1 **(a) Explain briefly the following:**

- **(i) Mantle plumes and Hot spots.**
    - Mantle plumes are buoyant columns of hot rock that originate deep within the Earth's mantle and rise towards the surface.
    - Hot spots are surface manifestations of these mantle plumes, characterized by volcanic activity that is often independent of tectonic plate boundaries.
    - As a tectonic plate moves over a stationary mantle plume, a chain of volcanoes can form, with the oldest volcanoes being furthest from the current hot spot.
- **(ii) Isostasy.**
    - Isostasy is the concept that the Earth's lithosphere (crust and upper mantle) floats on the denser, more fluid asthenosphere.
    - It describes the gravitational equilibrium between large blocks of the Earth's lithosphere, where the weight of a lithospheric column is balanced by the buoyancy force exerted by the displaced asthenosphere.
    - This principle explains why mountains have deep roots and why continents rise or fall in response to changes in overlying loads, such as the growth or melting of ice sheets.
- **(iii) Magma.**
    - Magma is molten rock material found beneath the Earth's surface.
    - It is formed by the melting of rocks in the Earth's mantle or crust due to high temperatures and pressures.
    - Magma contains dissolved gases and various minerals. When magma erupts onto the Earth's surface, it is called lava.
- **(iv) Layers of the Earth.**

- The Earth is composed of several concentric layers, primarily divided by their chemical composition and physical properties.
- **Crust:** The outermost solid layer, relatively thin and composed of continental and oceanic crust.
- **Mantle:** The thickest layer, located beneath the crust, composed mainly of silicate rocks; it is solid but behaves plastically over geological timescales.
- **Outer Core:** A liquid layer composed primarily of iron and nickel, responsible for generating the Earth's magnetic field.
- **Inner Core:** The innermost solid layer, also composed mainly of iron and nickel, despite extremely high temperatures, it remains solid due to immense pressure.

- **(v) Seismograph.**
  - A seismograph is an instrument used to detect and record seismic waves generated by earthquakes, volcanic eruptions, and other sources.
  - It consists of a sensor (seismometer) that detects ground motion and a recording device that creates a seismogram.
  - Seismographs are crucial for studying the Earth's interior structure and monitoring seismic activity.

(b) True or False

- **(i) The theory of Continental drift was given by Alfred Wegener. (T/F).**
  - True
- **(ii) Feldspar and quartz are the most common minerals found in igneous rocks. (T/F).**
  - True

- **(iii) All the rivers of India drain in the Bay of Bengal. (T/F).**
  - False
- **(iv) The most abundant element in the Earth's crust is Oxygen. (T/F).**
  - True
- **(v) Marble is a type of metamorphic rock that originates from limestone. (T/F).**
  - True

2 **Write short notes on any three of the following:**

- **(i) Geological Time Scale.**
  - The Geological Time Scale (GTS) is a system of chronological dating that relates geological strata (stratigraphy) to time.
  - It is used by geologists and other scientists to describe the timing and relationships of events that have occurred throughout Earth's history.
  - The GTS is divided into hierarchical units: Eons, Eras, Periods, Epochs, and Ages, based on significant geological and biological events, such as mass extinctions and the emergence of new life forms.
  - Key events like the formation of the Earth, the appearance of life, and major evolutionary developments are mapped onto this scale.
- **(ii) Sea floor spreading.**
  - Sea floor spreading is a geological process that occurs at mid-ocean ridges, where new oceanic crust is formed through volcanic activity and then gradually moves away from the ridge.

- Magma from the mantle rises to the surface, erupts, and solidifies, creating new seafloor.
- This new crust then spreads symmetrically outwards from the ridge axis, carrying continents with it.
- Evidence for seafloor spreading includes magnetic striping on the ocean floor, increasing age of rocks away from the ridge, and the presence of heat flow anomalies at mid-ocean ridges.

- **(iii) The Western Ghats.**
  - The Western Ghats are a mountain range that runs parallel to the western coast of India, stretching for about 1,600 kilometers from the Tapi River to the southern tip of India.
  - They are recognized as one of the world's eight "hottest hotspots" of biological diversity due to their rich variety of flora and fauna, many of which are endemic.
  - The range acts as a major barrier to the monsoon winds, leading to high rainfall on its western side and a rain shadow region on its eastern side.
  - The Western Ghats are older than the Himalayan mountain range and significantly influence India's climate, hydrology, and biodiversity.
- **(iv) Differentiation of the Earth.**
  - Differentiation of the Earth refers to the process by which the Earth's interior separated into distinct layers with different densities and compositions.
  - This process occurred early in Earth's history, when the planet was largely molten due to heat from accretion and radioactive decay.

  - Denser materials, primarily iron and nickel, sank to form the core, while lighter silicate materials rose to form the mantle and crust.
  - This gravitational differentiation is fundamental to understanding the Earth's internal structure and the processes that drive plate tectonics and volcanism.

- **(v) Evolution of the Earth's atmosphere.**
  - The Earth's atmosphere has undergone significant changes since its formation, evolving through several stages.
  - **Primordial Atmosphere:** The earliest atmosphere, likely composed of hydrogen and helium, was lost to space.
  - **Early Atmosphere:** Formed from volcanic outgassing, it was rich in water vapor, carbon dioxide, nitrogen, and sulfur compounds, with little to no free oxygen.
  - **Oxygenation Event:** The emergence of photosynthetic organisms (cyanobacteria) led to the gradual accumulation of free oxygen in the atmosphere, starting around 2.5 billion years ago. This event, known as the Great Oxidation Event, profoundly changed Earth's environment and paved the way for complex life.
  - **Modern Atmosphere:** Over geological time, the atmosphere reached its current composition, primarily nitrogen (78%), oxygen (21%), argon (0.9%), and trace amounts of other gases, supporting diverse life forms.

3 **(a) What are the physical properties used to identify minerals?**

- **Color:** The most obvious property, but often unreliable for identification as many minerals can have varied colors due to impurities, and different minerals can have the same color.

- **Streak:** The color of a mineral in its powdered form, obtained by rubbing the mineral across an unglazed porcelain plate. Streak is often more consistent than the mineral's apparent color.
- **Luster:** Describes how the surface of a mineral reflects light. Common lusters include metallic (looks like metal), glassy (vitreous), pearly, silky, earthy (dull), and greasy.
- **Hardness:** A mineral's resistance to scratching. It is typically measured using the Mohs Hardness Scale, which ranks minerals from 1 (softest, talc) to 10 (hardest, diamond).
- **Cleavage:** The tendency of a mineral to break along specific planes of weakness, producing smooth, flat surfaces. Described by the number of cleavage directions and the angles between them.
- **Fracture:** The way a mineral breaks when it does not exhibit cleavage. Types include conchoidal (shell-like, curved), uneven, fibrous, or hackly.
- **Specific Gravity:** The ratio of the density of a mineral to the density of water. It indicates how heavy a mineral feels for its size.
- **Crystal Form/Habit:** The characteristic external shape of a mineral crystal. This property is often well-developed when minerals grow in unrestricted spaces.
- **Tenacity:** A mineral's resistance to breaking, bending, or tearing. Terms include brittle, malleable, ductile, sectile, and elastic.
- **Magnetism:** Some minerals are attracted to a magnet (e.g., magnetite).
- **Effervescence (Reaction to Acid):** Some minerals, especially carbonates, will effervesce (fizz) when dilute hydrochloric acid is applied to them.
- **Odor:** Some minerals have a characteristic smell when freshly broken or rubbed (e.g., sulfur).

(b) What is erosion, and how does it differ from weathering? What are its main agents?

- **Erosion:**
  - Erosion is the process by which soil and rock materials are detached, transported, and deposited from one location to another on the Earth's surface.
  - It involves the dynamic movement of particles by natural agents.
- **Difference from Weathering:**
  - **Weathering** is the in-situ (on-site) breakdown and decomposition of rocks and minerals at or near the Earth's surface into smaller fragments or dissolved components. It does not involve significant movement of the material.
  - **Erosion**, on the other hand, *involves the transportation* of these weathered materials away from their original location. Weathering breaks the rock, and erosion moves the broken pieces.
- **Main Agents of Erosion:**
  - **Water:**
    - **Running water (Rivers and Streams):** Carries sediments in suspension, dissolved load, and by bedload transport (rolling, sliding, saltation), forming valleys, canyons, and floodplains.
    - **Rainfall/Sheet Erosion:** Raindrops dislodge soil particles, and surface runoff carries them away in thin sheets.
    - **Ocean Waves and Currents:** Erode coastlines, cliffs, and beaches, forming features like sea caves, arches, and stacks.

- **Wind:**
  - Erodes dry, loose material, especially in arid and semi-arid regions.
  - Carries sand and dust particles, causing abrasion (sandblasting effect) and deflation (removal of fine particles).
- **Ice (Glaciers):**
  - Massive bodies of ice that move slowly, carving out U-shaped valleys, cirques, and fjords through processes like plucking (lifting rocks) and abrasion (grinding with embedded rocks).
- **Gravity (Mass Wasting):**
  - The downward movement of rock and soil under the direct influence of gravity.
  - Includes processes like landslides, mudflows, rockfalls, and creep. While often triggered by water or seismic activity, gravity is the primary driving force for transport.

4 **(a) Explain the types of tectonic plate boundaries and the topographic structures formed because of tectonic activity.**

- Tectonic plate boundaries are regions where two or more lithospheric plates meet, and the majority of Earth's geological activity, such as earthquakes and volcanoes, occurs along these boundaries. There are three main types:
- **i. Divergent Plate Boundaries:**
  - **Explanation:** Plates move away from each other. Magma rises from the mantle to fill the gap, creating new oceanic crust. This process is called seafloor spreading.
  - **Topographic Structures Formed:**

        - **Mid-Ocean Ridges:** Undersea mountain ranges with a central rift valley, like the Mid-Atlantic Ridge.
        - **Rift Valleys:** On continents, continental crust stretches and thins, leading to the formation of grabens (down-dropped blocks) and rift valleys, such as the East African Rift Valley.
        - **Volcanic Activity:** Effusive basaltic volcanism occurs along the rifts.
        - **Shallow Earthquakes:** Common along the rift zones due to the stretching and fracturing of the crust.
- **ii. Convergent Plate Boundaries:**
    - **Explanation:** Plates move towards each other, resulting in one plate being forced beneath the other (subduction) or the collision of two continental plates.
    - **Topographic Structures Formed:**
        - **Oceanic-Continental Convergence:**
            - **Subduction Zones:** Where the denser oceanic plate slides beneath the lighter continental plate.
            - **Volcanic Arcs/Mountain Ranges:** The subducting plate melts, forming magma that rises to create chains of volcanoes (e.g., Andes Mountains, Cascade Range).
            - **Oceanic Trenches:** Deep, narrow depressions on the ocean floor marking the subduction zone (e.g., Peru-Chile Trench).
            - **Deep Earthquakes:** Occur along the subducting slab.
        - **Oceanic-Oceanic Convergence:**

        - **Subduction Zones:** One oceanic plate subducts beneath another.
        - **Volcanic Island Arcs:** A chain of volcanic islands forms on the overriding plate (e.g., Mariana Islands, Aleutian Islands).
        - **Oceanic Trenches:** Associated with the subduction zone (e.g., Mariana Trench).
        - **Deep Earthquakes:** Similar to oceanic-continental convergence.
    - **Continental-Continental Convergence:**
        - **Collision Zones:** Neither plate fully subducts due to similar densities; instead, the crust is intensely folded, faulted, and uplifted.
        - **Large Mountain Ranges:** Formation of high, non-volcanic mountain ranges (e.g., Himalayas, Alps).
        - **Plateau Formation:** Extensive elevated regions (e.g., Tibetan Plateau).
        - **Shallow to Intermediate Earthquakes:** Common, but typically no volcanism.

- **iii. Transform Plate Boundaries:**
    - **Explanation:** Plates slide horizontally past each other, neither creating nor destroying crust.
    - **Topographic Structures Formed:**
        - **Fault Lines:** Characterized by long, linear valleys or scarps (cliffs) where the plates grind past each other (e.g., San Andreas Fault in California).
        - **Offset Features:** Streams, roads, or other features may be offset along the fault line over time.

- **Frequent Earthquakes:** Often shallow and powerful, as stress builds up and is released.
- **No Volcanism:** No significant magmatic activity at these boundaries.

(b) Explain the formation of Himalaya.

- The Himalayas are the world's highest mountain range, formed as a result of a colossal continental-continental collision between the Indian Plate and the Eurasian Plate.
- **Initial Stage (Gondwana Breakup):** Approximately 180 million years ago, the supercontinent Gondwana began to break apart. The Indian Plate, then a large island, started its northward journey, moving at a relatively fast pace.
- **Tethys Ocean Closure:** As the Indian Plate moved northward, it began to subduct the oceanic crust of the Tethys Ocean beneath the Eurasian Plate. This subduction led to the formation of volcanoes and initial uplift on the southern margin of the Eurasian Plate.
- **Continental Collision:** Around 50 to 55 million years ago, the Indian Plate finally collided with the Eurasian Plate. Since both are continental plates, neither could be easily subducted.
- **Crustal Shortening and Thickening:** Instead, the immense compressional forces caused the continental crust to buckle, fold, fault, and thrust over itself. The sediments and rocks of the former Tethys Ocean basin, along with the margins of both continental plates, were severely deformed and uplifted.
- **Continued Uplift:** The collision is still ongoing, with the Indian Plate continuing to push northward into the Eurasian Plate at a rate of several centimeters per year. This ongoing compression causes continued uplift of the Himalayas, making them tectonically active with frequent earthquakes.

- **Formation of Peaks:** The immense pressure and uplift resulted in the formation of the towering peaks, including Mount Everest, and the extensive high plateau of Tibet to the north. The Himalayas are a classic example of a fold-and-thrust belt, where layers of rock are stacked and shortened due to compressional forces.

5 **(a) Describe the development and movement of monsoons across India.**

- Monsoons are seasonal winds that reverse their direction due to differential heating of land and sea, bringing distinct wet and dry seasons. In India, the monsoon is a crucial climatic phenomenon.
- **Development of Monsoons (Causes):**
  - **Differential Heating:** The primary cause is the differential heating and cooling of the landmass (Indian subcontinent) and the surrounding ocean (Arabian Sea and Bay of Bengal). In summer, the land heats up much faster and to a greater extent than the ocean.
  - **ITCZ Shift:** The Inter-Tropical Convergence Zone (ITCZ), a low-pressure belt where trade winds converge, shifts northward over the Indian subcontinent during summer due to the intense heating of the land. This creates a strong thermal low-pressure system over North India.
  - **High Pressure over Ocean:** Simultaneously, a relatively high-pressure area develops over the Indian Ocean, particularly south of the equator, due to cooler temperatures.
  - **Mascarene High:** A semi-permanent high-pressure cell (Mascarene High) in the Southern Indian Ocean intensifies, providing a continuous source of moisture-laden winds.
  - **Coriolis Effect:** The trade winds, originating from the high-pressure area over the ocean, are deflected to their right

(southwest direction) as they cross the equator due to the Coriolis effect, becoming the Southwest Monsoon winds.

- **Upper Air Circulation (Jet Streams):** The position of the Subtropical Westerly Jet Stream plays a role. In winter, it flows over the Himalayas, but in summer, it shifts north of the Himalayas, allowing for the development of the tropical easterly jet stream which helps pull the monsoon winds northward.

- **Movement of Monsoons Across India:**
  - **Southwest (Summer) Monsoon (June to September):**
    - **Onset:** The Southwest Monsoon typically sets in over the Kerala coast around June 1st, marking the official beginning of the rainy season.
    - **Two Branches:** As the moisture-laden winds approach the Indian subcontinent, they split into two main branches:
      - **Arabian Sea Branch:** This branch moves northward along the Western Ghats, causing heavy orographic rainfall on the windward side (western slopes) and a rain shadow effect on the leeward side (eastern slopes). A part of this branch also moves towards Central India and Rajasthan.
      - **Bay of Bengal Branch:** This branch moves towards the Northeast Indian states and Myanmar. It then turns westward, bringing heavy rainfall to the Ganga Plains and further contributing to rainfall in North India.
    - **Progression:** Both branches gradually advance inland, covering most of India by mid-July.
    - **Rainfall Distribution:** Rainfall varies significantly across regions, with Western Ghats, Northeast India, and the

Himalayan foothills receiving very high rainfall, while parts of Rajasthan and Ladakh remain relatively dry.

- **Retreating Monsoon / Northeast (Winter) Monsoon (October to December):**
  - **Weakening of Low Pressure:** By early October, as the sun moves southward, the landmass begins to cool, and the low-pressure system over North India weakens and is replaced by a high-pressure system.
  - **ITCZ Shift Southward:** The ITCZ shifts southward, and the trade winds reverse direction.
  - **Northeast Winds:** Dry, cool winds blow from the land (northeast) towards the Bay of Bengal.
  - **Rainfall in South India:** As these winds cross the Bay of Bengal, they pick up moisture and bring rainfall to the Coromandel Coast (Tamil Nadu, parts of Andhra Pradesh), particularly in October and November. This is the primary rainy season for these regions.
  - **Clear Skies in North India:** Most of North India experiences dry and clear weather during this period.

(b) Why does the Earth behave like a giant magnet?

- The Earth behaves like a giant magnet primarily due to a process called the **geodynamo**.
- **Molten Outer Core:** The Earth's outer core is composed predominantly of molten iron and nickel. This liquid metal is a good electrical conductor.
- **Convection Currents:** Heat from the inner core and the decay of radioactive elements within the outer core drive vigorous convection currents in this molten metal. These currents involve the movement of electrically charged particles (electrons within the molten iron).

- **Coriolis Effect:** As the Earth rotates, the Coriolis effect acts on these convecting currents, causing them to twist and organize into spiraling flows.
- **Self-Exciting Dynamo:** This organized movement of electrically conducting fluid generates electric currents. According to Maxwell's equations and the principles of electromagnetism, moving electric currents generate magnetic fields. This generated magnetic field, in turn, influences the fluid motion, creating a self-sustaining feedback loop known as a self-exciting dynamo.
- **Resultant Magnetic Field:** The continuous operation of this geodynamo within the outer core produces the Earth's main magnetic field, which extends into space, forming the magnetosphere. This magnetic field protects Earth from harmful solar radiation and plays a crucial role in navigation (compasses).

6 **(a) What are the stages of river development according to the model proposed by the geomorphologists?**

- Geomorphologists often describe river development in terms of an idealized sequence of stages, though actual rivers may not perfectly fit this model or may exhibit characteristics of multiple stages along their course. The three main stages are:
- **i. Youthful Stage (Upper Course):**
    - **Location:** Typically found in mountainous or hilly regions, closer to the source of the river.
    - **Characteristics:**
        - **Dominant Erosion:** Vertical erosion (downcutting) is the primary process, creating deep valleys.
        - **Valley Shape:** Valleys are typically V-shaped, narrow, and steep-sided.

        - **Gradient:** High gradient (steep slope), leading to fast-flowing water.
        - **Features:** Characterized by features like waterfalls, rapids, potholes, and gorges.
        - **Load:** The river carries a large amount of coarse sediment (boulders, cobbles) due to its high energy.
        - **Meanders:** Relatively straight course, with few or no meanders.

- **ii. Mature Stage (Middle Course):**
    - **Location:** Occurs as the river descends from higher elevations into flatter terrain.
    - **Characteristics:**
        - **Balanced Erosion and Deposition:** Both vertical and lateral erosion (sideways cutting) are significant, but lateral erosion becomes more prominent. Deposition also starts to occur.
        - **Valley Shape:** Valleys widen, becoming U-shaped or open valleys with gentler slopes.
        - **Gradient:** Moderate gradient, resulting in a slower flow than the youthful stage.
        - **Features:** Meanders (bends in the river) start to develop, and a floodplain begins to form. Some oxbow lakes might start to form as meanders become more pronounced. Tributaries join the main river.
        - **Load:** Carries a mix of coarse and fine sediments.
- **iii. Old Stage (Lower Course):**
    - **Location:** Found in very flat, low-lying areas, typically near the river's mouth.

- **Characteristics:**
  - **Dominant Deposition:** Deposition is the primary process, as the river loses much of its energy due to very low gradient.
  - **Valley Shape:** Very wide, flat valleys with extensive floodplains.
  - **Gradient:** Extremely low gradient, leading to very slow-flowing, sluggish water.
  - **Features:** Highly developed and often exaggerated meanders, oxbow lakes (formed when meanders are cut off), levees (natural embankments), braided channels (where the river divides into multiple channels), and deltas at the mouth where sediments are deposited into a larger body of water.
  - **Load:** Carries mostly fine suspended sediments.

(b) What is a glacier? Describe the erosional and depositional landforms of glaciers.

- **What is a Glacier?**
  - A glacier is a large, perennial accumulation of crystalline ice, snow, rock, sediment, and liquid water that originates on land and moves downslope under the influence of its own weight and gravity.
  - They form in areas where snow accumulation exceeds snowmelt over many years, leading to the compaction and recrystallization of snow into ice.
- **Erosional Landforms of Glaciers:** Glaciers are powerful agents of erosion, sculpting landscapes through processes like:

- **Plucking (Quarrying):** The glacier freezes onto rock fragments, and as it moves, it pulls these fragments away from the bedrock.
- **Abrasion:** Rocks embedded in the base and sides of the glacier grind and polish the bedrock as the glacier slides over it, like sandpaper.
- **Common Erosional Landforms:**
    - **U-shaped Valleys (Glacial Troughs):** Valleys that have been widened and deepened by glacial erosion, resulting in a characteristic U-shaped cross-section, unlike the V-shaped river valleys.
    - **Cirques (Corries):** Bowl-shaped depressions with steep sides and a flat or gently sloping floor, often found at the head of a glacial valley. They are formed by glacial erosion at the headwall.
    - **Arêtes:** Sharp, knife-edge ridges formed when two cirques or two glacial valleys erode parallel to each other.
    - **Horns:** Sharp, pyramid-shaped mountain peaks formed when three or more cirques erode a mountain from different sides (e.g., The Matterhorn).
    - **Fjords (Fiords):** Long, narrow, deep inlets of the sea, flanked by steep cliffs, which were once glaciated valleys submerged by rising sea levels.
    - **Hanging Valleys:** Tributary glacial valleys that enter a main glacial valley at a much higher elevation, often marked by waterfalls where streams plunge from them.
    - **Roche Moutonnées (Sheep Rocks):** Asymmetrical bedrock hills sculpted by glacial abrasion on the upstream side (smooth and polished) and plucking on the downstream side (steep and jagged).

        - **Striations:** Scratches or grooves etched into bedrock surfaces by rock fragments dragged along by the moving glacier.

- **Depositional Landforms of Glaciers:** As glaciers melt and retreat, they deposit the sediment (till) they have carried.
    - **Till:** Unsorted and unstratified glacial sediment ranging from fine clay to large boulders.
    - **Outwash:** Sorted and stratified sediments deposited by meltwater streams flowing away from the glacier.
    - **Common Depositional Landforms:**
        - **Moraines:** Accumulations of till deposited directly by the glacier. Different types include:
            - **Terminal Moraine (End Moraine):** A ridge of till that marks the furthest extent of a glacier's advance.
            - **Lateral Moraine:** Ridges of till deposited along the sides of a valley glacier.
            - **Medial Moraine:** A ridge of till formed in the middle of a glacier when two lateral moraines from converging glaciers merge.
            - **Ground Moraine:** A sheet of till deposited as the glacier melts and retreats, forming an undulating plain.
        - **Drumlins:** Elongated, streamlined hills of till, shaped like an inverted spoon or half-egg, with the blunt end facing the direction of ice flow. They often occur in "fields" or "swarms."

- **Eskers:** Long, sinuous ridges composed of sand and gravel, formed by meltwater streams flowing in tunnels beneath or within the glacier.
- **Kames:** Irregularly shaped hills or mounds of sand and gravel deposited by meltwater streams flowing into crevasses or depressions on the glacier surface.
- **Kettles/Kettle Lakes:** Depressions in glacial outwash plains formed by the melting of buried blocks of ice, which then fill with water to become lakes.
- **Outwash Plains:** Extensive, relatively flat plains of stratified sand and gravel deposited by meltwater streams beyond the glacier's terminus.