PUNJAB | PCTB / PECTAA

10th Class Physics Notes Punjab Board Full Book Notes

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

These notes follow the chapters of the current Punjab Physics book for Class 10 (Chapters 10 to 21), in the order given below.

Prepared for students of the Punjab Boards of Intermediate and Secondary Education.
For the current model paper and official announcements, check your Board's official website.

About These Notes

These notes cover the full Class 10 Physics course of the Punjab Boards, following the current Punjab Curriculum and Textbook Board / Punjab Education Curriculum, Training and Assessment Authority (PCTB/PECTAA) Physics 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, 5 short questions and 2 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 and practise the numericals.
- Revise the key terms of every chapter before the examination.

Chapters in This Book

1. **Chapter 10:** Thermal Physics
2. **Chapter 11:** Transfer of Thermal Energy
3. **Chapter 12:** Waves
4. **Chapter 13:** Sound
5. **Chapter 14:** Light
6. **Chapter 15:** Electrostatics
7. **Chapter 16:** Electricity
8. **Chapter 17:** Electromagnetism
9. **Chapter 18:** Electromagnetic Induction and Electromagnetic Waves
10. **Chapter 19:** Electronics
11. **Chapter 20:** Atomic and Nuclear Physics
12. **Chapter 21:** Space and Environment

A Note on the Book and the Examination Paper

Which book? The chapter list in this book is the current PECTAA book for session 2026-27 (Chapters 10 to 21: Thermal Physics to Space and Environment). The older PCTB edition had 9 units (10 Simple Harmonic Motion and Waves to 18 Atomic and Nuclear Physics); its topics reappear under the new titles, so students with the older book should check their own book's contents page against the list above.

Paper pattern (third-party reproduced, not officially confirmed). The theory paper is commonly reported as 60 marks: 12 MCQs (1 mark each), 15 short questions (2 marks each, 30 marks) and long questions worth 18 marks (attempt any 2 of 3, each 9 marks), with 15 marks for the practical, making 75 marks in total. This pattern is reproduced from third-party pairing-scheme material, NOT from an official PCTB, PECTAA or BISE document, and may change. Check the current model paper on your Board's official website.

Chapter 10: Thermal Physics

Thermal physics is the study of heat and temperature and how they change matter. This chapter explains thermal expansion, temperature scales, specific heat capacity, latent heat, change of state and the unusual behaviour of water, and introduces the idea of heat as a form of energy.

Key Concepts

- Temperature is a measure of the hotness or coldness of a body. Heat is the energy transferred from a hotter body to a colder body because of a temperature difference. Heat is measured in joules (J).
- Most substances expand on heating and contract on cooling. Solids expand least, liquids more, and gases most. Thermal expansion is allowed for in bridges, railway tracks and pipelines, where gaps and expansion joints are provided.
- Linear expansion is the increase in length of a solid on heating. The increase in length depends on the original length, the rise in temperature and the material; different materials expand by different amounts.
- 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.
- The Celsius scale fixes the ice point at 0 degrees C and the steam point at 100 degrees C. The Kelvin scale starts at absolute zero, -273.15 degrees C, the lowest possible temperature. The Fahrenheit scale fixes the ice point at 32 degrees F and the steam point at 212 degrees F.
- Specific heat capacity 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, 4200 J/(kg K), so it is used as a coolant and coastal areas have mild climates.
- When a substance changes state, its temperature stays constant while heat is absorbed or given out. Latent heat of fusion is the heat needed to change 1 kg of a solid into liquid at its melting point without a change in temperature; latent heat of vaporisation is the heat needed to change 1 kg of a liquid into vapour at its boiling point.
- Evaporation is the change of a liquid into vapour from its surface at any temperature. It causes cooling, because the fastest molecules escape and take energy with them. That is why sweat cools the body and an earthen pot (surahi) keeps water cool.
- Water shows anomalous expansion: it contracts when heated from 0 degrees C to 4 degrees C, and has its maximum density at 4 degrees C. This is why ice floats on water and why water in a lake freezes only at the surface in winter, letting fish survive below.
- At very low temperatures some materials lose all electrical resistance. This is called superconductivity. A superconductor can carry current without energy loss, and is used in strong electromagnets such as those in MRI scanners.

Important Definitions

Term	Definition
Temperature	The measure of the hotness or coldness of a body; it decides the direction of heat flow.
Heat	Energy transferred from a hotter body to a colder body because of a temperature difference.
Thermal expansion	The increase in the size of a substance when its temperature rises.
Absolute zero	The lowest possible temperature, 0 K or -273.15 degrees C, at which the motion of particles is minimum.

Specific heat capacity	The heat needed to raise the temperature of 1 kg of a substance by 1 K.
Latent heat of fusion	The heat needed to change 1 kg of a solid into liquid at its melting point without a change in temperature.
Latent heat of vaporisation	The heat needed to change 1 kg of a liquid into vapour at its boiling point without a change in temperature.
Evaporation	The change of a liquid into vapour from its surface at any temperature below its boiling point.
Superconductivity	The complete loss of electrical resistance shown by some materials at very low temperatures.
Bimetallic strip	A strip of two metals with different rates of expansion joined together, which bends on heating.

Important Formulas

> Heat gained or lost: Q = m c (change in temperature)
>
> Linear expansion: change in length = original length x coefficient of linear expansion x temperature change
>
> K = C + 273 (kelvin from Celsius)
>
> C / 100 = (F - 32) / 180
>
> Latent heat: Q = m L, where L is the specific latent heat
>
> Specific heat capacity of water = 4200 J/(kg K); density of water = 1000 kg/m^3
>
> Water has maximum density at 4 degrees C

Key Terms to Remember

temperature, **heat**, **thermal expansion**, **absolute zero**, **specific heat capacity**, **latent heat**, **fusion**, **vaporisation**, **evaporation**, **anomalous expansion of water**, **superconductivity**, **bimetallic strip**

Chapter 10: Thermal Physics — Practice Questions

Multiple Choice Questions

1. The SI unit of heat is:

(a) Watt (b) Calorie (c) Joule (d) Newton

2. Which of the following expands the most on heating?

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

3. Absolute zero is equal to:

(a) 0 degrees C (b) -100 degrees C (c) -273.15 degrees C (d) 273.15 degrees C

4. The specific heat capacity of water is:

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

5. During a change of state, the temperature of the substance:

(a) Rises steadily (b) Falls steadily (c) Becomes zero (d) Stays constant

6. The heat needed to change 1 kg of ice into water at 0 degrees C is called the latent heat of:

(a) Vaporisation (b) Sublimation (c) Condensation (d) Fusion

7. Evaporation causes cooling because:

(a) The liquid freezes (b) Heat is supplied from outside (c) Fast molecules escape taking energy with them (d) Slow molecules escape

8. Water has its maximum density at:

(a) 2 degrees C (b) 0 degrees C (c) 4 degrees C (d) 10 degrees C

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

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

10. A superconductor is a material that at very low temperature has:

(a) Zero resistance (b) Constant resistance (c) Infinite resistance (d) Very high resistance

Short Questions

1. Distinguish between heat and temperature.
2. Why are gaps left between railway tracks and in bridges? Explain with reference to thermal expansion.
3. Define specific heat capacity. Why is water used as a coolant in car radiators?
4. Define latent heat of fusion and latent heat of vaporisation.
5. Explain the anomalous expansion of water and why ice floats on water.

Long Questions

1. Explain thermal expansion in solids, liquids and gases. Describe the construction and working of a bimetallic strip and give two of its uses, and explain why expansion joints are provided in bridges and railway tracks.
2. Define specific heat capacity and latent heat. Describe how the heat gained or lost by a body is calculated, and explain evaporation and why it causes cooling, with daily-life examples.

Chapter 11: Transfer of Thermal Energy

Heat moves from a hotter body to a colder one in three ways: conduction, convection and radiation. This chapter explains each method, the factors that affect them, and how they are used in daily life, in heating systems and in keeping the Earth warm.

Key Concepts

- Conduction is the transfer of heat through a solid by the vibration and collision of particles, without the material itself moving. Metals are good conductors because their free electrons carry heat quickly; wood, plastic and air are poor conductors (insulators).
- The rate of conduction depends on the temperature difference, the area of cross-section, the thickness of the material and the material itself. A thick copper rod conducts heat faster than a thin rod of the same length, and faster than a glass rod.
- Convection is the transfer of heat by the actual movement of a fluid (liquid or gas). When a fluid is heated it expands, becomes less dense and rises; cooler, denser fluid sinks to take its place. This sets up convection currents.
- Convection currents explain the heating of water in a pan, the circulation of air in a room heated by a heater, sea breezes and land breezes, and the movement of air in the atmosphere.
- Radiation is the transfer of heat by electromagnetic waves. It needs no medium and can travel through a vacuum, which is how heat from the Sun reaches the Earth. All hot bodies give out thermal radiation.
- A black, dull surface is a good absorber and a good emitter of radiation, while a white, shiny surface is a poor absorber and a poor emitter but a good reflector. This is why light-coloured clothes are cooler in summer and why a thermos flask has a shiny inner surface.
- Leslie's cube is a metal cube with one black face, one white face, one dull face and one shiny face, filled with hot water. A thermometer placed near each face shows that the black face gives out the most radiation and the shiny face the least.
- The greenhouse effect happens when gases in the atmosphere, such as carbon dioxide, absorb thermal radiation from the Earth and re-emit some of it back downwards, warming the Earth. Without it the Earth would be much colder, but too much greenhouse gas warms the planet more than is safe.
- Good insulation reduces heat loss. Double-glazed windows, woollen clothes, cavity walls and the vacuum in a thermos flask all reduce heat transfer by conduction, convection and radiation.
- A thermos flask reduces heat loss by all three methods: the vacuum between its double walls stops conduction and convection, the shiny walls reduce radiation, and the stopper reduces conduction and convection through the opening.

Important Definitions

Term	Definition
Conduction	Transfer of heat through a solid by the vibration and collision of particles, without movement of the material.
Convection	Transfer of heat by the actual movement of a fluid (liquid or gas).
Radiation	Transfer of heat by electromagnetic waves, which needs no medium.
Conductor	A material that allows heat to pass through it easily, such as a metal.
Insulator	A material that does not allow heat to pass through it easily, such as wood, plastic or air.

Convection current	The circulation of a fluid set up when the hotter, less dense part rises and the cooler, denser part sinks.
Thermal radiation	Electromagnetic waves given out by a hot body, which carry heat energy.
Greenhouse effect	The warming of the Earth caused by gases in the atmosphere absorbing and re-emitting thermal radiation.
Leslie's cube	A cube with faces of different colours and finishes, used to compare how much radiation different surfaces emit.
Insulation	Material or a method used to reduce the transfer of heat.

Important Formulas

> Rate of conduction increases with temperature difference and area, and decreases with thickness
>
> Heat from the Sun reaches the Earth by radiation, through a vacuum
>
> Black dull surface: good absorber and good emitter; white shiny surface: poor absorber, good reflector
>
> Thermos flask: vacuum stops conduction and convection; shiny walls reduce radiation

Key Terms to Remember

conduction, **convection**, **radiation**, **conductor**, **insulator**, **convection current**, **thermal radiation**, **greenhouse effect**, **Leslie's cube**, **thermos flask**, **sea breeze**, **land breeze**

Chapter 11: Transfer of Thermal Energy — Practice Questions

Multiple Choice Questions

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

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

2. Which of the following is the best conductor of heat?

(a) Copper (b) Plastic (c) Wood (d) Air

3. Convection can take place in:

(a) Metals only (b) Solids only (c) Liquids and gases (d) Vacuum

4. Heat from the Sun reaches the Earth by:

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

5. A black dull surface is a:

(a) Poor absorber and poor emitter (b) Good reflector (c) Good absorber and good emitter (d) Poor emitter only

6. A white shiny surface is a:

(a) Good absorber (b) Good emitter (c) Good conductor (d) Good reflector and poor absorber

7. In Leslie's cube, the face that gives out the most radiation is the:

(a) Black face (b) Dull face (c) White face (d) Shiny face

8. The greenhouse effect is caused mainly by gases that:

(a) Block all radiation (b) Reflect sunlight (c) Cool the atmosphere (d) Absorb and re-emit thermal radiation

9. The vacuum in a thermos flask prevents heat loss by:

(a) Conduction and convection (b) Evaporation only (c) Radiation only (d) Conduction only

10. Wool keeps us warm in winter mainly because it:

(a) Reflects heat (b) Absorbs radiation (c) Traps air, which is a poor conductor (d) Produces heat

Short Questions

1. Define conduction, convection and radiation, giving one example of each.
2. Why are cooking pots made of metal while their handles are made of wood or plastic?
3. Explain how convection currents are set up when water in a pan is heated.
4. State the result of Leslie's cube experiment and what it shows about surfaces.
5. What is the greenhouse effect? Why is it important, and why can too much of it be harmful?

Long Questions

1. Explain conduction, convection and radiation with one daily-life example of each. Describe how a thermos flask reduces heat loss by all three methods.
2. Describe the experiment with Leslie's cube and explain what it shows about the emission of radiation from different surfaces. Explain the greenhouse effect and its importance for life on Earth.

Chapter 12: Waves

A wave carries energy from one place to another without carrying matter with it. This chapter explains wave motion, the types of waves, the terms used to describe them, and the behaviour of waves, including the ripple tank.

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 (regions where particles are close together) and rarefactions (regions where particles are spread apart).
- A mechanical wave needs a material medium to travel through, for example sound in air or a wave on a rope. An electromagnetic wave, such as light or a radio wave, can travel through a vacuum.
- The amplitude of a wave is the maximum displacement of a vibrating particle from its mean position. The wavelength is the distance between two consecutive crests, troughs, compressions or rarefactions.
- The time period is the time taken for one complete vibration. The frequency is the number of vibrations per second, measured in hertz (Hz). Frequency and time period are related by f = 1 / T.
- The speed of a wave is given by v = f x wavelength. If the frequency increases while the speed stays the same, the wavelength becomes shorter.
- Simple harmonic motion is a to-and-fro motion in which the acceleration is directly proportional to the displacement from the mean position and is always directed towards it. A mass on a spring and a simple pendulum show simple harmonic motion when the swing is small.
- The time period of a simple pendulum depends on its length and on the acceleration due to gravity, but not on the mass of the bob or on the amplitude (for small swings). A longer pendulum swings more slowly.
- A ripple tank is a shallow tank of water with a light above it. A vibrating bar makes straight waves and a small dipper makes circular waves on the surface. It is used to study reflection, refraction and diffraction of waves.

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 vibrating particle from its mean position.

Wavelength	The distance between two consecutive crests, troughs, compressions or rarefactions.
Time period	The time taken for one complete vibration.
Frequency	The number of vibrations per second; measured in hertz (Hz).
Crest	The highest point of a transverse wave.
Trough	The lowest point of a transverse wave.
Simple harmonic motion	A to-and-fro motion in which the acceleration is proportional to the displacement and always directed towards the mean position.

Important Formulas

> Frequency f = 1 / T, where T is the time period
>
> Wave speed v = f x wavelength
>
> Time period of a simple pendulum T = 2 pi x square root of (l / g)
>
> 1 Hz = 1 vibration per second
>
> Wavelength = wave speed / frequency

Key Terms to Remember

wave, **transverse wave**, **longitudinal wave**, **crest**, **trough**, **compression**, **rarefaction**, **amplitude**, **wavelength**, **frequency**, **time period**, **simple harmonic motion**, **ripple tank**, **mechanical wave**, **electromagnetic wave**

Chapter 12: Waves — Practice Questions

Multiple Choice Questions

1. A wave transfers:

(a) Energy without transferring matter (b) Matter only (c) Both matter and energy (d) Neither matter nor energy

2. In a transverse wave, the particles vibrate:

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

3. Sound is an example of a:

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

4. Light is an example of a:

(a) Sound wave (b) Mechanical wave (c) Longitudinal wave (d) Electromagnetic wave

5. The distance between two consecutive crests is called the:

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

6. The unit of frequency is:

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

7. If the time period of a vibration is 0.5 s, its frequency is:

(a) 5 Hz (b) 0.5 Hz (c) 2 Hz (d) 1 Hz

8. For a wave of frequency 50 Hz and wavelength 2 m, the speed is:

(a) 52 m/s (b) 25 m/s (c) 100 m/s (d) 200 m/s

9. The time period of a simple pendulum depends on its:

(a) Amplitude (b) Mass of the bob (c) Colour of the bob (d) Length

10. A ripple tank is used to study:

(a) Heat transfer (b) Electric current (c) Magnetism (d) Wave behaviour such as reflection and refraction

Short Questions

1. Define a wave. Distinguish between a transverse wave and a longitudinal wave with one example of each.
2. Define amplitude, wavelength, time period and frequency.
3. Write the wave equation v = f x wavelength and use it: find the speed of a wave of frequency 20 Hz and wavelength 3 m.
4. What is simple harmonic motion? Give two examples.
5. What is a ripple tank used for? Name two kinds of waves it can produce.

Long Questions

1. Explain transverse and longitudinal waves with labelled descriptions of their parts. Define amplitude, wavelength, time period and frequency, derive the wave equation v = f x wavelength, and solve: a wave has frequency 100 Hz and wavelength 0.5 m; find its speed and time period.
2. Describe the motion of a simple pendulum and explain why it shows simple harmonic motion for small swings. State the factors on which its time period depends, and describe how a ripple tank is used to study waves.

Chapter 13: Sound

Sound is produced by a vibrating body and travels as a longitudinal wave through a material medium. This chapter explains how sound is produced and heard, its characteristics, echo, the speed of sound and the uses of ultrasound.

Key Concepts

- Sound is produced by a vibrating body. When a drum is struck, its skin vibrates; when a string is plucked, it vibrates. The vibrations travel through the surrounding medium as a longitudinal wave.
- Sound needs a material medium (solid, liquid or gas) to travel. 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 340 m/s at ordinary temperature. It increases with temperature: sound travels faster in warm air than in cold air.
- Loudness depends on the amplitude of the vibration: a larger amplitude makes a louder sound. Pitch depends on the frequency: a higher frequency gives a higher-pitched (shriller) sound. Quality (timbre) depends on the shape of the wave and lets us tell one musical instrument from another.
- An echo is the reflection of sound from a distant surface. It is heard when the reflected sound reaches the ear a short time after the direct sound. Echoes are used to measure the depth of the sea and the distance of a wall.
- The distance to a reflecting surface can be found from the time between the sound and its echo: distance = (speed of sound x time) / 2, because the sound travels to the surface and back.
- Noise pollution is unwanted, unpleasant sound, for example from traffic, loudspeakers and machines. It can damage hearing, disturb sleep and cause stress. It is reduced by silencers, sound-proof walls and by limiting the use of horns and loudspeakers.
- The audible frequency range for a normal human ear is about 20 Hz to 20,000 Hz. Sounds below 20 Hz are called infrasound and sounds above 20,000 Hz are called ultrasound.
- Ultrasound is used in medicine to make images of the inside of the body (ultrasound scan), in industry to detect cracks in metal, and by bats and in SONAR to find the position of objects under water.
- Acoustics is the study of sound. Good acoustics in a hall means that sound can be heard clearly everywhere in it. Soft materials on walls absorb sound and reduce echoes, while a curved ceiling can focus sound.

Important Definitions

Term	Definition
Sound	A form of energy produced by a vibrating body, travelling as a longitudinal wave through a medium.
Echo	The reflection of sound from a distant surface, heard after the direct sound.
Loudness	The characteristic of sound that depends on the amplitude of vibration; a larger amplitude gives a louder sound.
Pitch	The characteristic of sound that depends on its frequency; a higher frequency gives a higher pitch.

Quality (timbre)	The characteristic of sound that lets us distinguish between two sounds of the same loudness and pitch.
Ultrasound	Sound of frequency above 20,000 Hz, beyond the range of human hearing.
Infrasound	Sound of frequency below 20 Hz, below the range of human hearing.
Noise pollution	Unwanted and unpleasant sound that harms health and disturbs people.
SONAR	A system that uses ultrasound echoes to find the position and depth of objects under water.
Acoustics	The study of the production, properties and effects of sound, including sound in buildings.

Important Formulas

> Speed of sound in air is about 340 m/s
>
> Distance to a reflecting surface = (speed of sound x time for echo) / 2
>
> Loudness depends on amplitude; pitch depends on frequency
>
> Audible range: about 20 Hz to 20,000 Hz
>
> v = f x wavelength (for sound waves too)

Key Terms to Remember

sound, **vibration**, **longitudinal wave**, **echo**, **loudness**, **pitch**, **quality**, **ultrasound**, **infrasound**, **noise pollution**, **SONAR**, **acoustics**, **audible range**

Chapter 13: Sound — Practice Questions

Multiple Choice Questions

1. Sound is produced by a:

(a) Hot body (b) Magnetic body (c) Vibrating body (d) Still body

2. Sound cannot travel through a:

(a) Liquid (b) Gas (c) Solid (d) Vacuum

3. Sound travels fastest in:

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

4. The speed of sound in air is about:

(a) 150 m/s (b) 1500 m/s (c) 300,000 km/s (d) 340 m/s

5. Loudness of sound depends on its:

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

6. Pitch of sound depends on its:

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

7. The audible frequency range for humans is about:

(a) 0 to 200,000 Hz (b) 20 Hz to 20,000 Hz (c) 20,000 Hz to 200,000 Hz (d) 0 to 20 Hz

8. Sounds of frequency above 20,000 Hz are called:

(a) Echo (b) Noise (c) Infrasound (d) Ultrasound

9. An echo is the:

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

10. SONAR uses:

(a) Light waves (b) Heat waves (c) Ultrasound echoes (d) Radio waves

Short Questions

1. How is sound produced? Why can sound not travel through a vacuum?
2. State the speeds of sound in air, water and iron in order, and explain why sound travels fastest in solids.
3. Distinguish between loudness, pitch and quality of sound.
4. What is an echo? How is it used to measure the depth of the sea?
5. Define ultrasound and give three of its uses.

Long Questions

1. Explain how sound is produced and how it travels through air as a longitudinal wave. Describe the characteristics of sound (loudness, pitch and quality) and state the factors on which each depends.
2. Define an echo. Derive the formula for finding the distance of a reflecting surface from the time of the echo, and solve: a sound is heard as an echo 2 seconds after it was made; find the distance of the wall if the speed of sound is 340 m/s. Also explain noise pollution and how it can be reduced.

Chapter 14: Light

Light is the form of energy that lets us see. This chapter covers reflection and refraction, mirrors and lenses, total internal reflection, optical instruments, the human eye and its defects, and the nature of light.

Key Concepts

- Light travels in straight lines and in a vacuum at a speed of about 3 x 10^8 m/s. It is an electromagnetic wave and needs no medium. Light from the Sun takes about 8 minutes to reach the Earth.
- The laws of reflection are: the incident ray, the reflected ray and the normal all lie in the same plane; and the angle of incidence is equal to the angle of reflection.
- A plane mirror forms an image that is the same size as the object, upright, laterally inverted (left and right are swapped) and as far behind the mirror as the object is in front of it.
- A concave mirror converges light and can form a real, inverted image or a virtual, upright, magnified image, depending on the position of the object. It is used in shaving mirrors, headlights and solar furnaces.
- A convex mirror diverges light and always forms a virtual, upright, diminished image. It is used as a rear-view mirror in vehicles because it gives a wide field of view.
- 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.
- The laws of refraction include Snell's law: the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a pair of media. The refractive index of a medium is the ratio of the speed of light in a vacuum to its speed in the medium.
- Total internal reflection happens when light travels from a denser to a rarer medium and the angle of incidence is greater than the critical angle. It is used in optical fibres, which carry light signals over long distances, and in the sparkling of a diamond.
- A convex lens converges light to a focus and can form real or virtual images. It is used as a magnifying glass, in cameras and in correcting long-sight. A concave lens diverges light and always forms a virtual, upright, diminished image; it is used in correcting short-sight.
- The human eye focuses light on the retina with the help of the eye lens, whose shape is changed by the ciliary muscles. Short-sight (myopia) is corrected with a concave lens and long-sight (hypermetropia) with a convex lens.
- The simple microscope uses one convex lens to give a magnified virtual image. The compound microscope uses two convex lenses (objective and eyepiece) for much greater magnification. A telescope uses lenses to make distant objects look closer and larger.
- The mirror formula is 1/f = 1/v + 1/u, and the lens formula is the same in form. Here f is the focal length, u the object distance and v the image distance.

Important Definitions

Term	Definition
Reflection	The bouncing back of light from a surface into the same medium.
Refraction	The bending of light when it passes from one medium into another because its speed changes.
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.

Refractive index	The ratio of the speed of light in a vacuum to its speed in a medium.
Critical angle	The angle of incidence in a denser medium for which the angle of refraction in the rarer medium 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 principal focus of a mirror or lens.
Real image	An image that can be formed on a screen, made by rays that actually meet.
Virtual image	An image that cannot be formed on a screen, made by rays that only appear to meet.

Important Formulas

> Speed of light in a vacuum c = 3 x 10^8 m/s
>
> Angle of incidence = angle of reflection
>
> Snell's law: sin i / sin r = constant (refractive index)
>
> Mirror formula: 1/f = 1/v + 1/u
>
> Lens formula: 1/f = 1/v - 1/u (with sign convention)
>
> Magnification m = height of image / height of object = v / u
>
> Refractive index n = speed of light in vacuum / speed of light in the medium

Key Terms to Remember

reflection, **refraction**, **plane mirror**, **concave mirror**, **convex mirror**, **lens**, **refractive index**, **critical angle**, **total internal reflection**, **optical fibre**, **myopia**, **hypermetropia**, **microscope**, **telescope**

Chapter 14: Light — Practice Questions

Multiple Choice Questions

1. The speed of light in a vacuum is about:

(a) 3 x 10^6 m/s (b) 1500 m/s (c) 340 m/s (d) 3 x 10^8 m/s

2. The angle of incidence is equal to the:

(a) Angle of refraction (b) Angle of deviation (c) Critical angle (d) Angle of reflection

3. The image formed by a plane mirror is:

(a) Virtual, upright and the same size as the object (b) Real and magnified (c) Real and inverted (d) Virtual and diminished

4. A concave mirror is used as a:

(a) Street light reflector (b) Periscope mirror (c) Rear-view mirror (d) Shaving mirror

5. A convex mirror is used as a:

(a) Shaving mirror (b) Magnifying mirror (c) Rear-view mirror in vehicles (d) Solar furnace mirror

6. Refraction happens because light:

(a) Is reflected (b) Slows to zero (c) Is absorbed (d) Changes speed when it enters another medium

7. Total internal reflection can happen when light travels from:

(a) Vacuum to glass (b) Glass to vacuum at a small angle (c) Air to water (d) Water to air at a large angle of incidence

8. Optical fibres work on the principle of:

(a) Refraction (b) Dispersion (c) Total internal reflection (d) Reflection

9. Short-sight is corrected with a:

(a) Concave lens (b) Prism (c) Convex lens (d) Plane mirror

10. Long-sight is corrected with a:

(a) Convex lens (b) Concave mirror (c) Concave lens (d) Plane glass

Short Questions

1. State the laws of reflection.
2. Describe the image formed by a plane mirror.
3. Define refraction and state Snell's law.
4. What is total internal reflection? State its two conditions and give two uses.
5. How are short-sight and long-sight corrected? Name the lens used in each case.

Long Questions

1. Explain reflection from a concave mirror. Describe, with the help of ray diagrams described in words, the images formed when an object is (a) beyond the centre of curvature, (b) at the focus, and (c) between the pole and the focus, and state two uses of a concave mirror.
2. Explain refraction of light and derive Snell's law in words. Define the critical angle and total internal reflection, and describe the construction and working of an optical fibre and its uses.

Chapter 15: Electrostatics

Electrostatics is the study of electric charges at rest. This chapter explains how charges are produced, the forces between them, the electric field, electric potential and capacitors, and the uses and dangers of static electricity.

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.
- Charges can be produced by friction (rubbing), for example by rubbing a plastic rod with fur or a glass rod with silk. The rod that is rubbed gains or loses electrons.
- Electrostatic induction is the process by which a charged body causes charges to separate in a nearby uncharged conductor without touching it. The near end gets the opposite charge and the far end gets the same charge as the inducing body.
- A gold-leaf electroscope is used to detect charge, to find whether a charge is positive or negative, and to test whether a material is a conductor or an insulator.
- 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 electric field intensity at a point is the force per unit positive charge placed at that point. Field lines leave a positive charge and enter a negative charge.
- Electric potential at a point is the work done in bringing a unit positive charge from infinity to that point. Its SI unit is the volt (V). The potential difference between two points is the work done in moving a unit charge between them.
- A capacitor is a device that stores electric charge and energy. It consists of two conducting plates separated by an insulator (dielectric). Its capacitance is the charge stored per unit potential difference: C = Q / V. The SI unit of capacitance is the farad (F).
- Capacitors in parallel add their capacitances (C = C1 + C2 + ...), so the total capacitance increases. Capacitors in series store the same charge, and the total capacitance is smaller than the smallest one (1/C = 1/C1 + 1/C2 + ...).
- Static electricity is useful in photocopiers, spray painting and removing dust from air, but it can also be dangerous: a spark from static charge can cause a fire or an explosion, so fuel tankers are earthed with a metal chain.
- Lightning is a huge spark caused by the build-up of static charge in clouds. A lightning conductor protects a building by giving the charge a safe path to the Earth.

Important Definitions

Term	Definition
Electric charge	A property of matter that causes it to feel electric forces; there are positive and negative charges.
Coulomb's law	The force between two point charges is 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 experiences a force.
Electric field intensity	The force per unit positive charge placed at a point in an electric field; its unit is N/C.
Electric potential	The work done in bringing a unit positive charge from infinity to a point; its unit is the volt.
Potential difference	The work done in moving a unit positive charge between two points; its unit is the volt.
Capacitor	A device that stores electric charge and energy, made of two conductors separated by an insulator.
Capacitance	The charge stored by a capacitor per unit potential difference (C = Q / V); its unit is the farad.
Dielectric	The insulating material between the plates of a capacitor.
Electrostatic induction	The separation of charges in a conductor caused by a nearby charged body without contact.

Important Formulas

> Coulomb's law: F = k q1 q2 / r^2
>
> Electric field intensity E = F / q
>
> Potential difference V = W / Q
>
> Capacitance C = Q / V
>
> Capacitors in parallel: C = C1 + C2 + C3 + ...
>
> Capacitors in series: 1/C = 1/C1 + 1/C2 + 1/C3 + ...
>
> Energy stored in a capacitor = (1/2) C V^2
>
> 1 volt = 1 joule per coulomb

Key Terms to Remember

electric charge, **positive charge**, **negative charge**, **Coulomb's law**, **electric field**, **electric potential**, **volt**, **capacitor**, **capacitance**, **farad**, **dielectric**, **electroscope**, **electrostatic induction**, **lightning conductor**

Chapter 15: Electrostatics — Practice Questions

Multiple Choice Questions

1. Like charges:

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

2. A body becomes negatively charged when it:

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

3. The SI unit of charge is the:

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

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

(a) Sum of the charges (b) Product of the charges (c) Distance (d) Square of the distance

5. Electric field lines leave a:

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

6. The SI unit of electric potential is the:

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

7. A capacitor stores:

(a) Power (b) Current (c) Charge and energy (d) Resistance

8. The SI unit of capacitance is the:

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

9. Capacitors in parallel have a total capacitance that is:

(a) Equal to the largest (b) Equal to the sum of the capacitances (c) Smaller than the smallest (d) Zero

10. A lightning conductor protects a building by:

(a) Reflecting the light (b) Absorbing the rain (c) Giving the charge a safe path to the Earth (d) Stopping lightning

Short Questions

1. State the law of attraction and repulsion of electric charges.
2. How does a body become positively or negatively charged?
3. State Coulomb's law and write its mathematical form.
4. Define electric field intensity and electric potential. State their SI units.
5. Define a capacitor and capacitance. State the unit of capacitance.

Long Questions

1. State and explain Coulomb's law. Describe the factors on which the force between two charges depends, and solve: find the force between two charges of 2 microcoulomb and 3 microcoulomb placed 10 cm apart in air (k = 9 x 10^9 N m^2/C^2). Explain why the charges used in laboratory experiments are so small.
2. Describe the construction and working of a gold-leaf electroscope and explain how it is used to detect charge and to find its sign. Explain electrostatic induction with an example, and describe two uses and two dangers of static electricity.

Chapter 16: Electricity

Electricity is the flow of electric charge through a conductor. This chapter explains electric current, potential difference, resistance, Ohm's law, series and parallel circuits, and electric power and energy, including the cost of electricity in the home.

Key Concepts

- Electric current is the rate of flow of charge through a conductor: I = Q / t. Its SI unit is the ampere (A). Conventional current flows from the positive terminal to the negative terminal, while electrons actually flow in the opposite direction.
- Potential difference (voltage) between two points is the work done in moving a unit charge between them: V = W / Q. Its SI unit is the volt (V). A cell or battery provides the potential difference that drives the current.
- Electromotive force (e.m.f.) is the energy supplied by a cell per unit charge. It is the potential difference across the terminals of a cell when no current is drawn from it.
- Resistance is the opposition offered by a conductor to the flow of current. Its SI unit is the ohm. Resistance depends on the length, cross-sectional area, material and temperature of the conductor: a longer wire has more resistance, a thicker wire has less.
- Ohm's law states that the current through a conductor is directly proportional to the potential difference across it, provided the temperature stays constant: V = IR.
- An ohmic conductor, such as a metal wire at constant temperature, obeys Ohm's law and its V-I graph is a straight line. A non-ohmic conductor, such as a filament lamp, does not obey Ohm's law because its resistance changes with temperature.
- In a series circuit the same current flows through all components, the total resistance is the sum of the resistances (R = R1 + R2 + ...), and the total voltage is shared between the components.
- In a parallel circuit the same potential difference is across each component, the total current is the sum of the branch currents, 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). The electrical energy used is E = P x t, and the commercial unit is the kilowatt-hour (kWh), the unit on which electricity bills are based.
- In the home, appliances are connected in parallel so that each gets the full mains voltage and can be switched on and off independently. A fuse or circuit breaker protects the circuit: it melts or trips when the current is too large, breaking the circuit before the wires overheat.

Important Definitions

Term	Definition
Electric current	The rate of flow of charge through a conductor (I = Q / t); its unit is the ampere.
Ampere	The SI unit of current; one ampere is one coulomb per second.
Potential difference	The work done in moving a unit charge between two points (V = W / Q); its unit is the volt.
Electromotive force (e.m.f.)	The energy supplied by a cell per unit charge; the potential difference across a cell on open circuit.
Resistance	The opposition offered by a conductor to the flow of current; its unit is the ohm.

Ohm's law	The current through a conductor is directly proportional to the potential difference across it, at constant temperature (V = IR).
Ohmic conductor	A conductor that obeys Ohm's law, such as a metal wire at constant temperature.
Series circuit	A circuit in which components are connected one after another so the same current flows through each.
Parallel circuit	A circuit in which components are connected across the same two points so each has the same potential difference.
Electric power	The rate at which electrical energy is used (P = VI); its unit is the watt.

Important Formulas

> Current I = Q / t
>
> Potential difference V = W / Q
>
> Ohm's law: V = IR
>
> Resistors in series: R = R1 + R2 + R3 + ...
>
> Resistors in parallel: 1/R = 1/R1 + 1/R2 + 1/R3 + ...
>
> Electric power P = VI = I^2 R = V^2 / R
>
> Electrical energy E = P x t; 1 kWh = 3.6 x 10^6 J
>
> Resistance of a wire R = (resistivity x length) / area

Key Terms to Remember

electric current, **ampere**, **potential difference**, **volt**, **e.m.f.**, **resistance**, **ohm**, **Ohm's law**, **ohmic conductor**, **series circuit**, **parallel circuit**, **electric power**, **kilowatt-hour**, **fuse**, **circuit breaker**

Chapter 16: Electricity — Practice Questions

Multiple Choice Questions

1. The SI unit of electric current is the:

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

2. Current is defined as:

(a) Charge x time (b) Charge / time (c) Work / charge (d) Voltage x resistance

3. The SI unit of potential difference is the:

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

4. Ohm's law is stated as:

(a) I = VR (b) P = VI (c) R = VI (d) V = IR

5. The resistance of a wire increases when its:

(a) Length increases (b) Length decreases (c) Temperature decreases (d) Area increases

6. In a series circuit, the same quantity flows through all components is:

(a) Voltage (b) Resistance (c) Power (d) Current

7. In a parallel circuit, the same quantity across all components is:

(a) Resistance (b) Current (c) Charge (d) Potential difference

8. Three resistors of 2 ohm each in series have a total resistance of:

(a) 0.67 ohm (b) 2 ohm (c) 4 ohm (d) 6 ohm

9. Electric power is given by:

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

10. One kilowatt-hour is equal to:

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

Short Questions

1. Define electric current and potential difference. State their SI units.
2. Define resistance and state the factors on which the resistance of a wire depends.
3. State Ohm's law and write its mathematical form.
4. Distinguish between a series circuit and a parallel circuit.
5. Define electric power. A 100 W bulb is used for 5 hours; how much energy does it use in kWh?

Long Questions

1. State and explain Ohm's law. Describe an experiment to verify Ohm's law using a voltmeter and an ammeter, draw the V-I graph for an ohmic conductor, and explain why a filament lamp is a non-ohmic conductor.
2. Explain series and parallel combinations of resistors with the formulas for total resistance in each case. Solve: two resistors of 4 ohm and 6 ohm are connected (a) in series and (b) in parallel across a 10 V battery; find the total resistance and the current drawn in each case. Also explain why home appliances are connected in parallel.

Chapter 17: Electromagnetism

A current-carrying conductor produces a magnetic field, and a magnet can exert a force on a current-carrying conductor. This chapter explains the magnetic effect of current, the force on a conductor in a magnetic field, the electric motor, electromagnetic induction and the transformer.

Key Concepts

- Oersted discovered that an electric current produces a magnetic field around the conductor. A compass needle placed near a wire carrying current is deflected, showing that a magnetic field is present.
- The magnetic field around a straight wire carrying current is in the form of concentric circles around the wire. The direction of the field is given by the right-hand rule: if the thumb points in the direction of the current, the curled fingers show the direction of the field.
- A solenoid is a long coil of wire. When current flows through it, it behaves like a bar magnet, with a north pole at the end where the current flows anticlockwise. Its magnetic field is strong and nearly uniform inside the coil.
- An electromagnet is a solenoid with a soft iron core. Its strength can be increased by increasing the current or the number of turns, and it can be switched off by switching off the current. Electromagnets are used in cranes, electric bells and relays.
- A current-carrying conductor placed in a magnetic field feels a force. The direction of the force is given by Fleming's left-hand rule: the thumb shows the force, the first finger the field and the second finger the current, when the three are held at right angles.
- The force on a conductor is greatest when the current is at right angles to the magnetic field, and zero when the current is parallel to the field. The force increases with the current and with the strength of the magnetic field.
- A simple d.c. motor works on the force on a current-carrying coil in a magnetic field. The coil turns, and a split-ring 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 e.m.f.) in a coil when the magnetic field through it changes. It was discovered by Faraday. Moving a magnet into or out of a coil, or changing the current in a nearby coil, induces a current.
- Faraday's law states that the induced e.m.f. is proportional to the rate of change of the magnetic field through the coil. Lenz's law states that the induced current flows in a direction that opposes the change that produced it.
- An a.c. generator converts mechanical energy into electrical energy by rotating a coil in a magnetic field. The induced e.m.f. reverses direction every half-turn, giving alternating current. A d.c. generator uses a split-ring commutator to give current in one direction only.
- A transformer changes the voltage of alternating current. It has a primary coil and a secondary coil wound on the same iron core. A step-up transformer increases the voltage and a step-down transformer decreases it. Transformers work only on a.c., not on d.c.
- High-voltage transmission is used to send electricity over long distances: raising the voltage lowers the current for the same power, which greatly reduces the energy lost as heat in the transmission lines.

Important Definitions

Term	Definition
Electromagnetism	The study of the magnetic effects of electric current and the electric effects of changing magnetic fields.

Solenoid	A long coil of wire which behaves like a magnet when current flows through it.
Electromagnet	A temporary magnet made by passing current through a coil wound on a soft iron core.
Fleming's left-hand rule	A rule giving the direction of the force on a current-carrying conductor in a magnetic field.
Electromagnetic induction	The production of an induced e.m.f. and current in a coil when the magnetic field through it changes.
Induced e.m.f.	The e.m.f. produced in a coil by a changing 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 (more turns in the secondary coil than in the primary).
Step-down transformer	A transformer that decreases the voltage (fewer turns in the secondary coil than in the primary).
Alternating current (a.c.)	Current that reverses its direction repeatedly, as in the mains supply.

Important Formulas

> Force on a conductor F = B I L (when the current is at right angles to the field)
>
> Transformer equation: Vs / Vp = Ns / Np
>
> For an ideal transformer: Vp x Ip = Vs x Is (power in = power out)
>
> Frequency of mains a.c. supply is 50 Hz in Pakistan
>
> Induced e.m.f. is proportional to the rate of change of magnetic flux

Key Terms to Remember

Oersted, **solenoid**, **electromagnet**, **Fleming's left-hand rule**, **d.c. motor**, **commutator**, **electromagnetic induction**, **Faraday's law**, **Lenz's law**, **a.c. generator**, **transformer**, **step-up transformer**, **step-down transformer**

Chapter 17: Electromagnetism — Practice Questions

Multiple Choice Questions

1. The magnetic effect of electric current was discovered by:

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

2. The magnetic field around a straight current-carrying wire is in the form of:

(a) Squares (b) Ellipses (c) Straight lines (d) Concentric circles

3. A solenoid with a soft iron core is called an:

(a) Compass (b) Electromagnet (c) Permanent magnet (d) Bar magnet

4. The strength of an electromagnet can be increased by:

(a) Increasing the current and the number of turns (b) Using a steel core (c) Decreasing the current (d) Decreasing the number of turns

5. The direction of the force on a current-carrying conductor in a magnetic field is given by:

(a) Lenz's law (b) Fleming's right-hand rule (c) Right-hand grip rule (d) Fleming's left-hand rule

6. A d.c. motor converts:

(a) Chemical energy into heat (b) Heat into light (c) Mechanical energy into electrical energy (d) Electrical energy into mechanical energy

7. Electromagnetic induction was discovered by:

(a) Edison (b) Faraday (c) Maxwell (d) Oersted

8. The induced current flows in a direction that opposes the change producing it. This is:

(a) Coulomb's law (b) Lenz's law (c) Faraday's law (d) Ohm's law

9. A transformer works on:

(a) Both a.c. and d.c. (b) A.C. only (c) D.C. only (d) Neither a.c. nor d.c.

10. A step-up transformer has:

(a) No iron core (b) Fewer turns in the secondary coil (c) More turns in the secondary coil than in the primary (d) Equal turns in both coils

Short Questions

1. Describe Oersted's experiment and state what it shows.
2. Define a solenoid and an electromagnet. State two factors that increase the strength of an electromagnet.
3. State Fleming's left-hand rule.
4. What is electromagnetic induction? State Faraday's law and Lenz's law.
5. What is a transformer? Distinguish between a step-up and a step-down transformer.

Long Questions

1. Describe the construction and working of a simple d.c. motor. Explain the role of the split-ring commutator and state two uses of electric motors.
2. Explain electromagnetic induction with an experiment. State Faraday's law and Lenz's law, describe the construction and working of an a.c. generator, and explain why a transformer works only on alternating current.

Chapter 18: Electromagnetic Induction and Electromagnetic Waves

Changing magnetic fields produce electricity, and changing electric fields produce magnetic fields. Together they form electromagnetic waves that travel through space at the speed of light. This chapter explains induction in more depth and the whole electromagnetic spectrum.

Key Concepts

- When the magnetic flux through a coil changes, an e.m.f. is induced in the coil. The magnetic flux is the product of the magnetic field strength and the area through which it passes.
- The induced e.m.f. is larger when the magnet moves faster, when the coil has more turns, and when a stronger magnet is used. If the circuit is closed, an induced current flows.
- Mutual induction happens when a changing current in one coil induces an e.m.f. in a nearby coil. This is the principle on which a transformer works: the changing current in the primary coil induces a voltage in the secondary coil.
- Self-induction happens when a changing current in a coil induces an e.m.f. in the same coil. The induced e.m.f. opposes the change in the current, so a coil resists sudden changes in current.
- An inductor is a coil that stores energy in its magnetic field. Inductors are used in circuits to smooth current, in filters, and in transformers.
- Maxwell showed that a changing electric field produces a magnetic field and a changing magnetic field produces an electric field. The two travel together as an electromagnetic wave, which needs no medium and travels at the speed of light in a vacuum, 3 x 10^8 m/s.
- In an electromagnetic wave the electric and magnetic fields vibrate at right angles to each other and at right angles to the direction in which the wave travels. The wave carries energy from one place to another.
- The electromagnetic spectrum, in order of increasing frequency, is: radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X-rays and gamma rays. All travel at the same speed in a vacuum but have different wavelengths.
- Radio waves are used for radio, television and mobile phones. Microwaves are used in microwave ovens and in satellite communication. Infrared rays are used in remote controls, night-vision cameras and for heating.
- Visible light is the small part of the spectrum our eyes can see. Ultraviolet rays come from the Sun and can damage skin; X-rays pass through soft tissue and are used in medicine; gamma rays are the most energetic and are used in cancer treatment and in sterilising medical equipment.

Important Definitions

Term	Definition
Magnetic flux	The product of the magnetic field strength and the area through which the field passes.
Mutual induction	The production of an induced e.m.f. in one coil by a changing current in a nearby coil.
Self-induction	The production of an induced e.m.f. in a coil by a change in its own current.
Inductor	A coil that stores energy in its magnetic field and opposes changes in current.
Electromagnetic wave	A wave of electric and magnetic fields travelling through space at the speed of light, needing no medium.

Electromagnetic spectrum	The full range of electromagnetic waves, from radio waves to gamma rays, in order of frequency.
Radio waves	The longest-wavelength electromagnetic waves, used for radio, television and mobile communication.
Microwaves	Electromagnetic waves of shorter wavelength than radio waves, used in ovens and satellite links.
Infrared rays	Electromagnetic waves just below visible light, felt as heat, used in remote controls and night vision.
X-rays	High-energy electromagnetic waves that pass through soft tissue, used in medical imaging.

Important Formulas

> Induced e.m.f. is proportional to the rate of change of magnetic flux
>
> Transformer equation: Vs / Vp = Ns / Np
>
> Speed of all electromagnetic waves in a vacuum c = 3 x 10^8 m/s
>
> Wave equation for electromagnetic waves: c = f x wavelength
>
> Order of the spectrum: radio, microwave, infrared, visible, ultraviolet, X-ray, gamma (increasing frequency)

Key Terms to Remember

magnetic flux, **mutual induction**, **self-induction**, **inductor**, **electromagnetic wave**, **electromagnetic spectrum**, **radio waves**, **microwaves**, **infrared rays**, **ultraviolet rays**, **X-rays**, **gamma rays**

Chapter 18: EM Induction and EM Waves — Practice Questions

Multiple Choice Questions

1. An e.m.f. is induced in a coil when:

(a) The coil is at rest in a steady field (b) The coil is made of copper (c) The magnetic field through it changes (d) The coil is short-circuited

2. The induced e.m.f. increases when the magnet moves:

(a) Sideways only (b) Faster (c) Not at all (d) More slowly

3. Mutual induction is the principle of the:

(a) Transformer (b) Electric motor (c) Battery (d) Fuse

4. An electromagnetic wave travels in a vacuum at:

(a) 3 x 10^8 m/s (b) 1500 m/s (c) 340 m/s (d) 3 x 10^6 m/s

5. In an electromagnetic wave, the electric and magnetic fields vibrate:

(a) Not at all (b) Along the direction of travel (c) In the same direction (d) At right angles to each other

6. Which has the longest wavelength in the electromagnetic spectrum?

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

7. Microwaves are used in:

(a) Sunbeds (b) Sterilising equipment (c) Microwave ovens and satellite communication (d) Medical imaging

8. Infrared rays are used in:

(a) Radio broadcasts (b) Remote controls and night-vision cameras (c) Cancer treatment (d) X-ray imaging

9. X-rays are used in medicine because they:

(a) Pass through soft tissue but not bone (b) Carry sound (c) Are the longest waves (d) Are visible

10. Gamma rays have the:

(a) Lowest frequency (b) Highest frequency and energy (c) Longest wavelength (d) Slowest speed

Short Questions

1. Define magnetic flux. On what factors does the induced e.m.f. in a coil depend?
2. Distinguish between mutual induction and self-induction.
3. What is an electromagnetic wave? State its speed in a vacuum.
4. List the electromagnetic spectrum in order of increasing frequency.
5. Name one use of each part of the electromagnetic spectrum.

Long Questions

1. Explain electromagnetic induction and mutual induction. Describe an experiment showing an induced e.m.f. when a magnet moves into a coil, and explain how a transformer uses mutual induction.
2. List the electromagnetic spectrum in order of frequency and give uses and dangers of four of its parts.

Chapter 19: Electronics

Electronics is the study of devices that control the flow of electrons. This chapter explains thermionic emission, the cathode-ray oscilloscope, semiconductors, diodes, transistors and logic gates, and how they are used in computers and other devices.

Key Concepts

- Thermionic emission is the giving out of electrons from a heated metal surface. When a metal filament is heated, its electrons gain enough energy to escape from the surface.
- In an electron gun, a heated cathode gives out electrons, which are then accelerated by a positive anode and focused into a narrow beam. The beam can be deflected by electric or magnetic fields.
- Cathode rays are streams of fast-moving electrons. They travel in straight lines, carry negative charge, are deflected by electric and magnetic fields, and make a fluorescent screen glow where they strike it.
- The cathode-ray oscilloscope (CRO) uses an electron beam to show a waveform on a screen. It is used to measure voltage, time period and frequency, and to display the shape of a wave, for example a sound wave or an a.c. waveform.
- A semiconductor is a material, such as silicon or germanium, whose electrical 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).
- Doping silicon with a pentavalent element (such as phosphorus) gives an n-type semiconductor, which has extra free electrons. Doping with a trivalent element (such as boron) gives a p-type semiconductor, which has holes (missing electrons) that behave like positive charges.
- A p-n junction diode is made by joining p-type and n-type semiconductors. It allows current to flow easily in one direction (forward bias) and almost not at all in the opposite direction (reverse bias). Diodes are used as rectifiers, which change a.c. into d.c.
- A transistor is a semiconductor device with three parts: the emitter, the base and the collector. It can be used as a switch and as an amplifier: a small current in the base controls a larger current between the emitter and the collector.
- An amplifier increases the strength of a weak signal, for example in a radio or a hearing aid. A transistor as a switch is the basis of digital electronics and computers, where it is either on or off.
- Logic gates are the building blocks of digital circuits. An AND gate gives an output of 1 only when both inputs are 1. An OR gate gives 1 when at least one input is 1. A NOT gate reverses its input. NAND and NOR gates are combinations of these with a NOT gate.
- The integrated circuit (chip) packs thousands or millions of transistors and other components onto a tiny piece of silicon. It is used in computers, mobile phones, televisions and almost every modern electronic device.
- Analogue signals vary continuously, like the sound from a microphone. Digital signals have only two values, 0 and 1. Digital circuits are used in computers because they are fast, reliable and easy to store and copy.

Important Definitions

Term	Definition
Thermionic emission	The giving out of electrons from a heated metal surface.
Cathode rays	Streams of fast-moving electrons given out from a heated cathode.

Cathode-ray oscilloscope (CRO)	An instrument that uses an electron beam to display waveforms on a screen.
Semiconductor	A material whose conductivity is between that of a conductor and an insulator, such as silicon.
Doping	Adding a small amount of another element to a semiconductor to increase its conductivity.
n-type semiconductor	A semiconductor doped to have extra free electrons as charge carriers.
p-type semiconductor	A semiconductor doped to have holes as charge carriers.
Diode	A semiconductor device that allows current to flow in one direction only.
Transistor	A semiconductor device used as a switch or an amplifier, with emitter, base and collector.
Logic gate	A digital circuit that gives an output based on the logical combination of its inputs.

Important Formulas

> Diode: conducts in forward bias, blocks in reverse bias
>
> Transistor as amplifier: a small base current controls a larger collector current
>
> AND gate: output 1 only when both inputs are 1
>
> OR gate: output 1 when at least one input is 1
>
> NOT gate: output is the opposite of the input
>
> NAND gate = AND followed by NOT; NOR gate = OR followed by NOT

Key Terms to Remember

thermionic emission, **electron gun**, **cathode rays**, **CRO**, **semiconductor**, **doping**, **n-type**, **p-type**, **diode**, **rectifier**, **transistor**, **amplifier**, **logic gate**, **integrated circuit**, **analogue signal**, **digital signal**

Chapter 19: Electronics — Practice Questions

Multiple Choice Questions

1. Thermionic emission is the giving out of:

(a) Electrons from a heated metal (b) Neutrons (c) Light from a cold metal (d) Protons

2. Cathode rays are streams of:

(a) Protons (b) Electrons (c) Neutrons (d) Photons

3. A CRO is used to:

(a) Display waveforms and measure voltage and frequency (b) Measure temperature (c) Detect magnetism (d) Measure mass

4. Silicon is an example of a:

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

5. An n-type semiconductor has extra:

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

6. A p-type semiconductor has as its main charge carriers:

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

7. A diode allows current to flow:

(a) In neither direction (b) In one direction only (c) Only in reverse bias (d) In both directions equally

8. A rectifier is used to change:

(a) Voltage into current (b) Heat into light (c) D.C. into a.c. (d) A.C. into d.c.

9. A transistor can be used as a:

(a) Switch and an amplifier (b) Motor (c) Battery (d) Fuse

10. An AND gate gives an output of 1 when:

(a) Both inputs are 1 (b) The input is 0 (c) Both inputs are 0 (d) At least one input is 1

Short Questions

1. Define thermionic emission and cathode rays.
2. What is a cathode-ray oscilloscope used for? Name two quantities it can measure.
3. Define a semiconductor and doping. Give one example of a semiconductor.
4. Distinguish between n-type and p-type semiconductors.
5. Define a diode and a transistor. State one use of each.

Long Questions

1. Explain thermionic emission and the working of an electron gun. Describe the construction and working of a cathode-ray oscilloscope and state three of its uses.
2. Explain n-type and p-type semiconductors and how a p-n junction diode works. Describe how a diode is used as a rectifier, and explain how a transistor works as a switch and as an amplifier.

Chapter 20: Atomic and Nuclear Physics

The atom has a tiny, dense nucleus at its centre, and some nuclei are unstable and give out radiation. This chapter explains the structure of the atom, radioactivity, half-life, fission and fusion, and the uses and dangers of nuclear radiation.

Key Concepts

- An atom consists of a small, dense, positively charged nucleus (protons and neutrons) with electrons moving around it. Most of the atom is empty space. The atomic number is the number of protons; the mass number is the number of protons plus neutrons.
- Isotopes are atoms of the same element with the same atomic number but different mass numbers, because they have different numbers of neutrons. For example, carbon-12 and carbon-14 are isotopes of carbon.
- Rutherford's scattering experiment showed that most alpha particles passed straight through a thin gold foil, some were deflected by small angles, and a very few bounced back. This proved that the atom has a small, dense, positively charged nucleus.
- Radioactivity is the spontaneous giving out of radiation from the nucleus of an unstable atom. The three types of radiation are alpha, beta and gamma rays.
- An alpha particle is a helium nucleus (2 protons and 2 neutrons). It has a positive charge, a large mass, a short range in air (a few centimetres) and is stopped by a sheet of paper. It is the most ionising of the three types.
- A beta particle is a fast-moving electron given out by the nucleus. It has a negative charge, a small mass, a longer range than alpha radiation, and is stopped by a few millimetres of aluminium.
- Gamma rays are high-energy electromagnetic waves. They have no charge and no mass, travel at the speed of light, have a very long range, and are stopped only by thick lead or concrete. They are the least ionising but the most penetrating.
- Half-life is the time taken for half of the atoms of a radioactive sample to decay. After one half-life, half the sample remains; after two half-lives, one quarter remains. Carbon dating uses the half-life of carbon-14 (about 5730 years) to find the age of old organic material.
- Nuclear fission is the splitting of a heavy nucleus, such as uranium-235, into two lighter nuclei, releasing a large amount of energy and more neutrons. In a nuclear reactor the chain reaction is controlled with control rods; in an atomic bomb it is not controlled.
- Nuclear fusion is the joining of two light nuclei, such as hydrogen nuclei, to form a heavier nucleus, releasing energy. Fusion is the source of the Sun's energy. Einstein's equation E = mc^2 shows that a small loss of mass releases a huge amount of energy.
- Radioisotopes have many uses: in medicine to treat cancer and to trace the flow of blood, in industry to detect leaks in pipes and to check the thickness of sheets, in agriculture to kill pests and to improve crops, and in carbon dating.
- Background radiation comes from natural sources such as rocks, soil, cosmic rays and the air, and from man-made sources such as medical X-rays. Large doses of radiation are dangerous: they can damage cells, cause cancer and harm unborn children, so radioactive materials are handled with shielding and at a safe distance.

Important Definitions

Term	Definition
Atomic number	The number of protons in the nucleus of an atom.
Mass number	The total number of protons and neutrons in the nucleus of an atom.

Isotope	An atom of the same element with the same atomic number but a different mass number.
Radioactivity	The spontaneous giving out of radiation from the nucleus of an unstable atom.
Alpha particle	A helium nucleus (2 protons and 2 neutrons) given out in radioactive decay.
Beta particle	A fast-moving electron given out by a radioactive nucleus.
Gamma ray	A high-energy electromagnetic wave given out by a radioactive nucleus.
Half-life	The time taken for half of the atoms in a radioactive sample to decay.
Nuclear fission	The splitting of a heavy nucleus into two lighter nuclei, releasing energy.
Nuclear fusion	The joining of two light nuclei to form a heavier nucleus, releasing energy.

Important Formulas

> Mass number A = number of protons (Z) + number of neutrons (N)
>
> Einstein's mass-energy equation: E = mc^2
>
> After one half-life, 1/2 of the sample remains; after two half-lives, 1/4 remains
>
> Carbon-14 half-life is about 5730 years
>
> Alpha radiation is stopped by paper; beta by a few mm of aluminium; gamma by thick lead

Key Terms to Remember

atom, **nucleus**, **proton**, **neutron**, **electron**, **atomic number**, **mass number**, **isotope**, **radioactivity**, **alpha**, **beta**, **gamma**, **half-life**, **fission**, **fusion**, **carbon dating**, **background radiation**

Chapter 20: Atomic and Nuclear Physics — Practice Questions

Multiple Choice Questions

1. The atomic number of an atom is the number of:

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

2. Isotopes of an element have the same:

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

3. Rutherford's experiment showed that the atom has a:

(a) Large empty nucleus (b) Small dense positively charged nucleus (c) Uniform positive charge (d) Solid structure

4. An alpha particle is a:

(a) Proton (b) Neutron (c) Electron (d) Helium nucleus

5. Beta radiation is stopped by:

(a) A few millimetres of aluminium (b) Thick lead (c) A sheet of paper (d) Nothing

6. Gamma rays are:

(a) Helium nuclei (b) High-energy electromagnetic waves (c) Electrons (d) Charged particles

7. The half-life of a radioactive sample is the time for:

(a) The radiation to stop (b) The sample to double (c) All atoms to decay (d) Half the atoms to decay

8. Nuclear fission is the:

(a) Splitting of a heavy nucleus (b) Formation of an isotope (c) Joining of light nuclei (d) Decay of an electron

9. The energy of the Sun comes mainly from:

(a) Fusion (b) Chemical burning (c) Radioactive decay (d) Fission

10. Carbon dating uses the isotope:

(a) Carbon-14 (b) Cobalt-60 (c) Uranium-235 (d) Carbon-12

Short Questions

1. Define atomic number and mass number. An atom has 6 protons and 6 neutrons; find its atomic and mass numbers.
2. Define isotopes and give one example.
3. Name the three types of radiation and state the charge and penetrating power of each.
4. Define half-life. A sample has a half-life of 10 days; how much remains after 20 days?
5. Distinguish between nuclear fission and nuclear fusion.

Long Questions

1. Describe Rutherford's alpha-particle scattering experiment and explain how its results led to the nuclear model of the atom. Compare alpha, beta and gamma radiation in terms of their nature, charge, ionising power and penetrating power.
2. Define half-life and explain carbon dating. Describe nuclear fission and fusion, state Einstein's equation E = mc^2, and discuss three uses and three dangers of radioactivity and the safety measures used when handling radioactive materials.

Chapter 21: Space and Environment

Physics helps us understand the universe we live in and the environment we depend on. This chapter covers the solar system, the Sun and the stars, the Earth's atmosphere, weather, global warming and the sources of the energy that powers our planet.

Key Concepts

- The solar system consists of the Sun and the bodies that orbit it: eight planets, their moons, asteroids and comets. The planets in order from the Sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.
- The Sun is a star, a huge ball of hot gas that produces energy by nuclear fusion. Its light takes about 8 minutes to reach the Earth. The Earth orbits the Sun once a year and rotates on its axis once a day, giving day and night and the seasons.
- The Moon orbits the Earth once in about 27 days. Its phases (new moon, crescent, full moon) are caused by the changing amount of its sunlit side that we can see from the Earth.
- The Earth's atmosphere is the layer of gases around the Earth, mostly nitrogen (about 78 percent) and oxygen (about 21 percent). It protects life by blocking harmful radiation and by keeping the planet warm.
- Weather is the day-to-day state of the atmosphere (temperature, wind, rain, clouds), while climate is the average weather of a region over a long period. Both are driven by energy from the Sun.
- Cyclones (hurricanes and typhoons) are huge rotating storms formed over warm ocean water. They bring strong winds and heavy rain and can cause great damage to coastal areas. They are tracked by satellites so that people can be warned in advance.
- Global warming is the rise in the Earth's average temperature caused by the increase in greenhouse gases such as carbon dioxide, mainly from burning fossil fuels. It melts glaciers, raises sea levels and changes rainfall patterns.
- The greenhouse effect is natural and keeps the Earth warm enough for life, but human activities have strengthened it too much. Reducing it means using less fossil fuel and more renewable energy, planting trees and saving energy.
- Geothermal energy is heat from inside the Earth, used in some countries to generate electricity and to heat buildings. It is a renewable source of energy that does not depend on the weather.
- Environmental background radiation comes from natural sources: cosmic rays from space, radioactive rocks and soil, and radon gas. It is a small part of the radiation we receive, but it adds to the total dose over a lifetime, so monitoring it matters.
- Artificial satellites are used to study the Earth and space: weather satellites track storms and clouds, communication satellites carry telephone and television signals, and remote-sensing satellites watch crops, forests and pollution.
- Space exploration has given us new knowledge and useful technology, from satellite navigation to weather forecasting. Telescopes, including space telescopes, let astronomers study stars and galaxies far beyond what the eye can see.

Important Definitions

Term	Definition
Solar system	The Sun and all the bodies that orbit it, including the planets, moons, asteroids and comets.
Star	A huge ball of hot gas that produces its own light and heat by nuclear fusion.

Planet	A large body that orbits a star and does not produce its own light.
Atmosphere	The layer of gases surrounding the Earth.
Weather	The day-to-day state of the atmosphere, including temperature, wind and rain.
Climate	The average weather of a region over a long period of time.
Cyclone	A large rotating storm formed over warm ocean water, with strong winds and heavy rain.
Global warming	The rise in the Earth's average temperature caused by increased greenhouse gases.
Geothermal energy	Heat energy from inside the Earth, used to generate electricity and heat buildings.
Satellite	An object placed in orbit around the Earth, used for communication, weather study or observation.

Important Formulas

> Planets in order from the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune
>
> Atmosphere: about 78 percent nitrogen, about 21 percent oxygen
>
> Light from the Sun takes about 8 minutes to reach the Earth
>
> One year = one orbit of the Earth around the Sun; one day = one rotation of the Earth
>
> Geothermal energy and solar energy are renewable sources

Key Terms to Remember

solar system, **Sun**, **planet**, **Moon**, **atmosphere**, **weather**, **climate**, **cyclone**, **global warming**, **greenhouse effect**, **geothermal energy**, **background radiation**, **satellite**, **space exploration**

Chapter 21: Space and Environment — Practice Questions

Multiple Choice Questions

1. The planets in order from the Sun begin with:

(a) Mercury, Venus, Earth (b) Earth, Mars, Jupiter (c) Venus, Mercury, Earth (d) Mars, Earth, Venus

2. The Sun produces energy mainly by:

(a) Fusion (b) Chemical reactions (c) Fission (d) Burning coal

3. Light from the Sun takes about:

(a) 8 seconds (b) 8 hours (c) 8 days (d) 8 minutes

4. The main gas in the Earth's atmosphere is:

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

5. Weather is the:

(a) Temperature of the sea only (b) Average state of the atmosphere over many years (c) Day-to-day state of the atmosphere (d) Climate of a desert

6. Cyclones form over:

(a) Deserts (b) Mountains (c) Warm ocean water (d) Cold land

7. Global warming is caused mainly by the increase in:

(a) Nitrogen (b) Water vapour only (c) Oxygen (d) Greenhouse gases such as carbon dioxide

8. Geothermal energy comes from:

(a) Heat inside the Earth (b) Flowing water (c) The wind (d) The Sun

9. Weather satellites are used to:

(a) Stop cyclones (b) Make rain (c) Track storms and clouds (d) Measure earthquakes

10. Background radiation comes from:

(a) Natural sources such as rocks, soil and cosmic rays (b) Mobile phones only (c) Electric wires only (d) Television sets only

Short Questions

1. Name the eight planets in order from the Sun.
2. How does the Sun produce its energy? How long does its light take to reach the Earth?
3. Distinguish between weather and climate.
4. What is a cyclone? How are people warned about it in advance?
5. What is global warming? Name two of its effects and two ways to reduce it.

Long Questions

1. Describe the solar system: the Sun, the eight planets in order, the Moon and its phases, and the difference between a star and a planet. Explain how the Earth's rotation and its orbit around the Sun give day and night and the seasons.
2. Explain the greenhouse effect and global warming: their causes, effects on the Earth, and the steps that can reduce them. Also describe geothermal energy and the uses of artificial satellites in studying weather and the environment.

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	C	C	C	B	D	D	C	C	C	A
Ch. 11	B	A	C	A	C	D	A	D	A	C
Ch. 12	A	B	B	D	A	A	C	C	D	D
Ch. 13	C	D	C	D	D	B	B	D	B	C
Ch. 14	D	D	A	D	C	D	D	C	A	A
Ch. 15	B	B	A	D	B	A	C	C	B	C
Ch. 16	B	B	B	D	A	D	D	D	C	B
Ch. 17	D	D	B	A	D	D	B	B	B	C
Ch. 18	C	B	A	A	D	B	C	B	A	B
Ch. 19	A	B	A	D	C	A	B	D	A	A
Ch. 20	A	A	B	D	A	B	D	A	A	A
Ch. 21	A	A	D	B	C	C	D	A	C	A

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.

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