# SSC-II Physics: Chapter Notes (FBISE, NBF 2025 book)

Built from the 12 book chapters (Units 10 to 21) and the 2025 and 2026 FBISE papers (all sets). Each chapter has: key definitions, formulas, must-know points, and the past-paper questions with short model answers.

## Paper pattern

- Section A: 12 MCQs. Section B: 11 short parts of 3 marks each (every part has an OR choice, marks split like 2+1, 1+2, 1.5+1.5). Section C: 4 long questions of 5 marks each (each has an OR).
- The paper gives a formula sheet: $V=IR$, $Q=mc\Delta T$, $P=VI$, $W=I^2Rt$, $R=\rho L/A$, $v=f\lambda$, $f=1/T$, $1/f=1/p+1/q$, $m=q/p$, $M=hi/ho$, $n=\sin i/\sin r$, $1/Ceq=1/C1+1/C2$, $Ceq=C1+C2$, $Req=R1+R2$, $Veq=V1+V2$, $V=W/q$, $A=\pi d^2/4$, $A=\pi r^2$, $E=mc^2$.

## Most repeated questions (appear in nearly every set)

- Electric field: meaning, effect on a test charge, two characteristics.
- Order of electromagnetic spectrum by wavelength (six regions).
- Echo: meaning, production, minimum time (0.1 s), why not heard in a small room.
- Lenz's law and how it obeys conservation of energy.
- d.c. vs a.c. (two differences or one advantage each); why a.c. is preferred for homes.
- Ohm's law with a numerical; electricity bill and power numericals.
- Half-life and a half-life numerical.
- Three differences: boiling vs evaporation; real vs virtual image.
- Lens image, magnification and focal length numerical.
- Diffraction: effect of gap size or wavelength.
- Transformer (step-up, step-down, turns numerical); cells in series and parallel.
- Specific heat capacity and $Q=mc\Delta T$ numerical; sea breeze and land breeze; greenhouse effect.

# Unit 10: Heat Capacity and Modes of Heat Transfer

### Definitions

- Specific heat capacity (c): heat needed to change the temperature of 1 kg of a substance by 1 K (or 1 °C). SI unit: J $kg^{-1}$ $K^{-1}$. Water 4200, dry soil 800, aluminium 900.
- Heat capacity: heat needed to raise the temperature of a whole object by 1 K. Unit J $K^{-1}$ (= mc).
- Conduction: transfer of heat in solids by collisions of atoms/molecules and by motion of free electrons, from the hot part to the cold part.
- Convection: transfer of heat by bulk movement of molecules in fluids (liquids and gases) because of density differences. It cannot occur in solids.
- Radiation: transfer of heat as electromagnetic (infrared) waves. No medium needed. It is the fastest method (speed of light).
- Thermal equilibrium: object absorbs and radiates heat at the same rate, so its temperature stays constant.
- Greenhouse effect: greenhouse gases ($CO_2$, methane, water vapour) absorb heat radiated by Earth and send part of it back, keeping Earth warm. Global warming: gradual rise in Earth's average temperature due to extra greenhouse gases from human activity.

### Formulas

- $Q = m\,c\,\Delta T$ ($\Delta T$ in °C equals $\Delta T$ in K).
- Method of mixtures: heat lost by hot solid = heat gained by water + calorimeter, so $m_s c_s (T2 - T3) = m_w c_w (T3 - T1) + m_c c_c (T3 - T1)$.
- Electrical method: $V I t = m c \Delta T$.

## Must-know points

- Uses of the large specific heat of water: moderate climate near the sea; lakes and oceans change temperature slowly so aquatic life survives; helps the body (about 60 % water) keep 37 °C; coolant in car radiators and power plants; good for cooking and keeps tea hot.
- Why coastal areas are moderate: land has small c (about 5 times smaller than water), so it heats and cools fast. Sea heats and cools slowly, so coast temperature range is small (Karachi 19 to 32 °C).
- Metals conduct well because of many free electrons, which carry energy quickly in addition to vibrating atoms. Non-metals only pass energy by vibrating atoms, so they conduct slowly. Experiment: wax and drawing pins on rods of copper, aluminium and iron; the pin on the best conductor drops first.
- Convection experiment: potassium permanganate crystals at the bottom of a beaker; the coloured stream rises when heated.
- Convection and marine life: warm water rises, cold dense water sinks. Upwelling brings cold, nutrient-rich water up (food for phytoplankton and fish); downwelling carries oxygen down; currents spread heat and stabilise temperature.
- Sea breeze (day): land heats faster, hot air above land rises, cool air from sea moves in. Land breeze (night): land cools faster, so air above the warmer sea rises and cool air from land moves out to sea. Together they keep coastal weather moderate.
- Birds (eagles, hawks) ride thermals (columns of rising warm air) with wide wings, circling inside them, so they rise and glide without flapping. Cyclones: warm ocean water evaporates, moist air rises, cools, condenses and releases latent heat, pressure falls and Earth's rotation makes it spin.
- Radiation and surfaces: black/dull/rough = best absorber and best emitter, worst reflector. Shiny silver/white/smooth = best reflector, worst absorber and emitter. Larger surface area and higher temperature mean more radiation. Leslie cube compares emission from four faces using an infrared thermometer.
- Applications: thermos flask (vacuum stops conduction and convection, silvering reflects radiation, plastic lid and steel inside reduce conduction); insulation of buildings (double glazing, false ceilings); gas heater warms a room by convection; household geyser (hot water rises to the top); IR thermometer (distance to spot ratio).
- Global warming effects: glacier melt, sea level rise, flooding; stronger hurricanes; heavier rain; droughts; wildfires; winter storms. Pakistan: 2022 floods and heatwave above 51 °C. Remedies: stop deforestation, plant trees, use clean energy.
- Geothermal activity: Earth has core (about 6000 °C, iron and nickel), mantle (thickest, plastic), crust. Magma moves by convection, makes volcanoes, and drags tectonic plates (7 major plates), causing earthquakes. Core stays hot because of residual heat from formation, radioactive decay (U-238, Th-232, K-40), gravitational compression, and the crust acting as insulator.

## Past-paper questions with model answers

- Heat to raise 2 kg from 40 to 45 °C, c = 420: $Q = 2 \times 420 \times 5 = 4200$ J.
- Heat to warm 25 kg of water by 50 °C: $Q = 25 \times 4200 \times 50 = 5.25 \times 10^6$ J (5.25 MJ).
- Why coastal areas have moderate temperatures: high specific heat of water plus sea and land breezes (explain both as above).
- How convection in seawater supports marine life: upwelling brings nutrients, convection carries oxygen to deeper water, spreads heat.
- Sea and land breezes help moderate coastal climate (3 marks): explain day and night cases with direction of air.

- Explain greenhouse effect, is it good or bad, consequences (Section C, 2+1+2): effect needed for life (without it Earth would be extremely cold at night); becomes harmful when extra gases from fossil fuels and deforestation trap more heat (global warming); consequences: floods, droughts, hurricanes, heatwaves, melting glaciers.
- Heat conduction in solids through lattice vibrations and in metals through free electrons; compare metals and non-metals (Section C).

# Unit 11: Thermal Transformations

## Definitions

- Melting: solid to liquid. Freezing: liquid to solid. Vaporization: liquid to gas on boiling. Evaporation: liquid to vapour at any temperature, from the surface. Condensation: gas to liquid. Sublimation: solid directly to gas. Deposition: gas directly to solid.
- Thermal expansion: increase in size of matter on heating. Linear expansion: increase in length. Volume expansion: increase in volume.
- Coefficient of linear expansion ($\alpha$): fractional change in length per kelvin. Coefficient of volume expansion ($\beta$): fractional change in volume per kelvin. For solids $\beta = 3\alpha$.
- Real expansion of a liquid: expansion of the liquid itself. Apparent expansion: expansion seen when the container's expansion is ignored. Real = apparent + expansion of container.
- Latent heat: heat absorbed or released during a change of state without any change in temperature. Latent heat of fusion: heat to change unit mass solid to liquid at melting point (water: $3.3 \times 10^5$ J kg$^{-1}$, 336 J g$^{-1}$). Latent heat of vaporization: heat to change unit mass liquid to gas at boiling point (water: $2.26 \times 10^6$ J kg$^{-1}$).
- Superconductor: material with zero resistance below its critical temperature (near absolute zero).
- Bimetallic strip: two different metals joined; bends on heating because one expands more.

## Formulas

- $\Delta L = \alpha L_o \Delta T$. $\Delta V = \beta V_o \Delta T$. $\beta = 3\alpha$.
- $Q = m L_f$ (melting), $Q = m L_v$ (boiling). Boiling point of water 100 °C (212 °F, 373 K), melting point 0 °C.

## Must-know points

- Kinetic theory of expansion: on heating, particles vibrate with bigger amplitude and push each other apart, so the solid expands.
- Why temperature stays constant during change of state: the supplied energy is used to break or weaken bonds between particles (potential energy), not to increase kinetic energy.
- Three differences between boiling and evaporation: (1) boiling occurs at one fixed temperature, evaporation at any temperature; (2) boiling occurs throughout the liquid with bubbles, evaporation only at the surface; (3) boiling is fast and needs a heat source, evaporation is slow and cools the liquid.
- Factors increasing evaporation: higher temperature, larger surface area, lower humidity, air movement over the surface.
- Evaporation causes cooling: the fastest molecules escape, so the average kinetic energy (temperature) of the rest falls. Used in refrigerators (refrigerant cycling between liquid and gas, non-CFC).
- Uses and effects of expansion: gaps in railway tracks and expansion joints in bridges and pavements (avoid bending and cracks); sagging cables; bimetallic strips in thermostats, fire alarms; fitting metal tyres on wheels.
- Gas pressure: particles hit the container walls, force per unit area. In a tyre on a hot drive, particles move faster so pressure rises.

- Superconductivity: no energy loss; limits: needs extremely low temperatures; uses: powerful magnets, MRI, maglev trains, lossless cables.

### Past-paper questions with model answers

- State three differences between boiling and evaporation (asked in every set): use the three above.
- State three factors that affect the rate of evaporation: temperature, surface area, humidity, wind speed (any three).
- What is linear expansion of solids? Why are gaps left between railway tracks (5 marks): define, give $\Delta L = \alpha L_0 \Delta T$, explain that tracks expand in summer and would bend without gaps.
- Thermal expansion of liquids, real and apparent (5 marks): define both, explain with a flask filled with liquid (level first drops as flask expands, then rises), real = apparent + container.
- Steel track 10 m, 15 °C to 30 °C, $\alpha = 1.2 \times 10^{-5}$: $\Delta L = 1.2 \times 10^{-5} \times 10 \times 15 = 1.8 \times 10^{-3}$ m = 1.8 mm.
- Heat to melt 15 kg ice: $Q = 15 \times 3.3 \times 10^5 = 4.95 \times 10^6$ J.

# Unit 12: Waves

## Definitions

- Wave: a mechanism that transfers energy without transferring the medium.
- Mechanical waves need a medium (sound, water, string). Electromagnetic waves need no medium (light, radio).
- Transverse wave: particles vibrate perpendicular to the direction of the wave (light, water, string). Longitudinal wave: particles vibrate parallel to the direction (sound, spring).
- Amplitude: maximum displacement from the mean position. Wavelength ($\lambda$): distance between two successive crests (or troughs). Frequency (f): vibrations per second, Hz. Time period (T): time for one vibration, seconds.
- Reflection: wave bounces back from a surface. Refraction: change of direction when speed changes on entering another medium. Diffraction: bending of waves around the edges of an obstacle or through a gap.
- Simple harmonic motion: vibratory motion in which acceleration is proportional to displacement and directed to the mean position. Damped oscillation: amplitude decreases with time because energy is lost to friction.

## Formulas

- $v = f\lambda$, $T = 1/f$, f = number of waves / time. For EM waves in vacuum $c = 3 \times 10^8$ m/s. Wave energy is proportional to $(\text{amplitude})^2$.

## Must-know points

- Ripple tank: electrical vibrator makes waves; frequency = 1/T of vibrator. Decreasing T raises frequency; speed in the same depth stays constant, so wavelength decreases.
- Deep to shallow water: speed decreases, wavelength decreases, frequency and time period do not change; waves bend towards the normal (refraction, like light entering glass).
- Reflection: angle of incidence = angle of reflection; speed, frequency and wavelength unchanged.
- Diffraction is maximum when the gap width is about equal to the wavelength. Smaller gap or longer wavelength gives more diffraction. Example: radio waves reach valleys; we hear sound around corners.
- Sun fusion sound: we feel heat (EM radiation) but hear nothing because sound is mechanical and cannot cross vacuum.
- Seismic waves: P waves are longitudinal and faster, travel through solids and liquids; S waves are transverse, slower, only through solids. Tsunamis: huge ocean waves from underwater earthquakes,

landslides or eruptions; they slow down and grow taller in shallow water.
- Energy transfer in a transverse wave: each particle passes energy to the next while it only moves up and down, perpendicular to the direction of energy flow. Draw a wave form with crest, trough, amplitude and wavelength labelled.

### Past-paper questions with model answers

- What is time period? Write its SI unit: time for one complete vibration, second (s).
- Damped oscillation with sketch: oscillation whose amplitude gradually decreases; sketch a sine wave with shrinking amplitude.
- How is energy transferred in a transverse wave? Make the wave form (3 marks).
- Draw wave forms to compare vibration directions of transverse and longitudinal waves (1.5 + 1.5).
- Diffraction of water waves with the ripple tank (Section C): plane waves pass through a gap; wide gap gives little bending; gap near wavelength gives circular waves; draw both diagrams.
- How does wavelength or gap size affect diffraction? Longer wavelength or narrower gap gives more bending.
- 200 waves in 40 s, wavelength 4 cm: $f = 200/40 = 5$ Hz, $T = 0.2$ s, $v = f\lambda = 5 \times 0.04 = 0.2$ m/s. 50 Hz and 2 mm: $v = 50 \times 0.002 = 0.1$ m/s.
- Radio wave of 90 MHz: $\lambda = 3 \times 10^8 / 90 \times 10^6 = 3.33$ m.

# Unit 13: Sound

### Definitions

- Sound: a disturbance (longitudinal mechanical wave) that travels in a medium and produces the sensation of hearing. It is produced by a vibrating body. It cannot travel in vacuum.
- Compression: region of high pressure. Rarefaction: region of low pressure.
- Loudness: perception of intensity; depends on amplitude. Pitch: perception of frequency; high frequency means shrill. Quality (timbre): number and relative strength of harmonics; lets us tell two sources apart even when loudness and pitch are the same.
- Intensity: energy per second through unit area, SI unit W $m^{-2}$. Intensity level: loudness measured on a scale, unit decibel (dB). Frequency: Hz.
- Audible range 20 Hz to 20,000 Hz. Infrasound is below 20 Hz (used by elephants, earthquake detection). Ultrasound is above 20 kHz (cleaning, imaging, bats, SONAR, dog whistles).
- Echo: reflected sound heard separately after at least 0.1 s. Reverberation: reflected sound that merges with the original (less than 0.1 s). Noise: unpleasant, irregular sound. Musical sound: pleasant and regular.

### Formulas

- $v = f\lambda$. Echo / SONAR distance: $d = v\,t / 2$. Minimum distance for an echo = $340 \times 0.1 / 2 = 17$ m. Speed in air about 330 to 350 m/s; seawater 1500 m/s; steel about 5000 m/s.

### Must-know points

- Speed of sound is greatest in solids, then liquids, then gases because particles are closer and pass the disturbance faster. It does not depend on frequency, and increases with temperature.
- Three parts of the ear: outer ear (collects sound, ear drum vibrates), middle ear (three ossicles amplify), inner ear (cochlea changes vibrations into electrical signals sent to the brain by the auditory nerve).
- Echo is not heard in a small room because the reflected sound returns in less than 0.1 s and merges with the original sound (reverberation).

- To reduce echo and reverberation: use soft, porous materials such as curtains, carpets and acoustic panels; avoid bare hard walls.
- Differences between pitch and loudness: pitch depends on frequency, loudness on amplitude; pitch is measured in Hz, loudness in dB; high pitch means shrill sound, loud means high energy. Loudness is related to amplitude, pitch to frequency.
- Lightning is seen before thunder is heard because light is much faster than sound.

### Past-paper questions with model answers

- What is echo? How is it produced? (1+2): reflection of sound from a hard obstacle, heard after at least 0.1 s.
- What is the minimum time for an echo? Why not heard in a small room? 0.1 s (1+2).
- Nature of sound waves, compression and rarefaction (3 marks).
- How is loudness related to amplitude? Bigger amplitude, more energy, louder sound.
- Differentiate between pitch and loudness (any three).
- SI units of intensity (W $m^{-2}$), intensity level (dB), frequency (Hz).
- Effect of changing amplitude and frequency on sound waves, with diagrams (Section C): larger amplitude gives louder sound; higher frequency gives higher pitch; draw waveforms.
- Echo after 5 s, speed 344 m/s: d = 344 × 5 / 2 = 860 m. Sonar 8.5 s, 1500 m/s: depth = 6375 m.

# Unit 14: Optics

### Definitions

- Laws of reflection: (1) incident ray, reflected ray and normal lie in the same plane; (2) angle of incidence = angle of reflection.
- Plane mirror image: virtual, erect, same size, laterally inverted, as far behind the mirror as the object is in front.
- Refraction: change in direction of light on passing from one medium to another because its speed changes. Refractive index n = speed of light in vacuum / speed in the medium = sin i / sin r (Snell's law).
- Total internal reflection (TIR): a ray in a denser medium is completely reflected back when the angle of incidence is greater than the critical angle. Critical angle: angle of incidence in the denser medium for which the angle of refraction is 90°. sin c = 1/n.
- Optical fibre: thin glass or plastic tube working on TIR. Uses: telecommunication, internet, endoscopy.
- Lens: convex (converging, thick in the middle) and concave (diverging, thin in the middle). Focal length: distance from lens to principal focus. Power of lens P = 1/f in dioptre (D) with f in metres.
- Dispersion: splitting of white light into seven colours by a prism because each colour is refracted by a different amount (violet most, red least).
- Real image: formed by actual meeting of rays, can be taken on a screen, inverted. Virtual image: rays only appear to meet, cannot be taken on a screen, erect.
- Gravitational lensing: bending of light by the gravity of a massive object (Einstein rings); used to study dark matter. Acoustic lensing: using materials to focus or spread sound (non-destructive testing).

### Formulas

- n = c/v. n = sin i / sin r. sin c = 1/n (or n2/n1). 1/f = 1/p + 1/q. Magnification m = q/p = hi/ho. Light speed in vacuum $3 \times 10^8$ m/s.

### Must-know points

- Glass slab: ray bends towards the normal entering, away on leaving, emerges parallel to the incident ray but shifted sideways. Label incident ray, refracted ray, emergent ray, normal, angles i and r.
- Conditions for TIR: light must travel from denser to rarer medium; angle of incidence must be greater than the critical angle. Examples: mirage, diamond sparkle, optical fibre, prism binoculars.
- Three differences between real and virtual images: real can be received on a screen, virtual cannot; real is inverted, virtual is erect (for a lens); real is formed by actual intersection of rays, virtual by apparent intersection.
- Image by magnifying glass (object inside the focal length): virtual, erect, magnified, on the same side as the object.
- Convex lens ray diagrams: beyond 2F gives real, inverted, diminished image between F and 2F; at 2F gives real, inverted, same size at 2F; between F and 2F gives real, inverted, magnified beyond 2F; at F gives image at infinity; inside F gives virtual, erect, magnified image.
- Magnification greater than 1 when object is between F and 2F (real) or inside F (virtual).
- Human eye: cornea and lens focus light on the retina, which has rods (dim light, about 100 million) and cones (colour, about 6 million). Short-sightedness (myopia): far objects blurred, corrected with concave lens. Long-sightedness (hypermetropia): near objects blurred, corrected with convex lens. Draw ray diagrams with and without the lens.
- Visible spectrum about 400 to 750 nm. Rainbow: refraction, TIR and dispersion in raindrops. Object in water looks raised because of refraction.

### Past-paper questions with model answers

- What is refractive index? Calculate it if the speed of light in the medium is $2 \times 10^8$ m/s: $n = 3 \times 10^8 / 2 \times 10^8 = 1.5$.
- Labelled sketch of refraction through a parallel-sided glass slab (3 marks).
- Snell's law with mathematical expression: $n = \sin i / \sin r$.
- Critical angle with formula, conditions for TIR (5 marks, Section C).
- Object 2 cm from a convex lens, image 6 cm away (virtual): $1/f = 1/2 - 1/6 = 1/3$, $f = 3$ cm, $m = 6/2 = 3$.
- Image 10 cm, object 5 cm: $m = 2$; m greater than 1 when the object is within 2F (between F and 2F or inside F).
- $M = 0.5$, object 2 cm tall at 5 cm: $q = M\,p = 2.5$ cm, image height $= 0.5 \times 2 = 1$ cm.
- Characteristics of image by magnifying glass; three differences between real and virtual images.
- Lenses for long and short sight with diagrams; ray diagram of convex lens for object beyond 2F and at F (Section C); optical fibre principle and two advantages (no loss, light weight, no interference).

# Unit 15: Electrostatics

### Definitions

- Electrification: process of giving an object an electric charge (friction, contact, induction).
- Conservation of charge: charge can neither be created nor destroyed, only transferred. Quantization: charge exists in whole multiples of $e = 1.6 \times 10^{-19}$ C ($q = ne$).
- Conductor: material with free electrons that allows charge to flow (copper). Insulator: tightly bound electrons, resists charge flow (rubber, plastic).
- Electric field: region around a charge where another charge feels a force. Electric field intensity $E = F/q$, unit N $C^{-1}$, direction is the direction of force on a positive test charge.
- Electric field lines: imaginary lines from positive to negative charge; closer lines mean stronger field; never cross.
- Electric potential (potential difference): work done per unit charge, $V = W/q$ (volt = J/C).
- Capacitor stores charge, $C = Q/V$ (farad). Series: $1/Ceq = 1/C1 + 1/C2$. Parallel: $Ceq = C1 + C2$.

### Must-know points

- Charging by friction: electrons transfer from one material to the other (rubber rod rubbed with fur becomes negative, fur positive). Charging by contact: gives the same sign. Charging by induction: no contact; the induced charge is opposite to the charged object, then the conductor is earthed.
- Effect on a test charge: a positive test charge is pushed away from a positive source and pulled towards a negative source. Characteristics (any two): field lines start on positive and end on negative; they never cross; density shows strength; field is uniform between parallel plates; the field has direction and magnitude.
- Electroscope detects charge and its sign; leaves diverge because of repulsion between like charges.
- Discharging: by conduction (earthing), convection (charged air), corona or spark. A charged insulator is discharged by holding it over a flame because the flame ionises the air, and the ions neutralise the charge. Heating gives the same effect. Moisture in humid air makes the surface conducting so the charge leaks away.
- Corona discharge: glow around sharp points of a conductor at high voltage. Lichtenberg figures: fern-like patterns left on an insulator by a high-voltage discharge.
- Electrostatic precipitator: charges dust particles and attracts them to plates to clean smoke. Photocopier uses charged drum and toner.
- Lightning is a huge discharge between cloud and ground. A lightning rod (pointed metal rod, earthed) gives the charge an easy path to ground. Safe place in a storm: inside a metal car, not under a tree.

### Past-paper questions with model answers

- What is electric field? How does it affect a test charge? Write two characteristics (every set): use the points above.
- Electric potential and work: charge 10 C moved from 120 V to 220 V: $W = q\Delta V = 10 \times 100 = 1000$ J.
- Role of moisture in discharging an insulator; why heating helps an insulator lose its charge; how a charged insulator is discharged on a flame (3 marks each).
- Electric field intensity with formula, SI unit and direction (Section C, 2+2+1).
- Capacitors 3 F and 4 F in series: $C_{eq} = (3 \times 4)/(3 + 4) = 1.71$ F.
- Force on a charge: $F = qE$.

# Unit 16: Current Electricity

### Definitions

- Electric current: rate of flow of charge, $I = Q/t$. Unit ampere = one coulomb per second. Conventional current flows from positive to negative; electron flow is opposite.
- DC: current in one direction only (cells, batteries). AC: current that reverses direction continuously (mains, 50 Hz).
- Potential difference $V = W/q$. Volt = joule per coulomb. EMF: energy given by a source to each coulomb of charge (device converting non-electrical energy to electrical). The p.d. across a source in a closed circuit is less than its emf because of internal resistance.
- Ohm's law: at constant temperature, current through a conductor is directly proportional to the potential difference across it: $V = IR$.
- Resistance: opposition to flow of current, unit ohm (Ω). Resistivity: resistance of a wire of unit length and unit cross-section, unit Ω m.
- Temperature coefficient of resistance: change in resistance per unit resistance per kelvin (unit $K^{-1}$).

### Formulas

- $I = Q/t$, $V = W/q$, $V = IR$, $R = \rho L/A$, $A = \pi d^2/4$, $\rho t = \rho 0\ (1 + \alpha \Delta T)$. 1 Ah = 3600 C.

### Must-know points

- Resistance increases with length and temperature (metals), decreases with area. Semiconductor resistance decreases when temperature rises.
- Ammeter is connected in series (low resistance); voltmeter in parallel (high resistance).
- Non-ohmic devices (diode, bulb filament, thermistor) give a curved I-V graph; ohmic conductors give a straight line through the origin.
- Two differences between d.c. and a.c.: d.c. has constant direction, a.c. reverses direction; d.c. comes from cells, a.c. from generators; a.c. can be stepped up or down by transformers, d.c. cannot.
- Why a.c. is preferred for domestic use (three reasons): it can be transformed to high voltage for cheap, low-loss transmission; it is cheap and easy to generate; it can be converted to d.c. easily and works motors and heaters.
- A current-carrying wire is neutral because the number of protons equals electrons inside it.

### Past-paper questions with model answers

- State Ohm's law; resistor 10 Ω with 2 A: $V = IR = 20$ V. 12 V and 3 A: $R = 4$ Ω. 6 Ω with 12 V: $I = 2$ A.
- Bulb on 6 V battery drawing 2 A: $R = V/I = 3$ Ω.
- Copper wire 1 m long, 2 mm diameter: $A = \pi(2\times10^{-3})^2/4 = 3.14 \times 10^{-6}$ m²; $R = \rho L/A = 1.7 \times 10^{-8} \times 1 / 3.14 \times 10^{-6} \approx 5.4 \times 10^{-3}$ Ω.
- Two differences between d.c. and a.c.; describe d.c. and a.c. with one advantage each; why a.c. for home use.
- Charge in 3 A for 2 min: $Q = It = 360$ C.

# Unit 17: Electric Circuits

### Definitions

- Series circuit: components in one path; the same current flows; voltages add. Parallel circuit: components on separate branches; same voltage across each; currents add.
- Electric power: rate of using electrical energy, unit watt. Electrical energy: unit joule or kilowatt hour (1 kWh = $3.6 \times 10^6$ J, also called one unit).
- Potential divider: series resistors that split a voltage into smaller fractions.
- Thermistor: resistor whose resistance changes with temperature. NTC: resistance falls as temperature rises. PTC: resistance rises as temperature rises.

### Formulas

- Series: $R_{eq} = R1 + R2 + R3$. Parallel: $1/R_{eq} = 1/R1 + 1/R2$ (two resistors: $R_{eq} = R1R2/(R1 + R2)$). Identical resistors R in parallel: $R/n$.
- Cells: in series emf adds ($V_{eq} = V1 + V2$); in parallel the emf is the same as one cell (but it lasts longer).
- $P = VI = I^2R = V^2/R$. $E = Pt$. $W = I^2Rt$. Bill = kWh × rate per unit.
- Colour code: first two bands digits, third band multiplier (brown, black, red = $10 \times 10^2 = 1$ kΩ).

### Must-know points

- Derivation for resistors in parallel: same V across each; total $I = I1 + I2 = V/R1 + V/R2$; since $I = V/R_{eq}$, $1/R_{eq} = 1/R1 + 1/R2$. In series: the same I, $V = V1 + V2 = IR1 + IR2 = I(R1 + R2)$, so $R_{eq} = R1 + R2$. Draw both circuits.
- Homes are wired in parallel so each device gets full voltage and works independently; in series one fault would switch everything off.

- Safety devices (name three): fuse, circuit breaker, earth (ground) wire, switch on the live wire, insulation, RCD. Circuit breaker cuts the supply when current is too high. Earthing sends fault current to ground. Do not touch switches with wet hands because water conducts and the body resistance drops.
- Brighter bulb in parallel has the lower resistance (higher power at same voltage).

### Past-paper questions with model answers

- Cost of a 1000 W heater for 5 h at Rs 30/unit: energy 5 kWh, cost Rs 150. 2 kW iron for 3 h at Rs 25: 6 kWh, Rs 150.
- Energy of a 100 W bulb for 10 h: 1 kWh = $3.6 \times 10^6$ J.
- Power at 220 V and 2 A: P = 440 W. 220 V and 0.5 A: 110 W. Energy of 220 V, 1 A for 5 s: E = VIt = 1100 J.
- Total emf of three 1.5 V cells: series 4.5 V; parallel 1.5 V. Four 2 V cells: 8 V and 2 V. Two 3 V cells: 6 V and 3 V.
- Req of R1 and R2 in parallel with sketch (2+1).
- 200 W bulb on 220 V (Section C): I = P/V = 0.91 A, R = V/I = 242 Ω, energy in 10 h = 2 kWh, cost at Rs 40 = Rs 80.
- Name any three safety devices used in household circuits.

# Unit 18: Electronics

### Definitions

- Semiconductor: conductivity between conductor and insulator (silicon, germanium). Intrinsic: pure. Extrinsic: doped with impurities.
- n-type: doped with pentavalent atoms (P, As, Sb), called donors; majority carriers are electrons. p-type: doped with trivalent atoms (B, Al, In, Ga), called acceptors; majority carriers are holes. Both types are electrically neutral overall.
- pn junction (diode): n and p joined; a depletion region forms at the junction. Barrier potential: 0.7 V silicon, 0.3 V germanium.
- Forward bias: p-side to positive terminal, depletion region narrows, current flows. Reverse bias: depletion region widens, almost no current.
- LED: emits light when current passes through it in forward bias.
- Transistor: three layers (NPN or PNP), emitter (heavily doped), base (thin, lightly doped), collector (largest). Used as amplifier and switch.
- Relay: electrically operated switch. ADC: analogue to digital converter. DAC: digital to analogue converter. Bit: binary digit 0 or 1.
- Logic gates: AND, OR, NOT are fundamental. NAND and NOR are universal gates (any gate can be built from them).

### Formulas

- $I_e = I_b + I_c$. Current gain $\beta = I_c / I_b$ (also $\Delta I_c / \Delta I_b$).

### Truth tables (A, B to X)

- AND ($X = A \cdot B$): 00 to 0, 01 to 0, 10 to 0, 11 to 1.
- OR ($X = A+B$): 00 to 0, 01 to 1, 10 to 1, 11 to 1.
- NOT: 0 to 1, 1 to 0.
- NAND: 00 to 1, 01 to 1, 10 to 1, 11 to 0.
- NOR: 00 to 1, 01 to 0, 10 to 0, 11 to 0.

### Must-know points

- Functions of a diode in electronic circuits (give two): rectifier (a.c. to d.c.), protects circuits from reverse polarity, switch, used in LEDs and detectors.
- Rectification: a diode conducts only in forward bias, so it passes one half of the a.c. cycle and blocks the other; draw input a.c. and output pulsating d.c.
- Diode forward bias (with diagram): battery positive to p-side; free electrons and holes move towards the junction, the depletion region narrows and current flows once the barrier potential is passed.
- Transistor action: small base current controls large collector current; as a switch, base current on gives collector current (on), none gives off.
- Digital systems are better than analogue: less noise, easy storage and copying, accurate processing. Storage devices (three): hard disk, USB flash drive, memory card, CD/DVD, SSD.
- Fax machine (not checked in the book text, from general knowledge): scans the page into light and dark points, converts them to electrical signals, sends them through the telephone line, and a printer at the other end rebuilds the page.

### Past-paper questions with model answers

- State two functions of a diode in electronic circuits (1.5 + 1.5).
- Role of a diode in rectification, with diagram; working of a diode under forward bias, with diagram.
- Draw the symbol of an AND gate and its truth table (1+2). Truth tables of AND, OR, NAND, NOR and NOT (Section C).
- Calculation: Ie = 5.82 mA, Ib = 120 μA, Ic = 5.7 mA; β = 30 mA / 600 μA = 50.

# Unit 19: Electromagnetism

### Definitions

- Magnetic field around a current-carrying wire: circles around the wire. Right-hand grip rule: thumb along the current, curled fingers show the field direction.
- Solenoid right-hand rule: curl the fingers along the current; the thumb points to the north pole. Two long parallel wires with current in the same direction attract each other.
- Force on a current-carrying conductor in a magnetic field: F = B I L (perpendicular). Fleming's left-hand rule: thumb = force (motion), forefinger = field, middle finger = current, all mutually perpendicular.
- Electric motor: converts electrical energy to mechanical energy. Generator: converts mechanical energy to electrical energy.
- Electromagnetic induction: an emf is induced in a conductor when the magnetic flux through it changes.
- Lenz's law: the direction of the induced current is always such that it opposes the cause producing it.
- Mutual induction: changing current in one coil induces an emf in a nearby coil.
- Transformer: device to increase or decrease an alternating voltage. Step-up: more turns on the secondary. Step-down: fewer turns on the secondary.

### Formulas

- Vs/Vp = Ns/Np. Ideal transformer: Vp Ip = Vs Is (power in = power out). Transformation ratio = Ns/Np.

### Must-know points

- Factors affecting the induced emf: strength of magnet, speed of relative motion, number of turns of the coil, area of the coil.

- Lenz's law and conservation of energy: when the north pole of a magnet is pushed towards a coil, the coil end becomes north and repels the magnet, so work must be done against this repulsion; that work becomes electrical energy. If induced current helped the motion, energy would be created from nothing, which is impossible.
- DC motor (5 marks): parts: armature coil, permanent magnets, split-ring commutator, carbon brushes, battery. Working: current in the coil in the field feels forces (Fleming's left hand rule) on opposite sides, producing a torque; the commutator reverses the current each half turn so the coil keeps rotating the same way.
- AC generator: coil rotating in a magnetic field, slip rings and brushes, gives alternating emf. Transformer is ineffective with d.c. because d.c. gives no changing flux.
- Transformer working: a.c. in the primary makes a changing magnetic flux in the laminated soft iron core; it links the secondary and induces an emf by mutual induction. Energy changes: electrical to magnetic to electrical. Losses: heat in coils, eddy currents, flux leakage.
- High voltage for long-distance transmission: for the same power, higher voltage means lower current, so less $I^2R$ heat loss in the cables.
- Cathode rays (2025 paper): streams of fast electrons from a heated cathode in a vacuum tube. They travel in straight lines, are deflected by electric field towards the positive plate, are deflected by a magnetic field (perpendicular to field and motion), and cause fluorescence.
- CRO components: electron gun (heated filament, grid, anodes), X and Y deflecting plates, fluorescent screen, evacuated glass tube. Waveform is controlled by applying a suitable electric field to the plates.
- Burglar alarm (Section C, 2026 Set M): a door or window switch and relay in a circuit; when opened the circuit changes, the relay closes the alarm circuit and the bell sounds. Draw a circuit with battery, switch, relay, bell.

### Past-paper questions with model answers

- State Lenz's law; how it determines the direction of induced current; why the induced current opposes the change; how it obeys conservation of energy (asked in every set).
- Factors affecting the magnitude of induced emf.
- Describe d.c. and a.c.; a.c. preferred for domestic use (three reasons).
- Step-up and step-down transformers; step-down 240 V to 12 V with 2000 primary turns: $N_s = N_p \times V_s/V_p = 2000 \times 12/240 = 100$ turns.
- Mutual induction in a transformer with diagram; energy transformation in a transformer (3+2).
- Electric motor with split-ring and brushes, neat sketch (4+1); construction and working of a DC motor (3+2).
- How do cathode rays behave in electric and magnetic fields; components of CRO with diagram (1+4).

# Unit 20: Electromagnetic Waves

### Definitions

- EM waves: transverse waves of oscillating electric and magnetic fields; need no medium; produced by accelerating charged particles; speed $c = 3 \times 10^8$ m/s in vacuum.
- EM spectrum in order of increasing wavelength (decreasing frequency and energy): gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves, radio waves. (Reverse for increasing frequency.)
- Photon: a massless packet (particle) of light energy. Light shows both wave and particle nature. Radiation pressure: pressure light exerts because photons carry momentum. Solar sail: spacecraft pushed by radiation pressure (no fuel).
- Scattering of light: light waves sent in different directions by particles of the medium.

### Formulas

- $c = f\lambda$. Photon energy $E = hf$. Photon momentum $p = h/\lambda = E/c$. $h = 6.63 \times 10^{-34}$ J s. Energy depends on frequency.

### Uses and hazards

- Radio waves: radio and TV broadcast, astronomy (longest wavelength). Microwaves: radar, Wi-Fi, Bluetooth, satellite TV, ovens. Infrared: remote controls, heaters, thermal imaging, intruder alarms, optical fibres.
- Visible light: vision (about 400 nm violet to 750 nm red). Ultraviolet: sterilising water, detecting fake notes, security marks; overexposure causes skin cancer. X-rays: medical imaging, security scanners, cracks in metal. Gamma rays: cancer treatment, sterilising food and equipment, most penetrating.
- X-rays and gamma rays are ionising and are dangerous to living tissue; radio waves and microwaves are non-ionising.

### Must-know points

- Blue sky: short wavelengths (blue) are scattered most by air molecules, so the scattered blue light reaches the eye from all directions.
- Sunset is red or orange: sunlight travels a longer path through the atmosphere, blue is scattered away and mostly red remains. Clouds look white because large droplets scatter all colours about equally.
- Particle nature of light: light is made of photons with energy hf and momentum; evidence is radiation pressure; application: solar sail (or solar cells).

### Past-paper questions with model answers

- Name any six regions of the EM spectrum in increasing order of wavelength (every set): gamma rays, X-rays, ultraviolet, visible, infrared, microwaves (and radio waves).
- What is the colour of the sky on a clear day? How does scattering determine it? Blue, as above (1+2).
- Why does the colour of the sky change at sunset? Name the phenomenon: scattering (explain longer path).
- Particle nature of light with one application (2+1).
- Frequency $5 \times 10^{14}$ Hz: $\lambda = 3 \times 10^{8} / 5 \times 10^{14} = 600$ nm.

# Unit 21: Nuclear Physics

### Definitions

- Nucleus: central core of the atom with protons and neutrons. Nucleon: a proton or a neutron. Nuclide: a type of atom with a specific number of protons and neutrons.
- Notation: ${}^{A}_{Z}\mathrm{X}$. A = nucleon number = protons + neutrons, Z = proton number, neutrons $N = A - Z$. Example: uranium-239 has $239 - 92 = 147$ neutrons.
- Isotopes: atoms of the same element (same Z) with different numbers of neutrons. They have the same chemical properties (same number of electrons) but different physical properties (mass, stability).
- Radioactivity: spontaneous emission of radiation from unstable nuclei. Nuclei become radioactive because they are unstable (too many neutrons or protons, or too large).
- Half-life: time for half of the original radioactive nuclei in a sample to decay. Stable isotopes have infinite half-life.
- Radioactive dating: finding the age of an object from the remaining radioactivity; carbon-14 dating for once-living things (limit about 50,000 years); needs C-14 which is taken in only while alive.
- Nuclear fission: heavy nucleus splits into smaller nuclei releasing large energy. Nuclear fusion: light nuclei join to form a heavier nucleus releasing large energy (source of the Sun's energy).

- Background radiation: ionising radiation always present (radon gas is the largest natural source, also cosmic rays, rocks, food). Units: becquerel (activity), gray (absorbed dose), sievert (effective dose).
- Dark matter: unseen matter inferred from its gravity (more than 80 % of matter). Falsifiability: a scientific hypothesis must be capable of being disproved.

## Decay and formulas

- Alpha decay: $^{A}_{Z}X$ to $^{A-4}_{Z-2}Y + {}^{4}_{2}He$. Beta decay: $^{A}_{Z}X$ to $^{A}_{Z+1}Y + e^{-}$ (nucleon number unchanged, proton number up by 1). Gamma: no change in A or Z, a photon leaves.
- Half-life: remaining $N = N_0 (1/2)^n$, $n = t/T_{½}$. After 1, 2, 3 half-lives the fraction left is 1/2, 1/4, 1/8.
- Mass-energy: $E = mc^2$, $c = 3 \times 10^8$ m/s.
- Fission example: $^{235}U + n$ to $^{144}Ba + {}^{89}Kr + 3n$ + energy. Fusion: $^{2}H + {}^{3}H$ to $^{4}He + n$ + energy.

## Properties of radiations

- Alpha: helium nucleus, charge +2, highly ionising, stopped by paper or a few cm of air. Beta: electron, charge −1, medium ionisation, stopped by a few mm of aluminium, travels farther in air. Gamma: EM wave, no charge, least ionising, most penetrating, needs thick lead or concrete.
- Uses: radiotherapy (cobalt-60 gamma), food sterilisation, smoke alarms, tracers, thickness gauges, dating. Safety: keep distance, limit time, use shielding (lead), store waste safely.
- Controlled fission in a reactor: neutrons keep the chain reaction going; moderator slows neutrons, control rods absorb extra neutrons, coolant removes heat. Uncontrolled fission is a bomb.
- Fusion needs very high temperature (millions of kelvin) and pressure to overcome repulsion between nuclei.
- Alpha particle scattering (Rutherford): most alpha particles passed straight through (atom mostly empty space); a few deflected at large angles (nucleus is small, dense, positive); very few bounced straight back (almost all the mass is in the nucleus).

## Past-paper questions with model answers

- What is an isotope? Do isotopes have similar chemical properties? Yes (same electron arrangement) (2+1).
- What is half-life? Explain with an example; why is half-life a characteristic property of a radioisotope (each isotope has a fixed value that is not changed by heat or pressure).
- What is radioactivity? Why do some nuclei become radioactive? (1+2).
- Briefly describe alpha particles with one reaction (2+1), e.g. $^{226}_{88}Ra$ to $^{222}_{86}Rn + {}^{4}_{2}He$.
- Evidence from the alpha scattering experiment (any three facts, above).
- Process of nuclear fission with an example reaction; controlled nuclear fission in reactors with diagram (Section C).
- Radioisotopes and their use in carbon dating (1+4).
- Lead-212, 50 mg, half-life 10 h, after 50 h: 5 half-lives, 50/32 = 1.56 mg.
- One-eighth left after 420 days: 3 half-lives, $T_{½}$ = 140 days. 1 kg to 250 g (quarter) in 2 half-lives of radium = 3200 years.
- $E = mc^2$ for 2 μg: $2 \times 10^{-9}$ kg $\times 9 \times 10^{16} = 1.8 \times 10^8$ J = 180 MJ.

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Revision tip: for each chapter, first learn the definitions and formulas, then draw the diagrams (wave forms, ray diagrams, circuits, transformer, motor, truth tables), and finally solve the numericals above without looking.