GEOGRAPHY OPTIONAL PAPER 1 MODEL ANSWERS

SECTION A

Q1 Answer the following in about 150 words each : 10×5=50

a) Explain the causes of glacial lake outburst flood.

A **Glacial Lake Outburst Flood (GLOF)** is a sudden, catastrophic release of water from a glacial lake, usually formed by meltwater dammed behind moraines or ice. GLOFs occur when the natural dam fails due to internal or external triggers.

1. Climatic and Hydrological Causes

(a) Rapid melting due to warming

- Rising temperatures accelerate **glacial retreat**, increasing meltwater volume.
- Sudden heatwaves cause sharp rise in lake levels, stressing moraine dams.

(b) Intense or prolonged rainfall

- Monsoon bursts/cloudbursts can rapidly fill lakes.
- Added water increases **hydrostatic pressure**, destabilizing moraine dams.

(c) Snow/ice avalanches entering the lake

- Avalanches from surrounding slopes can create **displacement waves** that overtop and breach the dam.

2. Geomorphological and Structural Causes

(a) Weak, unconsolidated moraine dams

- Moraines consist of loose debris with high permeability → prone to seepage, piping, and collapse.
- Many Himalayan lakes are **young**, fragile, and structurally unstable.

(b) Ice-cored moraines

- Melting of buried ice weakens the structure, leading to sudden failures.

(c) Steep valley walls

- Encourage frequent landslides and rockfalls, which can fall into the lake causing overtopping.

3. Geophysical / Tectonic Causes

(a) Earthquakes and tremors

- Trigger cracks, slumping, or liquefaction of moraine dams.
- Himalayan high seismicity increases the risk.

(b) Volcanic or geothermal activity (rare, but seen in Andes/Iceland)

- Can destabilize ice masses and trigger rapid melting.

4. Anthropogenic Causes

(a) Infrastructure development near glacial lakes

- Road blasting, tunneling, or vibrations weaken lake walls.
- Construction reduces stability of surrounding slopes.

(b) Climate change due to human activities

- Accelerates glacier melt → formation and expansion of glacial lakes.
- Increases frequency of extreme rainfall events.

5. Lake-Internal Processes

(a) Seepage and piping through the dam

- Continuous seepage enlarges internal tunnels inside the moraine → sudden collapse.

(b) Buoyant uplift pressure

- Meltwater below ice dams can lift and rupture them.

b) What is solifluction? What are its impacts?

What is Solifluction?

Solifluction is the **slow downslope movement of water-saturated soil or regolith** under the influence of gravity.
It occurs mainly in **periglacial (cold, permafrost or seasonally frozen) environments**, where the **upper soil layer thaws in summer** while the lower layer remains **permanently frozen (permafrost)**.

Because the lower layer is impermeable, the upper saturated soil **creeps downslope** even on gentle gradients.

Key characteristics

- Slow mass movement (few cm to a few meters per year)
- Requires **freeze–thaw cycles**
- Soil becomes **waterlogged** due to frozen subsoil
- Produces lobes, terraces, and sheets of moving earth

Mechanism (simplified)

1. In winter → ground surface freezes.
2. Summer → surface layer thaws, becomes saturated with meltwater.
3. The thawed, saturated soil slides over the still-frozen layer → **solifluction creep**.

Impacts of Solifluction

1. Formation of distinctive landforms

- **Solifluction lobes**: tongue-shaped masses of soil.

- **Solifluction terraces**: step-like features on slopes.
- **Sheets of saturated soil movement**: gentle surface deformation.

These are common in **Arctic, Sub-Arctic, high mountain** regions.

2. Slope instability and degradation

- Weakens slope integrity over a long time.
- Encourages **erosion** and slow ground movement.
- May lead to **mass wasting** if combined with other processes.

3. Impacts on human infrastructure

- Damage to **roads**, **buildings**, **pipelines**, and **foundations** in permafrost regions.
- Causes surface warping and tilting of structures.
- Increases maintenance costs in cold environments (e.g., Canada, Russia, Himalayas).

C) What are Nappes?

Nappes are **large, sheet-like masses of rock that have been intensely folded and thrust over long distances (often tens of kilometres)** during mountain-building (orogeny).
They represent **extreme compressional deformation** in collisional tectonic settings.

Geological & Tectonic Processes Leading to Nappe Formation

1. Plate Convergence and Compressional Stress

- In a collision zone (e.g., **continent–continent** or **continent–arc** collision), plates converge strongly.
- Intense **horizontal compressional forces** push rock layers laterally.
- This causes **over-thrusting** and formation of large-scale folds that eventually become nappes.

Example: India–Eurasia collision → Himalayan nappes.

2. Development of Large-Scale Recumbent Folds

- Under strong compression, upright folds become **overturned**.
- Further compression produces **recumbent folds** where limbs are almost horizontal.
- The upper limbs detach and move further to form **nappe structures**.

Key mechanism: Fold tightening + shearing → detachment of the upper limb.

3. Thrust Faulting and Detachment Surfaces

- Nappes detach from their roots along **low-angle thrust planes** or **décollements** (detachment horizons).
- These surfaces often develop along:
  - shale layers
  - evaporites
  - weak, ductile strata

Once detached, huge rock slabs glide laterally to form **thrust sheets** or nappes.

4. Gravity Gliding & Gravitational Collapse

- After uplift of an orogenic belt, elevated terrain creates **gravitational potential energy**.
- The unstable, over-thickened crust encourages **gravity-driven sliding** of large rock masses.
- This assists in the **transport of nappes over long distances**, sometimes >100 km.

5. Ductile Deformation under High Pressure–Temperature Conditions

- At mid-crustal depths (10–20 km), high P–T conditions produce:
  - **Plastic flow** of rocks
  - **Shear-zone development**

- Rocks deform ductilely, enabling large sheets to fold, stretch, and slide with reduced friction.

6. Role of Shear Zones and Mélange

- Strong **ductile shear zones** localize deformation.
- They act like geological "conveyor belts," enabling nappes to move.
- In subduction or collision settings, mélange zones provide a **ductile substrate** facilitating nappe transport.

D) What geological and tectonic processes lead to the formation of nappes in orogenic belts?

Nappes are large, sheet-like rock units that have been intensely deformed and transported tens to hundreds of kilometers during mountain building. Their formation is a hallmark of many collisional orogens such as the Alps, Himalaya, and Appalachians.
Here's how they form, step by step:

Initial Conditions: Weak or Layered Lithology

Nappe formation requires:

- Mechanical layering (e.g., alternating strong and weak rocks).
- Weak, ductile horizons such as shales, evaporites, or overpressured sediments that can act as décollement (detachment) surfaces.

These layers decouple deformation between upper and lower crust, allowing large sheets to slide.

Plate Convergence and Crustal Shortening

During continental collision or subduction-related compression:

- The crust shortens horizontally.
- Rocks respond by folding, faulting, and thickening.
- At high strain, large recumbent folds begin to develop, often with:
    - Horizontal or overturned limbs

- Flat-lying axial planes

- Low friction (e.g., evaporites, shales)
- High-temperature ductile flow

This zone acts as the glide plane along which nappes travel.

e) Explain the relationship between air masses and local winds ?

Air masses and local winds are closely connected because air masses create the pressure and temperature contrasts that drive local wind systems. Local winds, in turn, are the small-scale responses to these contrasts. Here's how they relate:

1. Air Masses Create Pressure Differences

Each air mass has characteristic temperature, humidity, and density:

- Cold air masses → dense, high pressure
- Warm air masses → less dense, low pressure

When two different air masses meet or move into a region, they set up pressure gradients, and wind always blows from high toward low pressure.
These pressure gradients create many kinds of local winds.

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2. Fronts Between Air Masses Produce Local Winds

Where two air masses meet, they form fronts. These boundaries generate characteristic wind patterns:

Warm Front

- Warm air rises over retreating cold air
- Produces gentle, steady winds ahead of the front

Cold Front

- Cold air pushes under warm air
- Generates gusty, shifting winds, often with storms

Occluded or Stationary Fronts

- Can cause persistent or variable winds

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3. Local Winds Are Small-Scale Modifications of Air-Mass Behavior

Local topography and surface conditions modify large-scale air masses, producing distinct local winds:

a. Sea and Land Breezes

- Day: Land heats faster → warmer, lower pressure → sea breeze blows inland
- Night: Land cools faster → higher pressure → land breeze blows toward sea
  Air masses provide the warm or cool air; local temperature contrasts drive the wind.

b. Mountain and Valley Winds

- Day: Warm air rises up slopes → valley breeze
- Night: Cold dense air flows downslope → mountain breeze

These winds occur because the local surface warms or cools the air mass differently in valleys vs. slopes.

c. Katabatic and Anabatic Winds

- Katabatic: Cold, dense air flows downhill from glaciers or plateaus

- Anabatic: Warm air flows upslope as it becomes buoyant

Q2)

A) How does denudation chronology help in understanding the sequential development of landscapes and landforms? Elucidate

Denudation chronology refers to reconstructing the *timing*, *sequence*, and *rates* of the processes that wear down the Earth's surface—weathering, mass wasting, erosion, transportation, and deposition. By establishing when different phases of denudation occurred, geomorphologists can better understand **how landscapes evolved step by step**.

Here's how it helps explain the **sequential development of landscapes and landforms**:

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1. Identifies the Order of Erosional Events

Denudation chronology helps determine **which surfaces or landforms formed first** and which ones came later.
By analyzing:

- Strath terraces
- Plantation surfaces
- Weathering profiles
- River incision sequences

geomorphologists can reconstruct the *temporal order* of landscape changes.
This reveals, for example, whether a valley was carved before a plateau was uplifted or afterward.

2. Reveals the Relationship Between Tectonics and Erosion

Landscape evolution is strongly controlled by uplift and erosion.
Denudation chronology allows us to:

- Link phases of **tectonic uplift** with phases of **accelerated erosion**

- Recognize periods of landscape stability vs. rapid incision
- Understand how mountains lower over time

For example, renewed uplift may rejuvenate rivers, causing a new cycle of valley deepening.

3. Helps Reconstruct Past Climates and Their Geomorphic Impacts

Climate shapes erosion rates.
By dating denudation surfaces, scientists can infer:

- Glacial vs. interglacial phases
- Arid vs. humid periods
- Shifts in dominant geomorphic processes

Example: deeply weathered lateritic surfaces indicate long, warm, humid conditions before being dissected by rivers in a later erosional cycle.

4. Establishes Erosion Rates Through Time

Techniques like:

- Cosmogenic nuclide dating
- Thermochronology (fission track, (U–Th)/He)
- Luminescence dating
- Paleosurface correlation

allow us to quantify how fast landscapes were lowered or stripped.
These rates help identify:

- Rapid incision events
- Long periods of stability

- Episodic vs. continuous denudation patterns

5. Explains Polycyclic and Polygenetic Landforms

Many landscapes reflect **multiple cycles of uplift, erosion, and stabilization**.
Denudation chronology helps disentangle these cycles, revealing:

- Old erosion surfaces buried and later exhumed
- Rivers cutting multiple terrace levels
- Old planation surfaces preserved beneath younger landforms

This helps explain why landscapes often show **mixed characteristics** from different periods.

6. Aids in Understanding Landscape Maturity

By determining how long erosional processes have been acting, we can classify landscapes into:

- **Youthful**: steep slopes, active incision
- **Mature**: rounded hills, reduced gradients
- **Old age**: low-relief surfaces, peneplains

Thus denudation chronology directly supports **Davisian and alternative models** of landscape evolution.

B) What is deep-sea mining? What are the potential benefits and risks associated with it?

Potential Benefits of Deep-Sea Mining

1. Access to Strategic and Critical Minerals

- Provides supply of minerals essential for **renewable energy technologies**, EV batteries, electronics, and high-performance alloys.
- Reduces dependency on terrestrial deposits that are becoming scarce or politically sensitive.

2. Lower Land-Based Environmental Pressure

- May reduce environmental degradation associated with land mining: deforestation, habitat destruction, soil contamination, displacement of communities.

3. Economic Growth and Strategic Advantages

- Offers new economic opportunities for coastal and island nations.
- Enhances national strategic security by diversifying mineral supply chains.

4. Technological Advancement

- Encourages innovation in underwater robotics, remote sensing, and marine engineering.
- Stimulates scientific research on deep-sea ecosystems.

5. Potential for Sustainable Resource Development (If regulated)

- With strong governance (e.g., through the **International Seabed Authority**), deep-sea mining *could* be managed to minimize harm compared to poorly regulated land operations.

Risks and Challenges of Deep-Sea Mining

1. Irreversible Damage to Deep-Sea Ecosystems

- Abyssal plains, hydrothermal vent communities, and seamounts host unique, slow-growing species.
- Habitat removal from nodule harvesting destroys ecosystems that may take **millennia** to recover—or may never recover.

2. Sediment Plumes

- Mining creates large sediment clouds that can spread kilometers, smothering organisms, clogging filter feeders, and altering food webs.
- Vertical plumes from riser discharge may introduce pollution to mid-water ecosystems.

3. Loss of Biodiversity

- Deep sea contains many endemic, undiscovered species.
- Disturbances may lead to extinction before species are even known.

4. Noise, Light, and Chemical Pollution

- Machinery noise disrupts deep-sea organisms relying on sound.
- Artificial lighting disturbs fauna adapted to total darkness.
- Release of toxic metals or chemicals can contaminate food chains.

5. Uncertain Geological and Oceanographic Impacts

- Risks of altering sediment stability, affecting carbon sequestration, and disturbing hydrothermal cycles.
- Potential to impact ocean chemistry at local or regional scales.

6. Governance, Ethical, and Social Issues

- Debate over whether deep-sea mining should proceed before adequate environmental knowledge is available ("**precautionary principle**").
- Concerns about equitable sharing of resources from international waters.
- Possible conflicts between mining companies, nations, and sustainability advocates.

7. High Costs and Technical Challenges

- Extreme depths, pressure, and remoteness make operations risky and expensive.
- Economic viability remains uncertain for many deposits.

Conclusion

Deep-sea mining presents a significant opportunity to access critical minerals essential for modern and green technologies. However, it also poses major environmental, ecological, and governance risks—many of which remain poorly understood. Balancing resource needs with long-term ocean health requires stringent regulation, robust scientific research, and consideration of alternative strategies such as recycling and improved land-based mining efficiency.

C) Man and wildlife conflicts are ever increasing. Discuss its causes, consequences and remedial measures ?

Human–wildlife conflict (HWC) refers to negative encounters between people and wild animals, usually arising when growing human activities intersect with wildlife habitats. It is increasing globally and in India due to rapid environmental and socio-economic changes.

1. Causes of Man–Wildlife Conflict

1. Habitat Loss and Fragmentation

- **Expanding agriculture, infrastructure, mining, and urbanization reduce and break wildlife habitats.**
- **Animals move into human areas in search of food and space.**

2. Decline of Natural Prey and Resources

- **Depletion of forests, water sources, and prey species forces carnivores and herbivores to depend on human-dominated landscapes.**

3. Expansion of Agriculture and Settlements Near Forests

- **Farms, orchards, and villages located close to forest boundaries attract elephants, wild boar, deer, monkeys, and carnivores.**

4. Seasonal Migrations and Climate Change

- **Drought, forest fires, and changing rainfall patterns push animals (e.g., elephants, leopards, tigers) toward human settlements.**

5. Human Encroachment into Wildlife Corridors

- **Roads, railways, fencing, and industries cut across traditional movement paths, increasing encounters.**

6. Attraction to Human Food Sources

- **Crop fields, fruit trees, garbage dumps, and livestock serve as easy food for wild animals.**

2. Consequences of Man–Wildlife Conflict

A. For Humans

- **Loss of human life and injuries**
- **Crop damage and economic loss**
- **Livestock depredation by carnivores**
- **Property damage (houses, water systems, granaries)**
- **Psychological stress and fear among rural communities**

B. For Wildlife

- **Retaliatory killings (poisoning, trapping, shooting)**
- **Accidental deaths (roadkill, electrocution, falling into wells)**
- **Disruption of movement and genetic exchange**
- **Decline in population of threatened species (e.g., elephants, leopards)**

C. For Ecosystems

- **Breakdown of ecological balance**
- **Loss of keystone and flagship species**
- **Increased human pressure on forest resources**

3. Remedial Measures

1. Habitat Protection and Restoration

- **Reforestation, restoration of degraded forests, securing water sources.**
- **Protection of core habitats within protected areas.**

2. Ensuring Wildlife Corridors

- **Identify and legally notify migration corridors.**
- **Build eco-bridges, underpasses, canopy bridges, and wildlife passages.**

3. Community-Based Conflict Management

- **Involve local communities in conservation committees.**
- **Provide timely and fair compensation for crop/livestock loss.**
- **Encourage alternative livelihoods, eco-tourism, and benefit-sharing.**

4. Reduce Attractants

- **Proper waste management to prevent animals from scavenging.**
- **Fencing of crop fields; use of chili fences, bio-fencing, bee fences.**
- **Stall-feeding and secure livestock enclosures.**

5. Technological Solutions

- **Early-warning systems (SMS alerts, GPS-collared elephant tracking).**
- **Solar-powered fences and sensor-based alarms.**
- **Drone monitoring in high-risk zones.**

6. Legal and Policy Measures

- **Strict enforcement of Wildlife Protection Act.**

- **Land-use planning around protected areas.**
- **National and state-level HWC mitigation plans.**

7. Awareness and Education

- **Training local communities about animal behavior and safety.**
- **School and village awareness programmes to reduce fear and encourage coexistence.**

Conclusion

Man–wildlife conflict is rising mainly due to increasing human pressure on natural ecosystems and shrinking wildlife habitats. Its impacts are severe for both people and animals. Sustainable solutions lie in scientific habitat management, community participation, technological tools, and policy interventions that promote coexistence rather than confrontation.

Q3 A) Examine the formation of atmospheric tricellular circulation systems. Describe how this system has been created considering the Earth a living planet ?

Formation of the Atmospheric Tricellular Circulation System

The tricellular circulation system consists of three major circulation cells in each hemisphere:

- Hadley Cell (0°–30°)
- Ferrel Cell (30°–60°)
- Polar Cell (60°–90°)

Its formation results from the interaction of solar heating, Earth's rotation, and pressure/temperature contrasts.

(a) Unequal Heating of the Earth's Surface

- The equator receives high, concentrated solar energy → intense heating.
- Poles receive oblique, low-intensity solar energy → strong cooling.
  This builds a large thermal gradient, establishing broad zones of low pressure (equator) and high pressure (subtropics, poles).

(b) Hadley Cell Formation

- Warm equatorial air rises due to convection → Intertropical Convergence Zone (ITCZ).
- Air spreads poleward aloft and sinks around 30° N/S, forming subtropical highs.
- Air returns to the equator as trade winds.
  This creates the first cell.

(c) Polar Cell Formation

- Cold, dense air sinks at the poles.
- It flows equatorward at the surface and rises around 60° latitude in the subpolar low.
  This creates the third cell.

(d) Ferrel Cell Formation

- Between Hadley and Polar cells lies an area where air is pushed and pulled by the adjacent circulations.
- This produces the indirect or thermally indirect Ferrel Cell, generating the westerlies.

(e) Coriolis Force

- Earth's rotation deflects winds:
  - Right in the Northern Hemisphere
  - Left in the Southern Hemisphere
    This organizes the large-scale wind belts that define each cell.

Thus, differential heating + rotation + pressure variations → the tricellular circulation system.

2. How This System Emerged Considering the Earth a "Living Planet"

Earth is unique as a living planet because of its dynamic atmosphere, hydrosphere, biosphere, and lithosphere. The tricellular circulation developed due to properties that also sustain life. Key factors include:

(a) Presence of a Life-Supporting Atmosphere

- Earth's atmosphere contains water vapour, oxygen, and greenhouse gases, largely maintained by life.
- Water vapour allows latent heat release, intensifying convection in the Hadley Cell.
- Vegetation influences humidity, albedo, and evapotranspiration, strengthening circulation patterns.

(b) Existence of Oceans

- Oceans store and transport huge quantities of heat.
- Sea–air interactions help anchor the ITCZ, monsoon systems, and trade winds.
  Earth's hydrosphere modulates the thermal gradient that powers the three cells.

(c) Suitable Earth–Sun Distance

- The "Goldilocks zone" ensures temperatures that allow liquid water and stable climate patterns.
- This provides the energy gradient necessary for atmospheric circulation.

(d) Earth's Rotation and Axial Tilt

- Rotation creates the Coriolis effect, shaping the three cells and global wind belts.
- Axial tilt produces seasons, shifting the cells north and south—supporting diverse climates and life zones.

(e) Biosphere–Atmosphere Feedbacks

- Forests, plankton, and microbial systems regulate CO_2, O_2, and aerosols.
- These influence cloud formation, rainfall patterns, and heat distribution.
  As life evolved, atmospheric composition changed, refining the circulation system.

(f) Plate Tectonics and Land–Sea Distribution

- Continents and oceans guide pressure belts and wind circulation.
- Mountain ranges modify jet streams and monsoons.
  Earth's geodynamics, vital for nutrient recycling, also shape global atmospheric

patterns.

Conclusion

The tricellular atmospheric circulation forms naturally from differential heating, pressure belts, and Earth's rotation. But its stability and complexity are intimately tied to Earth's identity as a living planet with oceans, a life-regulated atmosphere, plate tectonics, and biosphere–climate feedback. Together, they generate a dynamic yet balanced system that sustains life and maintains Earth's climatic diversity.

Q2. What is the 'UN Decade on Ecosystem Restoration'? How does it balance ecological goals with emerging socio-economic needs like food security and development?

The UN Decade on Ecosystem Restoration (2021–2030) is a global initiative proclaimed by the United Nations General Assembly to prevent, halt, and reverse the degradation of ecosystems across all continents and oceans. Coordinated by UNEP and FAO, its goal is to revive degraded forests, farmlands, grasslands, wetlands, mountains, coastal and marine ecosystems, while supporting human well-being and climate resilience.

It positions restoration as a foundation for sustainable development, addressing biodiversity loss, climate change, desertification, poverty, and food insecurity simultaneously.

How the UN Decade Balances Ecological Goals with Socio-Economic Needs

The initiative recognizes that restoration must work for nature and people together, not in isolation. It balances these priorities in several ways:

1. Nature-Based Solutions for Food Security

- Promotes agroecology, regenerative agriculture, soil restoration, agroforestry, and crop diversification.
- Restored soils retain more water and nutrients, increasing farm productivity and drought resilience.
- Enhancing pollinator habitats improves crop yields.

Thus ecological restoration strengthens long-term food production rather than competing with it.

2. Livelihood Generation and Green Jobs

- Restoration industries—nurseries, seed banks, community forestry, ecotourism, river and wetland rejuvenation—create millions of green jobs.
- Encourages community-based natural resource management, ensuring equitable economic benefits.

This supports development and poverty reduction while protecting ecosystems.

3. Climate Adaptation and Disaster Risk Reduction

- Restored wetlands, mangroves, floodplains, and forests protect communities from floods, storms, heatwaves, and coastal erosion.
- Reducing climate impacts safeguards infrastructure, agriculture, and livelihoods.

Healthy ecosystems act as natural climate shields, lowering long-term socio-economic vulnerabilities.

4. Integrating Restoration with National Development Plans

- Nations incorporate restoration in NDCs under the Paris Agreement, SDGs, Land Degradation Neutrality goals, and national agricultural and water strategies.
- This alignment ensures ecological projects support broader development and economic goals.

5. Community-Centric and Inclusive Approaches

- Emphasizes participation of indigenous peoples, women, youth, and local communities.
- Integrates traditional knowledge which is both ecologically sound and socially accepted.

Human needs are not sidelined; instead, communities become co-beneficiaries and co-managers.

6. Sustainable Use Rather Than Exclusion

- Promotes sustainable fishing, grazing, forest use, and water management, rather than blanket bans that harm livelihoods.
- Encourages mosaic landscapes combining conservation zones, managed forests, and productive farms.

The balance lies in restoring ecosystems without blocking development pathways.

7. Economic Valuation of Ecosystem Services

- Recognizes ecosystems as economic assets.
- Helps governments rationalize public spending by demonstrating benefits in water security, soil fertility, health, disaster protection, and tourism.

This frames restoration not as a cost, but as a long-term investment.

Conclusion

The UN Decade on Ecosystem Restoration seeks to repair damaged ecosystems while simultaneously meeting global socio-economic needs. By integrating nature-based solutions with agriculture, livelihoods, climate resilience, and inclusive development, it creates a model where ecological health becomes the backbone of sustainable food security and economic growth. In doing so, it positions restoration as a bridge between environmental integrity and human prosperity.

C) "The Himalaya is still rising." Expand this statement and describe the processes involved in it with suitable sketches and diagrams.

Explanation of the Statement

"The Himalaya is still rising" means that the Himalayan mountains are **geologically young and tectonically active**, and their elevation is increasing due to the **ongoing collision of the Indian Plate with the Eurasian Plate**. This process is still active today, causing uplift, earthquakes, and deformation in the region.

2. Processes Involved in the Rising of the Himalaya

(a) Plate Tectonics and Continental Collision

- The **Indian Plate** moves northwards at ~5 cm/year.
- It collides with the **Eurasian Plate**, causing **crustal shortening** and uplift.

(b) Thrust Faulting and Crustal Shortening

- The Himalaya has **thickened crust** due to stacking of rock layers along major thrusts:
    - **Main Central Thrust (MCT)**
    - **Main Boundary Thrust (MBT)**
    - **Main Frontal Thrust (MFT)**
- These thrusts push rock layers upward, increasing mountain height.

Sketch: Thrust Faults

(c) Seismic Activity

- Frequent **earthquakes** indicate that the crust is still adjusting.
- Earthquakes cause sudden vertical uplift of mountain blocks.

(d) Isostatic Rebound

- Erosion removes rocks from mountain tops.
- The crust **rebounds upward** to balance the weight (like a floating block in water).

Q4 A)What are the ecological consequences of agricultural deforestation in the Amazon and Congo Basins, particularly concerning biodiversity and climate regulation?

Impact on Biodiversity

(a) Habitat Loss

- Clearing forests for crops or cattle destroys natural habitats.
- Many species, including endemic plants, mammals, and birds, lose their home ranges.

(b) Species Extinction

- Loss of habitat and food sources can push species to extinction.
- Amazon: Jaguars, tapirs, many amphibians
- Congo: Gorillas, forest elephants, okapis

(c) Fragmentation

- Forest patches become isolated islands, preventing gene flow.
- Smaller populations are more vulnerable to disease, predation, and genetic problems.

(d) Disruption of Ecological Interactions

- Pollination, seed dispersal, and predator-prey relationships are disturbed.
- Many forest-dependent species cannot survive in agricultural landscapes.

2. Impact on Climate Regulation

(a) Carbon Storage and Greenhouse Gas Emissions

- Forests are major carbon sinks.
- Deforestation releases stored carbon → increased CO_2 in the atmosphere.
- Contributes to global warming.

(b) Local and Regional Climate Effects

- Forests help regulate rainfall patterns through evapotranspiration.
- Deforestation reduces moisture recycling → drier local climate.
- Can affect agriculture downstream and increase risk of droughts.

(c) Soil and Water Cycle Alteration

- Loss of tree cover → reduced transpiration and soil moisture retention.
- Leads to soil degradation, erosion, and reduced river flow, affecting climate resilience.

QB) Examine the distribution and balance of energy in the Earth's atmosphere system.

1. Source of Energy

- The **Sun** is the primary source of energy for the Earth's atmosphere.
- Energy arrives as **shortwave solar radiation (insolation)**.
- The Earth radiates energy back as **longwave (infrared) radiation**, maintaining the energy balance over time.

2. Distribution of Energy

(a) Latitudinal Variation

- The Equator receives **maximum solar energy** due to perpendicular sun rays.
- Poles receive **minimum energy** due to oblique sun rays and high albedo (snow/ice reflection).
- This **uneven heating** drives atmospheric circulation and ocean currents.

(b) Seasonal and Diurnal Variation

- **Seasonal changes** occur because of the Earth's axial tilt.
- **Day-night cycle** leads to fluctuations in temperature and radiation absorption.

(c) Atmospheric Absorption

- Some solar energy is **absorbed by the atmosphere**:
    - Ozone absorbs UV radiation.
    - Water vapor and CO_2 absorb some infrared.
- Remaining energy reaches the Earth's surface.

3. Reflection and Albedo

- Approximately **30% of incoming solar radiation** is reflected back into space.
- Reflection sources: clouds, ice, snow, deserts.
- **Albedo** regulates the amount of energy retained by the Earth.

4. Outgoing Radiation

- The Earth emits **longwave infrared radiation** back to space.
- **Greenhouse gases** trap part of this radiation, warming the lower atmosphere (greenhouse effect).
- Energy balance occurs when **incoming solar ≈ outgoing terrestrial radiation**.

5. Energy Transport

- The **latitudinal energy imbalance** drives heat transfer from equator to poles:
    1. **Atmospheric circulation** (winds, Hadley, Ferrel, Polar cells)
    2. **Ocean currents** (e.g., Gulf Stream)

- These processes **moderate temperatures** globally and prevent extreme gradients.

6. Implications of Energy Imbalance

- Local imbalances → **weather events** (storms, cyclones, monsoons).
- Global imbalances (e.g., excess greenhouse gases) → **climate change**.

C) Describe the process of formation of barrier islands and explain their significance.

Formation of Barrier Islands

Definition:
Barrier islands are long, narrow islands of sand that run parallel to the mainland coast and act as a buffer between the ocean and the shore.

Processes of Formation:

1. **Sediment Deposition:**
   - Rivers carry sand and silt to the coast.
   - Waves and currents deposit these sediments along the shoreline.
2. **Wave and Tidal Action:**
   - Continuous **wave action** shapes the sandbars.
   - **Tides** redistribute the sand, forming elongated islands parallel to the coast.
3. **Sea-Level Changes:**
   - Rising or falling sea levels separate these sandbars from the mainland.
   - This creates a lagoon or bay between the island and the coast.
4. **Stabilization by Vegetation:**

- Grasses and shrubs grow on the islands, **holding the sand together** and preventing erosion.

2. Significance of Barrier Islands

1. **Coastal Protection:**
    - Act as a buffer, protecting the mainland from **storm surges and waves**.
2. **Biodiversity:**
    - Provide habitat for birds, turtles, and other marine life.
3. **Economic Value:**
    - Important for **tourism, fishing, and recreation**.
4. **Climate Regulation:**
    - Reduce the impact of **coastal flooding and erosion**.
5. **Human Settlements:**
    - Some islands support small communities and resorts.

Summary:

Barrier islands are **dynamic coastal features formed by sediment deposition, wave and tidal action, and sea-level changes**, stabilized by vegetation. They are **ecologically and economically important**, providing protection, habitat, and resources.

<u>SECTION B</u>

<u>5(a) Why did the Welfare Approach in Human Geography emerge as a significant perspective in 1970s?</u>

Here's a step-by-step explanation to help you understand it clearly instead of just memorizing an answer:

The Welfare Approach in Human Geography emerged in the 1970s mainly because geographers wanted to shift focus from just mapping and describing places to understanding human well-being and quality of life. Before this, most geographical studies were either descriptive (like economic geography or physical features) or quantitative (like spatial patterns and models). By the 1970s, social changes—such as urbanisation, poverty, inequality, and regional disparities—made scholars realize that geography should address real-world human problems.

The Welfare Approach emphasizes access to resources, health, education, employment, and social services rather than just population numbers or industrial output. It also led to policy-oriented research, aiming to improve living conditions in disadvantaged regions. Essentially, it emerged as geographers sought to make their work relevant to human development and planning, rather than purely theoretical.

5(b)What are the key environmental and economic challenges linked to the extraction and processing of critical minerals?

The extraction and processing of critical minerals—such as lithium, cobalt, rare earth elements, and nickel—pose significant environmental and economic challenges. Environmentally, mining operations lead to deforestation, soil erosion, water pollution, and habitat destruction, while processing often generates toxic waste and greenhouse gas emissions, affecting ecosystems and local communities. Many critical minerals are located in ecologically sensitive areas, such as mountainous regions or forests, increasing the risk of biodiversity loss. Economically, mining is capital-intensive and requires advanced technology, making developing countries heavily dependent on imports. Price volatility, geopolitical risks, and concentrated supply in a few countries further threaten resource security and industrial development. These challenges highlight the need for sustainable mining practices, recycling, and international cooperation to balance economic growth with environmental protection.

5(c) "Pull factors in internal migration are often based on perceptions rather than reality." Explain.

Pull factors in internal migration refer to the conditions that attract people to move from one region to another, such as employment opportunities, better education, healthcare, or

urban lifestyle. Often, these factors are based on perceptions rather than actual conditions. For example, rural migrants may perceive cities like Mumbai, Delhi, or Bengaluru as lands of unlimited jobs and prosperity, but in reality, they may face high living costs, unemployment, poor housing, and lack of social security. Similarly, educational or healthcare facilities may exist in name, but accessibility and affordability can be limited. Such perception-driven migration can lead to urban congestion, slums, and increased competition for scarce resources, highlighting the gap between expectations and ground realities. Thus, pull factors often influence migration decisions more through hope and aspiration than through an accurate understanding of opportunities.

5(d) "Regional imbalances are the product of in situ and ex situ factors." Elucidate it with examples.

Regional imbalances refer to the unequal development of different regions in terms of economy, infrastructure, education, and employment. These imbalances arise from a combination of in situ (internal) and ex situ (external) factors. In situ factors are location-specific, such as availability of natural resources, soil fertility, climate, and terrain. For example, fertile plains like the Indo-Gangetic Plain support intensive agriculture, while arid regions like Rajasthan face developmental constraints. Ex situ factors are external influences like government policies, industrial investment, infrastructure development, and market access. For instance, the industrial corridor in Maharashtra and Gujarat has spurred regional growth, whereas northeastern states lag due to poor connectivity and limited investment. Thus, both natural endowments and human interventions combine to produce regional imbalances in India, highlighting the need for targeted planning and equitable resource distribution.

5(e) Why is systems analysis important in urban planning and what are its limitations?

Systems analysis is important in urban planning because it allows planners to view a city as an interconnected system of land use, transport, housing, utilities, and social infrastructure. By understanding the interactions among these components, planners can forecast urban growth, allocate resources efficiently, and design sustainable cities. It helps in decision-making, prioritising investments, and integrating multiple sectors like water supply, waste management, and traffic control. However, its limitations include over-reliance on quantitative data, which may not capture social, cultural, or behavioral aspects of urban life. It can also be time-consuming and costly, and the dynamic nature of cities means predictions may become quickly outdated. Additionally, systems analysis may ignore local community preferences, leading to top-down solutions that are not always practical.

6(A) How have dichotomy and dualism affected the methodological development of Geography? Describe.

The methodological development of geography has been significantly influenced by dichotomy and dualism, which initially divided the discipline into two contrasting approaches. The first major dichotomy was between physical and human geography, where physical geography focused on natural features and processes, and human geography concentrated on societies and their spatial behavior. This separation helped specialists develop rigorous methods within their domains but also limited holistic understanding of human-environment interactions. Another dualism emerged between quantitative (deterministic, model-based) and qualitative (descriptive, interpretive) approaches, which shaped research methods and data collection techniques. While dichotomies and dualism encouraged methodological rigor and theoretical clarity, they also caused fragmentation, reduced interdisciplinary integration, and delayed the emergence of integrated approaches like systems analysis and welfare geography, which aim to address real-world problems comprehensively.

6(B) Analyze the role of language and religion in delineating major cultural regions of the world.

Language and religion are primary markers of cultural identity and play a key role in delineating major cultural regions of the world. Language unites people through shared communication, literature, and traditions, forming linguistic regions such as the Francophone countries in Africa, the Arabic-speaking Middle East, or the Spanish-speaking Latin America. Religion shapes customs, festivals, moral values, and social institutions, creating religious cultural regions like the Islamic world across North Africa and the Middle East, the Buddhist regions of Southeast Asia, or the Christian-dominated Americas and Europe. While these factors provide cohesion and regional identity, overlapping languages and religions, as seen in countries like India and Nigeria, create cultural pluralism, making the boundaries of cultural regions flexible rather than rigid.

6(C) Analyze the spatial patterns and regional specialization of plantation crops across tropical and subtropical regions.

Plantation crops are commercial crops grown on large estates in tropical and subtropical regions, showing distinct spatial patterns and regional specialization due to climate, soil, and market demand. Crops like tea, coffee, rubber, sugarcane, and cocoa are concentrated in regions with high rainfall, fertile soils, and moderate to warm temperatures. For example, tea is specialized in India's Assam and Darjeeling, Sri Lanka, and Kenya; coffee thrives in India's Karnataka and Kerala, Brazil, and Colombia; rubber is concentrated in Kerala, Malaysia, and Indonesia; and cocoa in Ghana, Ivory Coast, and Nigeria. Regional specialization arises from suitable agro-climatic conditions, colonial legacies, access to ports, and labor availability, leading to export-oriented production. These spatial patterns influence regional economies, generate employment, and integrate local areas into the global commodity network, while also creating vulnerabilities to market fluctuations and monoculture risks

7. (a) Why is oil important for energy security? What is the role of oil in clean energy transition?

Oil is crucial for energy security because it remains the primary source of energy for transportation, industry, and electricity generation globally. It powers vehicles, ships, and airplanes, supports petrochemical industries, and ensures reliable economic functioning. Countries with limited domestic oil reserves depend on imports, making energy security a strategic priority to maintain economic stability and national security. In the context of clean energy transition, oil plays a transitional role by supporting hybrid and low-emission technologies, such as biofuels, synthetic fuels, and natural gas blending, while renewable infrastructure and electric mobility are scaled up. Although oil is a fossil fuel, efficient use, technological improvements, and gradual substitution with cleaner alternatives allow it to act as a bridge energy source toward a low-carbon future

7(B) Critically evaluate the role of primate cities in dominating the urban spheres of influence in developing countries

Primate cities are disproportionately large cities that dominate the economic, political, and cultural life of a country, often overshadowing other urban centers. In developing countries, they concentrate resources, employment, and services, creating urban spheres of influence that attract migration, investment, and infrastructure development. Examples include Mumbai in India, Bangkok in Thailand, and Lagos in Nigeria. While primate cities can drive national economic growth and act as hubs for trade, finance, and innovation, their dominance often leads to regional imbalances, overpopulation, congestion, housing shortages, and strain on public services. Smaller cities remain underdeveloped, and rural-urban disparities widen. Therefore, while primate cities play a catalytic role, excessive centralization can hinder balanced urban development, necessitating policies that promote secondary cities and regional urban networks.

7(C) "The global demographic landscape is evolving with rapid population growth in some places and rapid ageing in others." Elucidate with examples.

The global demographic landscape is increasingly uneven, with rapid population growth in some regions and rapid ageing in others. Developing countries, particularly in Sub-Saharan Africa (e.g., Nigeria, Ethiopia) and South Asia (e.g., India, Pakistan), experience high fertility rates and a youthful population, creating pressures on education, healthcare, and employment. In contrast, developed countries such as Japan, Germany, and Italy face low fertility and longer life expectancy, resulting in a rapidly ageing population and rising dependency ratios. This divergence affects global labor markets, migration, social security systems, and economic growth patterns. Policymakers must address these challenges through region-specific strategies, such as youth skill development in high-growth areas and pension reforms, healthcare expansion, and active ageing policies in ageing societies.

8(A) Why has F. Perroux's theory of growth pole as a model of regional growth been criticised? Explain with examples

F. Perroux’s growth pole theory posits that economic development is concentrated around specific industries or urban centres, which act as poles of growth, stimulating development in surrounding areas through linkages. While influential, the theory has faced criticism. Firstly, it assumes that growth in the pole automatically spreads to peripheral areas, which often does not happen, leading to regional disparities. For example, industrial hubs like Mumbai and Bengaluru in India have prospered, but nearby rural areas often remain underdeveloped. Secondly, the model overlooks social, political, and infrastructural constraints, assuming ideal conditions for diffusion. Finally, it is more descriptive than prescriptive, offering limited guidance on how to create poles or ensure equitable development. Thus, while the theory highlights the importance of strategic economic centres, its applicability is limited without complementary regional planning.

8(b) Analyze the role of demographic transition theory in explaining variations in fertility and mortality rates globally.

The Demographic Transition Theory (DTT) explains global variations in fertility and mortality rates by linking them to stages of socio-economic development. According to the theory, countries progress through four stages: Stage 1 (high birth and death rates), Stage 2 (declining death rates with sustained high birth rates), Stage 3 (declining birth rates), and Stage 4 (low birth and death rates). This framework helps explain why developing countries like Nigeria or India experience high fertility and declining mortality, resulting in rapid population growth, while developed countries like Japan or Germany face low fertility and low mortality, leading to ageing populations. Though the theory highlights the link between development and demographic change, it is criticized for being Eurocentric, ignoring cultural, policy, and technological factors that influence fertility and mortality in non-Western contexts.

8(C) How do regional components make the regional synthesis in spatial arrangement? Explain.

Regional synthesis in geography refers to the holistic understanding of a region by integrating its various components—physical, human, economic, and cultural. Regional components such as topography, climate, vegetation, population, settlements, economic activities, and infrastructure interact to shape the spatial arrangement of a region. For example, in the Indo-Gangetic Plains, fertile alluvial soils and favorable climate (physical) support dense population, intensive agriculture, and urban settlements (human and economic), while cultural factors like language and religion influence social organization. By analyzing these components together, geographers can understand patterns of resource use, regional development, and interrelationships within the space. Thus, regional synthesis emerges from the integration of multiple factors, enabling planners and policymakers to make informed, context-specific decisions.