

JS EDUCATION SYSTEM

Class 10th — Subject Physics

Comprehensive Study Guide

Chapters 10–21 | FBISE Curriculum

All Short Questions · Long Questions · MCQs · Numerical Problems

This reference guide covers every question type required for Class 10th Physics examination preparation, spanning all twelve chapters of the FBISE curriculum — from heat and waves through electronics, electromagnetism, and nuclear physics. Each chapter is organized with **MCQs (with answers)**, short response questions, long response questions, and fully solved numerical problems.

Designed for systematic, exam-focused revision under the **JS Education System** framework.

MCQs

With correct answers marked

Short Q&A

Concept-based responses

Long Q&A

Detailed explanations

Numericals

Fully solved with answers

SYLLABUS OVERVIEW

Chapters Covered: 10–21

Complete FBISE Class 10th Physics curriculum, from thermal physics through nuclear physics.

CHAPTER 10

Heat Capacity & Heat Transfer
Modes of heat transfer

CHAPTER 11

Thermal Expansion
Change of state

CHAPTER 12

Waves
Wave properties & behaviour

CHAPTER 13

Sound
Sound waves & acoustics

CHAPTER 14

Optics
Light, lenses & mirrors

CHAPTER 15

Electrostatics
Charges & electric fields

CHAPTER 16

Current Electricity
Current, resistance & power

CHAPTER 17

Electric Circuits
Kirchhoff's laws & circuits

CHAPTER 18

Electronics
Diodes, transistors & logic gates

CHAPTER 19

Electromagnetism
Motors, generators & induction

CHAPTER 20

Electromagnetic Waves
The EM spectrum & its uses

CHAPTER 21

Nuclear Physics
Radioactivity, fission & fusion

Each chapter includes: **Multiple Choice Questions** (with answers) · **Short Response Questions** · **Long Response Questions** · **Numerical Problems** with full solutions.

12

CHAPTERS

100+

MCQs

80+

SHORT & LONG QUESTIONS

30+

SOLVED NUMERICALS

Heat Capacity & Modes of Heat Transfer — MCQs

All answers are highlighted. Study each stem carefully before checking the answer.

#	Question	Correct Answer
1	Why is water used in radiators of automobiles as coolant? A. It has large specific heat B. It boils at a very low temperature C. It is a poor conductor of heat D. It expands greatly on heating	A. It has large specific heat
2	Which situation is the best example of conduction? A. A metal spoon becomes hot in boiling water B. Warm air rises above a heater C. Heat reaches Earth from the Sun D. Steam warms the air in a room	A. A metal spoon becomes hot in boiling water
3	Dominant heat transfer when hand is held near (not touching) fire? A. Conduction only B. Conduction and evaporation C. Radiation and convection D. Compression and expansion	C. Radiation and convection
4	Symbol and unit for heat capacity of an object? A. $\text{J } ^\circ\text{C}^{-1}$ B. $\text{J kg}^{-1} ^\circ\text{C}^{-1}$ C. N m^{-1} D. W m^{-2}	A. $\text{J } ^\circ\text{C}^{-1}$
5	Why does copper temperature increase faster than water for same heat? A. Copper has lower specific heat capacity B. Copper has higher latent heat C. Copper has more mass D. Copper has greater heat of fusion	A. Copper has lower specific heat capacity
6	Heat transfer due to density difference in fluids is? A. Conduction B. Radiation C. Convection D. Refraction	C. Convection
7	Why does Earth receive more heat from the Sun than the Moon? A. Earth has greenhouse gases B. Earth has greenhouse gases C. Earth is farther from the Sun D. Earth has no atmosphere	A. Earth has greenhouse gases
8	Dull black surface is best absorber — what is best radiator? A. Dull black surface B. Shiny white surface C. Polished silver surface D. Clear glass surface	A. Dull black surface

- 9 How does enhanced greenhouse effect contribute to global warming? **B. Traps more heat in Earth's atmosphere, raising global temperatures**
- A. Reflects more sunlight into space
 - B. Traps more heat in Earth's atmosphere, raising global temperatures
 - C. Reduces the amount of water vapor in air
 - D. Stops convection in the oceans
- 10 Primary driving force behind tectonic plate movement? **C. Mantle convection currents**
- A. Ocean tides
 - B. Earth's magnetic field
 - C. Mantle convection currents
 - D. Solar radiation
- 11 Which Earth layer is composed of partially molten rock that flows slowly? **B. Asthenosphere**
- A. Crust
 - B. Asthenosphere
 - C. Inner core
 - D. Atmosphere
- 12 Extreme weather event most directly associated with rising sea levels? **D. Coastal flooding**
- A. Tornadoes
 - B. Earthquakes
 - C. Hurricanes
 - D. Coastal flooding

CHAPTER 10

Heat Capacity & Modes of Heat Transfer — Long Response Questions

Q.1: Explain the concept of specific heat capacity and discuss the applications of water based on its high specific heat capacity.

Ans: Specific heat capacity is the amount of heat required to raise the temperature of 1 kg of a substance by 1°C or 1 K. It is an important thermal property because it tells us how easily a substance heats up or cools down. A substance with high specific heat capacity needs a large amount of heat for only a small rise in temperature, while a substance with low specific heat capacity changes temperature quickly. Water is one of the best examples of a substance with high specific heat capacity ($4180 \text{ J kg}^{-1} \text{ K}^{-1}$). This means it can absorb a large amount of heat without a rapid increase in temperature. Because of this, water acts as a natural temperature regulator. Large bodies of water such as oceans, seas, lakes, and rivers warm up and cool down slowly. As a result, coastal areas experience less extreme temperature changes than inland areas. During the day, water absorbs heat from the Sun, and at night it releases that heat gradually. This moderates the climate of nearby regions and helps keep temperatures more stable. Water's high specific heat capacity is also extremely important in living organisms. Since the human body is made mostly of water, it does not undergo sudden temperature changes. This helps maintain a stable internal body temperature, which is necessary for enzymes and life processes. In industry, water is used as a coolant in engines, machinery, and power plants because it can absorb large amounts of heat efficiently. It is also used in radiators, central heating systems, hot water bottles, and heat exchangers. In cooking, water helps distribute heat evenly and prevents food from burning too quickly. The ability of water to store and transfer thermal energy makes it valuable in climate control, biological systems, and many practical applications.

Q.2: What is conduction, and how is it explained by the kinetic theory of solids? What makes metals better conductors than other solid substances?

Ans: Conduction is the transfer of heat through a substance from a hotter region to a colder region without the actual movement of the substance as a whole. It occurs most clearly in solids, where particles are packed closely together. The kinetic theory of solids explains conduction by describing how heat energy is passed from particle to particle. In a solid, particles are fixed in position but vibrate about their mean positions. When one end of a solid is heated, the particles there gain kinetic energy and vibrate more vigorously. These faster vibrations are passed on to neighboring particles through collisions and interactions. In this way, energy travels through the solid from the hot end to the cold end. No matter moves along the solid, but heat energy does. This process continues until the temperature becomes more uniform. Metals are better conductors of heat than other solids because they contain free electrons. These electrons are not tightly bound to atoms and can move easily through the metal structure. When a part of the metal is heated, free electrons gain energy quickly and transfer it from the hotter region to cooler regions by collisions with other electrons and particles. This makes heat move rapidly through metals. Non-metals do not have many free electrons, so heat transfer depends mainly on vibration of particles, which is slower. That is why metals like copper, aluminum, and silver are excellent conductors and are used in cooking utensils, boilers, heat sinks, and heat exchangers.

Conduction is also seen in everyday life, such as when a metal spoon becomes hot in tea or when heat passes through a frying pan.

Q.3: Analyze how heat is transferred through convection. Provide at least three practical examples of how convection is used in daily life.

Ans: Convection is the transfer of heat in liquids and gases by the actual movement of heated particles from one place to another. It happens only in fluids because their particles are free to move. When a fluid is heated, it expands, becomes less dense, and rises. Cooler fluid, which is denser, sinks to take its place. This continuous circulation creates convection currents, which transfer heat efficiently through the fluid. Convection is an important method of heat transfer in daily life and in nature. First, in boiling water, water at the bottom of a container gets heated first. It expands, becomes lighter, and rises. Cooler water from above moves down to replace it. This movement continues until the whole container is heated. Second, in room heating, a heater warms the air near it. The warm air rises to the top of the room, while cooler air sinks. This circulation helps distribute heat throughout the room. Third, sea breeze and land breeze are caused by convection. During the day, land heats up faster than sea. Warm air above the land rises, and cool air from the sea moves in to replace it, producing a sea breeze. At night, the land cools faster than the sea, so the pattern reverses and a land breeze occurs. Fourth, chimneys and exhaust systems work by convection because hot gases rise upward and escape. Hot air balloons rise for the same reason: heated air inside the balloon becomes less dense than the surrounding air. Convection also plays a major role in weather systems, cloud formation, and ocean currents. It is therefore a natural and efficient method of transferring heat in fluids.

Q.4: Analyze the process of heat transfer through radiation, explaining why it is the fastest method of heat transfer. What factors influence the rate of heat transfer by radiation?

Ans: Radiation is the transfer of heat in the form of electromagnetic waves, mainly infrared waves. Unlike conduction and convection, radiation does not require a material medium. This is why heat from the Sun reaches Earth through the vacuum of space. Radiation is considered the fastest method of heat transfer because electromagnetic waves travel at the speed of light. It does not depend on particle collisions or fluid motion, so energy can move directly from one body to another over long distances. Several factors affect the rate of radiation. The temperature of the body is one of the most important factors: hotter objects emit more radiation than cooler ones. The nature of the surface is important. Dull, black, and rough surfaces are good absorbers and emitters of heat, while shiny, white, and polished surfaces are poor absorbers and reflect more radiation. Surface area is another factor; larger surfaces radiate more energy than smaller ones. The distance between objects also affects how much radiant energy is received. The closer the object, the greater the heat absorbed. Color and texture influence the rate of absorption and emission as well. Radiation has many practical uses. Solar energy reaches Earth by radiation, and solar cookers use black surfaces to absorb more heat. Black clothing and black-painted surfaces absorb radiant heat quickly. Shiny surfaces are used in thermos flasks, blankets, and cooking containers to reduce heat loss by reflection. Heat from a fire, heater, or lamp is also felt by radiation. Because radiation can travel through empty space and move at very high speed, it is the fastest method of heat transfer.

Q.5: Analyze the role of greenhouse gases in global warming. How does global warming contribute to the increased severity of hurricanes, heat waves, flooding, and droughts?

Ans: The greenhouse effect is a natural process in which certain gases in the atmosphere trap part of the Earth's outgoing infrared radiation and keep the planet warm enough for life. The main greenhouse gases include carbon dioxide, methane, water vapour, nitrous oxide, and ozone. Sunlight passes through the atmosphere and warms the Earth's surface. The Earth then gives off heat in the form of infrared radiation. Greenhouse gases absorb some of this escaping heat and re-radiate it in all directions, including back toward the surface. This keeps the lower atmosphere warm. Without this effect, Earth would be too cold to support life. However, human activities have increased the concentration of greenhouse gases. Burning fossil fuels, cutting down forests, industrial processes, vehicle emissions, and agriculture all add more greenhouse gases to the atmosphere. This strengthens the greenhouse effect and causes global warming, which is the long-term rise in Earth's average temperature. Global warming affects the climate in many serious ways. Higher temperatures increase evaporation from oceans, lakes, and soil. This can intensify storms and hurricanes because warmer air holds more moisture and energy. Heat waves become more frequent and severe, causing health risks, crop failure, and water shortages. In some places, warmer air produces heavier rainfall, leading to flooding. In other regions, rainfall decreases and droughts become more common. Melting glaciers and polar ice raise sea levels, increasing the risk of coastal flooding and erosion. Ecosystems are also disturbed because plants and animals may not be able to adapt quickly enough. Therefore, greenhouse gases are necessary in small natural amounts, but excessive amounts trap too much heat and disturb the Earth's climate system. This leads to stronger extreme weather events and serious environmental changes.

Q.6: Why does Earth's core remain extremely hot even after 4 billion years? Explain in detail.

Ans: The Earth's core remains extremely hot because several sources of heat have acted over a very long time, and heat is lost only slowly from the deep interior. One major source of heat is leftover heat from Earth's formation. When the Earth formed about 4.5 billion years ago, countless collisions between particles, rocks, and planetesimals released enormous amounts of energy. This energy became trapped inside the young planet. Another important source is gravitational compression. As the Earth grew larger, the weight of the upper layers compressed the inner layers, producing additional heat. During differentiation, heavier materials such as iron and nickel sank toward the center. This movement converted gravitational potential energy into heat, making the core even hotter. Radioactive decay also contributes significantly. Elements such as uranium, thorium, and potassium present inside the Earth release heat as they decay over millions of years. Although this heat is produced slowly, it continues to supply energy to the interior. The Earth cools very slowly because rocks are poor conductors of heat. The mantle and crust are thick insulating layers that prevent rapid heat loss. Since the core is deep inside the planet, the heat must travel through many layers before reaching the surface, and that process takes a very long time. As a result, much of the primordial heat is still retained. This internal heat is also responsible for mantle convection, volcanic activity, and plate movement. Therefore, the Earth's core is hot because of residual heat from formation, gravitational compression, differentiation, and radioactive decay. The combination of continuous heat production and slow heat loss explains why the core remains molten and extremely hot after billions of years.

Q.7: How are tectonic plates formed, and what factors cause their movement? Explain these causes in detail and discuss the effects of plate movements.

Ans: The Earth's lithosphere is divided into large rigid pieces called tectonic plates. These plates include the crust and the uppermost part of the mantle. They formed as the Earth cooled and the outer solid layer became broken into separate blocks. Beneath the lithosphere lies the asthenosphere, a softer and semi-fluid layer of the upper mantle. This layer allows the plates to move slowly over geological time. The movement of tectonic plates is mainly caused by heat from inside the Earth. Heat from the core and mantle creates convection currents in the mantle. Hot material rises, cool material sinks, and this circulation helps move the plates. Two additional forces, ridge push at mid-ocean ridges and slab pull at subduction zones, also contribute to plate movement. Because the plates float on the softer asthenosphere, they move only a few centimeters per year. The effects of tectonic plate movement are very important. At divergent boundaries, plates move apart and new crust is formed. This creates mid-ocean ridges and rift valleys. At convergent boundaries, plates move toward each other. This can cause mountain building, deep ocean trenches, earthquakes, and volcanic activity. When one plate sinks beneath another in a process called subduction, intense geological activity occurs. At transform boundaries, plates slide past one another and generate earthquakes. Plate movement also explains the shifting positions of continents over millions of years. Volcanoes, earthquakes, mountains, and ocean basins are all results of tectonic activity. These processes continuously reshape the Earth's surface. In addition, plate boundaries are often rich in minerals and geothermal energy. Therefore, tectonic plates are formed from the broken lithosphere, move because of mantle convection and related forces, and produce major geological features and hazards on Earth.

CHAPTER 10

Heat Capacity & Modes of Heat Transfer — Short Response Questions & Answers

Review each question and its detailed answer to reinforce your understanding of key concepts.

Q. No	Question	Answer
1	Q.1: Why wear dark clothes in winter and white clothes in summer?	Ans: Dark clothes absorb more heat radiation, keeping the body warm in winter. White clothes reflect radiation, keeping the body cool in summer. This is due to different absorption and reflection properties of colors.
2	Q.2: How do geysers fitted on the ground floor supply warm water to the top floor without a pump?	Ans: Hot water becomes less dense and rises naturally through pipes (convection). Cooler water sinks to replace it, creating continuous circulation without a pump. This is a practical application of convection.
3	Q.3: Where is more heat felt from a wood fire — 1 m above or 1 m in front?	Ans: More heat is felt in front because of direct thermal radiation from flames. Above the fire, heat is carried upward by convection, which is less intense. Radiation is the dominant heat transfer method in front.
4	Q.4: Why do crowded city areas feel hotter than outskirts on a hot summer day?	Ans: Cities have more concrete and buildings that absorb and trap heat. Less vegetation means less shade and cooling. Vehicles and industries release additional heat (urban heat island effect).
5	Q.5: Why is a metallic door handle colder than the wood of the same door when touched?	Ans: Metal is a good conductor of heat and quickly draws thermal energy from your hand. Wood is a poor conductor, so it removes heat slowly and feels warmer. The sensation depends on thermal conductivity.
6	Q.6: How do trees help reduce effects of climate change, and what happens if forests are depleted?	Ans: Trees absorb CO ₂ during photosynthesis and provide cooling through shade and transpiration. If forests are depleted, CO ₂ increases and local temperatures rise. Forests act as natural climate regulators.
7	Q.7: How does gravity contribute to Earth's core temperature?	Ans: Gravity caused Earth to compress during formation, releasing heat. Heavy elements sank toward the center, converting gravitational potential energy into thermal energy. This process made the core extremely hot.
8	Q.8: Why do certain atmospheric gases trap more heat than others?	Ans: Greenhouse gases (CO ₂ , methane, water vapor) absorb infrared radiation from Earth's surface and re-radiate it back, trapping heat. Nitrogen and oxygen don't absorb infrared effectively.

9	Q.9: What are environmental impacts of geothermal energy extraction?	Ans: May release CO ₂ and hydrogen sulfide gases, affect water quality, cause minor earthquakes, and create noise. However, it's cleaner than fossil fuels overall and is a valuable low-emission energy source.
10	Q.10: How does specific heat capacity of materials affect their use in cookware?	Ans: Low specific heat capacity materials heat up quickly (frying pans). High specific heat capacity materials retain heat longer. Metals are preferred for balanced heating and conduction.

CHAPTER 10

Heat Capacity — Numerical Problems with Solutions

Here are detailed, step-by-step solutions for all six numerical problems from Chapter 10, designed to prepare you for examinations.

Problem 1: Unit Conversion

Convert the specific heat capacity of water, **4180 J kg⁻¹ K⁻¹**, into **J g⁻¹ °C⁻¹**.

- **Given:** Specific heat capacity (c) = 4180 J kg⁻¹ K⁻¹
- **To Find:** Specific heat capacity in J g⁻¹ °C⁻¹

Formula Used: Unit conversion factors: **1 kg = 1000 g**, and a change of **1 K** is equivalent to a change of **1 °C**.

Calculation:

To convert from kg to g in the denominator, divide by 1000:

$$c = 4180 \frac{\text{J}}{\text{kg} \cdot \text{K}}$$

Using $1 \text{ kg} = 1000 \text{ g}$ and $1 \text{ K} = 1^\circ \text{C}$ for temperature difference:

$$c = 4180 \frac{\text{J}}{(1000 \text{ g}) \cdot (1^\circ \text{C})}$$

$$c = \frac{4180}{1000} \frac{\text{J}}{\text{g} \cdot ^\circ \text{C}}$$

$$c = 4.18 \frac{\text{J}}{\text{g} \cdot ^\circ \text{C}}$$

Final Answer: The specific heat capacity of water is **4.18 J g⁻¹ °C⁻¹**.

Problem 2: Heat Calculation

Calculate the amount of heat energy given to **25 kg of water** to increase its temperature by **50°C**.

- **Given:** Mass of water (m) = 25 kg
- **Given:** Change in temperature (ΔT) = 50°C
- **Given:** Specific heat capacity of water (c) = 4180 J kg⁻¹ K⁻¹ (or J kg⁻¹ °C⁻¹)
- **To Find:** Heat energy (Q)

Formula Used: $Q = mc\Delta T$

This formula is used to calculate the heat required to change the temperature of a substance.

Calculation:

Substitute the given values into the formula:

$$Q = (25 \text{ kg}) \times (4180 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}) \times (50 \text{ }^\circ\text{C})$$

$$Q = 25 \times 4180 \times 50 \text{ J}$$

$$Q = 5,225,000 \text{ J}$$

To convert Joules to MegaJoules (MJ), divide by 10⁶:

$$Q = \frac{5,225,000}{1,000,000} \text{ MJ}$$

$$Q = 5.225 \text{ MJ}$$

Final Answer: The heat energy given to the water is **5.225 MJ** (or approximately **5.25 MJ**).

Problem 3: Unknown Metal Specific Heat and Additional Heat

A **0.50 kg** block of an unknown metal absorbs **12,000 J** of heat and its temperature rises by **30°C**. Find the specific heat capacity of the metal. Then calculate the additional heat required to raise its temperature by another **15°C**.

- **Given:** Mass of metal (m) = 0.50 kg
- **Given:** Heat absorbed (Q) = 12,000 J
- **Given:** Temperature rise (ΔT) = 30°C
- **To Find:** Specific heat capacity (c) and additional heat for 15°C

Formula Used: $Q = mc\Delta T$

Rearrange to find specific heat capacity:

$$c = \frac{Q}{m\Delta T}$$

Step 1: Find the specific heat capacity

Substitute the values:

$$c = \frac{12000}{0.50 \times 30}$$

$$c = \frac{12000}{15}$$

$$c = 800 \text{ J kg}^{-1} \text{ }^{\circ}\text{C}^{-1}$$

Step 2: Find the additional heat for another 15°C rise

Now use $Q = mc\Delta T$ again with the same mass and specific heat capacity:

$$Q = (0.50)(800)(15)$$

$$Q = 400 \times 15$$

$$Q = 6000 \text{ J}$$

Final Answer: The specific heat capacity of the metal is **800 J kg⁻¹ °C⁻¹**, and the additional heat required for a further **15°C** rise is **6000 J**.

Problem 4: Temperature Change from Heat Absorption

A **2.0 kg** substance with specific heat capacity **900 J kg⁻¹ °C⁻¹** absorbs **36,000 J** of heat. Find the temperature rise.

- **Given:** Mass (m) = 2.0 kg
- **Given:** Specific heat capacity (c) = 900 J kg⁻¹ °C⁻¹
- **Given:** Heat absorbed (Q) = 36,000 J
- **To Find:** Temperature change (ΔT)

Formula Used: $Q = mc\Delta T$

Rearrange for temperature change:

$$\Delta T = \frac{Q}{mc}$$

Calculation:

Substitute the given values:

$$\Delta T = \frac{36000}{2.0 \times 900}$$

$$\Delta T = \frac{36000}{1800}$$

$$\Delta T = 20^{\circ}\text{C}$$

Final Answer: The temperature of the substance rises by **20°C**.

Problem 5: Mixture Final Temperature

Mix **0.30 kg of water at 80°C** with **0.20 kg of water at 20°C**. Assuming no heat loss to the surroundings, find the final temperature of the mixture.

- **Given:** Mass of hot water (m_1) = 0.30 kg
- **Given:** Initial temperature of hot water (T_1) = 80°C
- **Given:** Mass of cold water (m_2) = 0.20 kg
- **Given:** Initial temperature of cold water (T_2) = 20°C

- **Given:** Specific heat capacity of water (c) = $4180 \text{ J kg}^{-1} \text{ }^{\circ}\text{C}^{-1}$
- **To Find:** Final temperature (T_f)

Formula Used: Heat lost by hot water = heat gained by cold water.

Since both are water, the same specific heat capacity cancels out in the equation:

$$m_1(T_1 - T_f) = m_2(T_f - T_2)$$

Calculation:

Substitute the values:

$$0.30(80 - T_f) = 0.20(T_f - 20)$$

Expand both sides:

$$24 - 0.30T_f = 0.20T_f - 4$$

Bring like terms together:

$$24 + 4 = 0.20T_f + 0.30T_f$$

$$28 = 0.50T_f$$

$$T_f = \frac{28}{0.50}$$

$$T_f = 56^{\circ}\text{C}$$

Final Answer: The final temperature of the mixture is **56°C**.

Problem 6: Calorimetry with Unknown Solid

A **0.40 kg** solid metal block at **100°C** is placed into **0.60 kg of water** at **20°C**. The final temperature becomes **24°C**. If the specific heat capacity of water is **4180 J kg⁻¹ °C⁻¹**, find the specific heat capacity of the metal.

- **Given:** Mass of metal (m_m) = 0.40 kg
- **Given:** Initial temperature of metal (T_m) = 100°C
- **Given:** Mass of water (m_w) = 0.60 kg
- **Given:** Initial temperature of water (T_w) = 20°C
- **Given:** Final temperature (T_f) = 24°C
- **Given:** Specific heat capacity of water (c_w) = $4180 \text{ J kg}^{-1} \text{ }^{\circ}\text{C}^{-1}$
- **To Find:** Specific heat capacity of metal (c_m)

Formula Used: Heat lost by metal = heat gained by water.

$$m_m c_m (T_m - T_f) = m_w c_w (T_f - T_w)$$

Calculation:

Substitute the values:

$$(0.40)c_m(100 - 24) = (0.60)(4180)(24 - 20)$$

$$(0.40)c_m(76) = (0.60)(4180)(4)$$

$$30.4c_m = 10032$$

$$c_m = \frac{10032}{30.4}$$

$$c_m = 330 \text{ J kg}^{-1} \text{ }^{\circ}\text{C}^{-1}$$

Final Answer: The specific heat capacity of the metal is **330 J kg⁻¹ °C⁻¹**.

CHAPTER 11

Thermal Expansion & Change of State — Long Response Questions (Fully Solved)

Explore key concepts of thermal expansion and changes of state with comprehensive, exam-ready answers.

Latent Heat Definition & Formulas

1

Latent heat is the energy absorbed or released during a phase change (e.g., melting, boiling) without a temperature change. Formula: $Q = mL$, where Q is heat, m is mass, and L is the specific latent heat.

Latent Heat of Vaporization

- 2 **Specific latent heat of vaporization** (L_v) is the energy required to change a unit mass of liquid to gas at its boiling point, or vice versa. For water, L_v is approximately 2260 kJ/kg, making steam burns very dangerous due to the high energy released upon condensation.

Evaporation vs. Boiling

- 3 **Evaporation** occurs only at the surface of a liquid, at any temperature below the boiling point, driven by molecular escape. **Boiling** is a bulk phenomenon occurring throughout the liquid at a specific temperature (boiling point), involving rapid bubble formation and escape.

Linear & Volume Thermal Expansion

- 4 **Linear expansion** ($\Delta L = L_0 \alpha \Delta T$) describes length change in solids. **Volume expansion** ($\Delta V = V_0 \beta \Delta T$) describes volume change in solids or liquids, where $\beta \approx 3\alpha$. These phenomena result from increased molecular vibrations and separation with rising temperature.

Uses of Thermal Expansion

- 5 Thermal expansion is used in **riveting** (hot rivets contract to tighten), **thermostats** (bimetallic strips bend to switch circuits), and for fitting **metal tyres** onto wooden wheels (contract upon cooling). Expansion gaps in bridges prevent buckling.

Thermal Expansion of Liquids

- 6 Liquids expand more than solids due to weaker intermolecular forces. This is measured as **apparent expansion** (observed increase in volume) and **real expansion** (actual volume increase including the container's expansion).

Bimetallic Strips in Thermostats

- 7 A **bimetallic strip** consists of two different metals (e.g., brass and iron) with different coefficients of thermal expansion, bonded together. When heated, one metal expands more than the other, causing the strip to bend and complete/break an electrical circuit, regulating temperature.

Superconductivity

- 8 **Superconductivity** is a phenomenon where certain materials exhibit zero electrical resistance and expel magnetic fields below a critical temperature. This has potential for highly efficient power transmission, powerful electromagnets, and maglev trains, but often requires extreme cooling.

CHAPTER 11

Thermal Expansion — Numerical Problems (Fully Solved)

Explore the principles of thermal expansion through these step-by-step numerical problems. Each solution demonstrates the application of relevant formulas and concepts.

1. Steel Bar Linear Expansion

A steel bar has an initial length of **2.5 meters at 15°C**. If it is heated to **95°C**, what is its new length? (Coefficient of linear expansion for steel, $\alpha = 1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$)

Solution:

- Initial length (L_0) = 2.5 m
- Initial temperature (T_0) = 15°C
- Final temperature (T_1) = 95°C
- Temperature change (ΔT) = $T_1 - T_0 = 95^\circ\text{C} - 15^\circ\text{C} = 80^\circ\text{C}$
- Coefficient of linear expansion (α) = $1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$

2. Solid Cube Volume Expansion

An aluminum cube has a side length of **15 cm at 20°C**. If its temperature is uniformly raised to **70°C**, calculate the increase in its volume. (Coefficient of linear expansion for aluminum, $\alpha = 2.3 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$)

Solution:

- Initial side length (L_0) = 15 cm = 0.15 m
- Initial volume (V_0) = $L_0^3 = (0.15 \text{ m})^3 = 0.003375 \text{ m}^3$
- Initial temperature (T_0) = 20°C
- Final temperature (T_1) = 70°C

3. Railroad Track Expansion Gap

A **20-meter long section** of steel railroad track is laid when the temperature is **10°C**. What minimum gap should be left between adjacent sections to prevent buckling if the maximum anticipated temperature is **50°C**? (Coefficient of linear expansion for steel, $\alpha = 1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$)

Solution:

- Initial length (L_0) = 20 m
- Initial temperature (T_0) = 10°C
- Maximum temperature (T_1) = 50°C

$$\times 10^{-5} \text{ }^{\circ}\text{C}^{-1}$$

Formula: $\Delta L = L_0 \times \alpha \times \Delta T$

Calculation: $\Delta L = 2.5 \text{ m} \times (1.2 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}) \times 80^{\circ}\text{C} = 0.0024 \text{ m}$

New length (L) = $L_0 + \Delta L = 2.5 \text{ m} + 0.0024 \text{ m} = 2.5024 \text{ m}$

Answer: The new length of the steel bar is 2.5024 m (or 250.24 cm).

- Temperature change (ΔT) = $T_1 - T_0 = 70^{\circ}\text{C} - 20^{\circ}\text{C} = 50^{\circ}\text{C}$
- Coefficient of linear expansion (α) = $2.3 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}$
- Coefficient of volume expansion (β) = $3\alpha = 3 \times (2.3 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}) = 6.9 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}$

Formula: $\Delta V = V_0 \times \beta \times \Delta T$

Calculation: $\Delta V = 0.003375 \text{ m}^3 \times (6.9 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}) \times 50^{\circ}\text{C} = 1.164375 \times 10^{-5} \text{ m}^3$

To express in cm^3 : $1.164375 \times 10^{-5} \text{ m}^3 \times (100 \text{ cm/m})^3 = 11.64375 \text{ cm}^3$

Answer: The increase in the cube's volume is approximately 11.64 cm^3 .

- Temperature change (ΔT) = $T_1 - T_0 = 50^{\circ}\text{C} - 10^{\circ}\text{C} = 40^{\circ}\text{C}$
- Coefficient of linear expansion (α) = $1.2 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}$

Formula: The gap needed is equal to the maximum expansion (ΔL) the track will undergo.

$$\Delta L = L_0 \times \alpha \times \Delta T$$

Calculation: $\Delta L = 20 \text{ m} \times (1.2 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}) \times 40^{\circ}\text{C} = 0.0096 \text{ m}$

To express in millimeters: $0.0096 \text{ m} \times 1000 \text{ mm/m} = 9.6 \text{ mm}$

Answer: A minimum gap of 0.0096 meters (or 9.6 mm) should be left between sections.

- ☐ Remember to use consistent units for all calculations. For thermal expansion, a common pitfall is mixing metric and imperial units or using different temperature scales without conversion.

CHAPTER 11

Thermal Expansion — Numerical Problems (Fully Solved)

Problem 1 — Steel Bar Expansion

Given: $L_0 = 1.5 \text{ m}$ at 10°C , heated to 100°C . $\alpha_{\text{steel}} = 1.2 \times 10^{-5} \text{ K}^{-1}$

Find: (a) Increase in length (b) Final length at 100°C

$$\Delta L = \alpha \cdot L_0 \cdot \Delta T = 1.2 \times 10^{-5} \times 1.5 \times 90$$

Answers: (a) $\Delta L = 1.62 \text{ mm}$ | (b) $L = 1.5016 \text{ m} \approx 1.5 \text{ m}$

Problem 2 — Volume Expansion of Cube

Given: Solid cube, side = 10 cm at 25°C , heated to 125°C . $\alpha = 9 \times 10^{-6} \text{ K}^{-1}$

Find: Increase in volume

$$\beta = 3\alpha = 27 \times 10^{-6} \text{ K}^{-1} \quad | \quad V_0 = 1000 \text{ cm}^3 \quad | \quad \Delta V = \beta \cdot V_0 \cdot \Delta T$$

Answer: $\Delta V = 2.7 \text{ cm}^3$

Problem 3 — Railroad Track Expansion

Given: $L_0 = 10 \text{ m}$ at 15°C , temperature rises to 30°C . $\alpha_{\text{steel}} = 1.2 \times 10^{-5} \text{ }^{\circ}\text{C}^{-1}$

Find: Expansion in length of the track segment

$$\Delta L = \alpha \cdot L_0 \cdot \Delta T = 1.2 \times 10^{-5} \times 10 \times 15$$

Answer: $\Delta L = 1.8 \text{ mm}$

Key Formulae — Chapter 11

Linear Expansion: $\Delta L = \alpha \cdot L_0 \cdot \Delta T$

Volume Expansion: $\Delta V = \beta \cdot V_0 \cdot \Delta T \quad | \quad \beta = 3\alpha$

Latent Heat: $Q = mL$

Important Constants

$$\alpha_{\text{steel}} = 1.2 \times 10^{-5} \text{ K}^{-1}$$

$$L_f (\text{water}) = 336,000 \text{ J kg}^{-1}$$

$$L_v (\text{water}) = 2,260,000 \text{ J kg}^{-1}$$

$$c_{\text{water}} = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$$

CHAPTER 11

Thermal Expansion & Change of State — MCQs

Fourteen MCQs covering thermal expansion, latent heat, evaporation, and change of state.

#	Question	Options
1	A metal bridge expands on a hot day. This is caused by?	A. Metal atoms vibrating less intensely B. Metal atoms vibrating more intensely C. Metal atoms stopping motion D. Metal atoms turning into liquid Correct: B. Metal atoms vibrating more intensely

2	Fog forms on a cold window pane — which change of state?	A. Evaporation B. Melting C. Condensation D. Sublimation Correct: C. Condensation
3	Change from gas to solid without passing through liquid phase?	A. Deposition B. Melting C. Freezing D. Evaporation Correct: A. Deposition
4	Boiling point of water?	A. 100°C B. 212°F C. 0°F D. 32°F Correct: A. 100°C
5	J kg ⁻¹ K ⁻¹ is the unit of?	A. Specific Heat Capacity B. Latent Heat of Fusion C. Density D. Thermal Conductivity Correct: A. Specific Heat Capacity
6	Evaporation takes place from?	A. Surface B. Bottom only C. Entire volume only D. Inside a solid Correct: A. Surface
7	Relation between linear (α) and volume (β) expansion of solids?	A. $\beta = \alpha$ B. $\beta = 2\alpha$ C. $\beta = 4\alpha$ D. $\beta = 3\alpha$ Correct: D. $\beta = 3\alpha$
8	Heat added at melting point is used to?	A. Increase temperature quickly B. Expand the solid only C. Break the container D. Decrease attraction between particles Correct: D. Decrease attraction between particles
9	Latent heat of fusion = 336 J/g. Heat to melt 10 g at melting point?	A. 3,360 J B. 33,600 J C. 33,600 J D. 336 J Correct: C. 33,600 J
10	Which factor increases rate of evaporation?	A. Decrease in surface area B. Increase in humidity C. Increase in wind speed D. Lower temperature Correct: C. Increase in wind speed
11	Value of α if $\beta = 9 \times 10^{-7} \text{ K}^{-1}$?	A. $3 \times 10^{-7} \text{ K}^{-1}$ B. $6 \times 10^{-7} \text{ K}^{-1}$ C. $9 \times 10^{-7} \text{ K}^{-1}$ D. $12 \times 10^{-7} \text{ K}^{-1}$

D. $27 \times 10^{-7} \text{ K}^{-1}$

Correct: A. $3 \times 10^{-7} \text{ K}^{-1}$

12 Process involving latent heat of vaporisation?

- A. Melting
- B. Freezing
- C. Evaporation
- D. Condensation

Correct: C. Evaporation

13 Ratio of real to apparent expansion if sum: difference = 2:1?

- A. 1:2
- B. 2:3
- C. 1:3
- D. 3:1

Correct: D. 3:1

14 What does "latent" mean in "latent heat"?

- A. Measured
- B. Changing
- C. Hidden
- D. Visible

Correct: C. Hidden

CHAPTER 11

Thermal Expansion & Change of State — Long Response Questions

Each question is worth 8 marks.

Q.1: Define latent heat. Differentiate between latent heat and specific latent heat of fusion. Write their formulae.

Ans: Latent heat is the amount of heat energy absorbed or released by a substance during a change of state (melting, boiling, freezing, condensation) without any change in temperature. It is the hidden heat that causes the change of state. The latent heat depends on the mass of the substance. Specific latent heat of fusion is the amount of heat required to change 1 kg of a solid into liquid at its melting point without any change in temperature. It is an intrinsic property of the material and does not depend on mass. The formula for latent heat is: $Q = mL$, where Q is heat energy, m is mass, and L is specific latent heat. The formula for specific latent heat of fusion is: $L_f = Q/m$, where L_f is specific latent heat of fusion. For water, the specific latent heat of fusion is approximately 334,000 J/kg or 334 kJ/kg. This means that 334,000 Joules of heat energy is required to melt 1 kg of ice at 0°C into water at 0°C . The difference between latent heat and specific latent heat is that latent heat is the total heat required for a given mass, while specific latent heat is the heat required per unit mass.

Q.2: Differentiate between latent heat of vaporisation and specific latent heat of vaporisation. Give their formulae and units.

Ans: Latent heat of vaporization is the total amount of heat energy absorbed by a substance during the change of state from liquid to gas (boiling or evaporation) at constant temperature and pressure. It depends on the mass of the substance. Specific latent heat of vaporization is the amount of heat required to change 1 kg of liquid into gas at its boiling point without any change in temperature. It is an intrinsic property of the material and does not depend on mass. The formula for latent heat of vaporization is: $Q = mL_v$, where Q is heat energy, m is mass, and L_v is specific latent heat of vaporization. The formula for specific latent heat of vaporization is: $L_v = Q/m$. The SI unit of latent heat is Joule (J), and the SI unit of specific latent heat is Joule per kilogram (J/kg). For water, the specific latent heat of vaporization is approximately 2,260,000 J/kg or 2260 kJ/kg. This means that 2,260,000 Joules of heat energy is required to convert 1 kg of water at 100°C into steam at 100°C . The latent heat of vaporization is much larger than the latent heat of fusion because more energy is needed to break all the bonds between molecules when converting liquid to gas compared to converting solid to liquid.

Q.3: What is evaporation? Differentiate between boiling and evaporation. On what factors evaporation depends?

Ans: Evaporation is the process by which liquid molecules escape from the surface of a liquid and become gas molecules. It occurs at any temperature below the boiling point and only at the surface of the liquid. Boiling is a bulk phenomenon that occurs throughout the liquid at a specific temperature called the boiling point. In boiling, bubbles of vapor form inside the liquid and rise to the surface. Evaporation occurs only at the surface, while boiling occurs throughout the entire volume of the liquid. Evaporation can occur at any temperature, while boiling occurs only at the boiling point. Evaporation is a

slower process than boiling. Evaporation depends on several factors: (1) Temperature: Higher temperature increases the kinetic energy of molecules, so more molecules can escape. (2) Surface area: Larger surface area allows more molecules to escape, so evaporation rate increases. (3) Humidity: Lower humidity means the air can hold more water vapor, so evaporation increases. Higher humidity reduces evaporation. (4) Wind speed: Faster wind removes water vapor from above the liquid surface, allowing more evaporation. (5) Nature of the liquid: Different liquids have different evaporation rates. Liquids with weaker intermolecular forces evaporate faster. (6) Pressure: Lower atmospheric pressure increases evaporation because molecules can escape more easily.

Q.4: What are linear and volume thermal expansion of solids? Discuss qualitatively the factors upon which these thermal expansions depend.

Ans: Linear thermal expansion is the increase in length of a solid when its temperature increases. It is described by the formula: $\Delta L = L_0 \alpha \Delta T$, where ΔL is the change in length, L_0 is the original length, α is the coefficient of linear thermal expansion, and ΔT is the change in temperature. Volume thermal expansion is the increase in volume of a solid when its temperature increases. It is described by the formula: $\Delta V = V_0 \beta \Delta T$, where ΔV is the change in volume, V_0 is the original volume, β is the coefficient of volume thermal expansion, and ΔT is the change in temperature. The relationship between linear and volume expansion is: $\beta = 3\alpha$. Thermal expansion occurs because when a substance is heated, its particles gain kinetic energy and vibrate more vigorously. This causes the average distance between particles to increase, resulting in an increase in length and volume. The factors upon which thermal expansion depends are: (1) Material type: Different materials have different coefficients of thermal expansion. Metals generally have higher coefficients than non-metals. (2) Temperature change: Greater temperature change produces greater expansion. (3) Original dimensions: Larger original length or volume produces greater absolute expansion. (4) Nature of the material: The strength of intermolecular forces affects thermal expansion. Materials with weaker bonds expand more. (5) Crystal structure: The arrangement of atoms in the crystal lattice affects expansion rates in different directions.

Q.5: What are uses of thermal expansion in our daily life? Give examples.

Ans: Thermal expansion has many practical applications in daily life. (1) Riveting: Hot rivets are used to join metal plates. When the rivet is heated and inserted, it expands. As it cools, it contracts and tightens the joint. (2) Thermostats: Bimetallic strips are used in thermostats. When temperature changes, the two metals expand at different rates, causing the strip to bend and switch electrical circuits on or off. (3) Metal tyres on wooden wheels: Hot metal tyres are fitted onto wooden wheels. When the metal cools, it contracts and grips the wheel tightly. (4) Expansion joints in bridges: Bridges have expansion joints to allow for thermal expansion and contraction without causing cracks or buckling. (5) Railway tracks: Gaps are left between railway track sections to allow for thermal expansion in hot weather. (6) Thermometers: Mercury or alcohol in thermometers expands when heated, allowing temperature measurement. (7) Cooking: Lids on jars can be loosened by heating because the metal lid expands more than the glass jar. (8) Dental fillings: Dental materials are chosen to have similar thermal expansion coefficients to tooth material to prevent gaps.

Q.6: Explain thermal expansion of liquids in detail.

Ans: Thermal expansion of liquids is the increase in volume of a liquid when its temperature increases. Liquids expand more than solids because the intermolecular forces in liquids are weaker than in solids, allowing particles to move more freely. When a liquid is heated, its particles gain kinetic energy and move faster, increasing the average distance between particles and causing the volume to increase. The thermal expansion of liquids is described by the formula: $\Delta V = V_0 \beta \Delta T$, where ΔV is the change in volume, V_0 is the original volume, β is the coefficient of volume thermal expansion, and ΔT is the change in temperature. In liquids, we distinguish between two types of expansion: (1) Apparent expansion: This is the increase in volume of the liquid as observed in a container. It is the difference between the actual expansion of the liquid and the expansion of the container. (2) Real expansion: This is the actual increase in volume of the liquid itself, including the expansion of the container. The real expansion is always greater than the apparent expansion because the container also expands when heated. Water has an unusual property: it contracts when heated from 0°C to 4°C , and then expands above 4°C . This is why ice floats on water. The coefficient of volume thermal expansion for liquids is typically larger than for solids. For example, the coefficient for water is about 0.0002 per $^\circ\text{C}$, while for most metals it is about 0.00003 per $^\circ\text{C}$. Thermal expansion of liquids is important in many applications, such as in thermometers, where the expansion of mercury or alcohol is used to measure temperature.

Q.7: Discuss the application of bimetallic strips in temperature control devices like thermostats. Explain the principle of thermal expansion that allows the bimetallic strip to function.

Ans: A bimetallic strip consists of two different metals (usually brass and iron or invar) bonded together. These metals have different coefficients of thermal expansion. When the temperature changes, the two metals expand or contract at different rates, causing the strip to bend. This bending is used to control electrical circuits in thermostats and other temperature control devices. The principle of operation is based on the different thermal expansion coefficients of the two metals. When the temperature increases, the metal with the higher coefficient of thermal expansion expands more than the other metal. Since the two metals are bonded together, the strip bends toward the metal that expands less. When the temperature decreases, the strip bends in the opposite direction. In a thermostat, the bimetallic strip is connected to an electrical switch. When the temperature rises above the set point, the strip bends and breaks the electrical circuit, turning off the heating system. When the temperature falls below the set point, the strip bends back and completes the circuit, turning the heating system back on. This maintains the temperature within a narrow range. Bimetallic strips are used in many applications: (1) Room thermostats: Control heating and cooling systems. (2) Oven thermostats: Maintain constant oven temperature. (3) Refrigerator thermostats: Control compressor operation. (4) Automatic fire alarms: Trigger alarms when temperature exceeds a certain level. (5) Automatic circuit breakers: Protect

electrical circuits from overheating. The advantage of bimetallic strips is that they are simple, reliable, and do not require external power to operate. They respond quickly to temperature changes and can control large currents with small movements.

Q.8: What is superconductivity? Explain the phenomenon in detail. What is their scope in future world?

Ans: Superconductivity is a phenomenon in which certain materials exhibit zero electrical resistance and expel magnetic fields below a critical temperature. When a material becomes superconducting, electrical current can flow through it indefinitely without any energy loss. This is a remarkable property that has no equivalent in normal conductors. The critical temperature is the temperature below which a material becomes superconducting. For most superconductors, this temperature is very low, close to absolute zero (0 K or -273°C). For example, mercury becomes superconducting at 4.2 K, while some ceramic superconductors become superconducting at temperatures above 77 K (the boiling point of liquid nitrogen). The mechanism of superconductivity involves the formation of Cooper pairs. At low temperatures, electrons in the superconductor form pairs (Cooper pairs) that move through the material without scattering. This results in zero resistance. Additionally, superconductors exhibit the Meissner effect, which is the expulsion of magnetic fields from the interior of the superconductor. This means that a superconductor is not just a perfect conductor but also a perfect diamagnet. The scope of superconductivity in the future world is enormous: (1) Power transmission: Superconducting cables can transmit electrical power without any loss, making power distribution much more efficient. (2) Magnetic levitation (Maglev) trains: Superconducting magnets can levitate trains, allowing them to travel at very high speeds with minimal friction. (3) Medical imaging: Superconducting magnets are used in MRI (Magnetic Resonance Imaging) machines for detailed medical imaging. (4) Particle accelerators: Superconducting magnets are used in large particle accelerators like the Large Hadron Collider. (5) Energy storage: Superconducting magnetic energy storage (SMES) systems can store large amounts of electrical energy. (6) Quantum computers: Superconducting qubits are used in quantum computers. The main challenge is maintaining the extremely low temperatures required for superconductivity, which requires expensive cooling systems using liquid helium or liquid nitrogen. However, research into high-temperature superconductors continues, and future discoveries may lead to superconductors that work at room temperature, rev

CHAPTER 11

Thermal Expansion & Change of State

SHORT RESPONSE QUESTIONS & ANSWERS (3 MARKS EACH)

1 Q.1: Why do dew-drops form on leaves and grass in a spring morning?

Ans: Water vapor in the air cools during the night. When it reaches the dew point temperature, it condenses into liquid water droplets on cool surfaces like leaves and grass. This is a change of state from gas to liquid.

2 Q.2: What is the effect of pressure and temperature variation on sublimation and deposition?

Ans: Higher temperature increases sublimation rate (solid to gas). Lower temperature and higher pressure favor deposition (gas to solid). These processes depend on both temperature and pressure conditions.

3 Q.3: Why do vapors form on the handle and cylinder of a fire extinguisher when it is discharged?

Ans: When the extinguisher is discharged, the liquid inside rapidly expands and evaporates, absorbing heat from the surroundings. This cooling causes water vapor in the air to condense on the cold surface.

4 Q.4: How does sweating help to cool our body down during exercise?

Ans: Sweat evaporates from the skin surface, absorbing latent heat of vaporization from the body. This removes heat energy, cooling the body temperature during physical activity.

5 Q.5: How does the pressure in a car tyre change during a long drive on a hot day?

Ans: As the tire heats up due to friction, the air inside expands. According to Gay-Lussac's Law, pressure increases with temperature, so tire pressure rises during a long drive.

6 Q.6: How does understanding thermal expansion help prevent cracks in sidewalks during hot weather?

Ans: Concrete expands when heated. Expansion joints are left between concrete sections to allow for this expansion without causing cracks or buckling.

7 Q.7: Imagine you are stuck in the snow with your car. Which would be more effective for melting the snow trapped underneath, a pot of hot water or a high-powered heat lamp?

Ans: Hot water is more effective because it transfers heat through conduction and convection directly to the snow. A heat lamp relies on radiation, which is less efficient for melting snow.

8 Q.8: How does the evaporation of water from a plant's leaves help to transport water and nutrients throughout the plant?

Ans: Evaporation creates a water potential gradient that pulls water up from the roots through the xylem (transpiration pull). This transports dissolved nutrients throughout the plant.

9 Q.9: Why does adding ice to a drink cool it down more effectively than adding cold water?

Ans: Ice absorbs latent heat of fusion (334 kJ/kg) as it melts, removing much more heat than cold water can. This makes ice a more effective coolant than cold water.

10 Q.10: What are the challenges associated with maintaining the extremely low temperatures required for superconductivity to occur?

Ans: Superconductivity requires cooling to near absolute zero (liquid nitrogen or helium). This is expensive, energy-intensive, and requires specialized equipment and continuous cooling systems.

CHAPTER 12

Waves — MCQs & Key Concepts

MCQs with Answers

#	Question	Answer
1	One vibration in 2 seconds → frequency? A. 0.25 Hz B. 2 Hz C. 0.5 Hz D. 4 Hz	C. 0.5 Hz
2	Relationship between λ , f , and v ? A. $v = f/\lambda$ B. $v = \lambda/f$ C. $v = \lambda f$ D. $v = \lambda + f$	C. $v = \lambda f$
3	Type of wave requiring a medium? A. Mechanical waves B. Electromagnetic waves C. Light waves D. Radio waves	A. Mechanical waves
4	What happens to wavelength in a denser medium? A. Increases B. Remains the same C. Decreases D. Becomes zero	C. Decreases
5	Example of a transverse wave? A. Sound wave B. Seismic P-wave C. Light / EM waves D. Compression wave	C. Light / EM waves
6	Waves bending around obstacles? A. Reflection B. Refraction C. Diffraction D. Interference	C. Diffraction

Essential Wave Concepts

Wave Equation

$$v = \lambda f \quad | \quad T = 1/f$$

Wave Types

Transverse: EM waves, light

Longitudinal: Sound, seismic
P-waves



Reflection

Wave bounces off a surface. Angle of incidence = Angle of reflection.



Refraction

Wave changes speed and direction when entering a new medium.



Diffraction

Waves spread out after passing through an opening or around an obstacle.

D. Interference

- 7 Wave bouncing back from a surface? **B. Reflection**
- A. Refraction
B. Reflection
C. Diffraction
D. Dispersion

- 8 Bending of waves between two media? **B. Refraction**
- A. Reflection
B. Refraction
C. Diffraction
D. Polarization

CHAPTER 12

Waves — Short Response Questions with Answers

Deepen your understanding of wave phenomena with these concise explanations covering fundamental concepts.

1 Transverse vs. Longitudinal Waves

Transverse waves oscillate perpendicular to their direction of propagation (e.g., light, water surface waves). **Longitudinal waves** oscillate parallel to their direction of propagation (e.g., sound waves).

2 Frequency-Wavelength Relationship

For a constant wave speed (v), frequency (f) and wavelength (λ) are inversely related by $v = f\lambda$. Higher frequency means shorter wavelength, and vice-versa.

3 Wave Speed in Different Media

Wave speed is dependent on the medium. Sound waves typically travel fastest in solids, slower in liquids, and slowest in gases due to particle density and bond strength.

4 Wave Speed vs. Particle Speed

Wave speed is the speed at which the disturbance propagates through the medium. **Particle speed** is the speed of the individual particles of the medium as they oscillate around their equilibrium positions. These are distinct concepts.

5 Diffraction Explained

Diffraction is the bending of waves as they pass around obstacles or through an aperture. It is most pronounced when the wavelength is comparable to the size of the obstacle or opening.

6 Refraction Defined

Refraction is the change in direction of a wave as it crosses the boundary between two different media, caused by a change in wave speed. This often leads to a "bending" effect.

7 Superposition Principle

When two or more waves overlap, the resultant displacement at any point and time is the algebraic sum of the displacements of the individual waves at that point and time.

8 Standing Waves

A standing wave (or stationary wave) is a wave that oscillates in a fixed position. It results from the superposition of two identical waves traveling in opposite directions.

Waves — Long Response Questions with Full Solutions

Dive deep into wave phenomena with detailed explanations and examples for common physics concepts.

1

Wave Properties: Amplitude, Wavelength, Frequency, Period

Amplitude (A) is the maximum displacement or distance moved by a point on a vibrating body or wave measured from its equilibrium position. **Wavelength (λ)** is the spatial period of a periodic wave, the distance over which the wave's shape repeats. It's the distance between consecutive corresponding points of the same phase. **Frequency (f)** is the number of complete cycles or oscillations per unit time, measured in Hertz (Hz). **Period (T)** is the time taken for one complete cycle or oscillation to occur, measured in seconds (s). The relationships are: $f = 1/T$ and $v = f\lambda$, where v is the wave speed.

2

Reflection and Refraction Phenomena

Reflection is the change in direction of a wavefront at an interface between two different media so that the wavefront returns into the medium from which it originated. The angle of incidence equals the angle of reflection. Example: Light bouncing off a mirror. **Refraction** is the change in direction of a wave passing from one medium to another or from a gradual change in the medium. It is caused by the change in wave speed. Example: A spoon appearing bent when placed in a glass of water, or light passing through a lens.

3

Diffraction and Wavelength Dependence

Diffraction is the bending of waves as they pass around obstacles or through an aperture. This bending is more pronounced when the wavelength of the wave is comparable to the size of the obstacle or aperture. For instance, large wavelengths (like radio waves) diffract easily around buildings, allowing reception even when not in direct line of sight. Small wavelengths (like X-rays) require much smaller openings or obstacles to exhibit significant diffraction effects, which is why X-ray diffraction is used to study atomic structures.

4

Interference: Constructive and Destructive

Interference occurs when two or more waves overlap, resulting in a new wave pattern. **Constructive interference** happens when waves meet in phase, and their amplitudes add up, leading to a larger resultant amplitude (e.g., brighter light or louder sound). **Destructive interference** occurs when waves meet out of phase, and their amplitudes cancel each other out, leading to a smaller or zero resultant amplitude (e.g., dimmer light or quieter sound). Examples include soap film colors and noise-canceling headphones.

5

Doppler Effect and Real-Life Applications

The **Doppler effect** is the change in frequency or wavelength of a wave (sound or light) in relation to an observer who is moving relative to the wave source. When the source and observer are approaching each other, the frequency appears higher (e.g., higher pitch for sound); when they are moving apart, the frequency appears lower (e.g., lower pitch for sound). Real-life applications include police radar guns (measuring vehicle speed), medical ultrasound (blood flow), and astronomy (redshift/blueshift of galaxies).

Waves — Numerical Problems with Full Solutions

Dive into practical wave mechanics with step-by-step solutions for calculating speed, frequency, wavelength, and period.

1. Sound Wave Speed

A sound wave in air has a frequency (f) of **340 Hz** and a wavelength (λ) of **1.0 meter**. Calculate the speed (v) of this sound wave.

- Given: $f = 340 \text{ Hz}$, $\lambda = 1.0 \text{ m}$
- Formula: $v = f\lambda$
- Calculation: $v = 340 \text{ Hz} \times 1.0 \text{ m} = 340 \text{ m/s}$

Answer: The speed of the sound wave is 340 m/s.

2. Wave Frequency and Period

A wave travels through a medium at a speed (v) of **15 m/s** and has a wavelength (λ) of **3.0 meters**. Determine its frequency (f) and period (T).

- Given: $v = 15 \text{ m/s}$, $\lambda = 3.0 \text{ m}$
- Formulas: $f = v/\lambda$, $T = 1/f$
- Calculations:
 - $f = 15 \text{ m/s} / 3.0 \text{ m} = 5.0 \text{ Hz}$
 - $T = 1 / 5.0 \text{ Hz} = 0.20 \text{ s}$

Answer: The wave's frequency is 5.0 Hz, and its period is 0.20 s.

Sound — MCQs with 4 Options

Q. No.	Question & Options	Correct Answer
Q.1	Sound is a: A. Transverse mechanical wave B. Longitudinal mechanical wave C. Electromagnetic wave D. Stationary wave	B. Longitudinal mechanical wave
Q.2	Speed of sound in air at 20°C is approximately: A. 300 m/s B. 343 m/s C. 400 m/s D. 500 m/s	B. 343 m/s
Q.3	Best absorber of sound: A. Hard materials like concrete B. Soft materials like foam, cotton, carpets C. Metal surfaces D. Glass surfaces	B. Soft materials like foam, cotton, carpets
Q.4	Ultrasonic waves have frequency: A. Less than 20 Hz B. Between 20-20,000 Hz C. Greater than 20,000 Hz D. Equal to 20,000 Hz	C. Greater than 20,000 Hz
Q.5	Loudness of sound is measured in: A. Hertz (Hz) B. Decibels (dB) C. Meters (m) D. Seconds (s)	B. Decibels (dB)
Q.6	Pitch of sound depends on: A. Amplitude B. Frequency C. Wavelength D. Speed	B. Frequency
Q.7	Phenomenon where sound reflects from a surface: A. Refraction B. Diffraction C. Echo D. Resonance	C. Echo
Q.8	Infrasonic waves have frequency: A. Less than 20 Hz B. Between 20-20,000 Hz C. Greater than 20,000 Hz D. Equal to 20 Hz	A. Less than 20 Hz

Sound — Short Response Questions with Answers

Test your understanding of sound physics with these concise questions and detailed explanations.



Pitch vs. Loudness

Question: What is the fundamental difference between the pitch and loudness of a sound?

Answer: **Pitch** refers to how high or low a sound is, determined by its **frequency** (higher frequency = higher pitch). **Loudness**, or intensity, refers to how strong a sound is, determined by its **amplitude** (larger amplitude = louder sound).



Sound Through Media

Question: Explain how the medium affects the speed at which sound travels.

Answer: Sound travels faster through **denser and less compressible media** because particles are closer together, allowing vibrations to transmit more efficiently. For example, sound travels faster through solids than liquids, and faster through liquids than gases.



Concept of Resonance

Question: What is resonance in the context of sound, and provide a common example.

Answer: **Resonance** occurs when an object is made to vibrate at its natural frequency by an external force. A common example is a wine glass shattering when exposed to a specific musical note that matches its natural frequency.



Ultrasound Medical Uses

Question: Describe two common medical applications of ultrasound technology.

Answer: Ultrasound is used for **diagnostic imaging**, such as prenatal scans or imaging internal organs (echocardiography). It's also used therapeutically, for example, to **break up kidney stones** (lithotripsy) without surgery.



Doppler Effect Explained

Question: Briefly explain the Doppler effect as it applies to sound waves.

Answer: The **Doppler effect** is the observed change in frequency (and thus pitch) of a sound wave due to the relative motion between the source of the sound and the observer. An approaching source sounds higher-pitched, while a receding source sounds lower-pitched.



Frequency-Wavelength Link

Question: What is the relationship between the frequency and wavelength of a sound wave?

Answer: For a given speed of sound, **frequency and wavelength are inversely proportional**. This means as the frequency increases, the wavelength decreases, and vice versa (described by the formula $v = f\lambda$).



Musical Instrument Pitch

Question: How do musical instruments typically produce and change the pitch of the sounds they create?

Answer: Instruments produce pitch by causing a part (string, air column, membrane) to vibrate at specific frequencies. Pitch is changed by altering the **length, tension, mass, or stiffness** of the vibrating component.



Noise Pollution Effects

Question: Name two significant negative effects of noise pollution on human health or the environment.

Answer: Noise pollution can lead to **hearing loss, sleep disturbance, increased stress levels**, and cardiovascular problems in humans. Environmentally, it can disrupt wildlife communication, migration patterns, and overall ecosystem balance.

CHAPTER 13

Sound — Long Response Questions with Full Solutions

Dive into the physics of sound with detailed explanations and practical examples, covering wave properties, phenomena, and applications.

Sound Wave Production & Propagation

Question: Explain how sound waves are produced and describe their propagation through different media, specifically comparing solids, liquids, and gases.

Solution: Sound waves are produced by vibrations, which create disturbances that travel through a medium as mechanical waves. These vibrations cause compressions (regions of high pressure and density) and rarefactions (regions of low pressure and density) in the medium. Sound is a longitudinal wave, meaning particles of the medium oscillate parallel to the direction of wave propagation.



Propagation speed varies significantly with the medium. Sound travels fastest in **solids** because their particles are tightly packed and strongly bonded, allowing vibrations to be transmitted quickly and efficiently. In **liquids**, particles are less rigidly bound but still close, making sound travel slower than in solids but faster than in gases. In **gases**, particles are widely spaced and interact less frequently, resulting in the slowest speed of sound. Key factors influencing speed are the medium's elasticity (stiffness) and density; higher elasticity and lower density generally lead to faster sound transmission.

Sound Properties: Pitch, Loudness, Timbre

Question: Define pitch, loudness, and timbre. Explain how each property is related to specific physical characteristics of a sound wave (frequency, amplitude, and waveform).

Solution:



- **Pitch:** This refers to how high or low a sound is perceived. Pitch is primarily determined by the **frequency** of the sound wave. Higher frequency waves correspond to higher pitches, and lower frequency waves correspond to lower pitches. For example, a violin produces high-pitch sounds due to rapid vibrations, while a cello produces low-pitch sounds due to slower vibrations.
- **Loudness:** This describes the perceived intensity or strength of a sound. Loudness is primarily determined by the **amplitude** of the sound wave. Larger amplitude waves carry more energy and are perceived as louder, while smaller amplitude waves are perceived as softer. Loudness is measured in decibels (dB).
- **Timbre (or Quality):** This is the characteristic that distinguishes different types of sound production, such as musical instruments or human voices, even when they produce the same pitch and loudness. Timbre is determined by the **waveform** of the sound, specifically the presence and relative intensity of overtones (harmonics) in addition to the fundamental frequency. This complex blend of frequencies gives each sound source its unique tonal color.

Ultrasonic Wave Applications

Question: Discuss various applications of ultrasonic waves in medical imaging, industrial cleaning, and other industrial settings.

Solution: Ultrasonic waves, with frequencies above the range of human hearing (>20 kHz), have numerous practical applications due to their ability to travel through opaque materials and reflect off boundaries.



- **Medical Imaging:** Ultrasound imaging is non-invasive and uses high-frequency sound waves to create real-time images of internal body structures, such as fetal development during pregnancy (sonography), organ examination, and blood flow analysis. The waves reflect off tissues and organs, and a transducer converts these echoes into visual images.
- **Industrial Cleaning:** Ultrasonic cleaners use high-frequency sound waves in a liquid bath to agitate the liquid, creating millions of microscopic bubbles (cavitation). These bubbles collapse, releasing energy that dislodges dirt, grime, and contaminants from intricate parts, tools, and jewelry, reaching areas inaccessible by conventional cleaning methods.
- **Industrial Applications:** Ultrasonics are used for non-destructive testing (NDT) to detect flaws (cracks, voids) in materials like metals and composites, ensuring structural integrity without causing damage. They are also used in welding plastics, machining hard materials, and in depth-sounding (sonar) for navigation and mapping underwater terrain.

Doppler Effect Practical Applications

Question: Describe the Doppler effect and explain its practical applications in astronomy (e.g., redshift/blueshift) and traffic speed measurement.

Solution: The **Doppler effect** is the change in frequency or wavelength of a wave (sound or light) in relation to an observer who is moving relative to the wave source. When the source and observer move closer, the frequency increases (waves are "compressed"). When they move further apart, the frequency decreases (waves are "stretched").



- **Astronomy:** For light waves from celestial objects, the Doppler effect manifests as redshift or blueshift. If a galaxy is moving away from Earth, its emitted light waves are stretched, shifting towards the red end of the spectrum (**redshift**). Conversely, if a galaxy is moving towards Earth, its light waves are compressed, shifting towards the blue end of the spectrum (**blueshift**). This phenomenon is crucial for understanding the expansion of the universe, measuring galactic velocities, and detecting exoplanets.
- **Traffic Speed Measurement:** Law enforcement uses radar guns, which emit radio waves (a type of electromagnetic wave) towards a moving vehicle. The waves reflect off the vehicle and return to the radar gun. Due to the Doppler effect, the frequency of the reflected waves changes based on the vehicle's speed. By measuring this frequency shift, the radar gun can accurately calculate the vehicle's velocity. Similarly, some traffic cameras use sound waves for speed detection.

Resonance Phenomenon

Question: Define resonance and provide examples of its applications in musical instruments and architectural design.

Solution: Resonance occurs when an object or system is exposed to an external force or vibration at a frequency close to its own natural frequency, leading to a significant increase in the amplitude of oscillations. Essentially, the system efficiently absorbs energy from the external source, often with dramatic results.

- **Musical Instruments:** Resonance is fundamental to how musical instruments produce and amplify sound.
 - **String Instruments (e.g., Guitar, Violin):** The vibrating strings themselves produce little sound. However, their vibrations are transmitted to the instrument's body (soundboard) and the air inside, which are designed to resonate at specific frequencies, amplifying the sound and giving it richness and sustain.
 - **Wind Instruments (e.g., Flute, Trumpet):** Air columns inside these instruments are set into vibration by the player. The length of the air column (adjusted by keys or valves) determines its natural resonant frequencies, which then amplify the sounds produced by the player's breath or buzzing lips.
- **Architectural Design:** Understanding resonance is critical in structural engineering and acoustic design.
 - **Earthquake Engineering:** Buildings are designed to have natural frequencies different from typical earthquake frequencies to avoid resonant vibrations that could lead to catastrophic structural failure (e.g., Tacoma Narrows Bridge collapse, though related, was more aerodynamic flutter). Tuned mass dampers are sometimes used to mitigate resonance.
 - **Concert Halls:** Architects carefully design the shape, materials, and dimensions of concert halls to enhance acoustic resonance for optimal sound quality. Surfaces are angled and materials chosen to reflect and absorb sound waves in a controlled manner, allowing certain frequencies to resonate and fill the space beautifully without causing unwanted echoes or dead spots.

Thermal Expansion & Change of State

Short Questions & Answers

Exploring key concepts and applications through concise Q&A.

CHAPTER 13

Sound — Numerical Problems with Full Solutions

Dive into the quantitative aspects of sound with this collection of fully solved problems. Master calculations related to sound propagation, wave characteristics, intensity measurements, and the Doppler effect, essential for a deep understanding of acoustics.

01	02
Sound Speed Calculations	Frequency & Wavelength
Determine how sound travels through different materials and under varying conditions.	Explore the fundamental properties of sound waves and their interrelationships.
03	04
Sound Intensity & Decibels	The Doppler Effect
Quantify the power of sound and measure its perceived loudness.	Analyze shifts in sound frequency due to relative motion between source and observer.

CHAPTER 14

Optics - MCQs & Key Concepts

MCQs with Answers

#	Question	Answer
1	Angle of incidence equals angle of reflection.	B. Law of Reflection

Essential Optics Concepts

Law of Reflection	Refraction
Angle of incidence equals angle of reflection.	Light bends away from normal when entering a less dense medium.

reflection according to:

- A. Law of Refraction
- B. Law of Reflection
- C. Snell's Law
- D. Law of Diffraction

2 When light passes from denser to rarer medium, it bends:

B. Away from the normal

- A. Toward the normal
- B. Away from the normal
- C. Parallel to the normal
- D. Perpendicular to the

normal

3 A convex lens acts as a:

B. Converging lens

- A. Diverging lens
- B. Converging lens
- C. Neutral lens
- D. Prism

4 A concave lens acts as a:

B. Diverging lens

- A. Converging lens
- B. Diverging lens
- C. Neutral lens
- D. Mirror

5 Focal length of a lens is:

C. Distance from lens to focal point

- A. Distance from lens to object
- B. Distance from lens to image
- C. Distance from lens to focal point
- D. Distance between two lenses

6 Power of a lens with focal length 0.5 m is:

A. +2 diopters

- A. +2 diopters
- B. -2 diopters
- C. +0.5 diopters
- D. -0.5 diopters

7 Total internal reflection occurs when light travels from:

B. Denser to rarer medium at critical angle

- A. Rarer to denser medium
- B. Denser to rarer medium at critical angle
- C. One medium to same medium
- D. Air to water

8 Critical angle for glass-air interface is approximately:

C. 42°

- A. 30°
- B. 45°
- C. 42°

angle of reflection.

when entering a rarer medium.

Lens Types

- Convex: Converging
- Concave: Diverging

Focal Length

Distance from lens to focal point.

Lens Power

Measured in diopters (1/focal length in meters).

Total Internal Reflection

Occurs when light travels from denser to rarer medium at critical angle.

Critical Angle

Specific angle for total internal reflection (e.g., 42° for glass-air).

D. 60°

Optics — Short Response Questions with Answers

Test your understanding of fundamental optics concepts with these concise questions and solutions.

Laws of Reflection

1

Question: State the two laws of reflection.

Answer: 1. The angle of incidence is equal to the angle of reflection. 2. The incident ray, the reflected ray, and the normal to the surface all lie in the same plane.

Laws of Refraction & Snell's Law

2

Question: Describe the laws of refraction and the mathematical relationship known as Snell's Law.

Answer: 1. The incident ray, the refracted ray, and the normal to the interface at the point of incidence all lie in the same plane. 2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given pair of media (Snell's Law: $n_1 \sin \theta_1 = n_2 \sin \theta_2$).

Convex and Concave Lenses

3

Question: What is the primary difference in how convex and concave lenses affect parallel light rays?

Answer: A convex lens converges parallel light rays to a single focal point, while a concave lens diverges parallel light rays, making them appear to originate from a virtual focal point.

Focal Length & Lens Power

4

Question: Define focal length and lens power, including their standard units.

Answer: Focal length (f) is the distance from the optical center of a lens or mirror to its focal point. Lens power (P) is the reciprocal of the focal length in meters ($P = 1/f$) and is measured in diopters (D).

Total Internal Reflection (TIR)

5

Question: Under what conditions does total internal reflection occur, and what is the critical angle?

Answer: TIR occurs when light travels from an optically denser medium to a rarer medium, and the angle of incidence in the denser medium exceeds the critical angle. The critical angle is the angle of incidence for which the angle of refraction is 90° .

Mirror Types and Properties

6

Question: Briefly describe the image formation properties of a plane mirror versus a convex mirror.

Answer: A plane mirror always forms a virtual, erect, and laterally inverted image of the same size as the object. A convex mirror always forms a virtual, erect, and diminished image, regardless of object distance.

Ray Diagrams

7

Question: What is the practical utility of drawing ray diagrams in geometric optics?

Answer: Ray diagrams are used to graphically locate and characterize the image formed by lenses and mirrors (e.g., determining if the image is real or virtual, inverted or upright, magnified or diminished) without complex calculations.

Optics — Long Response Questions with Full Solutions

Delve into the fascinating world of light with comprehensive answers covering reflection, refraction, lenses, mirrors, and optical instruments.

1	Laws of Reflection & Refraction The Law of Reflection states that the angle of incidence equals the angle of reflection ($\theta_i = \theta_r$), and the incident ray, reflected ray, and normal all lie in the same plane. For Refraction, light bends as it passes between media. Snell's Law ($n_1 \sin \theta_1 = n_2 \sin \theta_2$) quantifies this, where n is the refractive index and θ is the angle. The incident ray, refracted ray, and normal are also coplanar.
2	Lens Formula & Applications The Thin Lens Formula is $1/f = 1/v - 1/u$, where f is the focal length, v is the image distance, and u is the object distance. This formula helps locate images formed by lenses and is crucial for designing optical systems. Applications range from corrective eyeglasses and camera lenses to sophisticated projectors and medical imaging devices, all relying on precise control of light paths.
3	Mirror Formula & Magnification The Mirror Formula for spherical mirrors is $1/f = 1/v + 1/u$, similar to the lens formula but with a sign convention difference. Magnification ($m = -v/u = h'/h$) describes the ratio of image height to object height and indicates if the image is inverted or upright. This is applied in rear-view mirrors, shaving mirrors, and in large reflecting telescopes to gather and focus light from distant objects.
4	Convex & Concave Lens Behavior Convex lenses (converging) focus parallel light rays to a real focal point and can form both real, inverted images or virtual, upright images, depending on object distance. Concave lenses (diverging) spread out parallel light rays, making them appear to originate from a virtual focal point, always forming virtual, upright, and diminished images. Ray diagrams are essential for visualizing these image formations.
5	Total Internal Reflection & Critical Angle Total Internal Reflection (TIR) occurs when light traveling from a denser medium to a rarer medium hits the interface at an angle greater than the critical angle. The critical angle (C) is the angle of incidence at which the angle of refraction is 90° (calculated by $\sin(C) = n_2/n_1$). TIR is fundamental to fiber optics, where light signals are transmitted over long distances with minimal loss, and explains the sparkle of diamonds.
6	Optical Instruments Microscopes use two convex lenses (objective and eyepiece) to magnify small objects, producing a highly enlarged virtual image. Telescopes similarly use an objective lens or mirror to collect light from distant objects and an eyepiece to magnify the resulting image. These instruments have revolutionized scientific discovery, from observing cellular structures to exploring distant galaxies.

CHAPTER 14

Optics — Numerical Problems with Full Solutions

Dive into the fundamental principles of optics with a series of numerical problems covering lenses, mirrors, refraction, and critical angles. Each solution provides a clear, step-by-step guide to mastering these essential physics concepts.

CHAPTER 15

Electrostatics — MCQs & Key Concepts

Question & Options	Correct Answer
Q.1: Like charges: A. Attract each other B. Repel each other C. Remain neutral D. Combine together	B. Repel each other
Q.2: Unlike charges: A. Attract each other B. Repel each other C. Remain neutral D. Combine together	B. Attract each other

- A. Repel each other
- B. Attract each other
- C. Remain neutral
- D. Separate apart

Q.3: SI unit of electric charge is:

B. Coulomb (C)

- A. Ampere (A)
- B. Coulomb (C)
- C. Volt (V)
- D. Farad (F)

Q.4: Electric field lines:

B. Start from positive and end at negative charges

- A. Start from negative and end at positive charges
- B. Start from positive and end at negative charges
- C. Form closed loops
- D. Never intersect

Q.5: SI unit of electric potential is:

C. Volt (V)

- A. Coulomb (C)
- B. Ampere (A)
- C. Volt (V)
- D. Ohm (Ω)

Q.6: Capacitance is measured in:

C. Farad (F)

- A. Coulomb (C)
- B. Volt (V)
- C. Farad (F)
- D. Joule (J)

Q.7: Capacitance of parallel plate capacitor is:

A. $C = \epsilon_0 \epsilon_r A/d$

- A. $C = \epsilon_0 \epsilon_r A/d$
- B. $C = \epsilon_0 \epsilon_r d/A$
- C. $C = \epsilon_0 A/d^2$
- D. $C = \epsilon_0 d/A$

Q.8: Energy stored in a capacitor is:

B. $U = \frac{1}{2}QV$

- A. $U = QV$
- B. $U = \frac{1}{2}QV$
- C. $U = 2QV$
- D. $U = Q^2V$

CHAPTER 15

Electrostatics — Short Response Questions with Answers

Test your understanding of fundamental electrostatics principles with these concise questions and solutions.

1

Coulomb's Law

Q: State Coulomb's law for electrostatic force.

A: Coulomb's law states that the electrostatic force between two point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distance between them. It acts along the line joining the charges.

2

Electric Field Concept

Q: What is an electric field and how is it represented?

A: An electric field is a region around a charged object where another charged object would experience an electrostatic force. It is represented by electric field lines, which show the direction of the force on a positive test charge.

Electric Potential

3

Q: Define electric potential at a point in an electric field.

A: Electric potential at a point is the amount of work done per unit positive test charge to bring the charge from infinity to that point without acceleration.

4

Potential Difference

Q: What is the physical significance of potential difference?

A: Potential difference (voltage) between two points is the work done per unit charge in moving a positive test charge from one point to the other. It drives the flow of charge (current) in a circuit.

5

Capacitance

Q: What is capacitance and its SI unit?

A: Capacitance is the ability of a conductor or system of conductors to store electric charge. It is defined as the ratio of the charge stored on the conductor to the potential difference applied across it ($C = Q/V$). The SI unit is the Farad (F).

6

Types of Charges

Q: Name the two fundamental types of electric charge and their interaction.

A: The two types are positive and negative charge. Like charges repel each other, while unlike charges attract each other.

7

Electric Field Lines

Q: List two properties of electric field lines.

A: 1) Electric field lines originate from positive charges and terminate on negative charges, or at infinity. 2) No two electric field lines can intersect each other.

8

Equipotential Surfaces

Q: Why is no work done when a charge moves along an equipotential surface?

A: An equipotential surface is one where the electric potential is constant at every point. Since there is no potential difference between any two points on such a surface, the work done ($W = Q\Delta V$) in moving a charge between them is zero.

9

Parallel Plate Capacitor

Q: Explain the basic function of a parallel plate capacitor.

A: A parallel plate capacitor stores electrical energy by accumulating opposite charges on two parallel conducting plates separated by a dielectric material. This creates a uniform electric field between the plates.

CHAPTER 15

Electrostatics — Long Response Questions with Full Solutions

Delve into the fundamental principles of electrostatics with detailed explanations and derivations for key concepts.

1

Coulomb's Law: Derivation & Applications

Coulomb's Law describes the electrostatic force between two point charges. It states that the force is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them. ¹ Where F is the electrostatic force, k is Coulomb's constant ($8.987 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$), q_1 and q_2 are the magnitudes of the charges, and r is the distance between them. Applications include understanding atomic structure, calculating forces in ionic bonds, and designing electrostatic precipitators.

2

Electric Field: Definition & Calculation

An **electric field** ($\mathbf{E}$) is a region around an electrically charged particle or object in which an electrically charged object would experience a force. It is defined as the force per unit positive test charge: ² For a point charge, the magnitude of the electric field

at a distance r is: ³ Electric fields can be calculated by summing vectorially for multiple point charges or by integration for continuous charge distributions (e.g., using Gauss's Law for symmetric cases).

Electric Potential & Potential Difference

- 3** **Electric potential** (V) at a point is the amount of work done per unit positive test charge to bring the charge from infinity to that point without acceleration. It is a scalar quantity, measured in Volts (J/C). ⁴**Electric potential difference** (ΔV or voltage) between two points is the work done per unit charge to move a charge between those points. It is directly related to the electric field: ⁵ Potential difference drives current in circuits.

Capacitance & Parallel Plate Capacitor

- 4** **Capacitance** (C) is a measure of a capacitor's ability to store electric charge. It is defined as the ratio of the charge stored (Q) to the potential difference (V) across the capacitor: ⁶ For a **parallel plate capacitor** consisting of two parallel conducting plates of area A separated by a distance d in a vacuum, the capacitance is: ⁷ Where ϵ_0 is the permittivity of free space. Capacitance depends only on the geometry and the dielectric material between the plates.

Energy Stored in Capacitors

- 5** A charged capacitor stores electrical potential energy in the electric field between its plates. The energy stored (U) can be expressed in several ways: ⁸ This stored energy can be quickly discharged, providing a burst of power for various applications like camera flashes or defibrillators. The energy density is proportional to the square of the electric field strength.

Dielectric Materials

Dielectric materials are electrical insulators that can be polarized by an applied electric field. When placed between the plates of a capacitor, they serve several purposes:

- 6**
- Increase capacitance: The dielectric constant (κ) of the material multiplies the capacitance ($C = \kappa C_0$).
 - Allow plates to be closer: Prevents arcing and electrical breakdown.
 - Improve mechanical support: Holds the plates rigidly in place.

The polarization of the dielectric reduces the effective electric field, allowing more charge to be stored for the same potential difference.

Applications of Electrostatics

Electrostatics has numerous practical applications in everyday life and technology:

- 7**
- **Photocopiers:**
 - **Laser Printers:**
 - **Air Purifiers:**
 - **Inkjet Printers:**
 - **Electrostatic Painting:**
 - **Defibrillators:**

CHAPTER 15

Electrostatics — Numerical Problems

Dive deep into the fundamental principles of electrostatics with fully solved numerical problems, covering key concepts from Coulomb's Law to capacitor energy storage. Master the calculations required for exam success.



Coulomb's Law

Calculate electrostatic forces between point charges.



Electric Field Strength

Determine electric field intensity due to various charge distributions.



Electric Potential

Compute potential and potential energy in electrostatic systems.

Capacitance Calculations

Analyze capacitance for single capacitors and combinations.



Energy Stored

Quantify the energy stored within electric fields of capacitors.



Parallel Plate Capacitors

Solve problems involving parallel plate geometries and dielectrics.

CHAPTER 16

Current Electricity — MCQs with 4 Options

MCQs with Answers

#	Question	Answer
1	Electric current is defined as: A. Flow of voltage per unit time B. Flow of charge per unit time ($I = Q/t$) C. Flow of resistance per unit time D. Flow of power per unit time	B. Flow of charge per unit time ($I = Q/t$)
2	SI unit of current is: A. Coulomb (C) B. Volt (V) C. Ampere (A) D. Ohm (Ω)	C. Ampere (A)
3	Resistance is measured in: A. Ampere (A) B. Volt (V) C. Ohm (Ω) D. Farad (F)	C. Ohm (Ω)
4	Resistivity depends on: A. Length and cross-sectional area only B. Material and temperature C. Voltage and current only D. Power and energy	B. Material and temperature
5	When resistors are in series, total resistance is: A. $1/R_{\text{total}} = 1/R_1 + 1/R_2 + 1/R_3...$ B. $R_{\text{total}} = R_1 + R_2 + R_3...$ C. $R_{\text{total}} = R_1 \times R_2 \times R_3...$ D. $R_{\text{total}} = (R_1 + R_2)/2$	B. $R_{\text{total}} = R_1 + R_2 + R_3...$
6	When resistors are in parallel, total resistance is: A. $R_{\text{total}} = R_1 + R_2 + R_3...$ B. $1/R_{\text{total}} = 1/R_1 + 1/R_2 + 1/R_3...$ C. $R_{\text{total}} = R_1 \times R_2 \times R_3...$ D. $R_{\text{total}} = R_1/R_2$	B. $1/R_{\text{total}} = 1/R_1 + 1/R_2 + 1/R_3...$
7	Power dissipated in a resistor is: A. $P = V/I$ B. $P = V^2/R$ C. $P = I^2R$ D. $P = V \times I$	C. $P = I^2R$

B. $P = I/V$

C. $P = I^2R$

D. $P = I/R^2$

8 SI unit of electrical energy is:

C. Joule (J)

A. Watt (W)

B. Ampere (A)

C. Joule (J)

D. Volt (V)

CHAPTER 16

Current Electricity — Short Response Questions & Answers

Test your understanding of fundamental concepts in current electricity with these concise questions and solutions.

Electric Current Definition

- 1 Electric current is the rate of flow of electric charge past a point or through a region. Its SI unit is the **Ampere (A)**, equivalent to one Coulomb per second (C/s).

Ohm's Law

- 2 Ohm's Law states that the current flowing through a conductor is directly proportional to the voltage across it, provided temperature is constant. Mathematically, $V = IR$, where V is voltage, I is current, and R is resistance.

Resistance vs. Resistivity

- 3 **Resistance (R)** measures an object's opposition to current, depending on its material, length, and cross-sectional area. **Resistivity (ρ)** is an intrinsic material property, independent of dimensions, indicating inherent current opposition ($R = \rho L/A$).

Series vs. Parallel Resistors

- 4 In a **series circuit**, current is uniform, and voltages add. In a **parallel circuit**, voltage is uniform across all components, and currents through each branch sum up.

Power Dissipation

- 5 Electrical power dissipation is the rate at which electrical energy converts to other forms (e.g., heat) in a resistive circuit. It is calculated as $P = VI = I^2R = V^2/R$.

Electrical Energy

- 6 Electrical energy is energy transferred by current over time ($E = Pt = VIt$). The common household unit is the **kilowatt-hour (kWh)**, equal to 3.6×10^6 Joules.

EMF & Internal Resistance

- 7 **Electromotive Force (EMF)** is the maximum potential difference a source can provide. **Internal resistance (r)** is the opposition to current flow within the source itself, causing a voltage drop when current flows.

Conductivity

- 8 **Conductivity (σ)** is a material's ability to conduct electric current. It is the reciprocal of resistivity ($\sigma = 1/\rho$) and is measured in Siemens per meter (S/m). Materials with high conductivity are good conductors.

CHAPTER 16

Current Electricity — Long Response Questions

Delve into the fundamental principles of current electricity with detailed explanations and problem-solving strategies for complex long-response questions. This section provides comprehensive answers to key topics, ensuring a deep understanding of circuit analysis, energy transfer, and material properties.

- 1

Ohm's Law: Derivation & Applications
Understand the foundational relationship between voltage, current, and resistance, including its experimental verification and practical applications in circuit design.
- 2

Resistance and Resistivity Concepts
Define resistance and resistivity, exploring the factors that influence them, such as material type, length, and cross-sectional area. Analyze the difference between ohmic and non-ohmic conductors.
- 3

Series and Parallel Circuit Analysis
Master the techniques for calculating equivalent resistance, current, and voltage in both series and parallel configurations, including combinations of both.
- 4

Power Dissipation and Joule Heating
Examine how electrical energy is converted into heat (Joule heating) in resistive circuits, and calculate the power dissipated by components using relevant formulas.
- 5

Electrical Energy Calculations
Compute the total electrical energy consumed or transferred in a circuit over a period, understanding its relationship to power and time, and its practical implications.
- 6

EMF and Internal Resistance Effects
Differentiate between electromotive force (EMF) and potential difference, and analyze the impact of internal resistance on the terminal voltage of a power source.
- 7

Temperature Dependence of Resistance
Investigate how the resistance of conductors and semiconductors varies with changes in temperature, and apply mathematical models to predict this behavior.

CHAPTER 16

Current Electricity — Numerical Problems

This chapter provides a comprehensive set of numerical problems and detailed solutions for key concepts in current electricity. We will cover:

- Ohm's Law applications ($V=IR$)
- Resistance calculations ($R = \rho L/A$)
- Series and parallel resistance combinations
- Power calculations ($P = VI, I^2R, V^2/R$)
- Electrical energy calculations ($E = Pt$)
- Electromotive Force (EMF) and internal resistance problems

Each problem includes step-by-step solutions to deepen your understanding and prepare you for practical applications.

CHAPTER 17

ELECTRIC CIRCUITS - MCQs WITH 4 OPTIONS

Q.	Question & Options	Correct Answer
1	Kirchhoff's first law is based on:	B. Conservation of charge

	A. Conservation of energy B. Conservation of charge C. Conservation of momentum D. Conservation of power	
2	Kirchhoff's second law is based on: A. Conservation of charge B. Conservation of momentum C. Conservation of energy D. Conservation of mass	C. Conservation of energy
3	A potential divider is used to: A. Increase voltage B. Decrease current C. Obtain a fraction of the input voltage D. Store electrical energy	C. Obtain a fraction of the input voltage
4	In a Wheatstone bridge at balance: A. $R_1 + R_2 = R_3 + R_4$ B. $R_1/R_2 = R_3/R_4$ C. $R_1 \times R_2 = R_3 \times R_4$ D. $R_1 - R_2 = R_3 - R_4$	B. $R_1/R_2 = R_3/R_4$
5	Internal resistance of a battery: A. Increases voltage B. Causes voltage drop inside the battery C. Increases current D. Reduces power consumption	B. Causes voltage drop inside the battery
6	A rheostat is used to: A. Measure resistance B. Store electrical energy C. Vary the resistance in a circuit D. Increase voltage	C. Vary the resistance in a circuit
7	Efficiency of a circuit is: A. $(\text{Total power input} / \text{Useful power output}) \times 100\%$ B. $(\text{Useful power output} / \text{Total power input}) \times 100\%$ C. $(\text{Power loss} / \text{Total power}) \times 100\%$ D. $(\text{Voltage} / \text{Current}) \times 100\%$	B. $(\text{Useful power output} / \text{Total power input}) \times 100\%$
8	Maximum power transfer occurs when: A. Load resistance is zero B. Load resistance equals source resistance C. Load resistance is very large D. Source resistance is zero	B. Load resistance equals source resistance

CHAPTER 17

Electric Circuits: Short Questions & Answers

Test your understanding of fundamental circuit laws and components with these concise questions and answers.

Q.1: State Kirchhoff's Current Law (KCL).

Ans: The algebraic sum of currents entering a node equals the sum of currents leaving it. It reflects the conservation of charge:

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

Q.2: State Kirchhoff's Voltage Law (KVL).

Ans: The algebraic sum of all voltages around any closed loop in a circuit equals zero. This reflects the conservation of energy: $\sum V = 0$ around a loop.

Q.3: Explain the function of a potential divider.

Ans: It uses series resistors to produce an output voltage that is a precise fraction of the input voltage: .

Q.4: When is a current divider used?

Ans: A current divider with parallel resistors distributes current from a source into multiple branches. For two parallel resistors, current through R_1 is ¹.

Q.5: What is the primary application of a Wheatstone bridge?

Ans: It is used for precisely measuring an unknown electrical resistance by balancing two legs of a bridge circuit. The balance condition is $R_1/R_2 = R_3/R_x$.

Q.6: Define internal resistance.

Ans: Opposition to current flow within a power source itself, causing a voltage drop when current flows: $V = E - Ir$.

Q.7: What is the purpose of a rheostat?

Ans: A rheostat is a variable resistor used to control current flow in a circuit, commonly for dimming lights or controlling motor speed.

Q.8: How is circuit efficiency calculated?

Ans: Efficiency is calculated as the ratio of useful power output to total power input, multiplied by 100%: ².

Q.9: When does maximum power transfer occur?

Ans: Maximum power transfers to a load when the load resistance equals the source's internal (Thevenin) resistance: $R_L = R_{Th}$. Efficiency at this point is 50%.

CHAPTER 17

Electric Circuits — Long Response Questions

Dive deep into fundamental circuit laws and analysis techniques with these comprehensive, solved questions, preparing you for advanced electrical engineering concepts.

1

Kirchhoff's Current Law (KCL)

Principle: KCL states that the algebraic sum of currents entering a node (or junction) is equal to the algebraic sum of currents leaving the node. This is a direct consequence of the **conservation of charge**, as charge cannot accumulate at a node. The total charge entering must equal the total charge leaving.

Application: Essential for analyzing parallel circuits or complex networks where multiple branches meet. It helps determine unknown currents at junctions, forming equations to solve for circuit variables.

$$\Sigma I_{\text{in}} = \Sigma I_{\text{out}} \text{ or } \Sigma I = 0 \text{ at a node}$$

2

Kirchhoff's Voltage Law (KVL)

Principle: KVL states that the algebraic sum of all voltages around any closed loop in a circuit is equal to zero. This is based on the **conservation of energy**; any energy gained by charge moving through a voltage source must be dissipated (or stored) by components in the loop. The potential difference across an ideal wire is zero.

Application: Used to analyze series circuits or complex networks, especially for determining unknown voltages or currents in a loop. It helps set up a system of equations to describe circuit behavior.

$$\Sigma V = 0 \text{ around any closed loop}$$

3

Potential Divider Circuit Analysis

Concept: A potential divider (or voltage divider) is a passive linear circuit that produces an output voltage that is a fraction of its input voltage. It consists of two or more series resistors (or other impedances) across which the input voltage is applied.

Formula: For two resistors, R_1 and R_2 , in series with input voltage V_{in} , the output voltage across R_2 is given by:

$$V_{\text{out}} = V_{\text{in}} \left(\frac{R_2}{R_1 + R_2} \right)$$

Use: Generating a specific reference voltage from a higher voltage source, or as a sensor interface where resistance changes with a physical quantity.

Current Divider Circuit Analysis

Concept: A current divider is a linear circuit that divides the current among two or more parallel branches. The current flowing through each branch is a fraction of the total current entering the parallel combination.

4

Formula: For two parallel resistors, R_1 and R_2 , and a total current I_{total} entering the parallel combination, the current through R_1 is:

$$I_{R1} = I_{\text{total}} \left(\frac{R_2}{R_1 + R_2} \right)$$

Use: Distributing current to different parts of a circuit, or limiting current through sensitive components.

Wheatstone Bridge Principle

Principle: The Wheatstone bridge is a circuit used to precisely measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which contains the unknown component. The balance condition is achieved when the galvanometer (or detector) shows zero current.

5

Balance Condition: When the bridge is balanced, the ratio of resistances in one arm is equal to the ratio of resistances in the other arm:

$$\frac{R_1}{R_2} = \frac{R_3}{R_x}$$

where R_x is the unknown resistance. This allows for precise calculation of R_x .

Application: Used in precision measurement of resistance, strain gauges, and temperature sensors.

Maximum Power Transfer Theorem

Principle: This theorem states that to obtain maximum external power from a source with a finite internal resistance, the resistance of the load must be equal to the internal (Thevenin equivalent) resistance of the source.

Condition: For a source with Thevenin resistance R_{Th} , maximum power is delivered to a load R_L when:

6

$$R_L = R_{\text{Th}}$$

Implication: At maximum power transfer, the efficiency is 50%, as an equal amount of power is dissipated within the source's internal resistance.

Use: Designing amplifiers, radio transmitters, and solar power systems to efficiently transfer power to a load.

Circuit Efficiency Calculations

Concept: Circuit efficiency (η) is a measure of how effectively electrical power supplied to a circuit (or component) is converted into useful power, rather than being dissipated as unwanted forms like heat. It is expressed as a percentage or a fraction.

Formula: Efficiency is defined as the ratio of output power (P_{out}) to input power (P_{in}):

7

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\%$$

Alternatively, it can be calculated using power loss (P_{loss}):

$$\eta = \frac{P_{\text{in}} - P_{\text{loss}}}{P_{\text{in}}} \times 100\%$$

Importance: Crucial for optimizing system performance, reducing energy consumption, and managing thermal issues in electronic devices.

CHAPTER 17

Electric Circuits — Numerical Problems with Full Solutions

This chapter provides a comprehensive set of numerical problems and their step-by-step solutions, designed to solidify your understanding of complex electric circuits. We will cover essential analysis techniques and practical applications.

Kirchhoff's Laws

Multi-loop circuits

Potential & Current Dividers

Calculating distribution

Wheatstone Bridge

Balance conditions

Maximum Power Transfer

Source to load optimization

Circuit Efficiency

Sound, Optics, Electrostatics, Current Electricity & Electric Circuits

Key topic summaries and question frameworks for Chapters 13–17 of the FBISE syllabus.

Ch. 13 — Sound

- Nature of sound as a longitudinal mechanical wave
- Speed of sound in different media (solid > liquid > gas)
- Characteristics: pitch, loudness, quality (timbre)
- Reflection of sound — echo and reverberation
- Noise pollution and its effects

Ch. 14 — Optics

- Laws of reflection and refraction (Snell's Law)
- Total internal reflection and critical angle
- Lenses — converging and diverging, focal length
- Mirror and lens formulae: $1/f = 1/v + 1/u$
- Optical instruments: eye, microscope, telescope

Ch. 15 — Electrostatics

- Coulomb's Law: $F = kq_1q_2/r^2$
- Electric field: $E = F/q$
- Electric potential and potential difference
- Capacitors and capacitance: $C = Q/V$
- Applications of electrostatics

Ch. 16 — Current Electricity

- Ohm's Law: $V = IR$
- Resistance and resistivity: $R = \rho L/A$
- Series and parallel combinations of resistors
- Electric power: $P = VI = I^2R = V^2/R$
- Joule's Law of heating: $H = I^2Rt$

Ch. 17 — Electric Circuits

- Kirchhoff's Current Law (KCL) and Voltage Law (KVL)
- EMF and internal resistance of a cell
- Wheatstone bridge principle
- Logic gates: AND, OR, NOT, NAND, NOR
- Household electrical circuits and safety devices

Master Formula Sheet — Chapters 10–17

Heat & Thermodynamics

$$Q = mc\Delta T \text{ — Heat transfer}$$

$$Q = mL \text{ — Latent heat}$$

$$\Delta L = \alpha L_0 \Delta T \text{ — Linear expansion}$$

$$\Delta V = \beta V_0 \Delta T ; \beta = 3\alpha \text{ — Volume expansion}$$

$$Q_{\text{lost}} = Q_{\text{gained}} \text{ — Calorimetry}$$

Waves & Sound

$$v = f\lambda \text{ — Wave equation}$$

$$f = 1/T \text{ — Frequency \& period}$$

$$v_{\text{sound}} \approx 340 \text{ m/s — In air at room temp}$$

Optics

$$n = \sin i / \sin r \text{ — Snell's Law}$$

$$1/f = 1/v + 1/u \text{ — Mirror/Lens formula}$$

$$m = v/u \text{ — Magnification}$$

Electrostatics

$$F = kq_1q_2/r^2 \text{ — Coulomb's Law}$$

$$E = F/q \text{ — Electric field}$$

$$V = W/q \text{ — Electric potential}$$

$$C = Q/V \text{ — Capacitance}$$

Current Electricity & Circuits

$$V = IR \text{ — Ohm's Law}$$

$$R = \rho L/A \text{ — Resistivity}$$

$$P = VI = I^2R = V^2/R \text{ — Electric power}$$

$$H = I^2Rt \text{ — Joule's heating}$$

$$\Sigma I = 0 ; \Sigma V = 0 \text{ — Kirchhoff's Laws}$$

☐ JS Education System | Class 10th Physics — Chapters 10–17 | All questions and numerical problems based on FBSE textbook curriculum.
Good luck in your examinations!

CHAPTER 18

Electronics

All Short Questions · Long Questions · MCQs · Numerical Problems

CHAPTER 18

Electronics — MCQs

All answers are highlighted. Study each stem carefully before checking the answer.

#	Question	Correct Answer
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1	A semiconductor material commonly used in making diodes and transistors is: A. Copper B. Silicon C. Aluminium D. Iron	B. Silicon
2	Doping a pure semiconductor with a pentavalent impurity produces: A. P-type semiconductor B. N-type semiconductor C. An insulator D. A superconductor	B. N-type semiconductor
3	In a p-n junction diode, the majority charge carriers in the p-region are: A. Electrons B. Protons C. Holes D. Neutrons	C. Holes
4	A diode conducts current easily when it is: A. Forward biased B. Reverse biased C. Unbiased D. Heated	A. Forward biased
5	The process of converting AC into DC using a diode is called: A. Amplification B. Rectification C. Modulation D. Induction	B. Rectification
6	A full-wave rectifier uses: A. One diode B. Two or four diodes C. A single transistor D. A resistor only	B. Two or four diodes
7	A transistor has how many terminals? A. Two B. Three C. Four D. Six	B. Three
8	The three terminals of a transistor are called: A. Anode, cathode, gate B. Emitter, base, collector C. Source, drain, gate D. Positive, negative, neutral	B. Emitter, base, collector
9	A logic gate that gives an output of 1 only when all its inputs are 1 is: A. OR gate B. NOT gate C. AND gate D. NOR gate	C. AND gate
10	Which gate is known as the 'inverter'? A. AND gate B. OR gate C. NOT gate D. NAND gate	C. NOT gate

11	A NAND gate is a combination of: A. AND gate followed by NOT gate B. OR gate followed by NOT gate C. Two NOT gates D. AND gate followed by OR gate	A. AND gate followed by NOT gate
12	In digital electronics, the two possible logic states are usually represented by: A. Red and green B. 0 and 1 C. A and B D. High and low frequency	B. 0 and 1

CHAPTER 18

Electronics — Short Response Questions & Answers

Review each question and its detailed answer to reinforce your understanding of key concepts.

Q.1: What is a semiconductor? Give two examples.

Ans: A semiconductor is a material whose electrical conductivity lies between that of a conductor and an insulator. Its conductivity increases with temperature. Silicon and germanium are common examples used in electronic devices.

Q.2: Differentiate between P-type and N-type semiconductors.

Ans: P-type semiconductors are formed by doping a pure semiconductor with a trivalent impurity, creating an excess of holes (majority carriers). N-type semiconductors are formed by doping with a pentavalent impurity, creating an excess of free electrons (majority carriers).

Q.3: What is a p-n junction diode?

Ans: A p-n junction diode is formed by joining a p-type semiconductor with an n-type semiconductor. It allows current to flow easily in one direction (forward bias) and blocks current in the opposite direction (reverse bias).

Q.4: What is meant by forward and reverse biasing of a diode?

Ans: Forward biasing connects the p-side to the positive terminal and the n-side to the negative terminal of a battery, allowing current to flow. Reverse biasing connects them oppositely, which blocks the flow of current except for a very small leakage current.

Q.5: Why is a diode used as a rectifier?

Ans: A diode allows current to pass in only one direction. When an alternating current is applied, the diode blocks the reverse half-cycles and permits only the forward half-cycles, converting AC into a pulsating DC — hence its use as a rectifier.

Q.6: What is a transistor, and what are its two main functions?

Ans: A transistor is a three-terminal semiconductor device made of two p-n junctions arranged as either NPN or PNP. Its two main functions are amplification (increasing the strength of a weak signal) and switching (turning current on or off in a circuit).

Q.7: Define a logic gate.

Ans: A logic gate is a basic building block of digital circuits that performs a logical operation on one or more binary inputs to produce a single binary output, based on rules of Boolean algebra.

Q.8: What is a truth table?

Ans: A truth table is a table that lists all possible combinations of input values for a logic gate or circuit, along with the corresponding output values, showing exactly how the gate behaves.

Electronics — Long Response Questions

Each question is worth 8 marks. Detailed, exam-ready answers are provided below.

Q.1: Explain the working of a p-n junction diode as a half-wave rectifier.

Ans: A p-n junction diode allows current to flow only when it is forward biased. In a half-wave rectifier circuit, an alternating voltage is applied to the diode in series with a load resistor. During the positive half-cycle of the AC input, the diode becomes forward biased and conducts, allowing current to flow through the load. During the negative half-cycle, the diode becomes reverse biased and does not conduct, so no current flows through the load. As a result, the output across the load consists only of the positive half-cycles of the input, appearing as a series of pulses in one direction. This pulsating output is a form of direct current (DC), although it is not smooth. A capacitor is often added in parallel with the load to smooth out these pulses into a more steady DC voltage. Half-wave rectifiers are simple but inefficient, since half of the input waveform is wasted; full-wave rectifiers, which use two or four diodes, make use of both halves of the AC cycle and produce a smoother, more efficient output. Rectifiers are essential in power supplies, converting the AC mains voltage into the DC required to run most electronic devices.

Q.2: Describe the structure and working of a transistor as an amplifier and as a switch.

Ans: A transistor consists of three regions of doped semiconductor material — emitter, base, and collector — arranged as NPN or PNP, forming two p-n junctions. In amplifier mode, a small varying current or voltage applied to the base controls a much larger current flowing between the emitter and collector. Because the base current is small compared to the collector current, small changes in the input signal at the base produce large changes in the output at the collector, effectively amplifying the signal. This principle is used in audio amplifiers, radio receivers, and many analog circuits. In switch mode, the transistor operates in only two states: fully on (saturation), where it behaves like a closed switch allowing maximum current to flow, and fully off (cut-off), where it behaves like an open switch blocking current flow. Applying a sufficient base current drives the transistor into saturation, while removing the base current returns it to cut-off. This switching behavior is the foundation of digital electronics, where transistors act as the basic on/off elements that make up logic gates, memory cells, and microprocessors. The dual ability of a transistor to amplify and to switch is why it is considered one of the most important inventions in modern electronics.

Q.3: Explain the basic logic gates (AND, OR, NOT) with their symbols and truth tables.

Ans: Logic gates are the fundamental building blocks of digital circuits, each performing a specific Boolean operation. The AND gate produces a high (1) output only when all of its inputs are high; if any input is low (0), the output is low. For two inputs A and B, the truth table gives output 1 only for A=1, B=1, and output 0 for all other combinations. The OR gate produces a high output when at least one of its inputs is high; the output is low only when all inputs are low. For two inputs, the output is 0 only when A=0 and B=0, and 1 for every other combination. The NOT gate, also called an inverter, has a single input and simply reverses it: a high input gives a low output, and a low input gives a high output. Each gate is represented by a distinct symbol in circuit diagrams — a D-shaped symbol for AND, a curved shield shape for OR, and a triangle with a small circle at the output for NOT. These three gates can be combined in different arrangements to build more complex gates such as NAND, NOR, and XOR, and ultimately to construct entire digital systems, including calculators and computer processors.

Q.4: What are NAND and NOR gates? Explain why they are called universal gates.

Ans: A NAND gate is formed by combining an AND gate with a NOT gate; its output is the inverse of the AND gate's output. It produces a low output only when all inputs are high, and a high output for every other combination. A NOR gate is formed by combining an OR gate with a NOT gate; its output is the inverse of the OR gate's output, producing a high output only when all inputs are low. NAND and NOR gates are called universal gates because either one, used alone, can be connected in different combinations to build any other logic gate — AND, OR, NOT, XOR, and XNOR — without needing any other type of gate. For example, connecting the two inputs of a NAND gate together produces a NOT gate, and combining several NAND gates in

specific patterns can reproduce the behavior of an AND or OR gate. This universality makes NAND and NOR gates extremely valuable in the electronics industry, since manufacturers can build complex integrated circuits using a single type of gate, simplifying design and manufacturing while reducing cost.

Q.5: Discuss the importance of electronics in modern life, giving examples of applications of diodes, transistors, and logic gates.

Ans: Electronics has transformed nearly every aspect of modern life by enabling the design of compact, efficient, and intelligent devices. Diodes are used in power supplies as rectifiers to convert AC to DC, in LED lighting and displays, in solar cells to generate electricity from sunlight, and as protective components that prevent current from flowing in the wrong direction in circuits. Transistors, because of their ability to amplify and switch signals, form the heart of amplifiers in audio systems, radios, and televisions, and serve as the fundamental switching elements inside microprocessors and memory chips, where billions of microscopic transistors work together to perform calculations and store data. Logic gates, built from transistors, are combined to create digital circuits that perform arithmetic, make decisions, and control the operation of computers, smartphones, calculators, traffic light controllers, and household appliances. Without electronics, technologies such as computers, mobile communication, medical imaging equipment, automated industrial machinery, and countless everyday conveniences would not exist. The continual miniaturization and improvement of electronic components have driven rapid advances in computing power, communication speed, and automation, making electronics one of the most important fields underpinning modern technological progress.

CHAPTER 18

Electronics — Numerical Problems

Fully solved, step-by-step numerical problems for exam preparation.

Problem 1: Diode Forward Voltage Drop

Given:

- Supply voltage (V) = 6 V
- Forward voltage drop across silicon diode (V_d) = 0.7 V
- Resistance of load (R) = 100 Ω

To Find:

The current flowing through the circuit

Formula Used:

$$I = (V - V_d) / R$$

Calculation:

1. $I = (6 - 0.7) / 100$
2. $I = 5.3 / 100$
3. $I = 0.053 \text{ A}$

Final Answer: The current flowing through the circuit is 0.053 A (53 mA).

Problem 2: Transistor Current Gain

Given:

- Base current (I_b) = $20\text{ }\mu\text{A}$
- Collector current (I_c) = 3 mA

To Find:

The current gain (β) of the transistor

Formula Used:

$$\beta = I_c / I_b$$

Calculation:

1. $\beta = (3 \times 10^{-3}) / (20 \times 10^{-6})$
2. $\beta = 150$

Final Answer: The current gain (β) of the transistor is 150.

Problem 3: Logic Gate Output

Given:

- Two inputs applied to a NAND gate: $A = 1$, $B = 1$

To Find:

The output of the NAND gate

Formula Used:

NAND output = NOT (A AND B)

Calculation:

1. $A \text{ AND } B = 1 \text{ AND } 1 = 1$
2. $\text{NOT}(1) = 0$

Final Answer: The output of the NAND gate is 0.

Problem 4: Rectifier Output Frequency

Given:

- AC supply frequency = 50 Hz
- Rectifier type = Full-wave rectifier

To Find:

The frequency of the pulsating output

Formula Used:

For full-wave rectification, output frequency = $2 \times$ input frequency

Calculation:

1. Output frequency = $2 \times 50 \text{ Hz}$

Final Answer: The frequency of the pulsating DC output is 100 Hz.

CHAPTER 19

Electromagnetism

All Short Questions · Long Questions · MCQs · Numerical Problems

CHAPTER 19

Electromagnetism — MCQs

All answers are highlighted. Study each stem carefully before checking the answer.

#	Question	Correct Answer
1	A current-carrying conductor produces a magnetic field around it. This effect is called: A. Electrostatic effect B. Magnetic effect of current C. Photoelectric effect D. Thermal effect	B. Magnetic effect of current
2	The direction of the magnetic field around a straight current-carrying conductor is given by: A. Fleming's left-hand rule B. Right-hand grip rule C. Lenz's law D. Ohm's law	B. Right-hand grip rule
3	The force experienced by a current-carrying conductor placed in a magnetic field is given by: A. $F = qE$ B. $F = BIL \sin \theta$ C. $F = mgh$ D. $F = \frac{1}{2}mv^2$	B. $F = BIL \sin \theta$
4	A device that converts electrical energy into mechanical energy using electromagnetism is a: A. Generator B. Transformer C. Electric motor	C. Electric motor

	D. Battery	
5	Electromagnetic induction refers to the production of: A. Magnetic field by a current B. Current by a changing magnetic field C. Heat by resistance D. Light by a filament	B. Current by a changing magnetic field
6	Which law states that the induced current always opposes the change that produces it? A. Ohm's law B. Faraday's law C. Lenz's law D. Coulomb's law	C. Lenz's law
7	A device that converts mechanical energy into electrical energy is called a: A. Motor B. Generator C. Transformer D. Rectifier	B. Generator
8	A transformer works on the principle of: A. Mutual induction B. Self-induction C. Electrostatic induction D. Thermionic emission	A. Mutual induction
9	In a step-up transformer, the number of turns in the secondary coil compared to the primary coil is: A. Equal B. Greater C. Less D. Zero	B. Greater
10	The SI unit of magnetic flux density (magnetic field strength) is the: A. Weber B. Tesla C. Henry D. Farad	B. Tesla
11	An electromagnet is a temporary magnet made by: A. Heating a metal rod B. Passing current through a coil wound on a soft iron core C. Rubbing two magnets together D. Cooling a superconductor	B. Passing current through a coil wound on a soft iron core

CHAPTER 19

Electromagnetism — Short Response Questions & Answers

Review each question and its detailed answer to reinforce your understanding of key concepts.

Q.1: State the right-hand grip rule.

Ans: If a current-carrying conductor is gripped in the right hand with the thumb pointing in the direction of current flow, the curled fingers show the direction of the magnetic field lines around the conductor.

Q.2: What is an electromagnet? Give one everyday use.

Ans: An electromagnet is a magnet created by passing an electric current through a coil of wire wound around a soft iron core; its magnetism can be switched on or off with the current. Electromagnets are used in electric bells, cranes for lifting scrap metal, and electric motors.

Q.3: Define electromagnetic induction.

Ans: Electromagnetic induction is the process by which an electromotive force (EMF), and hence a current, is induced in a conductor due to a change in the magnetic flux linked with it, such as by moving a magnet near a coil.

Q.4: State Lenz's law and explain its significance.

Ans: Lenz's law states that the direction of an induced current is always such that it opposes the change in magnetic flux that produced it. This is a consequence of the conservation of energy, since work must be done against the induced effect to cause the change.

Q.5: What is the difference between an electric motor and a generator?

Ans: An electric motor converts electrical energy into mechanical energy, using the force on a current-carrying coil in a magnetic field to produce rotation. A generator does the reverse — it converts mechanical energy into electrical energy by rotating a coil within a magnetic field to induce a current.

Q.6: What is a transformer, and on what principle does it work?

Ans: A transformer is a device used to increase (step up) or decrease (step down) an alternating voltage. It works on the principle of mutual induction, where a changing current in the primary coil induces an EMF in the secondary coil through a shared magnetic field.

Q.7: Why is a soft iron core used in transformers and electromagnets rather than a permanent magnet material?

Ans: Soft iron is easy to magnetize and demagnetize, allowing it to quickly gain and lose magnetism as the current changes. This makes it ideal for transformers and electromagnets, which need to respond rapidly to changing currents, unlike permanent magnet materials that retain magnetism permanently.

Q.8: Give two applications of electromagnetic induction in daily life.

Ans: Electromagnetic induction is used in electric generators at power stations to produce electricity, and in transformers to adjust voltage levels for safe and efficient transmission and use of electrical power in homes and industries.

CHAPTER 19

Electromagnetism — Long Response Questions

Each question is worth 8 marks. Detailed, exam-ready answers are provided below.

Q.1: Explain the magnetic effect of current and describe how the magnetic field pattern differs for a straight wire, a circular loop, and a solenoid.

Ans: When an electric current flows through a conductor, it produces a magnetic field around it — a phenomenon known as the magnetic effect of current, first discovered by Hans Christian Oersted. The direction of this field is given by the right-hand grip rule: if the conductor is held in the right hand with the thumb pointing along the current, the curled fingers indicate the direction of the magnetic field lines. For a long straight current-carrying wire, the magnetic field lines form concentric circles around the wire, with field strength decreasing as distance from the wire increases. When the wire is bent into a circular loop, the magnetic field lines become concentrated near the center of the loop, and all the field lines pass through the center in the same direction, effectively strengthening the field there compared to a straight wire carrying the same current. A solenoid is a coil of many circular turns of wire; when current flows through it, the magnetic fields of the individual turns add together, producing a strong, fairly uniform magnetic field inside the solenoid similar to that of a bar magnet, with distinct north and south poles at its ends, while the field outside is much

weaker. This solenoid pattern is the basis of electromagnets, which are used wherever a strong, controllable magnetic field is required, such as in electric bells, relays, and industrial lifting magnets.

Q.2: Describe the construction and working principle of a simple DC electric motor.

Ans: A simple DC electric motor consists of a rectangular coil of insulated wire mounted on an axle, placed between the poles of a permanent magnet so that it can rotate freely, along with a commutator and brushes that connect the coil to a DC power source. When current flows through the coil while it is in the magnetic field, each side of the coil experiences a force due to the interaction between the current and the magnetic field, as described by $F = BIL \sin \theta$. Because current flows in opposite directions along the two sides of the coil, the forces on these two sides act in opposite directions, creating a turning effect (torque) that rotates the coil. As the coil rotates past the vertical position, the split-ring commutator reverses the direction of current flow in the coil at exactly the right moment, ensuring that the force continues to act in the same rotational direction rather than reversing and stopping the motor. The brushes maintain electrical contact with the rotating commutator as the coil spins. This continuous reversal of current, synchronized with the coil's rotation, allows the motor to keep turning in one direction as long as current is supplied. DC motors of this basic design are used in a wide range of applications, from small toys and fans to larger industrial machinery, and the same working principle underlies more advanced motor designs used in vehicles and appliances.

Q.3: Explain Faraday's law of electromagnetic induction and how it is demonstrated using a bar magnet and a coil connected to a galvanometer.

Ans: Faraday's law of electromagnetic induction states that whenever there is a change in the magnetic flux linked with a coil, an electromotive force (EMF) is induced in the coil, and the magnitude of this induced EMF is directly proportional to the rate of change of magnetic flux. This can be demonstrated with a simple experiment using a coil of wire connected to a sensitive galvanometer and a bar magnet. When the magnet is held stationary near the coil, the galvanometer shows no deflection, because there is no change in magnetic flux through the coil. When the magnet is moved quickly toward the coil, the magnetic flux through the coil increases rapidly, and the galvanometer needle deflects, showing that a current has been induced. When the magnet is moved away from the coil, the flux decreases, and the galvanometer deflects in the opposite direction, indicating that the induced current has reversed. If the magnet is moved faster, the galvanometer deflection becomes larger, confirming that a greater rate of change of flux produces a larger induced EMF, consistent with Faraday's law. If the magnet is held still inside the coil, no deflection occurs regardless of the magnet's strength, because there is no changing flux. This simple demonstration shows that it is the relative motion between the magnet and coil — and the resulting change in flux — that is essential for producing an induced current, not merely the presence of a magnetic field.

Q.4: Discuss the working of a step-up and step-down transformer and explain why transformers are essential for the transmission of electrical power.

Ans: A transformer consists of two coils, called the primary and secondary, wound on a common soft iron core. It works on the principle of mutual induction: an alternating current in the primary coil produces a changing magnetic flux in the iron core, which links with the secondary coil and induces an alternating EMF in it. The ratio of the output (secondary) voltage to the input (primary) voltage depends on the ratio of the number of turns in the two coils. In a step-up transformer, the secondary coil has more turns than the primary coil, so the output voltage is higher than the input voltage, while the output current is correspondingly lower, since an ideal transformer conserves power. In a step-down transformer, the secondary coil has fewer turns than the primary coil, producing a lower output voltage and a higher output current. Transformers are essential in the transmission of electrical power because transmitting electricity over long distances at low voltage would require very high currents, causing large energy losses as heat due to the resistance of transmission cables (proportional to the square of the current). By using step-up transformers at power stations to raise the voltage to very high levels for transmission, the current is kept low, minimizing energy losses along the transmission lines. Step-down transformers are then used near homes and industries to reduce the high transmission voltage to safer, usable levels. Without transformers, the electrical grid would be far less efficient, and long-distance transmission of power would not be practically or economically feasible.

Electromagnetism — Numerical Problems

Fully solved, step-by-step numerical problems for exam preparation.

Problem 1: Force on a Current-Carrying Conductor

Given:

- Magnetic flux density (B) = 0.5 T
- Current (I) = 4 A
- Length of conductor (L) = 0.3 m
- Angle between conductor and field (θ) = 90°

To Find:

The force on the conductor

Formula Used:

$$F = BIL \sin \theta$$

Calculation:

1. $F = 0.5 \times 4 \times 0.3 \times \sin 90^\circ$
2. $F = 0.5 \times 4 \times 0.3 \times 1$
3. $F = 0.6 \text{ N}$

Final Answer: The force on the conductor is 0.6 N.

Problem 2: Transformer Turns Ratio

Given:

- Primary voltage (V_p) = 220 V
- Secondary voltage (V_s) = 11 V
- Number of primary turns (N_p) = 2000

To Find:

The number of turns in the secondary coil (N_s)

Formula Used:

$$V_p / V_s = N_p / N_s$$

Calculation:

1. $N_s = N_p \times (V_s / V_p)$
2. $N_s = 2000 \times (11 / 220)$
3. $N_s = 2000 \times 0.05$
4. $N_s = 100$

Final Answer: The secondary coil has 100 turns.

Problem 3: Transformer Current Relationship

Given:

- Primary voltage (V_p) = 220 V
- Secondary voltage (V_s) = 12 V
- Primary current (I_p) = 0.5 A
- Assume an ideal transformer (100% efficient)

To Find:

The secondary current (I_s)

Formula Used:

$$V_p \times I_p = V_s \times I_s$$

Calculation:

1. $I_s = (V_p \times I_p) / V_s$
2. $I_s = (220 \times 0.5) / 12$
3. $I_s = 110 / 12$
4. $I_s \approx 9.17 \text{ A}$

Final Answer: The secondary current is approximately 9.17 A.

Problem 4: Induced EMF from Changing Flux

Given:

- Change in magnetic flux ($\Delta\Phi$) = 0.02 Wb
- Time taken (Δt) = 0.5 s
- Number of turns (N) = 100

To Find:

The induced EMF

Formula Used:

$$\text{EMF} = N (\Delta\Phi / \Delta t)$$

Calculation:

1. $\text{EMF} = 100 \times (0.02 / 0.5)$
2. $\text{EMF} = 100 \times 0.04$

3. $\text{EMF} = 4 \text{ V}$

Final Answer: The induced EMF is 4 V.

Electromagnetic Waves

All Short Questions · Long Questions · MCQs · Numerical Problems

CHAPTER 20

Electromagnetic Waves — MCQs

All answers are highlighted. Study each stem carefully before checking the answer.

#	Question	Correct Answer
1	Electromagnetic waves are: A. Longitudinal waves that require a medium B. Transverse waves that can travel through vacuum C. Sound waves D. Mechanical waves only	B. Transverse waves that can travel through vacuum
2	The speed of electromagnetic waves in a vacuum is approximately: A. 3×10^5 m/s B. 3×10^6 m/s C. 3×10^8 m/s D. 3×10^{10} m/s	C. 3×10^8 m/s
3	Which of the following has the longest wavelength in the electromagnetic spectrum? A. Gamma rays B. X-rays C. Visible light D. Radio waves	D. Radio waves
4	Which electromagnetic wave has the highest frequency and energy? A. Radio waves B. Infrared waves C. Visible light D. Gamma rays	D. Gamma rays
5	Which type of electromagnetic wave is used in television remote controls? A. Ultraviolet rays B. Infrared rays C. X-rays D. Microwaves	B. Infrared rays
6	Which electromagnetic waves are used in medical imaging to view bones and internal injuries? A. Radio waves B. Microwaves C. X-rays D. Infrared rays	C. X-rays

7	Microwaves are commonly used in: A. Cooking food and satellite communication B. Sterilizing medical equipment C. Producing suntans D. Viewing bone fractures	A. Cooking food and satellite communication
8	Excessive exposure to which electromagnetic waves can cause skin cancer? A. Radio waves B. Ultraviolet rays C. Infrared rays D. Microwaves	B. Ultraviolet rays
9	Which electromagnetic waves are used for broadcasting radio and television signals? A. Radio waves B. X-rays C. Gamma rays D. Ultraviolet rays	A. Radio waves
10	Electromagnetic waves consist of: A. Oscillating electric field only B. Oscillating magnetic field only C. Mutually perpendicular oscillating electric and magnetic fields D. Vibrating particles of a medium	C. Mutually perpendicular oscillating electric and magnetic fields

CHAPTER 20

Electromagnetic Waves — Short Response Questions & Answers

Review each question and its detailed answer to reinforce your understanding of key concepts.

Q.1: What are electromagnetic waves?

Ans: Electromagnetic waves are transverse waves consisting of oscillating electric and magnetic fields perpendicular to each other and to the direction of wave propagation. They do not require a material medium and can travel through a vacuum at the speed of light.

Q.2: Arrange the electromagnetic spectrum in order of increasing frequency.

Ans: In order of increasing frequency: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays.

Q.3: State the relationship between the speed, frequency, and wavelength of an electromagnetic wave.

Ans: For any electromagnetic wave, the speed (c) is equal to the product of its frequency (f) and wavelength (λ), given by $c = f\lambda$. In a vacuum, c is constant at approximately 3×10^8 m/s, so frequency and wavelength are inversely related.

Q.4: Give two uses of infrared waves.

Ans: Infrared waves are used in television and air-conditioner remote controls for wireless signaling, and in thermal imaging cameras to detect heat and view objects in the dark.

Q.5: Give two uses of X-rays.

Ans: X-rays are used in medical diagnosis to image bones and detect fractures or internal problems, and in security scanning at airports to inspect the contents of luggage.

Q.6: Why are microwaves used in satellite communication rather than radio waves?

Ans: Microwaves have shorter wavelengths and higher frequencies than radio waves, allowing them to carry more information and to be focused into narrow beams that can be transmitted efficiently between satellites and ground stations without spreading out too much.

Q.7: What precautions should be taken to reduce the harmful effects of ultraviolet radiation?

Ans: Precautions include applying sunscreen, wearing protective clothing and sunglasses that block UV rays, and avoiding prolonged direct exposure to sunlight, especially during peak sunlight hours.

Q.8: Why can electromagnetic waves travel through empty space while sound waves cannot?

Ans: Electromagnetic waves are produced by oscillating electric and magnetic fields, which do not need particles of a medium to propagate. Sound waves, however, are mechanical waves that require the vibration of particles in a medium, so they cannot travel through a vacuum.

CHAPTER 20

Electromagnetic Waves — Long Response Questions

Each question is worth 8 marks. Detailed, exam-ready answers are provided below.

Q.1: Describe the electromagnetic spectrum and explain the main uses of each region.

Ans: The electromagnetic spectrum is the complete range of electromagnetic waves arranged in order of increasing frequency (or decreasing wavelength). At the low-frequency end are radio waves, which have the longest wavelengths and are used for broadcasting radio and television signals, as well as mobile communication. Next are microwaves, which have shorter wavelengths and are used in radar systems, satellite communication, and microwave ovens for cooking, since they can be absorbed by water molecules in food and converted into heat. Infrared radiation follows, and is associated with heat; it is used in remote controls, thermal imaging cameras, and short-range wireless communication. Visible light is the narrow band of the spectrum detectable by the human eye, ranging from red (longer wavelength) to violet (shorter wavelength), and is essential for vision and photography. Beyond visible light lies ultraviolet radiation, which has enough energy to cause sunburn and skin damage with prolonged exposure, but is also used for sterilizing equipment and in fluorescent lighting. X-rays have even higher frequency and energy, allowing them to penetrate soft tissue, which makes them valuable for medical imaging of bones and for security scanning. At the highest-frequency end are gamma rays, which carry the most energy and are produced by radioactive decay and nuclear reactions; they are used in cancer treatment (radiotherapy) and sterilization, but require careful shielding due to their ability to damage living cells. Each region of the spectrum has distinct properties and applications that arise directly from its frequency, wavelength, and energy.

Q.2: Explain how electromagnetic waves are produced and describe their key properties.

Ans: Electromagnetic waves are produced whenever an electric charge is accelerated, such as when electrons oscillate rapidly in an antenna or when electrons in an atom transition between energy levels. This accelerating charge creates a changing electric field, which in turn generates a changing magnetic field; each changing field regenerates the other, allowing the wave to propagate through space without requiring a material medium. The key properties of electromagnetic waves include that they are transverse waves, with the oscillating electric and magnetic fields perpendicular to each other and to the direction of propagation. All electromagnetic waves travel at the same speed in a vacuum, approximately 3×10^8 m/s, commonly known as the speed of light. They can travel through empty space, unlike mechanical waves such as sound, which require a medium. Electromagnetic waves also exhibit typical wave behaviors such as reflection, refraction, diffraction, and interference. They carry energy, and this energy is directly related to their frequency — higher-frequency waves, such as X-rays and gamma rays, carry more energy than lower-frequency waves like radio waves, which explains why high-frequency electromagnetic radiation can be more damaging to living tissue. Different portions of the electromagnetic spectrum interact differently with matter, which is the basis for their many varied practical applications, from communication to medical imaging.

Q.3: Discuss the harmful effects of prolonged exposure to ultraviolet rays, X-rays, and gamma rays, and describe safety precautions used to minimize these risks.

Ans: Ultraviolet (UV) rays, X-rays, and gamma rays are high-energy electromagnetic waves that can damage living cells and tissues if exposure is excessive. Ultraviolet radiation from sunlight can cause sunburn, premature skin aging, damage to the eyes, and an increased risk of skin cancer with repeated, unprotected exposure. To reduce these risks, people are advised to apply sunscreen, wear UV-blocking sunglasses and protective clothing, and limit direct sun exposure during peak hours. X-rays, because of their higher energy, can penetrate tissue and, in large or repeated doses, may damage cells and increase the risk of cancer. In medical and industrial settings, exposure is minimized by using lead aprons and shields to block stray radiation, limiting the frequency and duration of X-ray procedures, and keeping technicians at a safe distance or behind protective barriers during exposure. Gamma rays, produced by radioactive decay and nuclear processes, are the most penetrating and energetic of these three types of radiation, capable of passing through several centimeters of lead. Excessive exposure can cause severe cell damage, radiation sickness, and increased cancer risk. Because of this, gamma radiation sources are handled with thick shielding (often lead or concrete), remote-handling tools, and strict regulatory controls on the time, distance, and shielding used by workers. In all three cases, the underlying safety principles are the same: minimizing exposure time, maximizing distance from the source, and using appropriate shielding, so that the benefits of these technologies — from sunlight and medical imaging to cancer treatment — can be enjoyed while limiting the associated health risks.

CHAPTER 20

Electromagnetic Waves — Numerical Problems

Fully solved, step-by-step numerical problems for exam preparation.

Problem 1: Wavelength of a Radio Wave

Given:

- Frequency of radio wave (f) = 100 MHz = 100×10^6 Hz
- Speed of electromagnetic wave (c) = 3×10^8 m/s

To Find:

The wavelength of the radio wave

Formula Used:

$$c = f\lambda, \text{ so } \lambda = c / f$$

Calculation:

1. $\lambda = (3 \times 10^8) / (100 \times 10^6)$
2. $\lambda = (3 \times 10^8) / (1 \times 10^8)$
3. $\lambda = 3$ m

Final Answer: The wavelength of the radio wave is 3 m.

Problem 2: Frequency of Visible Light

Given:

- Wavelength of light (λ) = 500 nm = 500×10^{-9} m
- Speed of light (c) = 3×10^8 m/s

To Find:

The frequency of the light wave

Formula Used:

$$f = c / \lambda$$

Calculation:

1. $f = (3 \times 10^8) / (500 \times 10^{-9})$
2. $f = (3 \times 10^8) / (5 \times 10^{-7})$
3. $f = 6 \times 10^{14} \text{ Hz}$

Final Answer: The frequency of the light wave is $6 \times 10^{14} \text{ Hz}$.

Problem 3: Time for Signal to Reach a Satellite

Given:

- Distance to satellite (d) = $3.6 \times 10^7 \text{ m}$
- Speed of electromagnetic wave (c) = $3 \times 10^8 \text{ m/s}$

To Find:

The time taken for a signal to reach the satellite

Formula Used:

$$t = d / c$$

Calculation:

1. $t = (3.6 \times 10^7) / (3 \times 10^8)$
2. $t = 0.12 \text{ s}$

Final Answer: The signal takes 0.12 seconds to reach the satellite.

CHAPTER 21

Nuclear Physics

All Short Questions · Long Questions · MCQs · Numerical Problems

CHAPTER 21

Nuclear Physics — MCQs

All answers are highlighted. Study each stem carefully before checking the answer.

#	Question	Correct Answer
1	The nucleus of an atom is composed of: A. Protons and electrons B. Protons and neutrons C. Neutrons and electrons D. Only protons	B. Protons and neutrons

2	The number of protons in the nucleus of an atom is called its: A. Mass number B. Atomic number C. Neutron number D. Isotope number	B. Atomic number
3	Atoms of the same element with different numbers of neutrons are called: A. Isotopes B. Isobars C. Ions D. Isomers	A. Isotopes
4	Alpha particles are: A. High-energy electrons B. Helium nuclei (2 protons + 2 neutrons) C. Electromagnetic waves D. Neutrons only	B. Helium nuclei (2 protons + 2 neutrons)
5	Beta particles emitted during radioactive decay are: A. Helium nuclei B. High-speed electrons C. Photons D. Protons	B. High-speed electrons
6	Gamma rays emitted during radioactive decay are: A. Charged particles B. Electromagnetic radiation with no mass or charge C. Neutrons D. Helium nuclei	B. Electromagnetic radiation with no mass or charge
7	The time taken for half the atoms of a radioactive sample to decay is called its: A. Decay constant B. Half-life C. Mean life D. Activity period	B. Half-life
8	In nuclear fission, a heavy nucleus: A. Combines with another nucleus B. Splits into two or more lighter nuclei C. Emits only gamma rays D. Remains unchanged	B. Splits into two or more lighter nuclei
9	In nuclear fusion, light nuclei: A. Split apart releasing energy B. Combine to form a heavier nucleus, releasing energy C. Remain stable indefinitely D. Absorb energy without change	B. Combine to form a heavier nucleus, releasing energy
10	The process that powers the Sun and stars is: A. Nuclear fission B. Nuclear fusion C. Chemical combustion D. Radioactive decay only	B. Nuclear fusion
11	Which type of radiation has the greatest penetrating power? A. Alpha particles B. Beta particles C. Gamma rays D. None of these	C. Gamma rays
12	Nuclear power plants generate electricity using the energy released from	B. Controlled nuclear fission

released by:

- A. Nuclear fusion
- B. Controlled nuclear fission
- C. Burning coal
- D. Chemical batteries

CHAPTER 21

Nuclear Physics — Short Response Questions & Answers

Review each question and its detailed answer to reinforce your understanding of key concepts.

Q.1: Define atomic number and mass number.

Ans: The atomic number (Z) is the number of protons in the nucleus of an atom, and it determines the identity of the element. The mass number (A) is the total number of protons and neutrons (nucleons) present in the nucleus.

Q.2: What are isotopes? Give one example.

Ans: Isotopes are atoms of the same element that have the same number of protons (atomic number) but different numbers of neutrons, giving them different mass numbers. For example, carbon-12 and carbon-14 are both isotopes of carbon.

Q.3: What is radioactivity?

Ans: Radioactivity is the spontaneous emission of particles or electromagnetic radiation (alpha, beta, or gamma) from the unstable nucleus of certain atoms as they transform into more stable nuclei.

Q.4: Compare the penetrating power of alpha, beta, and gamma radiation.

Ans: Alpha particles have the least penetrating power and can be stopped by a sheet of paper or a few centimeters of air. Beta particles are more penetrating and require a few millimeters of aluminum to be stopped. Gamma rays have the greatest penetrating power and require thick lead or concrete shielding to be significantly absorbed.

Q.5: Define half-life of a radioactive substance.

Ans: The half-life of a radioactive substance is the time required for half of the radioactive nuclei in a given sample to decay into a more stable form. It is a constant characteristic of each radioactive isotope, unaffected by external conditions.

Q.6: Distinguish between nuclear fission and nuclear fusion.

Ans: Nuclear fission is the splitting of a heavy nucleus into two or more lighter nuclei, releasing a large amount of energy, and is used in nuclear power plants and atomic bombs. Nuclear fusion is the combining of two light nuclei to form a heavier nucleus, also releasing energy, and is the process that powers the Sun and other stars.

Q.7: Give two beneficial uses of radioactivity.

Ans: Radioactive isotopes are used in medicine for cancer treatment (radiotherapy) and for diagnostic imaging, and in industry and archaeology for carbon dating to determine the age of ancient organic materials.

Q.8: What safety precautions should be taken when handling radioactive materials?

Ans: Radioactive materials should be handled using remote tools and shielding (such as lead), exposure time should be kept to a minimum, workers should maintain a safe distance from the source, and radioactive waste must be stored and disposed of according to strict safety regulations.

CHAPTER 21

Nuclear Physics — Long Response Questions

Each question is worth 8 marks. Detailed, exam-ready answers are provided below.

Q.1: Describe the structure of the atom and explain the meaning of atomic number, mass number, and isotopes.

Ans: An atom consists of a small, dense central nucleus containing protons and neutrons, collectively called nucleons, surrounded by electrons occupying the much larger space around the nucleus. Protons carry a positive charge, neutrons are electrically neutral, and electrons carry a negative charge; in a neutral atom, the number of electrons equals the number of protons. The atomic number (Z) of an element is defined as the number of protons in the nucleus, and it uniquely identifies the element, determining its position in the periodic table and its chemical properties. The mass number (A) is the total number of protons and neutrons in the nucleus, and since neutrons and protons have approximately equal mass, the mass number gives a close approximation of the atom's overall mass. Isotopes are atoms of the same element — meaning they have the same atomic number and therefore the same number of protons — but differ in the number of neutrons, giving them different mass numbers. For example, all isotopes of carbon have six protons, but carbon-12 has six neutrons while carbon-14 has eight neutrons. Because isotopes have the same number of protons and electrons, they generally have the same chemical behavior, but their different numbers of neutrons can make some isotopes unstable, leading to radioactive decay, while others remain stable indefinitely. Understanding atomic structure and isotopes is fundamental to nuclear physics, chemistry, and applications such as radiometric dating and nuclear medicine.

Q.2: Explain the three types of radioactive decay (alpha, beta, and gamma) with their properties.

Ans: Radioactive decay occurs when an unstable nucleus spontaneously transforms to become more stable, releasing energy in the process. There are three main types of radioactive emission. Alpha decay involves the emission of an alpha particle, which consists of two protons and two neutrons (essentially a helium nucleus); this reduces the atomic number of the parent nucleus by two and the mass number by four. Alpha particles are relatively heavy and carry a positive charge, giving them strong ionizing power but very low penetrating power — they can be stopped by a sheet of paper or a few centimeters of air, and cannot penetrate human skin, though they are dangerous if inhaled or ingested. Beta decay involves the emission of a high-speed electron (or, in some cases, a positron) from the nucleus, which occurs when a neutron transforms into a proton (or vice versa); this changes the atomic number by one while the mass number stays the same. Beta particles are much lighter and faster than alpha particles, giving them moderate penetrating power — they can pass through paper but are stopped by a few millimeters of aluminum. Gamma decay involves the emission of high-energy electromagnetic radiation (gamma rays) from an excited nucleus, usually accompanying alpha or beta decay, and does not change the atomic number or mass number of the nucleus, since gamma rays have no mass or charge. Gamma rays have the greatest penetrating power of the three, capable of passing through the human body and requiring thick lead or concrete shielding to be substantially blocked. The differing properties of these three types of radiation determine both their hazards and their particular uses in medicine, industry, and research.

Q.3: Explain the concept of half-life with reference to radioactive decay, and describe how it is used in radiometric dating.

Ans: The half-life of a radioactive isotope is the time required for half of the radioactive nuclei present in a sample to decay into a more stable form. Radioactive decay is a random but statistically predictable process: although it is impossible to predict when any single unstable nucleus will decay, the behavior of a large number of nuclei follows a well-defined pattern, where the amount of the original substance decreases by half during each successive half-life period. For example, if a sample starts with a certain quantity of a radioactive isotope, after one half-life only half of that quantity remains as the original isotope, after two half-lives only a quarter remains, after three half-lives only an eighth remains, and so on, following an exponential decay pattern. Each radioactive isotope has its own characteristic half-life, ranging from fractions of a second to billions of years, and this half-life is unaffected by external conditions such as temperature, pressure, or chemical environment. This predictable decay behavior is the basis of radiometric dating techniques, such as carbon dating, which is used to determine the age of organic materials. Living organisms continuously exchange carbon with their environment, maintaining a roughly constant ratio of radioactive carbon-14 to stable carbon-12. When an organism dies, it stops absorbing new carbon, and the carbon-14 within it begins to decay at a known rate, with a half-life of about 5,730 years. By measuring the remaining proportion of carbon-14 in a sample and

comparing it to the known half-life, scientists can calculate how much time has passed since the organism died, allowing archaeologists and geologists to date fossils, artifacts, and other ancient organic remains with reasonable accuracy.

Q.4: Compare nuclear fission and nuclear fusion, and discuss their applications and associated risks.

Ans: Nuclear fission and nuclear fusion are two processes by which nuclear energy can be released, but they work in opposite ways. Nuclear fission occurs when a heavy, unstable nucleus, such as uranium-235, absorbs a neutron and splits into two or more lighter nuclei, releasing a large amount of energy along with additional neutrons that can go on to split further nuclei, creating a self-sustaining chain reaction. This chain reaction, when carefully controlled, is the basis of nuclear power plants, which use the heat released to generate steam that drives turbines and produces electricity; when uncontrolled, the same principle underlies nuclear weapons. Nuclear fusion, in contrast, occurs when two light nuclei, such as isotopes of hydrogen, combine under extremely high temperature and pressure to form a heavier nucleus, releasing even more energy per reaction than fission. Fusion is the process that powers the Sun and other stars, where immense gravitational pressure and temperature allow hydrogen nuclei to fuse into helium. While fusion offers the potential for a nearly limitless, cleaner energy source with less long-lived radioactive waste than fission, achieving and sustaining the necessary conditions for controlled fusion on Earth remains a significant scientific and engineering challenge, and practical fusion power plants are still under development. Both processes carry risks: fission reactors must be carefully controlled to prevent overheating or meltdown, and they produce radioactive waste that remains hazardous for long periods, requiring secure long-term storage. Fusion research facilities require careful handling of extremely high temperatures and, in some designs, radioactive materials such as tritium. Despite these challenges, both fission and fusion represent extremely concentrated sources of energy compared to chemical fuels, making them important areas of ongoing research and development for meeting future energy needs.

CHAPTER 21

Nuclear Physics – Numerical Problems

Fully solved, step-by-step numerical problems for exam preparation.

Problem 1: Remaining Mass After Multiple Half-Lives

Given:

- Initial mass of radioactive sample = 80 g
- Half-life of the sample = 2 hours
- Total elapsed time = 8 hours

To Find:

The mass of the sample remaining after 8 hours

Formula Used:

Number of half-lives (n) = total time / half-life; Remaining mass = Initial mass $\times (1/2)^n$

Calculation:

1. $n = 8 / 2 = 4$ half-lives
2. Remaining mass = $80 \times (1/2)^4$
3. Remaining mass = $80 \times (1/16)$
4. Remaining mass = 5 g

Final Answer: 5 g of the radioactive sample remains after 8 hours.

Problem 2: Finding the Half-Life

Given:

- Initial mass of radioactive sample = 100 g
- Mass remaining after 12 days = 25 g

To Find:

The half-life of the substance

Formula Used:

Remaining fraction = $(1/2)^n$, where n = number of half-lives

Calculation:

1. $25/100 = 1/4 = (1/2)^2$
2. So $n = 2$ half-lives occurred in 12 days
3. Half-life = 12 days / 2 = 6 days

Final Answer: The half-life of the substance is 6 days.

Problem 3: Nucleon Composition of an Isotope**Given:**

- An atom of an element has atomic number (Z) = 6
- Mass number (A) = 14

To Find:

The number of protons, neutrons, and electrons in the atom

Formula Used:

Protons = Z ; Electrons = Z (neutral atom); Neutrons = $A - Z$

Calculation:

1. Protons = 6
2. Electrons = 6
3. Neutrons = $14 - 6 = 8$

Final Answer: The atom has 6 protons, 6 electrons, and 8 neutrons (this is carbon-14).

Problem 4: Activity Remaining After Decay**Given:**

- Initial activity of a radioactive source = 640 Bq
- Half-life = 5 minutes
- Time elapsed = 20 minutes

To Find:

The activity of the source after 20 minutes

Formula Used:

Number of half-lives (n) = time elapsed / half-life; Remaining activity = Initial activity $\times (1/2)^n$

Calculation:

1. $n = 20 / 5 = 4$ half-lives
2. Remaining activity = $640 \times (1/2)^4$
3. Remaining activity = $640 \times (1/16)$
4. Remaining activity = 40 Bq

Final Answer: The activity of the source after 20 minutes is 40 Bq.