317	,,	,,	Steel	5200	,,	,,
Air	332	,,	,,	Copper	3950	,,	,,
Water	1435	,,	,,	Lead	1200	,,	,,

7. Interference phenomena.
   (*a*) Forks.
   (*b*) Lissajous' sectors.
   (*c*) Divided circuit.
   (*d*) Koenig's conduit.
   (*e*) Stationary waves.
   (*f*) Beats.

LECTURE XIX.

1. Harmonic scale 32, 64, 128, 256, 320, 384, 512, 1024
   C_1 C c c' e' g' c'' c'''
2. Quality of note and complex vibrations.
   (1) Forks; (2) strings; (3) pipes.
3. Flame analyser.
4. Organ mouthpieces and reeds (free and striking).
5. Larynx and function of vocal cords.
6. Vowel sounds *ou*, *o*, *a*, *e*, *i*.
7. Voice production.

LECTURE XX.

ELASTICITY.

1. Elasticity.
2. Experiment on metal wire, illustrating:
   (*a*) Region of perfect elasticity.
   (*b*) The elastic limit.
   (*c*) Yield point.
   (*d*) Permanent set.
   (*e*) Plasticity.
   (*f*) Breaking point.
3. Definition of *stress* and *strain*.
4. Stress causing
   (*a*) Change in volume
   (*b*) Change in shape (shear). Examples.
5. *Hooke's Law.*
   Stress = $c \times$ strain, where c is a constant = the modulus of elasticity.
6. Special cases of modulus.
   (*a*) Bulk modulus.
   (*b*) Modulus of rigidity.
   (*c*) Young's modulus.
7. Tables of values of the above for various materials.
8. Physiological applications.
9. Explanation of these various phenomena by the kinetic theory of matter.
   (*a*) Structure of metals.
   (*b*) Changes brought about by forces.

LECTURE XXI.

HYDROSTATICS.

Pressure in Liquids:

1. Definition of *pressure*. Uniform and variable.
2. Prop. I. Pressure at a point in a liquid is the same in all directions. Experimental proof.
3. Prop. II. Pressure is the same at all points in the same horizontal plane. Theoretical proof.
4. Prop. III. Pressure at a depth in a uniform liquid = weight of a column of liquid of same depth and of unit cross section.
5. Prop. IV. Difference of pressure at two points at different depths = weight of a column of liquid of unit cross section and of length equal to the difference between the two depths.
6. Prop. V. Extension of Prop. II. to case of two or more linked vessels. Experiments. Theory.
7. (1) Prop. VI. Free surface of liquid at rest is always horizontal. For same liquid in linked vessels, al free surfaces are at the same horizontal level.
   (2) Surface of separation of two liquids one resting on the other is horizontal.

LECTURE XXII.

Pressure in Liquids (continued):

1. Illustrations and applications.
2. Metal gauge. Different forms. Method of calibration.
3. *Hydrostatic paradox.* The pressure at a point depends only on the depth—not on size or shape of vessel.
4. Resultant vertical force.
   Archimedes' principle:—The resultant vertical force or "loss of weight" equals the weight of liquid displaced.

LECTURE XXIII.

1. *Pascal's principle.* Pressure is transmitted equally in all directions through a fluid.
2. Bramah's press, Hydraulic elevator, High pressure water system, City water-works, Niagara Power-Schemes.
3. *Specific gravities.* Methods of measuring:—
   (1) Direct measurement of weight and volume.
   (2) U-tube methods.
   (3) By Archimedes' principle—Hydrostatic balance, Mohr's balance, hydrometers.

LECTURE XXIV.

Gases:

1. Air a fluid.
2. Air has weight. Air denser near the surface of the earth than at great heights.
3. Air is expansible or compressible.
4. Air exerts pressure.
5. Archimedes' principle in air.
6. Measurement of air pressure.
7. Barometers. Various forms, *i.e.*, mercury and aneroid.

LECTURE XXV.

1. Barometer. Height independent of form.
2. Gauges and manometers:
   (1) Gauges for high pressure.
   (2) U-tube manometers for pressures (*a*) nearly atmospheric, (*b*) very small, (*c*) very great.
   (3) Maximum and minimum manometers.
3. *Illustrations of application of pressure laws for gases:* pipette, siphon, intermittent spring, soda water siphon.

LECTURE XXVI.

1. *Pumps for liquids:* common pump, force pump, heart.
2. *Pumps for gases:* mechanical (bicycle, Fleuss), liquid air plant, filter pumps (water and Sprengel), bellows, lungs, Toepler-Hagan mercury pump, Gaede rotary pump.
3. *Boyle's Law is* $p \times v =$ a constant.
   Application to gauges.
4. The barometer and weather forecasting.
5. Flow of liquids:
   Flow (1) in uniform tubes with rigid walls, (2) in tubes of variable section, (3) in tubes with elastic walls. Distribution of pressure along the line of flow.
   Ball nozzles, atomisers, filter pumps, aspirators, forced draughts.

LECTURE XXVII.

1. *Capillarity:*
   Experiments to shew skin at liquid surface; camel's hair brush, water drop, Kelvin's model drop.
2. Strength of water skin; floating needle, sieves.
3. Strength of skin varies with liquid.
   Oil on water, camphor on water, tears of wine.
4. Strength of skin varies with temperature.
5. Liquid skin a store-room of energy.
   Energy = Surface Tension × area.
6. Criterion for spreading of one liquid on another. Rise in capillary tubes, spherical drops.
7. Application to solution in organic cells.
8. Filtration, dyeing, soil physics, etc.

LECTURE XXVIII.

HEAT.

1. The caloric theory. Its failures.
2. Review of the evidence of molecular forces and motions in matter.
3. Sensation of heat:
   Meaning of temperature. Hydrostatic analogy. Electrical analogy. Necessity for an accurate indicator of temperature. Sensation depends on the condition of the body.
4. Measurement of temperature.
   Variations in properties of matter with the application of heat:
   (*a*) Expansion of gases, expansion of liquids, expansion of solids.
   (*b*) Resistance to an electric current. Metal resistance thermometers.
   (*c*) Production of an electric current. Thermocouples.
5. Necessity for fixed points. Common fixed points.
6. Thermometer scales in use:
   Centigrade, Fahrenheit.
7. Transformation from one scale to another.
   Centigrade to Fahrenheit $F = \frac{9}{5}(C+32)$.
   Fahrenheit to Centigrade $C = \frac{5}{9}(F-32)$.

LECTURE XXIX.

1. Thermometers based on variation in properties:
   (*a*) Mercury thermometer. Construction and calibration. Range -39^0 C. to 360^0 C.
   (*b*) Other liquid thermometers. Alcohol -130^0 C. to 60^0 C. Pentane -200^0 C. to 36^0 C.
2. Special liquid thermometers:
   (*a*) high temperature mercury thermometers.
   (*b*) maximum and minimum thermometers.
   (*c*) clinical thermometer.
   (*d*) Beckmann thermometer.
3. Gas thermometer.
4. Solid thermometers.
5. Electrical thermometers.

LECTURE XXX.

1. Definition of linear coefficient of expansion.
   Method of determining linear coefficient of expansion.
2. Method of determining volume coefficient of expansion: (*a*) of a solid, (*b*) of a liquid.
3. Illustrations of the application of expansion and contraction of matter: metals and alloys for teeth, tire setting, Brooklyn bridge, manufacture of coins, track laying, type casting, air and water currents, steamfitting, iron casting, gridiron pendulum.
4. Meaning of volume coefficient of a gas.
   Meaning of pressure coefficient of a gas.
5. Method of determining the volume coefficient of a gas.
   Method of determining the pressure coefficient of a gas.
6. Meaning of absolute zero and absolute temperature.

LECTURE XXXI.

1. Meaning of quantity of heat.
2. Method of determining specific heat: (1) of a liquid, (2) of a solid.
3. Table of specific heats.
4. Applications of the property of high and low heat capacities of different substances.
5. Prevention of destructive frosts. Use of water bottles.
6. Meaning of latent heat of fusion and latent heat of vaporisation.
7. Method of determining the latent heat of fusion of ice.
8. Method of determining the latent heat of vaporisation of water.

LECTURE XXXII.

1. Explanation of boiling and freezing by the kinetic theory.
2. (*a*) Change in the boiling and freezing points of a liquid by the addition of a substance which dissolves in the liquid.
   (*b*) Change in boiling point and freezing point by change in pressure.
3. Cooling by solution. Freezing mixtures.
4. Distinction between evaporation and boiling.
5. Cooling by evaporation. Alcohol bath.
6. Meaning of saturated vapour.
7. Hygrometry: (*a*) method of obtaining the density of saturated water vapour at a particular temperature; (*b*) method of obtaining the pressure of saturated water vapour at a particular temperature.
8. Meaning of relative humidity.
9. Effects of high and low humidity on animal and vegetable life.
10. Relative humidity for normal healthful conditions.

LECTURE XXXIII.

1. The Conservation of Energy, Determination of the Mechanic Equivalent of Heat.
2. Heat is produced by the compression of a gas and absorbed when a gas expands.
   Illustrations: manufacture of liquid air, heating of barrel bicycle pump, formation of clouds.
3. The transference of heat:
   (*a*) By conduction. Definition of conductors and non-co ductors. Illustrations—Davy safety lamp, water pi and steam pipe coverings, nature of clothing.
   (*b*) By convection. Illustrations—air currents, ocean a lake currents, effects on climate.
   (*c*) By radiation. Illustrations—heat from sun, fires,
4. Heating and ventilation of buildings.
   (*a*) Hot air system, (*b*) hot water system, (*c*) steam syst

LECTURE XXXIV.

ELECTRICITY AND MAGNETISM.

1. Early experiments with amber, Thales, 640 B.C.
2. *Attractions*, fundamental phenomena: (1) pith balls, (2) water spray, (3) bar electroscope, (4) paper hoop.
3. *Repulsions:* (1) pith ball charged by ebonite; (2) two pith balls similarly charged; (3) gold leaf electroscope.
4. Pith ball and gold leaf electroscope. Depend on attractions or repulsions.
5. Two kinds of electrification illustrated by rod electroscope. ebonite and fur, glass and silk, brass and rubber.
6. Laws of electrification: all charged bodies attract neutral bodies. Similarly charged bodies repel one another. Dissimilarly charged bodies attract one another.
7. Character of electrification produced by friction depends on nature of articles in contact.

(1)

+fur	with	−ebonite	−brass	with	+fur
+ebonite	,,	−leather (amalgam)	−brass	,,	+silk
+fur	,,	−glass (rough)	+brass	,,	−rubber
−fur	,,	+glass (smooth)	+sealing-wax	,,	−rubber
+glass (smooth)	,,	−silk	+fur	,,	−sealing-wax
−glass (rough)	,,	+silk			

(2) If any two substances in this list are rubbed together the one higher in the list becomes electrified positively and the one lower negatively.

Positive:

glass (smooth)
fur
flannel
cotton
paper
silk
glass (rough)
wood
ebonite
sealing-wax
resin
amber
sulphur
leather (amalgam: tin 1, zinc 1, mercury 5)
brass
rubber

Negative

LECTURE XXXV.

1. Flow of electrification.
2. Charging an electroscope or other body by conduction.
3. Conductors: metals, solutions, etc.
   Non-conductors; glass, ebonite, sulphur, amber, paraffin, quartz.
4. Lines of force and electrons.
5. Charging by induction.
6. Testing charges.
7. Lantern electroscope

LECTURE XXXVI.

1. Conductors and non-conductors.
2. Laws of electrical action.
3. All bodies may be electrified and the character of the electrification depends on the substances in contact and on their condition.
4. Electrifying by contact and by induction.
5. Electricity resides on the outside of a conductor.
6. No action inside a hollow conductor.
7. Measurement of quantity of electricity.
8. Equal and opposite quantities of electrification produced simultaneously.

LECTURE XXXVII.

1. Coulomb's Law $F = \frac{e_1 e_2}{r^2}$
2. Development of idea of *potential difference*.
3. Potential and flow of electricity.
4. Conductors in equilibrium at one potential.
5. Analogies.
6. Definition of potential difference.
7. Measurement of potential difference.
8. Capacity of conductors.
9. Lowering potential by approach of an oppositely charged plate, Condensing electroscope.

LECTURE XXXVIII.

1. Capacity of a conductor affected by
   (1) Distance from it of the oppositely charged conductor.
   (2) Dielectric substance.
2. Potential, capacity and quantity. Capacity of the earth.
3. Construction of condensers: Leyden jar, sets of plates.
4. The dielectric of a condenser. Dielectric constants:—Air 1, paraffin wax 2, shellac 3, sulphur 4, paraffin oil 5, glass 6, mica 7.
5. The electrophorus. The electric machine.

LECTURE XXXIX.

1. Volta effect. The simple cell.
2. Kinds of cells: Daniell, gravity battery, Leclanché cell, commercial dry cell, storage cell.
3. Fall of potential down a wire carrying a current.
4. Difference of potential meters and current meters.
5. Ohm's law:—When a current flows through a given wire kept at constant temperature, the ratio between the fall of potential down the wire to the current through the wire is constant. The constant is the *resistance* of the wire.

LECTURE XL.

1. (*a*) Resistances R_1, R_2, R_3, arranged in series, give altogether a resistance R_s

$$R_s = R_1 + R_2 + \text{etc.}$$

(*b*) Resistances R_1, R_2, R_3, ... arranged in parallel, give altogether a resistance

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc.}$$

2. Applications to the lighting of buildings.
3. Methods of measuring electrical resistance.
4. Electrical action in liquids; electrolytes, laws of electrolysis.

LECTURE XLI.

1. Lodestone: (*a*) action on iron filings, (*b*) direction when suspended.
2. Magnetic needles. North and south poles.
   Unlike poles attract one another. Like poles repel one another.
3. Iron filings about a bar magnet.
   Magnetic lines of force. The field of a magnet.
4. The dip of a magnetic needle. Experiment.
5. The earth a magnet.
   (*a*) Position of the magnetic poles of the earth.
   (*b*) Dip (or inclination).
   (*c*) Declination.
6. Molecular magnetism: (*a*) broken magnet, (*b*) Ewing's model, (*c*) recalescence, (*d*) pounding soft iron, (*e*) magnetostriction.

LECTURE XLII.

1. Magnetic effects of an electric current in a wire:
   (*a*) Deflection by magnetic needle, (*b*) influence on iron filings.
2. Magnetic lines of force about a wire bearing a current.
3. The construction of an electromagnet:
   (*a*) Single coil bearing a current, (*b*) a solenoid bearing a current, (*c*) influence of a soft iron core.
4. Applications of electromagnetism:
   (*a*) Electric bell, (*b*) relays, (*c*) telegraph, (*d*) telephone.
5. Galvanometers, ammeters, and voltmeters.

LECTURE XLIII.

1. Induced currents:
   (*a*) Produced by the motion of a magnet in a coil of wire.
   (*b*) Produced by the use of an electromagnet.
2. Properties of induced currents:
   (*a*) Of short duration.
   (*b*) Depend on the rate of change of magnetic field.
   (*c*) Depend on the nature of the change—an increase or decrease.
3. Experiments on self-induction.

LECTURE XLIV.

1. The induction coil:
   (*a*) Primary coil, (*b*) secondary coil, (*c*) automatic break, (*d*) condenser.
2. Transformer.
3. Induced currents of high frequency; Tesla arrangement.
4. Thomson's electrodeless bulbs.
5. Electrical resonance.
6. Electromagnetic waves in air and in wires.

LECTURE XLV.

1. Discharge of electricity through gases:
   (*a*) Pumping out a vacuum discharge tube.
   (*b*) Various stages of discharge.
   (*c*) Cathode dark space, positive column and Crookes' dark space.
   (*d*) Cathode rays; anode or canal rays.
   (*e*) Röntgen rays.
2. Ray phenomena of radioactivity.

LECTURE XLVI.

LIGHT.

1. *Light:* the agency by which objects are revealed to the sense of sight.
2. *Luminous and illuminated bodies.*
   Distribution of light around a source. Rays, pencils, beams. Eye sees source by means of a pencil coming from each point on it to pupil of eye. Optical diagrams.
3. *Laws of the propagation of Light.*
   (*a*) Rectilinear Propagation in homogeneous media. Illustrations: sighting, principle of parallax.
   (*b*) Reflection and Refraction at surface of separation of different media. Angle of Incidence, Reflection, Refraction. Index of Refraction and occurrence of total reflection. Illustrations.

LECTURE XLVII.

Images. Formed when the light from a source is reflected or refracted by the parts of any optical instrument such as a plane or curved mirror, a plane refracting surface, a lens or a lens system.

1. *Properties of Images* correspond point for point with source: have definite size and position in space.
2. *Real and virtual images.* Class depends on position in space relative to the optical instrument. Parallax test. Real images may form picture of source on a screen.
3. *Optical diagrams* shewing paths of typical rays through optical instrument and also pencil of rays from point on object to an eye placed in a suitable position to view the image.
4. Illustrations of properties of images as exhibited by a *convex* or *converging lens.*

LECTURE XLVIII.

(*a*) Construction of convex lens.
(*b*) Cardinal Points and Cardinal Rays. Rays parallel to axis are converged to pass through *Principal Focus*. Rays directed towards *Optical Centre* are not deviated.
Optical diagrams for typical cases and paths of rays to eye placed to view the images.
(*c*) Focal length. Power; the dioptre.
(*d*) Numerical relations between object and image distances and dimensions.
Let u = object distance, v = image distance, m = magnification, f = focal length. Sign convention.
Case (1) object moving from $u = 0$ to $u = f$
Case (2) object moving (*a*) from $u = f$ to $u = 2f$
and (*b*) from $u = 2f$ to $u =$ infinity.

	Case 1.	Case 2.
Class	Virtual	Real
Attitude	Erect	Inverted
Magnification (m)	increases 1 to infinity	(*a*) decreases infinity to 1 (*b*) decreases 1 to 0
Image distance (v)	increases 0 to infinity	(*a*) decreases infinity to $2f$ (*b*) decreases $2f$ to f
Formula	$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$	$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

(*e*) *Other image-forming optical systems.* Optical diagrams should be worked out for each of these.
(1) *Plane mirror.*
(2) *Plane refracting surface.* Image distance from surface divided by object distance equals index of refraction from first medium to second medium.
(3) Converging lens system.
(4) Diverging lens.
(5) *Concave and convex mirrors.*

LECTURE XLIX.

OPTICAL INSTRUMENTS.

1. *The Artificial Horizon*, the Sextant, the Total Reflection Prism.

2. *The Eye.* The optical system consists of (*a*) the cornea, (*b*) aqueous humour, (*c*) crystalline lens, (*d*) vitreous humour, (*e*) retina. Whole system constitutes a converging lens system, which forms real image on retina.
Accommodation for different object distances accomplished by altering power of system. Illustrate.
Nearest normal distance of distinct vision is 25 cm. or 10 ins.
Long and short sighted eyes. Remedy.
Cardinal points of eye; focus, nodal point.

3. *The Magnifying Glass.*

4. *The Photographic Camera*, the Optical Lantern, the Refracting Telescope, the Opera Glass, the Prismatic Binoculars, the Reflecting Telescope.

5. *The Compound Microscope.* Consists of two specially designed converging lens systems, the objective and the eyepiece. Functions: objective produces real enlarged image at distance 16 cm. (optical tube length) from focus; eyepiece produces virtual enlarged image of first image at 25 cm. from its eye end. Resolving power limited by nature of light.

6. *The Ultra Microscope.*

LECTURE L.

Spectroscopy: the analysis of light.

1. Light composite, consisting of different wave lengths. Components separated by refraction.

2. *Spectroscopes.* Consist of (*a*) a dispersing system (one or more prisms of glass), (*b*) a focussing system (slit and collimator placed before (*a*) and a telescope placed after it), (*c*) a subsidiary scale for making records. Optical diagram of typical system.

3. *Spectrum* of light entering slit consists of row of virtual images of slit, one image corresponding to each constituent.
Classes: (*a*) emission, line, fluted, continuous; (*b*) absorption. Typical examples.

4. *Solar spectrum.* Fraunhofer lines; situation of principal lines. Reversal experiment.

5. Illustrations and applications.

LECTURE LI.

Polarisation of Light.

1. Vibration form of particles propagating waves.
In plane polarised light all vibrations take place in parallel straight lines which are at right angles to the rays.
Mechanical wave model, waves on strings.

2. *The Nicol prism:* transmits only vibrations parallel to one plane, *i.e.*, polarised light; can be used to test light for polarisation.

3. Other polarisers: natural crystals, reflection, small particles (sky light, the Tyndall experiment).

4. *Rotation of the plane of polarisation*, by quartz, sugar solutions, organic liquids.
Saccharimeter consists essentially of two Nicol prisms (a polariser and an analyser). To measure rotation determine vibration direction of analysed light before and after inserting substance between analyser and polariser; the analyser is rotated through the required angle.

LECTURE LII.

Interference and Diffraction of Light.

1. Resultant of two superposed wave motions. Interference and Reinforcement.
2. Interference phenomena in thin films; two sets of waves coming respectively from front and back surface of film.
   Experiments: bright and dark fringes in sodium light; colours of soap films in white light.
3. *Diffraction phenomena.* Light bending into shadow; interference in free space.
   Illustrations:—
   (*a*) Shadows of small openings and small obstacles in light from point source.
   (*b*) Character of image of point source formed by lenses of small or peculiar aperture. Resolving power of lenses: the diffraction grating.
4. Wave length of light measured by a study of interference and diffraction phenomena.

LECTURE LIII.

Electromagnetic waves:

1. Electric waves—wireless telegraphy and telephony.
2. Electric waves may be screened, reflected, refracted and polarised.
3. Light waves may be affected by electric and magnetic forces. Zeeman effect.
4. Electromagnetic theory of light.