10th Class Physics Notes
Federal Board (FBISE)
Full Book Notes

Complete chapter-wise study notes with original practice questions
and an MCQ answer key

These notes follow the chapters of the National Book Foundation (NBF)
Physics book for Class 10, Federal Board (FBISE), in the order given below.

Prepared for students of the Federal Board of Intermediate and Secondary Education, Islamabad.
For the current model paper and official announcements, visit fbise.edu.pk.

About These Notes

These notes cover the full Class 10 Physics course of the Federal Board (FBISE), following the National Book Foundation (NBF) book, Chapters 10 to 21. Each chapter gives the key concepts, important definitions, the formulas you must know, and the key terms to revise. After the notes, every chapter has original practice questions: 10 multiple choice questions, 10 short questions and 3 long questions. An answer key for all multiple choice questions is given at the end of the book.

How to Use This Book

- Read one chapter's notes first and learn the definitions and formulas by heart.
- Attempt the MCQs without looking at the key, then check your answers and re-read the parts you got wrong.
- Write the short and long questions in your own words; practise the numerical examples with the formulas given.
- Revise the key terms of every chapter before the examination.

Chapters in This Book

1. **Chapter 10:** Heat Capacity and Modes of Heat Transfer
2. **Chapter 11:** Thermal Expansion and Change of State
3. **Chapter 12:** Waves
4. **Chapter 13:** Sound
5. **Chapter 14:** Optics
6. **Chapter 15:** Electrostatics
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9. **Chapter 18:** Electronics
10. **Chapter 19:** Electromagnetism
11. **Chapter 20:** Electromagnetic Waves

12.**Chapter 21:** Nuclear Physics

A Note on the Examination Paper

The FBISE Physics paper is SLO-based, in line with the Student Learning Outcomes of the course. The Board has introduced a restructured pattern with 50% multiple choice questions and 50% descriptive questions for this subject, and it reaches all SSC-II students in stages; most SSC-II students in the first year of the change still sit the existing pattern. The paper pattern, including any marks distribution and time allowed, is set by the Board and may change, so no marks figures or paper-pattern figures are printed in these notes. Students should check the current model paper on the official FBISE website, fbise.edu.pk, before the examination.

All practice questions in this book are original and written for these notes. They are not copied from any past paper or guide. Figures such as the value of g (about 10 m/s^2 near the Earth's surface), the density of water (1000 kg/m^3) and the speed of light (3 x 10^8 m/s) are standard textbook values used in the NBF book.

Chapter 10: Heat Capacity and Modes of Heat Transfer

Heat is energy in transfer, and temperature measures how hot or cold a body is. This chapter explains heat capacity and specific heat capacity, the three modes of heat transfer (conduction, convection and radiation), and the greenhouse effect, global warming and geothermal energy.

Key Concepts

- Heat is energy transferred from a hotter body to a colder body because of a temperature difference. Temperature is the measure of the hotness or coldness of a body and decides the direction of heat flow.
- Heat capacity (C) of a body is the heat needed to raise its temperature by 1 K. Specific heat capacity (c) is the heat needed to raise the temperature of 1 kg of a substance by 1 K. Its SI unit is J/(kg K).
- Water has a high specific heat capacity, about 4200 J/(kg K). This is why water is used in cooling systems and in hot-water bottles, and why places near the sea have mild climates.
- Conduction is the transfer of heat through a solid by the vibration of particles, without the movement of the material. Metals are good conductors; wood, plastic and air are poor conductors (insulators).

- Convection is the transfer of heat by the actual movement of a fluid (a liquid or a gas). Warm fluid rises and cold fluid sinks, forming convection currents, as in heating water or in sea and land breezes.
- Radiation is the transfer of heat by electromagnetic waves, which needs no medium. Heat from the Sun reaches the Earth by radiation. Dark, dull surfaces absorb and give out radiation better than bright, shiny surfaces.
- The greenhouse effect is the warming of the Earth because gases such as carbon dioxide trap heat radiation in the atmosphere. It keeps the Earth warm enough for life, but extra greenhouse gases from burning fuels increase global warming.
- Global warming is the rise in the average temperature of the Earth. It can melt ice, raise sea levels and change rainfall. Using less fuel, planting trees and using renewable energy reduce it.
- Geothermal energy is heat from inside the Earth. Hot rocks heat water underground, and the steam can drive turbines to make electricity. It is a renewable source of energy.

Important Definitions

Term	Definition
Heat	Energy transferred from a hotter body to a colder body because of a temperature difference.
Temperature	The measure of the hotness or coldness of a body.
Heat capacity	The heat needed to raise the temperature of a body by 1 K; SI unit J/K.
Specific heat capacity	The heat needed to raise the temperature of 1 kg of a substance by 1 K; SI unit J/(kg K).
Conduction	Transfer of heat through a solid by the vibration of particles, without movement of the material.
Convection	Transfer of heat by the actual movement of a fluid.
Radiation	Transfer of heat by electromagnetic waves, which needs no medium.
Greenhouse effect	The trapping of heat radiation in the atmosphere by gases such as carbon dioxide, which warms the Earth.
Global warming	The rise in the average temperature of the Earth, mainly from extra greenhouse gases.
Geothermal energy	Heat energy from inside the Earth, used to make electricity or to heat buildings.

Important Formulas

> Heat gained or lost: Q = m c (T2 - T1), where m is mass, c is specific heat capacity and (T2 - T1) is the temperature change.

> Heat capacity: C = Q / change in temperature; specific heat capacity: c = Q / (m x change in temperature).

> Specific heat capacity of water = 4200 J/(kg K); specific heat capacity of iron is about 450 J/(kg K).

> Example: heat to warm 2 kg of water by 10 K = 2 x 4200 x 10 = 84,000 J.

> 1 calorie = 4.2 J (approximately).

Key Terms to Remember

heat, **temperature**, **heat capacity**, **specific heat capacity**, **conduction**, **convection**, **radiation**, **insulator**, **greenhouse effect**, **global warming**, **geothermal energy**, **convection current**, **thermal equilibrium**

Chapter 10: Heat Capacity and Modes of Heat Transfer — Practice Questions

Multiple Choice Questions

1. Heat flows from a body at higher temperature to a body at lower temperature because of:

(a) Pressure difference (b) Temperature difference (c) Mass difference (d) Volume difference

2. The SI unit of specific heat capacity is:

(a) J/K (b) J/(kg K) (c) J/kg (d) W

3. The specific heat capacity of water is about:

(a) 420 J/(kg K) (b) 4200 J/(kg K) (c) 42,000 J/(kg K) (d) 4.2 J/(kg K)

4. Heat is transferred through a metal rod mainly by:

(a) Convection (b) Radiation (c) Conduction (d) Evaporation

5. Heat from the Sun reaches the Earth by:

(a) Conduction (b) Convection (c) Radiation (d) Evaporation

6. Which surface absorbs heat radiation best?

(a) Bright and shiny (b) Dark and dull (c) White and smooth (d) Silver and polished

7. The heat needed to raise 2 kg of water by 10 K (c = 4200 J/(kg K)) is:

(a) 8,400 J (b) 42,000 J (c) 84,000 J (d) 840,000 J

8. The greenhouse effect is caused by gases such as:

(a) Oxygen (b) Nitrogen (c) Carbon dioxide (d) Helium

9. Which of the following is a renewable source of energy?

(a) Coal (b) Geothermal energy (c) Petrol (d) Natural gas

10. Water is used as a coolant because it has:

(a) Low specific heat capacity (b) High specific heat capacity (c) Low density (d) High density

Short Questions

1. Distinguish between heat and temperature.
2. Define heat capacity and specific heat capacity. State their SI units.
3. Why does water have a high specific heat capacity, and why is it used in cooling systems?
4. Define conduction, convection and radiation, and give one example of each.
5. Why are the handles of cooking pots made of wood or plastic?
6. Explain the greenhouse effect in your own words.

7. What is global warming? State two of its effects.
8. How does a thermos flask reduce heat loss by conduction, convection and radiation?
9. What is geothermal energy? How is it used to make electricity?
10. Calculate the heat needed to raise the temperature of 0.5 kg of water from 20 degrees C to 60 degrees C. (c = 4200 J/(kg K))

Long Questions

1. Define specific heat capacity. Describe an experiment to find the specific heat capacity of a metal block, and explain why water is used in car radiators and hot-water bottles.
2. Explain conduction, convection and radiation with one daily-life example of each. Describe how a thermos flask reduces heat loss by all three methods.
3. Explain the greenhouse effect and global warming: their causes, their effects on the Earth, and the steps that can reduce global warming. Describe geothermal energy as a renewable source.

Chapter 11: Thermal Expansion and Change of State

Most substances expand when heated and contract when cooled, and change from one state to another at fixed temperatures. This chapter explains thermal expansion, the kinetic theory of matter, evaporation and boiling, latent heat, the pressure of gases and superconductivity.

Key Concepts

- The kinetic theory of matter says that matter is made of tiny particles that are always moving. In a solid the particles vibrate about fixed positions; in a liquid they can slide past each other; in a gas they move freely and fast.
- Most substances expand on heating and contract on cooling. Solids expand least, liquids more, and gases most. The expansion of a solid in one direction is called linear expansion.
- Gaps are left between railway tracks and in bridges, and expansion joints are fitted in pipelines, so that the material can expand on hot days without bending or cracking.
- A bimetallic strip is made of two metals with different rates of expansion joined together. On heating it bends towards the metal that expands less. It is used in thermostats and fire alarms.
- Evaporation is the change of liquid into vapour from the surface at any temperature. It is faster when the temperature is higher, the surface area is larger, and air is moving over the liquid. Evaporation causes cooling.
- Boiling is the change of liquid into vapour throughout the liquid at a fixed temperature (the boiling point) and a fixed pressure. Water boils at 100 degrees C at standard atmospheric pressure.
- Latent heat is the heat needed to change the state of a substance without changing its temperature. Latent heat of fusion melts a solid; latent heat of vaporisation turns a liquid into vapour. For water, the latent heat of vaporisation is much larger than that of fusion.
- The pressure of a gas is caused by gas particles hitting the walls of their container. Heating a gas makes its particles move faster, so they hit harder and more often, and the pressure rises if the volume is fixed.
- A superconductor is a material whose electrical resistance becomes zero below a very low temperature (its critical temperature). Superconductors are used in strong magnets, such as in MRI scanners and fast trains.

Important Definitions

Term	Definition
Thermal expansion	The increase in size of a substance when its temperature rises.
Linear expansion	The increase in the length of a solid when its temperature rises.
Bimetallic strip	A strip of two metals with different rates of expansion joined together, which bends on heating.
Evaporation	The change of liquid into vapour from the surface at any temperature.
Boiling	The change of liquid into vapour throughout the liquid at a fixed temperature and pressure.
Latent heat	The heat needed to change the state of a substance without changing its temperature.
Latent heat of fusion	The heat needed to change 1 kg of a solid into liquid at its melting point without a temperature change.
Latent heat of vaporisation	The heat needed to change 1 kg of a liquid into vapour at its boiling point without a temperature change.
Gas pressure	The pressure caused by gas particles hitting the walls of their container.
Superconductor	A material whose electrical resistance becomes zero below its critical temperature.

Important Formulas

> Change in length = original length x coefficient of linear expansion x temperature change.

> Heat for a change of state: Q = mL, where m is mass and L is the latent heat.

> Latent heat of fusion of ice = 336,000 J/kg; latent heat of vaporisation of water = 2,260,000 J/kg.

> Boiling point of water = 100 degrees C; melting point of ice = 0 degrees C (at standard atmospheric pressure).

> Gas pressure rises with temperature when the volume is fixed, because the particles move faster and hit the walls harder.

Key Terms to Remember

kinetic theory, **thermal expansion**, **linear expansion**, **bimetallic strip**, **thermostat**, **evaporation**, **boiling**, **latent heat**, **fusion**, **vaporisation**, **gas pressure**, **superconductor**, **critical temperature**

Chapter 11: Thermal Expansion and Change of State — Practice Questions

Multiple Choice Questions

1. According to the kinetic theory, the particles of a gas:

(a) Do not move (b) Vibrate about fixed positions (c) Move freely and fast (d) Are packed tightly

2. Which expands the most on heating?

(a) Iron (b) Water (c) Air (d) Glass

3. Gaps are left between railway tracks to allow for:

(a) Contraction (b) Thermal expansion (c) Rain (d) Noise

4. A bimetallic strip bends on heating because the two metals have:

(a) Different densities (b) Different rates of expansion (c) Different masses (d) Different colours

5. Evaporation takes place:

(a) Only at the boiling point (b) From the surface at any temperature (c) Only in a closed container (d) Only at 0 degrees C

6. Water boils at 100 degrees C at:

(a) Any pressure (b) Standard atmospheric pressure (c) Zero pressure (d) High altitude only

7. Latent heat is the heat needed to change the state of a substance:

(a) With a temperature change (b) Without a temperature change (c) Only for gases (d) Only for solids

8. The latent heat of vaporisation of water is:

(a) 336,000 J/kg (b) 2,260,000 J/kg (c) 4200 J/kg (d) 100,000 J/kg

9. Gas pressure is caused by:

(a) The weight of the gas (b) Gas particles hitting the walls of the container (c) The colour of the gas (d) The volume only

10. A superconductor has:

(a) Very high resistance (b) Zero resistance below its critical temperature (c) Zero mass (d) Infinite resistance

Short Questions

1. State the kinetic theory of matter and describe the motion of particles in solids, liquids and gases.
2. Why are gaps left between railway tracks and in bridges?
3. What is a bimetallic strip? How does it work, and where is it used?
4. Distinguish between evaporation and boiling.
5. State three factors that increase the rate of evaporation.
6. Define latent heat of fusion and latent heat of vaporisation.
7. Why does steam cause a worse burn than boiling water at the same temperature?
8. How does the pressure of a gas change when its temperature rises at fixed volume? Explain with kinetic theory.
9. What is a superconductor? Give two uses of superconductors.
10. How much heat is needed to melt 2 kg of ice at 0 degrees C? (Latent heat of fusion of ice = 336,000 J/kg)

Long Questions

1. Explain thermal expansion in solids, liquids and gases. Describe the construction and working of a bimetallic strip and give two uses of thermal expansion in daily life.
2. Explain evaporation and boiling, and latent heat of fusion and vaporisation. Describe why evaporation causes cooling, and why steam causes a worse burn than boiling water.
3. Explain the kinetic theory of matter and how it explains gas pressure. Describe superconductivity and its uses, and explain why a gas exerts more pressure when it is heated at fixed volume.

Chapter 12: Waves

A wave carries energy from one place to another without carrying matter with it. This chapter explains wave motion, transverse and longitudinal waves, amplitude, wavelength, frequency, time period and wave speed, and how waves behave when they meet a surface.

Key Concepts

- A wave is a disturbance that transfers energy from one place to another without the transfer of matter. The particles of the medium vibrate about their mean positions while the wave moves on.
- In a transverse wave the particles vibrate at right angles to the direction in which the wave travels, as in a water wave or a light wave. The wave has crests (high points) and troughs (low points).
- In a longitudinal wave the particles vibrate along the direction in which the wave travels, as in a sound wave. The wave has compressions (where particles are close together) and rarefactions (where they are far apart).
- Amplitude is the maximum displacement of a particle from its mean position. Wavelength is the distance between two nearest points that vibrate in the same way, such as two crests. Frequency is the number of waves passing a point in one second, measured in hertz (Hz).
- Time period is the time taken for one complete wave to pass a point. Frequency and time period are related by f = 1/T, where f is frequency and T is time period.
- Wave speed is the distance the wave travels in one second. It is given by v = f x wavelength, where f is frequency and wavelength is the length of one wave.
- When a wave meets a surface it can be reflected (bounce back), refracted (bend as it enters a new medium) or diffracted (spread out as it passes an edge or a gap).
- Electromagnetic waves (such as light and radio waves) can travel through a vacuum, while mechanical waves (such as sound and water waves) need a medium to travel through.

Important Definitions

Term	Definition
Wave	A disturbance that transfers energy from one place to another without the transfer of matter.
Transverse wave	A wave in which the particles vibrate at right angles to the direction of travel of the wave.

Longitudinal wave	A wave in which the particles vibrate along the direction of travel of the wave.
Amplitude	The maximum displacement of a particle from its mean position.
Wavelength	The distance between two nearest points of a wave that vibrate in the same way, such as two crests.
Frequency	The number of waves passing a point in one second; SI unit hertz (Hz).
Time period	The time taken for one complete wave to pass a point.
Wave speed	The distance travelled by a wave in one second.
Crest	The highest point of a transverse wave.
Trough	The lowest point of a transverse wave.

Important Formulas

> Wave speed: v = f x wavelength, where f is frequency and wavelength is the length of one wave.

> Frequency and time period: f = 1 / T, where T is the time period.

> Example: a wave of frequency 50 Hz and wavelength 2 m has speed v = 50 x 2 = 100 m/s.

> 1 Hz = 1 wave per second; 1 kHz = 1000 Hz.

> Speed of light in a vacuum = 3 x 10^8 m/s.

Key Terms to Remember

wave, **transverse wave**, **longitudinal wave**, **crest**, **trough**, **compression**, **rarefaction**, **amplitude**, **wavelength**, **frequency**, **hertz**, **time period**, **wave speed**, **reflection**, **refraction**, **diffraction**

Chapter 12: Waves — Practice Questions

Multiple Choice Questions

1. A wave transfers:

(a) Matter only (b) Energy without matter (c) Both matter and energy (d) Nothing

2. In a transverse wave the particles vibrate:

(a) Along the direction of travel (b) At right angles to the direction of travel (c) In circles only (d) Not at all

3. Sound is an example of a:

(a) Transverse wave (b) Longitudinal wave (c) Electromagnetic wave (d) Standing wave

4. Light is an example of a:

(a) Longitudinal wave (b) Transverse wave (c) Sound wave (d) Water wave

5. The SI unit of frequency is:

(a) Metre (b) Second (c) Hertz (d) Joule

6. The time period of a wave of frequency 50 Hz is:

(a) 0.02 s (b) 0.2 s (c) 2 s (d) 50 s

7. A wave of frequency 50 Hz and wavelength 2 m has a speed of:

(a) 25 m/s (b) 50 m/s (c) 100 m/s (d) 200 m/s

8. The distance between two nearest crests is the:

(a) Amplitude (b) Wavelength (c) Frequency (d) Time period

9. Which wave can travel through a vacuum?

(a) Sound (b) Water wave (c) Light (d) A wave on a rope

10. The maximum displacement of a particle from its mean position is the:

(a) Wavelength (b) Frequency (c) Amplitude (d) Time period

Short Questions

1. Define a wave. Does a wave carry matter with it?
2. Distinguish between transverse and longitudinal waves with one example of each.
3. Define amplitude, wavelength and frequency.
4. State the relation between frequency and time period, and find the time period of a wave of frequency 200 Hz.
5. Write the wave equation and use it to find the speed of a wave of frequency 100 Hz and wavelength 3 m.
6. What are compressions and rarefactions in a longitudinal wave?
7. Define crest and trough.
8. What happens when a wave meets a surface? Name three behaviours.
9. Why can light travel through a vacuum but sound cannot?
10. A wave has a wavelength of 0.5 m and a speed of 340 m/s. Find its frequency.

Long Questions

1. Explain transverse and longitudinal waves with diagrams. Describe amplitude, wavelength, frequency and time period, and derive the wave equation v = f x wavelength.
2. Describe an experiment to show that a wave transfers energy without transferring matter. Explain reflection, refraction and diffraction of waves with one example of each.
3. Explain the difference between mechanical waves and electromagnetic waves. Solve: a sound wave of frequency 500 Hz travels at 340 m/s; find its wavelength and time period, and explain why sound needs a medium to travel.

Chapter 13: Sound

Sound is produced by vibrating bodies and travels as a longitudinal wave through a medium. This chapter explains how sound is produced and how it travels, the speed of sound, echo, the audible range, ultrasound and the qualities of sound.

Key Concepts

- Sound is produced by a vibrating body, such as a stretched string, a drum skin or the vocal cords.

The vibrations make the air particles vibrate, and the sound travels as a longitudinal wave of compressions and rarefactions.

- Sound needs a medium to travel through: a solid, a liquid or a gas. It cannot travel through a vacuum, because there are no particles to carry the vibrations. Sound travels fastest in solids, slower in liquids and slowest in gases.
- The speed of sound in air is about 343 m/s at room temperature. It increases when the temperature rises, because the air particles move faster.
- An echo is the reflection of sound from a hard surface, such as a wall or a cliff. An echo is heard as a separate sound only if the reflecting surface is at least about 17 m away, so that the reflected sound returns after at least 0.1 s.
- The audible range of the human ear is about 20 Hz to 20,000 Hz. Sounds below 20 Hz are called infrasound; sounds above 20,000 Hz are called ultrasound.
- Ultrasound is used in medicine to see inside the body (ultrasound scans), in industry to find cracks in metal, and by bats and in sonar to find objects under water.
- The loudness of a sound depends on its amplitude: a larger amplitude gives a louder sound. The pitch depends on its frequency: a higher frequency gives a higher-pitched sound. The quality (timbre) of a sound depends on its waveform and lets us tell two instruments apart even when they play the same note.
- Noise is unwanted sound. Loud noise over a long time can damage hearing. Noise is reduced by keeping a distance from the source, using ear protection and putting barriers between the source and the listener.

Important Definitions

Term	Definition
Sound	A form of energy produced by a vibrating body, which travels as a longitudinal wave through a medium.
Echo	The reflection of sound from a hard surface, heard as a repeated sound.
Audible range	The range of frequencies the human ear can hear, about 20 Hz to 20,000 Hz.
Infrasound	Sound with a frequency below 20 Hz, which the human ear cannot hear.
Ultrasound	Sound with a frequency above 20,000 Hz, which the human ear cannot hear.
Loudness	How loud a sound seems; it depends on the amplitude of the sound wave.
Pitch	How high or low a sound seems; it depends on the frequency of the sound wave.
Timbre (quality)	The character of a sound that lets us tell two instruments apart when they play the same note.
Sonar	A method of finding objects under water by sending ultrasound and timing its echo.
Noise	Unwanted sound, which can damage hearing if it is loud and long-lasting.

Important Formulas

> Speed of sound in air is about 343 m/s at room temperature.

- Distance to a reflecting surface from an echo: distance = (speed of sound x time) / 2.
- Example: an echo returns after 2 s, so the distance is (343 x 2) / 2 = 343 m.
- Frequency and time period: f = 1 / T; wave speed: v = f x wavelength.
- Audible range: 20 Hz to 20,000 Hz; ultrasound is above 20,000 Hz.

Key Terms to Remember

sound, **vibration**, **longitudinal wave**, **compression**, **rarefaction**, **echo**, **audible range**, **infrasound**, **ultrasound**, **loudness**, **pitch**, **timbre**, **sonar**, **noise**

Chapter 13: Sound — Practice Questions

Multiple Choice Questions

1. Sound is produced by:

(a) A still body (b) A vibrating body (c) A vacuum (d) A mirror

2. Sound travels as a:

(a) Transverse wave (b) Longitudinal wave (c) Electromagnetic wave (d) Standing wave

3. Sound travels fastest in:

(a) Air (b) Water (c) Steel (d) A vacuum

4. The speed of sound in air at room temperature is about:

(a) 150 m/s (b) 343 m/s (c) 3 x 10^8 m/s (d) 1500 m/s

5. An echo is the:

(a) Bending of sound (b) Reflection of sound (c) Absorption of sound (d) Speed of sound

6. The audible range of the human ear is about:

(a) 0 to 20 Hz (b) 20 Hz to 20,000 Hz (c) 20,000 Hz to 40,000 Hz (d) 0 to 100 Hz

7. Ultrasound has a frequency:

(a) Below 20 Hz (b) Between 20 Hz and 20,000 Hz (c) Above 20,000 Hz (d) Equal to 0 Hz

8. Loudness of a sound depends on its:

(a) Frequency (b) Amplitude (c) Speed (d) Wavelength

9. Pitch of a sound depends on its:

(a) Amplitude (b) Frequency (c) Speed (d) Distance

10. Sonar uses:

(a) Light (b) Ultrasound (c) X-rays (d) Radio waves

Short Questions

1. How is sound produced? Give two examples of vibrating bodies that produce sound.
2. Why can sound not travel through a vacuum?
3. In which medium does sound travel fastest: air, water or steel? Why?
4. What is an echo? Why must the reflecting surface be at least about 17 m away for a clear echo?

5. State the audible range of the human ear. Define infrasound and ultrasound.
6. Give three uses of ultrasound.
7. Distinguish between loudness and pitch. On what does each depend?
8. What is timbre? How does it help us tell a flute from a violin?
9. An echo returns after 2 seconds. Find the distance of the reflecting surface. (Speed of sound = 343 m/s)
10. How can loud noise damage hearing, and how can it be reduced?

Long Questions

1. Explain how sound is produced and how it travels through air as a longitudinal wave. Explain why sound needs a medium, and compare its speed in solids, liquids and gases.
2. Explain echo and how it is used to find the distance of a reflecting surface. Describe sonar and the uses of ultrasound in medicine and industry.
3. Explain loudness, pitch and quality (timbre) of sound. Describe the audible range, infrasound and ultrasound, and explain the harmful effects of noise and how noise can be reduced.

Chapter 14: Optics

Optics is the study of light: how it reflects, refracts and forms images. This chapter explains reflection and refraction, mirrors and lenses, total internal reflection, dispersion by a prism and the optical instruments we use every day.

Key Concepts

- Light travels in straight lines. Reflection is the bouncing back of light from a surface. The laws of reflection are: the angle of incidence equals the angle of reflection, and the incident ray, the reflected ray and the normal all lie in the same plane.
- A plane mirror forms a virtual, upright image of the same size as the object, as far behind the mirror as the object is in front of it, with left and right reversed.
- A concave mirror curves inwards and can form a real or a virtual image; it is used in shaving mirrors, headlights and solar furnaces. A convex mirror curves outwards and always forms a small, virtual, upright image; it is used as a rear-view mirror in vehicles.
- The mirror formula is 1/f = 1/do + 1/di, where f is the focal length, do is the object distance and di is the image distance. Magnification m = height of image / height of object = -di/do.
- Refraction is the bending of light when it passes from one medium into another, because its speed changes. Light bends towards the normal when it enters a denser medium and away from the normal when it enters a rarer medium.
- Snell's law states that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for two given media; this constant is the refractive index (n = sin i / sin r).
- Total internal reflection happens when light travels from a denser to a rarer medium at an angle greater than the critical angle, and is reflected back into the denser medium. It is used in optical fibres and in the sparkling of diamonds.
- A convex lens converges light and can form real or virtual images; it is used in magnifying glasses, cameras and the eye. A concave lens diverges light and always forms a small, virtual, upright image; it is used in correcting short sight.
- The lens formula is 1/f = 1/do + 1/di, the same form as the mirror formula. The power of a lens is

P = 1/f (with f in metres), measured in dioptres; a convex lens has positive power and a concave lens has negative power.

- Dispersion is the splitting of white light into its colours (a spectrum) by a prism, because different colours bend by different amounts. The eye, the camera, the microscope and the telescope are optical instruments that form images with lenses.

Important Definitions

Term	Definition
Reflection	The bouncing back of light from a surface into the same medium.
Angle of incidence	The angle between the incident ray and the normal to the surface.
Angle of reflection	The angle between the reflected ray and the normal to the surface.
Refraction	The bending of light when it passes from one medium into another because its speed changes.
Refractive index	The ratio of the speed of light in a vacuum to its speed in a medium; also n = sin i / sin r.
Critical angle	The angle of incidence in a denser medium at which the angle of refraction is 90 degrees.
Total internal reflection	The complete reflection of light back into a denser medium when the angle of incidence is greater than the critical angle.
Focal length	The distance between the pole (or optical centre) and the focus of a mirror or lens.
Magnification	The ratio of the height of the image to the height of the object.
Dispersion	The splitting of white light into its seven colours by a prism.

Important Formulas

> Mirror formula: 1/f = 1/do + 1/di, where f is focal length, do is object distance and di is image distance.

> Magnification: m = height of image / height of object = -di/do (mirror); m = di/do (lens, with sign convention).

> Snell's law: n = sin i / sin r, where i is the angle of incidence and r is the angle of refraction.

> Refractive index: n = speed of light in vacuum / speed of light in the medium.

> Lens formula: 1/f = 1/do + 1/di; power of a lens: P = 1/f (f in metres), in dioptres.

> Example: a concave mirror of focal length 10 cm forms an image of an object 30 cm away at di = 15 cm (1/di = 1/10 - 1/30 = 1/15).

Key Terms to Remember

reflection, **refraction**, **normal**, **angle of incidence**, **angle of reflection**, **plane mirror**, **concave mirror**, **convex mirror**, **focal length**, **magnification**, **refractive index**, **critical angle**, **total internal reflection**, **convex lens**, **concave lens**, **dispersion**, **spectrum**, **dioptre**

Chapter 14: Optics — Practice Questions

Multiple Choice Questions

1. The angle of incidence is equal to the angle of:

(a) Refraction (b) Reflection (c) Deviation (d) Dispersion

2. The image formed by a plane mirror is:

(a) Real and inverted (b) Virtual and upright (c) Real and upright (d) Virtual and inverted

3. A concave mirror is used in:

(a) Rear-view mirrors (b) Shaving mirrors (c) Security mirrors (d) Shop mirrors

4. A convex mirror is used as a:

(a) Shaving mirror (b) Rear-view mirror (c) Magnifying glass (d) Projector

5. A concave mirror of focal length 10 cm forms an image of an object 30 cm away at:

(a) 10 cm (b) 15 cm (c) 20 cm (d) 30 cm

6. Refraction happens because light:

(a) Changes speed in a new medium (b) Stops (c) Disappears (d) Becomes sound

7. According to Snell's law, n is equal to:

(a) sin r / sin i (b) sin i / sin r (c) i / r (d) r / i

8. Total internal reflection happens when the angle of incidence is:

(a) Less than the critical angle (b) Greater than the critical angle (c) Equal to zero (d) Equal to 90 degrees

9. A convex lens is used in a:

(a) Magnifying glass (b) Rear-view mirror (c) Short-sight glasses (d) Security mirror

10. The power of a lens of focal length 0.5 m is:

(a) 0.5 dioptres (b) 1 dioptre (c) 2 dioptres (d) 5 dioptres

Short Questions

1. State the two laws of reflection.
2. Describe the image formed by a plane mirror.
3. Distinguish between a concave and a convex mirror, and give one use of each.
4. Write the mirror formula and define each symbol in it.
5. Define refraction and state Snell's law.
6. What is the critical angle? What is total internal reflection?
7. Give two uses of total internal reflection.
8. Distinguish between a convex and a concave lens, and give one use of each.
9. Write the lens formula and the formula for the power of a lens.

10. What is dispersion? Name the seven colours of the spectrum in order.

Long Questions

1. State and explain the laws of reflection. Describe the images formed by a concave mirror for an object at different positions, with ray diagrams, and give two uses of concave mirrors.
2. Explain refraction and Snell's law. Describe total internal reflection, the critical angle and its uses in optical fibres, and explain dispersion by a prism.
3. Explain the lens formula and the power of a lens. Describe how a convex lens forms images, how short sight and long sight are corrected, and how the eye and the camera are alike.

Chapter 15: Electrostatics

Electrostatics is the study of electric charges at rest. This chapter explains electric charge, Coulomb's law, the electric field, electric potential and capacitors, and how static electricity is used and controlled.

Key Concepts

- Electric charge is a property of matter. There are two kinds of charge: positive and negative. Like charges repel each other and unlike charges attract each other.
- An atom has a positively charged nucleus (protons) and negatively charged electrons around it. A body becomes positively charged when it loses electrons and negatively charged when it gains electrons.
- Charging by friction (rubbing) transfers electrons from one body to another, as when a plastic comb rubbed with dry hair attracts small pieces of paper. Charging by induction moves charges without touching.
- Coulomb's law states that the force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them: F = k q1 q2 / r^2.
- The electric field is the region around a charge in which another charge feels a force. The strength of the field is E = F/q, where F is the force on a small test charge q. Field lines leave a positive charge and enter a negative charge.
- Electric potential is the work done to bring a unit positive charge from infinity to a point in the field. Its SI unit is the volt (V). The potential difference between two points is the work done to move a unit charge between them.
- A capacitor is a device that stores electric charge. It is made of two conducting plates separated by an insulator (dielectric). Its capacitance is C = Q/V, where Q is the charge stored and V is the potential difference; the SI unit is the farad (F).
- Capacitors in parallel add their capacitances (C = C1 + C2); capacitors in series have a smaller total capacitance (1/C = 1/C1 + 1/C2). Capacitors are used in camera flashes, radios, computers and power supplies.
- Static electricity can be a danger: a spark can set fuel vapour alight, and lightning is a huge static discharge. Lightning conductors carry the charge safely to the ground, and earthing protects people and buildings.

Important Definitions

Term	Definition
Electric charge	A property of matter; there are two kinds, positive and negative.
Coulomb's law	The force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.
Electric field	The region around a charge in which another charge feels a force.
Electric field strength	The force per unit charge at a point in a field (E = F/q); SI unit N/C.
Electric potential	The work done to bring a unit positive charge from infinity to a point; SI unit volt (V).
Potential difference	The work done to move a unit charge between two points; SI unit volt (V).
Capacitor	A device that stores electric charge, made of two conducting plates separated by an insulator.
Capacitance	The charge stored per unit potential difference (C = Q/V); SI unit farad (F).
Dielectric	The insulating material between the plates of a capacitor.
Earthing	Connecting a body to the Earth so that extra charge flows safely to the ground.

Important Formulas

> Coulomb's law: F = k q1 q2 / r^2, where k = 9 x 10^9 N m^2/C^2.

> Electric field strength: E = F/q; also E = kQ / r^2 for a point charge Q.

> Electric potential: V = W/q; potential difference V = W/Q.

> Capacitance: C = Q/V; SI unit farad (F); 1 microfarad = 10^-6 F.

> Capacitors in parallel: C = C1 + C2; in series: 1/C = 1/C1 + 1/C2.

> Energy stored in a capacitor = (1/2) C V^2.

Key Terms to Remember

electric charge, **positive charge**, **negative charge**, **electron**, **proton**, **Coulomb's law**, **electric field**, **field lines**, **electric potential**, **volt**, **capacitor**, **capacitance**, **farad**, **dielectric**, **earthing**, **lightning conductor**

Chapter 15: Electrostatics — Practice Questions

Multiple Choice Questions

1. Like charges:

(a) Attract each other (b) Repel each other (c) Have no effect (d) Cancel each other

2. A body becomes negatively charged when it:

(a) Loses electrons (b) Gains electrons (c) Loses protons (d) Gains protons

3. According to Coulomb's law, the force between two charges is inversely proportional to:

(a) The distance (b) The square of the distance (c) The sum of the charges (d) The difference of the charges

4. The SI unit of electric charge is the:

(a) Volt (b) Ampere (c) Coulomb (d) Farad

5. Electric field lines leave a:

(a) Negative charge (b) Positive charge (c) Neutral body (d) Magnet

6. The SI unit of electric potential is the:

(a) Ampere (b) Volt (c) Ohm (d) Watt

7. Capacitance is defined as:

(a) Q x V (b) Q / V (c) V / Q (d) Q + V

8. The SI unit of capacitance is the:

(a) Volt (b) Farad (c) Coulomb (d) Ohm

9. Two capacitors of 2 microfarad each in parallel give:

(a) 1 microfarad (b) 2 microfarad (c) 4 microfarad (d) 8 microfarad

10. A lightning conductor protects a building by:

(a) Attracting lightning to the roof (b) Carrying the charge safely to the ground (c) Stopping the rain (d) Making the building taller

Short Questions

1. State the two kinds of electric charge and how they act on each other.
2. How does a body become positively or negatively charged?
3. Explain charging by friction with one example.
4. State Coulomb's law and write its mathematical form.
5. Define electric field and electric field strength. State the SI unit of each.
6. What are electric field lines? In which direction do they point near a positive charge?
7. Define electric potential and potential difference. State their SI unit.
8. What is a capacitor? Define capacitance and state its SI unit.
9. How do capacitors combine in series and in parallel? Give the formula for each.
10. How does a lightning conductor protect a building?

Long Questions

1. State and explain Coulomb's law. Describe the electric field and electric field lines, and explain how the field of a positive charge and of a negative charge looks.
2. Define electric potential and potential difference. Explain the construction and working of a capacitor, define capacitance, and describe how capacitors are combined in series and in parallel.
3. Explain how static electricity is produced by friction and by induction. Describe the dangers of static electricity and how earthing and lightning conductors protect people and buildings.

Chapter 16: Current Electricity

Current electricity is the flow of electric charge through a conductor. This chapter explains electric current, Ohm's law, resistance, series and parallel circuits, electric power and energy, and the difference between alternating and direct current.

Key Concepts

- Electric current is the rate of flow of electric charge: I = Q/t, where Q is the charge and t is the time. Its SI unit is the ampere (A). Conventional current flows from the positive to the negative terminal of a cell, opposite to the flow of electrons.
- Ohm's law states that the current through a conductor is directly proportional to the potential difference across it, if the temperature stays constant: V = IR, where V is potential difference, I is current and R is resistance.
- Resistance is the opposition to the flow of current. Its SI unit is the ohm. The resistance of a wire increases with its length, decreases with its cross-sectional area, and depends on the material and the temperature.
- Resistivity is the resistance of a unit cube of a material. Copper has low resistivity and is used for wires; nichrome has high resistivity and is used in heaters.
- In a series circuit the same current flows through every part, and the total resistance is the sum of the resistances (R = R1 + R2). In a parallel circuit the potential difference is the same across each part, and the total resistance is less than the smallest resistance (1/R = 1/R1 + 1/R2).
- Electric power is the rate at which electrical energy is used: P = VI = I^2 R = V^2/R. Its SI unit is the watt (W). A 100 W bulb uses more energy per second than a 60 W bulb.
- Electrical energy is E = P x t. The commercial unit of energy is the kilowatt-hour (kWh), called one unit: 1 kWh = 3.6 x 10^6 J. The electricity bill is based on the number of units used.
- Direct current (DC) flows in one direction only, as from a cell or a battery. Alternating current (AC) changes direction many times a second; mains electricity is AC at 50 Hz in Pakistan. AC can be changed in voltage with a transformer, which is why it is used for supply.
- When current flows through a resistor, electrical energy changes into heat (Joule heating). This is useful in heaters, bulbs and irons, but it wastes energy in wires and machines.

Important Definitions

Term	Definition
Electric current	The rate of flow of electric charge (I = Q/t); SI unit ampere (A).
Ampere	The SI unit of current; one ampere is one coulomb of charge per second.
Ohm's law	The current through a conductor is directly proportional to the potential difference across it, at constant temperature (V = IR).
Resistance	The opposition offered by a conductor to the flow of current; SI unit ohm.
Ohm	The SI unit of resistance; one ohm is one volt per ampere.
Resistivity	The resistance of a unit cube of a material; it depends on the material and temperature.

Electric power	The rate at which electrical energy is used (P = VI); SI unit watt (W).
Kilowatt-hour	The commercial unit of electrical energy; 1 kWh = 3.6 x 10^6 J.
Direct current (DC)	Current that flows in one direction only, as from a cell or battery.
Alternating current (AC)	Current that changes direction many times a second; mains electricity is AC.

Important Formulas

> Current: I = Q/t; charge: Q = It.

> Ohm's law: V = IR.

> Resistance of a wire: R = rho x L / A, where rho is resistivity, L is length and A is cross-sectional area.

> Resistors in series: R = R1 + R2; in parallel: 1/R = 1/R1 + 1/R2.

> Electric power: P = VI = I^2 R = V^2/R.

> Electrical energy: E = P x t; 1 kWh = 3.6 x 10^6 J.

> Example: a 100 W bulb used for 10 hours uses 1 kWh of energy.

Key Terms to Remember

electric current, **ampere**, **coulomb**, **Ohm's law**, **resistance**, **ohm**, **resistivity**, **series circuit**, **parallel circuit**, **electric power**, **watt**, **kilowatt-hour**, **direct current**, **alternating current**, **Joule heating**

Chapter 16: Current Electricity — Practice Questions

Multiple Choice Questions

1. The SI unit of electric current is the:

(a) Volt (b) Ampere (c) Ohm (d) Watt

2. Ohm's law states that V is equal to:

(a) I/R (b) IR (c) R/I (d) I + R

3. The resistance of a wire increases when its:

(a) Length decreases (b) Cross-sectional area increases (c) Length increases (d) Temperature decreases

4. Two resistors of 2 ohm each in series give:

(a) 1 ohm (b) 2 ohm (c) 4 ohm (d) 8 ohm

5. Two resistors of 2 ohm each in parallel give:

(a) 1 ohm (b) 2 ohm (c) 4 ohm (d) 0.5 ohm

6. Electric power is given by:

(a) P = V/I (b) P = VI (c) P = I/V (d) P = V + I

7. The commercial unit of electrical energy is the:

(a) Joule (b) Watt (c) Kilowatt-hour (d) Volt

8. 1 kWh is equal to:

(a) 3600 J (b) 3.6 x 10^6 J (c) 1000 J (d) 3.6 x 10^3 J

9. Mains electricity in Pakistan is AC at:

(a) 25 Hz (b) 50 Hz (c) 60 Hz (d) 100 Hz

10. A 100 W bulb used for 10 hours uses:

(a) 0.1 kWh (b) 1 kWh (c) 10 kWh (d) 100 kWh

Short Questions

1. Define electric current and state its SI unit and formula.
2. State Ohm's law and write its mathematical form.
3. Define resistance and state four factors on which the resistance of a wire depends.
4. What is resistivity? Why is copper used for wires and nichrome for heaters?
5. Distinguish between a series and a parallel circuit.
6. Two resistors of 3 ohm and 6 ohm are connected in series, then in parallel. Find the total resistance in each case.
7. Define electric power and write three formulas for it.
8. Define the kilowatt-hour and state its value in joules.
9. Distinguish between direct current and alternating current.
10. Why is alternating current used for the mains supply?

Long Questions

1. State and explain Ohm's law. Describe an experiment to verify Ohm's law with a circuit diagram, and explain the factors on which the resistance of a wire depends.
2. Explain series and parallel combinations of resistors with diagrams and formulas. Solve: three resistors of 2 ohm, 3 ohm and 6 ohm are connected in parallel across a 12 V battery; find the total resistance and the current in each resistor.
3. Define electric power and electrical energy. Explain the kilowatt-hour, how the electricity bill is calculated, and why alternating current is used for the mains supply instead of direct current.

Chapter 17: Electric Circuits

An electric circuit is a closed path in which current can flow. This chapter explains the parts of a circuit, how to draw circuit diagrams, how ammeters and voltmeters are used, and how household circuits are made safe with fuses, circuit breakers and earthing.

Key Concepts

- A circuit is a closed path for current. Its main parts are a source (cell or battery), connecting wires, a switch, and a load (such as a bulb or a motor). Current flows only when the circuit is closed; an open switch breaks the circuit.
- A cell gives a small voltage (about 1.5 V); a battery is a group of cells joined together to give a

larger voltage. The positive terminal of a cell is longer than the negative terminal.

- In a circuit diagram, each part has a symbol: a cell is a short and a long line, a battery is several cells, a switch is a break in the wire, a resistor is a rectangle or a zigzag, a bulb is a circle with a cross, and a wire is a straight line.
- An ammeter measures current and is always connected in series with the part being measured, so that the same current flows through it. An ideal ammeter has very low resistance.
- A voltmeter measures potential difference and is always connected in parallel across the part being measured. An ideal voltmeter has very high resistance, so it takes almost no current.
- In a series circuit there is only one path for the current, the same current flows everywhere, and if one bulb fails the whole circuit stops. In a parallel circuit there are several paths, each bulb gets the full voltage, and one bulb can fail while the others stay on.
- Household circuits are wired in parallel, so each appliance gets the full mains voltage and can be switched on and off on its own. Each circuit has a fuse or a circuit breaker and an earth wire for safety.
- A fuse is a thin wire that melts and breaks the circuit when the current is too large, protecting the wiring and the appliance. A circuit breaker does the same job and can be reset. The earth wire carries a fault current safely to the ground.
- A short circuit happens when the live wire touches the neutral wire directly, so a very large current flows. Overloading happens when too many appliances are used on one circuit. Both can cause fire, and both are stopped by a fuse or a circuit breaker.

Important Definitions

Term	Definition
Electric circuit	A closed path in which electric current can flow.
Cell	A device that changes chemical energy into electrical energy and gives a small voltage.
Battery	A group of cells joined together to give a larger voltage.
Switch	A device that opens or closes a circuit to start or stop the current.
Ammeter	An instrument that measures electric current; it is connected in series.
Voltmeter	An instrument that measures potential difference; it is connected in parallel.
Fuse	A thin wire that melts and breaks a circuit when the current becomes too large.
Circuit breaker	A safety switch that breaks a circuit when the current is too large and can be reset.
Earth wire	A wire that connects the metal case of an appliance to the Earth for safety.
Short circuit	A direct connection between the live and neutral wires, causing a very large current.

Important Formulas

> In a series circuit: the current is the same everywhere; total voltage = sum of the voltages across each part.

> In a parallel circuit: the voltage is the same across each part; total current = sum of the currents in

each part.

Ammeter: connected in series, very low resistance. Voltmeter: connected in parallel, very high resistance.

Power in a circuit: P = VI; energy used: E = P x t.

Fuse rating: a fuse must be rated a little above the normal current of the appliance it protects.

Example: a 1000 W heater on a 220 V supply draws about 4.5 A (I = P/V = 1000/220).

Key Terms to Remember

circuit, **cell**, **battery**, **switch**, **load**, **ammeter**, **voltmeter**, **series circuit**, **parallel circuit**, **fuse**, **circuit breaker**, **earth wire**, **short circuit**, **overloading**, **live wire**, **neutral wire**

Chapter 17: Electric Circuits — Practice Questions

Multiple Choice Questions

1. Current flows in a circuit only when it is:

(a) Open (b) Closed (c) Broken (d) Short

2. A battery is:

(a) One cell (b) A group of cells joined together (c) A wire (d) A switch

3. An ammeter is connected in:

(a) Parallel (b) Series (c) Any way (d) Across the battery only

4. A voltmeter is connected in:

(a) Series (b) Parallel (c) Any way (d) In the wire only

5. An ideal ammeter has:

(a) Very high resistance (b) Very low resistance (c) Infinite resistance (d) Zero voltage

6. An ideal voltmeter has:

(a) Very low resistance (b) Very high resistance (c) Zero resistance (d) No dial

7. In a series circuit, if one bulb fails:

(a) The others stay on (b) The whole circuit stops (c) The voltage rises (d) The current rises

8. Household circuits are wired in:

(a) Series (b) Parallel (c) Both (d) Neither

9. A fuse protects a circuit by:

(a) Increasing the current (b) Melting and breaking the circuit when the current is too large (c) Storing charge (d) Reducing the voltage

10. A short circuit is caused by:

(a) A broken wire (b) The live wire touching the neutral wire directly (c) A low voltage (d) A switched-off appliance

Short Questions

1. Define an electric circuit and name its four main parts.
2. Distinguish between a cell and a battery.
3. Draw the symbols for a cell, a battery, a switch, a resistor and a bulb.
4. Why is an ammeter connected in series and a voltmeter in parallel?
5. State the resistance of an ideal ammeter and an ideal voltmeter.
6. Distinguish between a series and a parallel circuit, and state one advantage of each.
7. Why are household circuits wired in parallel?
8. What is a fuse? How does it protect a circuit?
9. What is a circuit breaker? How is it different from a fuse?
10. What is a short circuit, and what is overloading? How are they stopped?

Long Questions

1. Explain the parts of an electric circuit and draw a circuit diagram with a cell, a switch, an ammeter, a voltmeter and two resistors in series. Explain how the ammeter and the voltmeter are connected and why.
2. Compare series and parallel circuits: the current, the voltage and what happens when one bulb fails. Explain why household circuits are wired in parallel, with examples.
3. Explain the safety devices in a household circuit: the fuse, the circuit breaker and the earth wire. Describe a short circuit and overloading, and how each safety device protects people and property.

Chapter 18: Electronics

Electronics is the study of how small devices control electric current. This chapter explains semiconductors, diodes, transistors and logic gates, and how they are used in radios, computers and control systems.

Key Concepts

- A semiconductor is a material, such as silicon, whose conductivity is between that of a conductor and an insulator. Its conductivity increases with temperature and when small amounts of other elements are added (doping).
- Intrinsic semiconductors are pure, such as pure silicon. Extrinsic semiconductors are doped: an n-type semiconductor has extra free electrons (from a pentavalent impurity such as phosphorus), and a p-type semiconductor has extra holes (from a trivalent impurity such as boron).
- A p-n junction diode is made by joining p-type and n-type material. In forward bias (p-side to the positive terminal) it conducts current; in reverse bias it blocks current almost completely. A diode lets current flow in one direction only.
- A diode is used as a rectifier: it changes alternating current (AC) into direct current (DC). A half-wave rectifier uses one diode and gives output in half the cycle; a full-wave rectifier uses four diodes (a bridge) and gives output in the whole cycle.
- A transistor has three layers and three terminals: the emitter, the base and the collector. An n-p-n transistor has a p-type base between two n-type layers; a p-n-p transistor has an n-type base between two p-type layers.

- A transistor works as a switch: a small current at the base controls a much larger current between the collector and the emitter. It also works as an amplifier: a small change in the base current gives a large change in the collector current, so a weak signal becomes strong.
- A logic gate is a circuit that takes one or more inputs and gives one output according to a rule. The basic gates are AND (output 1 only if all inputs are 1), OR (output 1 if any input is 1) and NOT (output is the opposite of the input).
- Combined gates are NAND (AND followed by NOT), NOR (OR followed by NOT) and XOR (output 1 only if the inputs are different). Logic gates are the building blocks of computers, calculators and control systems.
- Analogue signals change smoothly (such as the sound of a voice); digital signals have only two values, 0 and 1. Digital circuits use logic gates and are used in computers because they are fast and reliable.
- A cathode ray oscilloscope (CRO) shows a voltage as a trace on a screen. It is used to see waveforms, measure voltage and frequency, and check whether a circuit is working.

Important Definitions

Term	Definition
Semiconductor	A material, such as silicon, whose conductivity is between that of a conductor and an insulator.
Doping	Adding a small amount of another element to a semiconductor to change its conductivity.
n-type semiconductor	A semiconductor doped with a pentavalent impurity, so it has extra free electrons.
p-type semiconductor	A semiconductor doped with a trivalent impurity, so it has extra holes.
Diode	A two-terminal device made from a p-n junction that lets current flow in one direction only.
Rectifier	A circuit that changes alternating current (AC) into direct current (DC).
Transistor	A three-terminal semiconductor device that works as a switch and as an amplifier.
Amplifier	A circuit that makes a weak signal stronger.
Logic gate	A circuit that takes one or more inputs and gives one output according to a fixed rule.
Truth table	A table that lists all the possible inputs of a logic gate and the output for each.

Important Formulas

> Forward bias: p-side to the positive terminal, n-side to the negative terminal; the diode conducts.

> Reverse bias: p-side to the negative terminal, n-side to the positive terminal; the diode blocks current.

> Half-wave rectifier: one diode, output in half the cycle. Full-wave rectifier: four diodes (bridge), output in the whole cycle.

> AND gate: output 1 only if all inputs are 1. OR gate: output 1 if any input is 1. NOT gate: output is the opposite of the input.

> NAND gate: output 0 only if all inputs are 1. NOR gate: output 1 only if all inputs are 0. XOR gate: output 1 only if the inputs are different.

> Transistor as a switch: a small base current controls a large collector current.

Key Terms to Remember

semiconductor, **silicon**, **doping**, **n-type**, **p-type**, **hole**, **diode**, **forward bias**, **reverse bias**, **rectifier**, **transistor**, **emitter**, **base**, **collector**, **amplifier**, **logic gate**, **AND**, **OR**, **NOT**, **NAND**, **NOR**, **XOR**, **truth table**, **analogue**, **digital**, **CRO**

Chapter 18: Electronics — Practice Questions

Multiple Choice Questions

1. Silicon is a:

(a) Conductor (b) Insulator (c) Semiconductor (d) Superconductor

2. An n-type semiconductor has extra:

(a) Holes (b) Free electrons (c) Protons (d) Neutrons

3. A p-type semiconductor is doped with a:

(a) Pentavalent impurity (b) Trivalent impurity (c) Metal (d) Gas

4. A diode conducts current in:

(a) Both directions (b) One direction only (c) No direction (d) Reverse bias only

5. In forward bias, the p-side of a diode is connected to the:

(a) Negative terminal (b) Positive terminal (c) Earth (d) Neutral wire

6. A rectifier changes:

(a) DC into AC (b) AC into DC (c) AC into AC (d) DC into DC

7. A half-wave rectifier uses:

(a) One diode (b) Two diodes (c) Four diodes (d) No diode

8. A transistor has:

(a) Two terminals (b) Three terminals (c) Four terminals (d) One terminal

9. The AND gate gives output 1 only if:

(a) Any input is 1 (b) All inputs are 1 (c) All inputs are 0 (d) One input is 0

10. The NOT gate gives an output that is:

(a) The same as the input (b) The opposite of the input (c) Always 1 (d) Always 0

Short Questions

1. Define a semiconductor and give two examples.
2. Distinguish between intrinsic and extrinsic semiconductors.
3. Distinguish between n-type and p-type semiconductors.
4. What is a p-n junction diode? What is forward bias and reverse bias?
5. What is a rectifier? Distinguish between a half-wave and a full-wave rectifier.
6. Name the three terminals of a transistor and state the job of each.
7. How does a transistor work as a switch and as an amplifier?
8. Define a logic gate and name the three basic gates.
9. Write the truth tables of the AND, OR and NOT gates.
10. Distinguish between analogue and digital signals. What is a CRO used for?

Long Questions

1. Explain semiconductors, doping, n-type and p-type materials. Describe the p-n junction diode, forward and reverse bias, and how a diode is used as a rectifier.
2. Explain the construction and working of a transistor. Describe how it works as a switch and as an amplifier, with one example of each use.
3. Explain the basic logic gates (AND, OR, NOT) with truth tables, and the combined gates (NAND, NOR, XOR). Describe how logic gates are the building blocks of a computer, and distinguish between analogue and digital signals.

Chapter 19: Electromagnetism

Electricity and magnetism are linked: a current makes a magnetic field, and a changing magnetic field makes a current. This chapter explains electromagnets, the motor, electromagnetic induction, the generator and the transformer.

Key Concepts

- A current-carrying wire produces a magnetic field around it. The field is in circles around the wire, and its direction is given by the right-hand rule: if the thumb points in the direction of the current, the fingers curl in the direction of the field.
- A solenoid is a coil of wire. When current flows through it, it behaves like a bar magnet, with a north pole at one end and a south pole at the other. Its field is strong and uniform inside the coil.
- An electromagnet is a solenoid wound on a soft iron core. It is a temporary magnet: it works only while the current flows. Its strength increases with the current and with the number of turns, and it can be switched off. Electromagnets are used in cranes, electric bells and relays.
- A current-carrying conductor in a magnetic field feels a force. The force is largest when the conductor is at right angles to the field, and its direction is given by Fleming's left-hand rule. The force is F = BIL, where B is the field strength, I is the current and L is the length of the conductor in the field.
- An electric motor changes electrical energy into kinetic energy. A coil in a magnetic field turns because the forces on its two sides are in opposite directions. A commutator reverses the current every half turn so that the coil keeps turning in the same direction.
- Electromagnetic induction is the production of an induced current (or voltage) in a conductor

when the magnetic field through it changes. It was discovered by Faraday.

- Faraday's law states that the induced voltage is proportional to the rate of change of the magnetic flux. Lenz's law states that the induced current flows in a direction that opposes the change that caused it.
- An AC generator changes kinetic energy into electrical energy: a coil is turned in a magnetic field, and the changing flux induces an alternating voltage in the coil. Slip rings carry the current out of the coil.
- A transformer changes the voltage of alternating current. It has a primary coil and a secondary coil on an iron core. A step-up transformer increases the voltage (more turns in the secondary); a step-down transformer decreases it (fewer turns in the secondary). For an ideal transformer, Vs/Vp = Ns/Np = Ip/Is.
- Transformers are used to step up the voltage for long-distance transmission (so less energy is lost as heat) and to step it down for safe use in homes.

Important Definitions

Term	Definition
Electromagnetism	The link between electricity and magnetism: a current makes a magnetic field, and a changing magnetic field makes a current.
Solenoid	A coil of wire that behaves like a magnet when current flows through it.
Electromagnet	A temporary magnet made by passing a current through a coil wound on a soft iron core.
Motor	A device that changes electrical energy into kinetic energy using the force on a current-carrying coil in a magnetic field.
Electromagnetic induction	The production of an induced voltage or current when the magnetic field through a conductor changes.
Faraday's law	The induced voltage is proportional to the rate of change of the magnetic flux.
Lenz's law	The induced current flows in a direction that opposes the change that caused it.
Generator	A device that changes kinetic energy into electrical energy by turning a coil in a magnetic field.
Transformer	A device that changes the voltage of alternating current using two coils on an iron core.
Step-up transformer	A transformer that increases the voltage; it has more turns in the secondary coil than in the primary coil.

Important Formulas

> Force on a current-carrying conductor: F = BIL (when the conductor is at right angles to the field).

> Transformer: Vs/Vp = Ns/Np, where Vs and Vp are secondary and primary voltages and Ns and Np are the numbers of turns.

> For an ideal transformer: Vs/Vp = Ns/Np = Ip/Is, and power in = power out (Vp Ip = Vs Is).

> Example: a transformer with 100 primary turns and 1000 secondary turns steps 220 V up to 2200 V.

> Faraday's law: induced voltage is proportional to the rate of change of magnetic flux.

Key Terms to Remember

magnetic field, **right-hand rule**, **solenoid**, **electromagnet**, **Fleming's left-hand rule**, **motor**, **commutator**, **electromagnetic induction**, **Faraday's law**, **Lenz's law**, **generator**, **slip rings**, **transformer**, **step-up**, **step-down**, **primary coil**, **secondary coil**

Chapter 19: Electromagnetism — Practice Questions

Multiple Choice Questions

1. A current-carrying wire produces a magnetic field:

(a) In straight lines (b) In circles around the wire (c) Only at its ends (d) Only in iron

2. A solenoid behaves like a:

(a) Battery (b) Bar magnet (c) Bulb (d) Switch

3. An electromagnet is made with a core of:

(a) Steel (b) Soft iron (c) Copper (d) Wood

4. The strength of an electromagnet increases with:

(a) Less current (b) More current and more turns (c) Fewer turns (d) A longer wire only

5. The force on a current-carrying conductor in a magnetic field is largest when the conductor is:

(a) Parallel to the field (b) At right angles to the field (c) Outside the field (d) At 45 degrees

6. An electric motor changes:

(a) Kinetic energy into electrical energy (b) Electrical energy into kinetic energy (c) Heat into light (d) Sound into electricity

7. Electromagnetic induction was discovered by:

(a) Oersted (b) Faraday (c) Newton (d) Ampere

8. Lenz's law says the induced current opposes:

(a) The magnetic field (b) The change that caused it (c) The battery (d) The coil

9. A step-up transformer has:

(a) More turns in the primary (b) More turns in the secondary (c) Equal turns (d) No iron core

10. A transformer works on:

(a) Direct current only (b) Alternating current only (c) Both AC and DC (d) Neither

Short Questions

1. How can you find the direction of the magnetic field around a current-carrying wire?
2. What is a solenoid? How does it behave like a magnet?
3. What is an electromagnet? State two ways to increase its strength.
4. Write the formula for the force on a current-carrying conductor in a magnetic field and define each

symbol.

5. Explain how an electric motor works. What is the job of the commutator?
6. Define electromagnetic induction and state Faraday's law.
7. State Lenz's law.
8. How does an AC generator work?
9. What is a transformer? Distinguish between a step-up and a step-down transformer.
10. Why is the voltage stepped up for long-distance transmission of electricity?

Long Questions

1. Explain how a current-carrying wire and a solenoid produce a magnetic field. Describe the construction and working of an electromagnet and give three uses.
2. Explain the force on a current-carrying conductor in a magnetic field and describe how an electric motor works, including the role of the commutator.
3. Explain electromagnetic induction, Faraday's law and Lenz's law. Describe the AC generator and the transformer, and explain why transformers are used in the transmission of electricity.

Chapter 20: Electromagnetic Waves

Electromagnetic waves carry energy through space at the speed of light, and they need no medium. This chapter explains the electromagnetic spectrum, from radio waves to gamma rays, and how each part of the spectrum is used in daily life, medicine and communication.

Key Concepts

- Electromagnetic (EM) waves are made of changing electric and magnetic fields. They travel through a vacuum at the speed of light, 3 x 10^8 m/s, and they are transverse waves.
- All EM waves travel at the same speed in a vacuum, but they have different frequencies and wavelengths, related by c = f x wavelength. A higher frequency means a shorter wavelength and more energy.
- The electromagnetic spectrum, from the longest wavelength to the shortest, is: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays.
- Radio waves have the longest wavelength and the lowest frequency. They are used for radio, television, mobile phones and Wi-Fi. Different radio stations use different frequencies so that they do not mix.
- Microwaves are used in microwave ovens to heat food, in mobile phones, in Wi-Fi and in radar. In an oven, microwaves make water molecules in the food vibrate, and the food heats up.
- Infrared radiation is felt as heat. It is given out by hot objects and is used in remote controls, night-vision cameras, heaters and in finding people in the dark.
- Visible light is the only part of the spectrum the human eye can see. Its colours, from longest to shortest wavelength, are red, orange, yellow, green, blue, indigo and violet.
- Ultraviolet (UV) radiation comes mainly from the Sun. Small amounts help the body make vitamin D, but too much damages the skin and eyes. Sunscreen and sunglasses protect against UV.
- X-rays pass through soft tissue but are stopped by bone, so they are used to see broken bones and in security scanners. Gamma rays have the shortest wavelength and the most energy; they are used to treat cancer and to sterilise medical tools.
- Too much exposure to UV, X-rays and gamma rays is harmful, because they can damage living

cells. Their uses in medicine are controlled, and workers are shielded.

Important Definitions

Term	Definition
Electromagnetic wave	A wave of changing electric and magnetic fields that travels through a vacuum at the speed of light.
Electromagnetic spectrum	The full range of electromagnetic waves, from radio waves to gamma rays, arranged by frequency and wavelength.
Radio waves	Electromagnetic waves of the longest wavelength, used for radio, television and mobile phones.
Microwaves	Electromagnetic waves used in ovens, mobile phones, Wi-Fi and radar.
Infrared radiation	Electromagnetic waves felt as heat, given out by hot objects.
Visible light	The part of the electromagnetic spectrum that the human eye can see.
Ultraviolet radiation	Electromagnetic waves beyond violet light, coming mainly from the Sun.
X-rays	Electromagnetic waves that pass through soft tissue and are used to see bones and in security scanners.
Gamma rays	Electromagnetic waves of the shortest wavelength and highest energy, used to treat cancer.
Speed of light	The speed of electromagnetic waves in a vacuum, 3 x 10^8 m/s.

Important Formulas

- Speed of an EM wave: c = f x wavelength, where c = 3 x 10^8 m/s in a vacuum.
- Example: a radio wave of frequency 100 MHz (100 x 10^6 Hz) has wavelength 3 m.
- Frequency and wavelength: a higher frequency means a shorter wavelength.
- Order of the spectrum (longest to shortest wavelength): radio, microwave, infrared, visible, ultraviolet, X-ray, gamma.
- Visible colours (longest to shortest wavelength): red, orange, yellow, green, blue, indigo, violet.

Key Terms to Remember

electromagnetic wave, **electromagnetic spectrum**, **radio waves**, **microwaves**, **infrared**, **visible light**, **ultraviolet**, **X-rays**, **gamma rays**, **speed of light**, **frequency**, **wavelength**, **radar**, **Wi-Fi**

Chapter 20: Electromagnetic Waves — Practice Questions

Multiple Choice Questions

1. Electromagnetic waves travel through a vacuum at:

(a) 343 m/s (b) 1500 m/s (c) 3 x 10^8 m/s (d) 3 x 10^6 m/s

2. Electromagnetic waves are:

(a) Longitudinal (b) Transverse (c) Sound waves (d) Water waves

3. Which has the longest wavelength?

(a) Gamma rays (b) X-rays (c) Visible light (d) Radio waves

4. Which has the highest frequency?

(a) Radio waves (b) Microwaves (c) Infrared (d) Gamma rays

5. Microwaves are used in:

(a) Ovens and mobile phones (b) Seeing bones (c) Treating cancer (d) Making vitamin D

6. Infrared radiation is felt as:

(a) Sound (b) Heat (c) Light only (d) Cold

7. The only part of the spectrum the eye can see is:

(a) Ultraviolet (b) Infrared (c) Visible light (d) X-rays

8. Too much ultraviolet radiation can:

(a) Help the eyes (b) Damage the skin and eyes (c) Cool the body (d) Make bones stronger

9. X-rays are used to:

(a) Heat food (b) See broken bones (c) Send radio signals (d) Light a room

10. Gamma rays are used to:

(a) Treat cancer (b) Heat food (c) Make phone calls (d) Light streets

Short Questions

1. Define an electromagnetic wave and state its speed in a vacuum.
2. Write the relation between the speed, frequency and wavelength of an EM wave.
3. List the electromagnetic spectrum in order from the longest to the shortest wavelength.
4. Give two uses of radio waves.
5. Give two uses of microwaves.
6. What is infrared radiation? Give two uses of it.
7. List the seven colours of visible light in order of wavelength.
8. What is ultraviolet radiation? State one benefit and one harm of it.
9. Give one use of X-rays and one use of gamma rays.
10. Why must the use of X-rays and gamma rays be controlled?

Long Questions

1. Explain what electromagnetic waves are and how they differ from sound waves. Describe the electromagnetic spectrum in order, with the frequency and wavelength relation c = f x wavelength.

2. Describe the uses of radio waves, microwaves and infrared radiation in daily life and communication, giving two uses of each.
3. Describe visible light, ultraviolet radiation, X-rays and gamma rays. Explain their uses in medicine and daily life and the harm that too much exposure can cause.

Chapter 21: Nuclear Physics

Nuclear physics is the study of the nucleus of the atom. This chapter explains the structure of the atom, isotopes, radioactivity, half-life, fission and fusion, and the uses and dangers of nuclear energy.

Key Concepts

- An atom has a tiny, dense, positively charged nucleus at its centre, made of protons and neutrons, with electrons moving around it. Almost all the mass of the atom is in the nucleus.
- The atomic number (Z) is the number of protons in the nucleus; the mass number (A) is the number of protons plus neutrons. An element is fixed by its atomic number.
- Isotopes are atoms of the same element (same atomic number) with different numbers of neutrons, and so different mass numbers. Carbon-12 and carbon-14 are isotopes of carbon.
- Radioactivity is the spontaneous breaking up of an unstable nucleus, giving out radiation. It was discovered by Becquerel. The three kinds of radiation are alpha, beta and gamma.
- An alpha particle is a helium nucleus (2 protons and 2 neutrons). It is heavy, slow, strongly ionising and stopped by paper. A beta particle is a fast electron; it is more penetrating and is stopped by a few millimetres of aluminium.
- Gamma radiation is an electromagnetic wave of very short wavelength. It is the most penetrating of the three and is stopped only by thick lead or concrete. It is weakly ionising.
- Half-life is the time taken for half of the radioactive atoms in a sample to decay. After one half-life half the atoms remain; after two half-lives a quarter remains. Each radioactive substance has its own fixed half-life.
- Nuclear fission is the splitting of a heavy nucleus (such as uranium-235) into two lighter nuclei, giving out a large amount of energy and neutrons. The neutrons can cause further fission, making a chain reaction, which is controlled in a nuclear power station.
- Nuclear fusion is the joining of two light nuclei (such as hydrogen) into a heavier nucleus, giving out energy. Fusion powers the Sun and the stars, and it needs very high temperatures.
- Nuclear energy is used to make electricity, to treat cancer, to sterilise medical tools and to date old objects (carbon dating). Its dangers are radiation, which can damage living cells, and radioactive waste, which must be stored safely for a long time.
- Dark matter is matter that cannot be seen but whose gravity affects the motion of stars and galaxies. Scientists study it because the visible matter in the universe is not enough to explain how galaxies hold together.
- Falsifiability means that a scientific idea must be testable: it must be possible to show it is wrong by experiment or observation. An idea that cannot be tested is not science.

Important Definitions

Term	Definition
Nucleus	The tiny, dense, positively charged centre of an atom, made of protons and

	neutrons.
Atomic number (Z)	The number of protons in the nucleus of an atom.
Mass number (A)	The number of protons plus neutrons in the nucleus of an atom.
Isotopes	Atoms of the same element with the same atomic number but different numbers of neutrons.
Radioactivity	The spontaneous breaking up of an unstable nucleus, giving out radiation.
Alpha particle	A helium nucleus (2 protons and 2 neutrons) given out in radioactive decay.
Beta particle	A fast electron given out when a neutron in a nucleus changes into a proton.
Gamma radiation	Electromagnetic radiation of very short wavelength given out by a radioactive nucleus.
Half-life	The time taken for half of the radioactive atoms in a sample to decay.
Nuclear fission	The splitting of a heavy nucleus into two lighter nuclei, giving out energy.
Nuclear fusion	The joining of two light nuclei into a heavier nucleus, giving out energy.
Dark matter	Matter that cannot be seen but whose gravity affects stars and galaxies.

Important Formulas

> Mass number A = number of protons (Z) + number of neutrons (N).

> After one half-life, 1/2 of the atoms remain; after two half-lives, 1/4 remains; after three, 1/8 remains.

> Alpha decay: mass number falls by 4 and atomic number falls by 2.

> Beta decay: mass number stays the same and atomic number rises by 1.

> Gamma decay: no change in mass number or atomic number.

> Energy in fission and fusion follows E = mc^2: a small mass gives a large amount of energy.

Key Terms to Remember

nucleus, **proton**, **neutron**, **electron**, **atomic number**, **mass number**, **isotope**, **radioactivity**, **alpha particle**, **beta particle**, **gamma radiation**, **half-life**, **fission**, **fusion**, **chain reaction**, **dark matter**, **falsifiability**

Chapter 21: Nuclear Physics — Practice Questions

Multiple Choice Questions

1. The nucleus of an atom is made of:

(a) Protons and electrons (b) Protons and neutrons (c) Electrons and neutrons (d) Electrons only

2. The atomic number of an element is the number of:

(a) Neutrons (b) Protons (c) Protons plus neutrons (d) Electrons plus neutrons

3. Isotopes of an element have the same:

(a) Mass number (b) Atomic number (c) Number of neutrons (d) Number of nucleons

4. Radioactivity was discovered by:

(a) Faraday (b) Becquerel (c) Newton (d) Oersted

5. An alpha particle is a:

(a) Fast electron (b) Helium nucleus (c) Electromagnetic wave (d) Proton

6. Which radiation is most penetrating?

(a) Alpha (b) Beta (c) Gamma (d) All are equal

7. Alpha radiation is stopped by:

(a) Paper (b) Thick lead (c) Concrete (d) Aluminium of a few millimetres

8. Half-life is the time taken for:

(a) All atoms to decay (b) Half of the atoms to decay (c) The mass to double (d) The temperature to halve

9. Nuclear fission is the:

(a) Joining of light nuclei (b) Splitting of a heavy nucleus (c) Making of an atom (d) Cooling of a nucleus

10. Fusion powers the:

(a) Earth's core (b) Sun and the stars (c) Moon (d) Batteries

Short Questions

1. Describe the structure of an atom. Where is almost all its mass?
2. Define atomic number and mass number. An atom has 6 protons and 6 neutrons; find its atomic number and mass number.
3. What are isotopes? Give one example.
4. Define radioactivity and name its three kinds.
5. Compare alpha, beta and gamma radiation in terms of what they are and how penetrating they are.
6. Define half-life. A sample has a half-life of 5 days; how much of it remains after 10 days?
7. Distinguish between nuclear fission and nuclear fusion.
8. What is a chain reaction? How is it controlled in a nuclear power station?
9. Give three uses of nuclear energy and two of its dangers.
10. What is dark matter? What is falsifiability in science?

Long Questions

1. Describe the structure of the atom, atomic number, mass number and isotopes. Explain radioactivity and compare alpha, beta and gamma radiation in terms of what they are, their ionising power and their penetrating power.
2. Define half-life and explain it with an example. Describe nuclear fission and the chain reaction, and nuclear fusion, and explain how the Sun gets its energy.
3. Describe the uses of nuclear energy in medicine, industry and electricity, and its dangers,

including radiation and radioactive waste. Explain dark matter and falsifiability, and why they matter in science.

MCQ Answer Key

Check your answers below. Each chapter has 10 MCQs, numbered 1 to 10.

Chapter	1	2	3	4	5	6	7	8	9	10
Ch. 10	B	B	B	C	C	B	C	C	B	B
Ch. 11	C	C	B	B	B	B	B	B	B	B
Ch. 12	B	B	B	B	C	A	C	B	C	C
Ch. 13	B	B	C	B	B	B	C	B	B	B
Ch. 14	B	B	B	B	B	A	B	B	A	C
Ch. 15	B	B	B	C	B	B	B	B	C	B
Ch. 16	B	B	C	C	A	B	C	B	B	B
Ch. 17	B	B	B	B	B	B	B	B	B	B
Ch. 18	C	B	B	B	B	B	A	B	B	B
Ch. 19	B	B	B	B	B	B	B	B	B	B
Ch. 20	C	B	D	D	A	B	C	B	B	A
Ch. 21	B	B	B	B	B	C	A	B	B	B

Score guide: count your correct answers out of 120. Re-read the notes for every chapter in which you scored less than 7 out of 10.

End of notes. Good luck with your studies — revise regularly, practise the numericals, and check fbise.edu.pk for the current model paper.