Environmental Sustainability (DI02000051)

Winter 2025 Exam Solutions

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Date of Exam: 22-01-2026

Exam Overview

Exam Details

Subject: Environmental Sustainability
Code: DI02000051
Date: 22-01-2026
Time: 10:30 AM – 01:00 PM
Marks: 70

Topics at a Glance

Q.2 Pollution, Cycles, Ecosystems
Q.3 Renewable Energy, Pollution Control
Q.4 Climate Change, Wind/Bio Energy
Q.5 Biodiversity, Mitigation, ISO

Paper Structure

Q.1 14 MCQs (1 mark each = 14)
Q.2–5 (A) any 2 × 3 marks = 6 each
(B) any 2 × 4 marks = 8 each

Q.1 — MCQ Answers (1–8) [14 marks]

#	Key word	Ans	Option
1	Environmental sustainability	C	Maintaining resources
2	Biogeochemical cycle	B	Nitrogen cycle
3	BOD stands for	B	Biological Oxygen Demand
4	Source of air pollution	C	Vehicle exhaust
5	Effect of noise pollution	B	Hearing loss
6	PV in solar technology	B	Photovoltaic
7	Biofuel example	C	Ethanol
8	Blades rotate horizontally	C	HAWT

Quick Recall

- **Sustainability** = future generations' needs met
- **Nitrogen cycle** is biogeochemical; food chain is not
- **BOD** = Biological Oxygen Demand
- **Vehicles** emit CO, HC, NOx — major air polluters
- Noise pollution causes **hearing loss**, stress
- **PV** = Photovoltaic (light → electricity)
- **Ethanol** is biofuel; petrol/diesel are fossil fuels
- **HAWT** blades rotate on horizontal axis (like a fan)

Q.1 — MCQ Answers (9–14) [14 marks]

#	Key word	Answer
9	Greenhouse effect gas	**Carbon dioxide (CO_2)**
10	Wildlife protection law	**Wildlife Protection Act, 1972**
11	Five R's of 5R	**Refuse, Reduce, Reuse, Repurpose, Recycle**
12	Capturing CO_2	**Carbon Capture & Storage (CCS)**
13	Fermentation of organics	**Biogas**
14	Full form of ISO	**Intl. Org. for Standardization**

Quick Recall

- **CO_2** — main greenhouse gas from fossil fuels
- **Wildlife Protection Act 1972** — bans poaching/trade
- 5R: Refuse→Reduce→Reuse→Repurpose→Recycle
- **CCS** — captures CO_2 and stores underground
- **Biogas** — CH_4 from anaerobic fermentation
- **ISO** = Intl. Organization for Standardization

Q.2(A)(1) — Classification of Air Pollutants [3 marks]

Primary Pollutants

Emitted **directly** from a source into the atmosphere.

CO	Vehicles, incomplete combustion
SO_2	Coal/oil burning, smelters
NOx	Vehicles, power plants
SPM	Factories, construction dust
HC	Petroleum evaporation, vehicles

Secondary Pollutants

Formed by **chemical reactions** in atmosphere.

- **Ozone (O_3)** — NOx + sunlight
- **Photochemical smog** — HC + NOx + UV
- **Acid rain** — SO_2/NOx + $H_2O \rightarrow H_2SO_4/HNO_3$
- **PAN** (Peroxyacetyl nitrate)

Sources: Vehicles (30%), industries (25%), power plants (25%), agriculture (10%), natural (10%).

Q.2(A)(2) — BOD and COD [3 marks]

BOD — Biological Oxygen Demand

Amount of dissolved oxygen (mg/L) required by microorganisms to decompose organic matter in water at 20°C over 5 days.

Clean water: BOD < 2 mg/L
Polluted water: BOD > 10 mg/L

COD — Chemical Oxygen Demand

Oxygen needed to chemically oxidize **all** organic and inorganic matter using a strong oxidant ($K_2Cr_2O_7$).

COD $\geq$ BOD always.
Faster test than BOD.

Water Quality Assessment

Higher BOD/COD = more organic pollution = worse water quality. Industrial/sewage effluent has BOD 200–400 mg/L. Regulatory limit for discharge: BOD ≤ 30 mg/L, COD ≤ 250 mg/L.

Q.2(A)(3) — Sources and Types of Solid Waste [3 marks]

Types

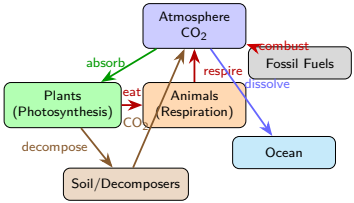
1. **Municipal Solid Waste (MSW)** — household garbage, food waste
2. **Industrial Waste** — manufacturing byproducts, slag
3. **Biomedical Waste** — hospital waste, syringes, bandages
4. **Agricultural Waste** — crop residues, animal dung
5. **E-waste** — computers, phones, TVs
6. **Hazardous Waste** — chemicals, batteries, paints

Sources

Domestic	Kitchens, households
Commercial	Shops, offices, markets
Industrial	Factories, power plants
Medical	Hospitals, clinics
Agricultural	Farms, dairy

Biodegradable: food, paper, wood
Non-biodegradable: plastic, glass, metals

Q.2(B)(1) — Carbon Cycle [4 marks]



Key Processes

1. **Photosynthesis** — Plants absorb $CO_2 + H_2O \rightarrow$ glucose + O_2
2. **Respiration** — Organisms release CO_2 back to atmosphere
3. **Decomposition** — Microbes break organic matter $\rightarrow CO_2/CH_4$
4. **Combustion** — Burning fossil fuels/wood $\rightarrow CO_2$
5. **Ocean absorption** — Seawater dissolves atmospheric CO_2

Q.2(B)(2) — Biodiversity and Sustainable Development [4 marks]

Definition

Biodiversity is the variety of **all living organisms** — plants, animals, microbes — in an ecosystem, including their genetic differences and the ecosystems they form.

Three levels:

- **Genetic diversity** — variation within a species
- **Species diversity** — number of different species
- **Ecosystem diversity** — variety of habitats

Importance for Sustainable Development

1. **Food security** — diverse crops resist pests/disease
2. **Medicine** — 25% drugs derived from plants
3. **Ecosystem services** — clean air, water, pollination
4. **Climate regulation** — forests absorb CO_2
5. **Economic value** — ecotourism, agriculture, fisheries
6. **Cultural value** — spiritual, aesthetic benefits

Q.2(B)(3) — Natural vs Artificial Ecosystems [4 marks]

Property	Natural Ecosystem	Artificial Ecosystem
Formation	Formed by nature without human intervention	Created and maintained by humans
Biodiversity	High — many species coexist	Low — limited to selected species
Self-sustaining	Yes — self-regulating	No — requires human inputs
Energy source	Solar energy only	Solar + fossil fuels/electricity
Stability	High — more resilient to disturbance	Low — fragile without maintenance
Waste recycling	Efficient natural nutrient cycling	Incomplete; waste accumulates
Examples	Forest, ocean, grassland, desert	Crop field, aquarium, garden, zoo

Q.3(A)(1) — Renewable Energy and Carbon Footprint [3 marks]

Carbon Footprint

Total greenhouse gases (mainly CO_2) released by an activity, product, or person, expressed in kg CO_2-equivalent.

Main contributors: electricity, transport, industry, agriculture.

How RE Reduces It

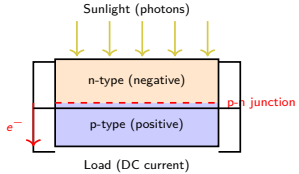
- Replaces coal/gas plants $\rightarrow$ no CO_2 emission
- EVs + solar/wind $\rightarrow$ zero tailpipe emissions
- Biogas replaces LPG $\rightarrow$ net-zero cycle

Renewable Sources and Impact

Solar PV	Replaces coal power
Wind	0 kg CO_2/kWh vs 1 kg
Hydro	Large-scale clean power
Biomass	Carbon-neutral cycle
Geothermal	Consistent baseload

Solar/wind emit $<$**10 g CO_2/kWh**; coal emits $\sim$**900 g CO_2/kWh**.

Q.3(A)(2) — Working Principle of Photovoltaic Solar Cells [3 marks]



Principle: Photovoltaic Effect

When **light (photons)** falls on a **p-n junction semiconductor** (silicon), electron-hole pairs are generated. The built-in electric field at the junction **separates** these charges, producing a **voltage and current**.

Working Steps

1. Photons strike the silicon p-n junction
2. Photons knock electrons free (electron-hole pairs)
3. Junction field separates electrons (n-side) and holes (p-side)
4. Electrons flow through external circuit $\rightarrow$ **DC current**

Efficiency: 15–22% for Si cells. No fuel, no emissions, 25-year life.

Q.3(A)(3) — Hydrogen Energy [3 marks]

Hydrogen as an Energy Carrier

Hydrogen (H_2) is the most abundant element. When burned or used in a fuel cell, it releases **only water** — zero CO_2 emission.

Combustion: $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$ + energy
Calorific value: 142 MJ/kg (3× petrol)

Types of Hydrogen

Green H_2: electrolysis using RE (best)
Blue H_2: from natural gas + CCS
Grey H_2: from natural gas (CO_2 released)

Role in Future Sustainability

1. **Transport** — fuel-cell vehicles (FCEV), buses, trains, ships
2. **Industry** — green steel, ammonia production
3. **Energy storage** — stores excess solar/wind energy
4. **Power generation** — fuel cells for off-grid use
5. **Aviation** — hydrogen-powered aircraft (future)

Q.3(B)(1) — Air Pollution Control Devices [4 marks]

1. Electrostatic Precipitator (ESP)

Principle: High-voltage electrodes charge dust particles; charged particles attracted to oppositely charged collection plates.

Working: Dirty gas enters → particles charged → migrate to plates → rapping removes collected dust.
Efficiency: Up to 99.5%
Use: Thermal power plants, cement factories

2. Cyclone Separator

Principle: Centrifugal force separates heavy particulates from gas stream.

Working: Gas enters tangentially → spins in cyclone → particles flung to walls → fall into hopper; clean gas exits top.
Efficiency: 70–90% for coarse particles
Use: Cement, steel, flour mills

Other devices: **Bag filter** (fabric traps fine dust), **Wet scrubber** (water absorbs gaseous pollutants like SO_2).

Q.3(B)(2) — Hazards of Plastic and E-waste [4 marks]

Plastic Hazards

1. **Non-biodegradable** — persists 500–1000 years
2. **Microplastics** — enter food chain; found in fish, drinking water, human blood
3. **Soil pollution** — blocks water percolation; kills soil organisms
4. **Marine pollution** — kills sea turtles, whales, seabirds
5. **Burning plastic** — releases toxic gases (dioxins, HCl)

E-waste Hazards

1. **Heavy metals** — Lead (Pb), Mercury (Hg), Cadmium (Cd) contaminate soil and groundwater
2. **Carcinogens** — flame retardants (BFRs) cause cancer
3. **Worker health** — informal recycling workers exposed to toxic fumes
4. **Air pollution** — burning e-waste releases toxic gases
5. **Data security** — improper disposal risks data theft

Q.3(B)(3) — Noise Pollution: Definition and Health Impacts [4 marks]

Definition

Noise pollution is the presence of unwanted, excessive, or disturbing sound in the environment that adversely affects human health and animal life.

Permissible limits (India):
Day: 55 dB (residential), 75 dB (industrial)
Night: 45 dB (residential)

Sources: Vehicles, aircraft, factories, construction, loudspeakers, firecrackers.

Health Impacts

1. **Hearing loss** (most common) — prolonged exposure > 85 dB causes permanent damage
2. **Cardiovascular effects** — high BP, increased heart rate
3. **Sleep disturbance** — insomnia, fatigue, poor concentration
4. **Stress and anxiety** — elevated cortisol levels
5. **Cognitive impairment** — affects learning and memory in children
6. **Communication problems** — difficulty in conversation

Q.4(A)(1) — Earth's Climate System and Greenhouse Effect [3 marks]

Earth's Climate System

Five major components:

- **Atmosphere** — layer of gases; traps heat
- **Hydrosphere** — oceans, rivers, ice; stores heat
- **Lithosphere** — land surface; absorbs solar energy
- **Cryosphere** — ice caps, glaciers; reflect sunlight
- **Biosphere** — living organisms; regulate CO_2

Greenhouse Effect

1. Sun's short-wave radiation passes through atmosphere
2. Earth's surface absorbs and re-emits long-wave (infrared) radiation
3. Greenhouse gases (CO_2, CH_4, N_2O) **trap** this outgoing IR
4. Earth stays warm (natural GHE: $+33°C$)
5. **Enhanced GHE**: excess GHGs $\rightarrow$ global warming

Without natural greenhouse effect, Earth's avg temp would be $-18°C$ instead of $+15°C$.

Q.4(A)(2) — Major Greenhouse Gases and Their Sources [3 marks]

Gas	Sources	GWP (100yr)
CO_2 (Carbon dioxide)	Fossil fuel burning, deforestation, cement	1 (baseline)
CH_4 (Methane)	Livestock, paddy fields, landfills, natural gas leaks	28
N_2O (Nitrous oxide)	Agricultural fertilizers, soil, sewage treatment	265
CFCs	Refrigerants, air-conditioners, aerosol sprays	4750–14400
H_2O vapour	Evaporation, transpiration	— (feedback)
O_3 (Ozone)	Vehicle exhaust + sunlight (troposphere)	1

GWP = Global Warming Potential relative to CO_2. CO_2 is most abundant; CH_4 and N_2O are far more potent per molecule.

Q.4(A)(3) — Climate Change: Sea Levels and Weather Patterns [3 marks]

Effects on Sea Levels

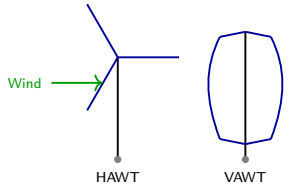
1. **Thermal expansion** of ocean water as temperature rises
2. **Melting ice sheets** (Greenland, Antarctica) add water
3. **Melting glaciers** worldwide contribute to rise
4. **Current rate:** $\sim$3.3 mm/year; projected $+1$ m by 2100
5. **Consequences:** Coastal flooding, saltwater intrusion, displacement of coastal populations

Effects on Weather Patterns

1. **More intense storms** — stronger cyclones/hurricanes
2. **Altered rainfall** — droughts in some regions, floods in others
3. **Heatwaves** — more frequent and prolonged
4. **Changing seasons** — earlier spring, shorter winters
5. **Arctic warming** — disrupts jet stream, causing extreme cold spells

Q.4(B)(1) — HAWT vs VAWT [4 marks]

Property	HAWT	VAWT
Axis orientation	Horizontal (parallel to ground)	Vertical (perpendicular to ground)
Blade rotation	Blades rotate on horizontal plane	Blades rotate on vertical axis
Wind direction	Faces into wind; needs yaw mechanism	Works with wind from any direction
Efficiency	Higher ($\sim$40–45%)	Lower ($\sim$30–35%)
Height	Tall towers (60–120 m)	Shorter, near ground level
Maintenance	Difficult (at height)	Easier (generator at base)
Noise	Moderate	Lower
Use	Large-scale wind farms	Urban/small-scale use
Example	Three-blade propeller turbine	Darrieus, Savonius turbine



HAWT is more common for utility-scale power. VAWT suited for urban rooftops.

Q.4(B)(2) — Types and Applications of Biofuels [4 marks]

1st Generation

Made from **food crops**.
Bioethanol — fermentation of sugarcane/maize
Biodiesel — transesterification of vegetable oils/animal fats
Use: Blended with petrol/diesel for vehicles

2nd Generation

Made from **non-food lignocellulosic biomass** (agricultural residues, wood waste).
No competition with food crops.
Use: Advanced biofuels for transport

3rd Generation

Derived from **algae** — high oil yield, grows in wastewater.
Algal biodiesel, bio-hydrogen.
Use: Future aviation and marine fuel

Applications

- Road transport (E10, E20 petrol blend)
- Aviation (Sustainable Aviation Fuel)
- Cooking (biogas/LPG replacement)
- Power generation
- Industrial heating

Q.4(B)(3) — Renewable vs Non-Renewable Energy [4 marks]

Property	Renewable	Non-Renewable
Replenishment	Naturally replenished (continuous)	Takes millions of years; effectively finite
Availability	Inexhaustible (sun, wind, water)	Exhaustible — reserves depleting
Environmental impact	Minimal/zero GHG emissions during use	Major source of CO_2, SO_2, pollution
Cost (operation)	Low running cost, high capital cost	Rising fuel costs; price volatility
Energy security	Reduces dependence on imports	Concentrated in few countries
Reliability	Intermittent (sun/wind dependent)	Reliable, available on demand
Examples	Solar, wind, hydro, biomass, geothermal	Coal, petroleum, natural gas, nuclear

Global energy transition: renewables share rising from 12% (2010) to 30% (2023). India targets 500 GW renewable capacity by 2030.

Q.5(A)(1) — Climate Change Impacts on Biodiversity [3 marks]

Direct Impacts

1. **Species extinction** — rising temperatures exceed thermal tolerance; species cannot adapt fast enough
2. **Habitat loss** — glaciers melt, coral bleaching, sea-level rise drowns coastal habitats
3. **Range shifts** — species migrate poleward or to higher altitudes
4. **Phenology shifts** — mismatched timing (flowering vs. pollinators)

Ecosystem Impacts

1. **Coral reef collapse** — bleaching from warm oceans; supports 25% of marine life
2. **Forest dieback** — Amazon, boreal forests threatened
3. **Ocean acidification** — CO_2 dissolves in ocean $\rightarrow$ carbonic acid $\rightarrow$ kills shellfish, coral
4. **Invasive species spread** — warmer areas colonized by non-native species

Q.5(A)(2) — Strategies for Climate Change Mitigation [3 marks]

Strategy 1: Renewable Energy Transition

Replace coal/gas power plants with solar, wind, hydropower.
Target: Net-zero electricity by 2050.
India: 500 GW RE capacity by 2030.

Strategy 2: Energy Efficiency

Improve efficiency of buildings (green buildings), transport (EVs), industry.
LED lighting, smart appliances, insulated buildings reduce demand significantly.

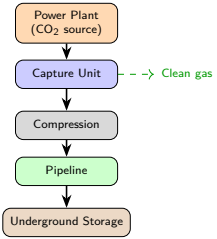
Strategy 3: Carbon Capture and Storage

Capture CO_2 from power plants/industry and store it underground (geological formations).
Also: **Afforestation** (natural CCS) — 1 hectare of forest absorbs $\sim$5 tonnes CO_2/year.

Other Strategies

Sustainable agriculture: reduce methane from livestock, rice paddies.
Circular economy: reduce waste, recycle materials.
International cooperation: Paris Agreement (limit warming to 1.5°C).

Q.5(A)(3) — Carbon Capture and Storage (CCS) [3 marks]



Definition

CCS is the process of capturing CO_2 from large emission sources (power plants, cement/steel factories), compressing it, transporting it via pipelines, and injecting it into deep geological formations for long-term storage.

How It Works

1. **Capture:** CO_2 separated from flue gas using solvents (post-combustion), membranes, or oxy-fuel combustion
2. **Compress:** CO_2 compressed to supercritical state ($>$74 bar)
3. **Transport:** Via pipeline to storage site

CCS can capture up to **90%** of CO_2 from large sources. Cost: US\$50–100/tonne CO_2.

Q.5(B)(1) — ISO 14000: Concept and Benefits [4 marks]

Concept

ISO 14000 is a family of international standards for **Environmental Management Systems (EMS)** developed by the International Organization for Standardization.

Key standard: ISO 14001 — specifies requirements for an EMS; helps organizations minimize environmental impact, comply with laws, and continually improve.

Other standards: ISO 14004 (EMS guidelines), ISO 14040–44 (Life Cycle Assessment), ISO 14064 (GHG accounting).

Benefits

1. **Legal compliance** — avoids fines, ensures regulatory conformity
2. **Cost reduction** — reduces energy, water, waste disposal costs
3. **Improved reputation** — demonstrates environmental commitment
4. **Market advantage** — access to global markets requiring EMS certification
5. **Employee engagement** — boosts morale; creates environmental culture
6. **Risk management** — reduces risk of environmental incidents/liabilities

Q.5(B)(2) — Green Building [4 marks]

Definition

A **green building** is a structure designed, constructed, and operated to **minimize environmental impact** and maximize **resource efficiency** — using less energy, water, and producing less waste than conventional buildings.

Key Features

- Solar panels and natural daylighting
- Rainwater harvesting and water recycling
- Efficient insulation and HVAC systems
- Eco-friendly construction materials
- Green roofs, waste management systems

Rating Systems in India

1. GRIHA (Green Rating for Integrated Habitat Assessment)

- Developed by TERI & MoNRE, India
- 5-star rating scale
- Evaluates site planning, energy, water, materials, occupant comfort

2. LEED (Leadership in Energy and Environmental Design)

- Developed by USGBC (USA); used globally including India
- Certified / Silver / Gold / Platinum ratings
- Evaluates similar categories as GRIHA

Q.5(B)(3) — Rainwater Harvesting [4 marks]

Definition

Rainwater harvesting is the collection, conveyance, and storage of rainwater from rooftops, land surfaces, or catchment areas for later use.

Methods

- **Rooftop harvesting** — gutters → storage tank
- **Surface runoff harvesting** — ponds, check dams
- **Ground recharge pits** — allows water to percolate
- **Percolation tanks** — large surface storage

Advantages

1. **Reduces water scarcity** — provides water during dry seasons
2. **Groundwater recharge** — replenishes depleted aquifers
3. **Reduces flood risk** — diverts surface runoff
4. **Low cost** — simple installation, low maintenance
5. **Reduces dependence** on municipal water supply
6. **Improves water quality** — soft, low-TDS water
7. **Reduces soil erosion** — by controlling surface runoff

Summary — Winter 2025 Solutions

Q	Topic	Marks
Q.1 (1–14)	MCQ + Fill in the Blanks	14
Q.2(A)(1)	Air Pollutant Classification	3
Q.2(A)(2)	BOD and COD	3
Q.2(A)(3)	Solid Waste: Sources and Types	3
Q.2(B)(1)	Carbon Cycle (with diagram)	4
Q.2(B)(2)	Biodiversity & Sustainable Dev.	4
Q.2(B)(3)	Natural vs Artificial Ecosystems	4
Q.3(A)(1)	Renewable Energy & Carbon Footprint	3
Q.3(A)(2)	Photovoltaic Solar Cells	3
Q.3(A)(3)	Hydrogen Energy	3
Q.3(B)(1)	Air Pollution Control Devices	4
Q.3(B)(2)	Plastic & E-waste Hazards	4
Q.3(B)(3)	Noise Pollution & Health Impacts	4

Q	Topic	Marks
Q.4(A)(1)	Earth Climate & Greenhouse Effect	3
Q.4(A)(2)	Major Greenhouse Gases	3
Q.4(A)(3)	Climate Change: Sea & Weather	3
Q.4(B)(1)	HAWT vs VAWT (with sketches)	4
Q.4(B)(2)	Biofuels: Types & Applications	4
Q.4(B)(3)	Renewable vs Non-Renewable	4
Q.5(A)(1)	Climate Change & Biodiversity	3
Q.5(A)(2)	3 Mitigation Strategies	3
Q.5(A)(3)	Carbon Capture & Storage (CCS)	3
Q.5(B)(1)	ISO 14000: Concept & Benefits	4
Q.5(B)(2)	Green Building & Rating Systems	4
Q.5(B)(3)	Rainwater Harvesting	4
	Total	**70**