Environment and Sustainability Solutions

4300003 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [03 marks]

Explain ecological footprint.

Solution

Ecological footprint measures the demand on nature by individuals, communities, or nations in terms of biologically productive land and water area required to sustain their lifestyle.

Table 1: Components of Ecological Footprint

Component	Description
Carbon Footprint	Land needed to absorb $CO_2 emissions$
Cropland	Area for food production
Grazing Land	Area for livestock
Forest Products	Area for timber and paper
Built-up Land	Infrastructure and urban areas

- **Global hectares**: Standard unit for measurement
- **Overshoot**: When footprint exceeds biocapacity
- **Sustainability**: Balance between consumption and regeneration

Mnemonic

"CGFBB" - Carbon, Cropland, Grazing, Forest, Built-up

Question 1(b) [04 marks]

Explain Eltonian pyramid.

Solution

Eltonian pyramid (Pyramid of Numbers) shows the number of organisms at each trophic level in an ecosystem, proposed by Charles Elton.

Diagram:

```
Tertiary Consumers
(Few {- 10)}

Secondary Consumers
(Moderate {- 100)}

Primary Consumers
(Many {- 1000)}

Producers
(Maximum {- 10000)}
```

Table 3: Pyramid Types

Type	Basis	Shape
Numbers	Individual count	Usually upright

Biomass	Total weight	Can be inverted
Energy	Energy flow	Always upright

- **Trophic levels**: Feeding positions in food chain
- **10% rule**: Only 10% energy transfers to next level
- **Exceptions**: Tree ecosystem shows inverted number pyramid

Mnemonic

"ELTON" - Energy Loss Through Organism Numbers

Question 1(c) [07 marks]

Explain Eco-system with its classification and component.

Solution

Ecosystem is a functional unit of nature where living organisms interact with each other and their physical environment, involving energy flow and nutrient cycling.

Table 5: Ecosystem Components

Component	Type	Examples
Abiotic	Non-living	Air, water, soil, climate
Biotic	Living	Plants, animals, microorganisms
Producers	Autotrophs	Green plants, algae
Consumers	Heterotrophs	Herbivores, carnivores, omnivores
Decomposers	Recyclers	Bacteria, fungi

Classification of Ecosystems:
Natural Ecosystems:
- **Terrestrial**: Forest, grassland, desert
- **Aquatic**: Freshwater (pond, river), Marine (ocean, sea)

Artificial Ecosystems:
- **Agricultural**: Crop fields, gardens
- **Urban**: Parks, artificial lakes

Diagram: Energy Flow

```
flowchart LR
    A[Sun] {-{-} B[Producers]}
    B {-{-} C[Primary Consumers]}
    C {-{-} D[Secondary Consumers]}
    D {-{-} E[Tertiary Consumers]}
    F[Decomposers] {-{-} B}
    C {-{-} F}
    D {-{-} F}
    E {-{-} F}
```

- **Energy flow**: Unidirectional from sun to decomposers
- **Nutrient cycling**: Cyclical movement of elements
- **Food chains**: Linear energy transfer
- **Food webs**: Interconnected food chains

Mnemonic

"PEACE" - Producers, Energy, Animals, Cycles, Environment

Question 1(c OR) [07 marks]

Explain Nitrogen cycle.

Solution

Nitrogen cycle is the biogeochemical cycle that converts nitrogen compounds through various chemical forms as it circulates through atmosphere, terrestrial and aquatic systems.

Diagram: Nitrogen Cycle

```
flowchart LR
    A[Atmospheric N_{2} {-}{-} B[Nitrogen Fixation]}
    B {-{-} C[Ammonia NH_{3}]}
    C {-{-} D[Nitrification]}
    D {-{-} E[Nitrites NO_{2}^{-}]}
    E {-{-} F[Nitrates NO_{3}^{-}]}
    F {-{-} G[Plant Uptake]}
    G {-{-} H[Animal Consumption]}
    H {-{-} I[Decomposition]}
    I {-{-} C}
    F {-{-} J[Denitrification]}
    J {-{-} A}
```

Table 7: Nitrogen Cycle Processes

Process	Conversion	Organisms
Fixation	$N_2 \rightarrow NH_3$	Rhizobium, Azotobacter
Nitrification	$NH_3 \rightarrow NO_2^- \rightarrow NO_3^-$	Nitrosomonas, Nitrobacter
Assimilation	$NO_3^- \rightarrow Proteins$	Plants
Decomposition	Proteins $\rightarrow NH_3$	Bacteria, fungi
Denitrification	$NO_3^- \rightarrow N_2$	Anaerobic bacteria

- **Biological fixation**: 80% of total fixation
- **Industrial fixation**: Haber process for fertilizers
- **Lightning**: Natural atmospheric fixation
- **Pollution**: Excess nitrates cause eutrophication

Mnemonic

"FNADD" - Fixation, Nitrification, Assimilation, Decomposition, Denitrification

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Question 2(a) [03 marks]

List the waste water quality parameter.

Solution

Table 9: Wastewater Quality Parameters

Physical	Chemical	Biological
Turbidity	**BOD**	**Coliform count**
Color	**COD**	**Pathogenic bacteria**
Odor	**pH**	**Algae**
Temperature	**DO**	**Virus**
Total Solids	**Ammonia**	**Protozoa**

- **Primary parameters**: BOD, COD, pH, suspended solids
- **Secondary parameters**: Heavy metals, nutrients
- **Indicator organisms**: E.coli for fecal contamination

Mnemonic

"PCB" - Physical, Chemical, Biological parameters

Question 2(b) [04 marks]

Explain E-waste classification and effects.

Solution

Electronic waste (E-waste) refers to discarded electrical and electronic equipment containing hazardous materials.

Table 11: E-waste Classification

Category	Examples	Hazardous Materials
Large Appliances	Refrigerators, washing machines	CFCs, heavy metals
Small Appliances	Microwaves, toasters	Lead, mercury
IT Equipment	Computers, printers	Cadmium, chromium
Telecom Equipment	Mobile phones, cables	Beryllium, flame retardants
Consumer Electronics	TVs, radios	Polyvinyl chloride (PVC)

Effects of E-waste:

- **Environmental**: Soil and water pollution, air contamination
- **Health**: Cancer, neurological disorders, respiratory problems
- **Resource depletion**: Loss of valuable metals like gold, silver
- **Ecosystem damage**: Bioaccumulation in food chain

Mnemonic

"LSITC" - Large, Small, IT, Telecom, Consumer electronics

Question 2(c) [07 marks]

Explain Electrostatic precipitators.

Solution

Electrostatic precipitators (ESP) are air pollution control devices that remove particulate matter from industrial gas streams using electrical charges.

Diagram: ESP Working

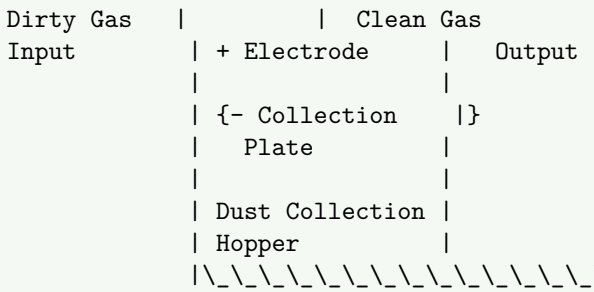

Table 13: ESP Components and Functions

Component	Function	Material
Discharge Electrode	Creates corona discharge	Tungsten wire
Collection Plate	Attracts charged particles	Steel plates

High Voltage Supply	Provides 30-100 kV DC	Transformer-rectifier
Rapper System	Removes collected dust	Mechanical vibrator
Hopper	Collects fallen particles	Steel container

Working Principle:

1. **Ionization**: High voltage creates corona discharge
2. **Charging**: Particles acquire negative charge
3. **Collection**: Charged particles move to positive plates
4. **Removal**: Rapping dislodges collected dust

Applications:

- **Power plants**: Coal-fired boilers
- **Cement industry**: Kiln gas cleaning
- **Steel industry**: Blast furnace gas
- **Chemical plants**: Process gas treatment

Advantages:

- **High efficiency**: 99%+ removal for fine particles
- **Low pressure drop**: Energy efficient operation
- **Handles high temperatures**: Up to 400

Mnemonic

"CHARGE" - Corona, High-voltage, Attract, Rapper, Gas, Efficiency

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Question 2(a OR) [03 marks]

Explain (1) BOD (2) COD

Solution

Table 15: BOD vs COD

Parameter	BOD	COD
Full Form	Biochemical Oxygen Demand	Chemical Oxygen Demand
Method	Biological oxidation	Chemical oxidation
Time	5 days at 20	2-3 hours
Oxidizing Agent	Microorganisms	Potassium dichromate

(1) BOD (Biochemical Oxygen Demand):

- **Definition**: Oxygen required by microorganisms to decompose organic matter
- **Standard conditions**: 5 days, 20·$darkconditions$
- **Units**: mg/L or ppm

(2) COD (Chemical Oxygen Demand):

- **Definition**: Oxygen equivalent to oxidize organic matter chemically
- **Oxidizing agent**: $K_2Cr_2O_7 inacidicmedium$
- **Higher than BOD**: Includes non-biodegradable compounds

Mnemonic

"BTCO" - Biological Time, Chemical Oxidation

Question 2(b OR) [04 marks]

Explain Recycle of E waste.

Solution

E-waste recycling is the process of recovering valuable materials from electronic waste while safely disposing of hazardous substances.

Table 17: E-waste Recycling Process

Stage	Process	Recovery
Collection	Gathering from households, offices	Whole devices
Dismantling	Manual separation of components	Plastics, metals, circuit boards
Shredding	Mechanical size reduction	Mixed material streams
Separation	Magnetic, density, optical sorting	Ferrous, non-ferrous metals
Refining	Chemical processing	Pure metals (Au, Ag, Cu, Pd)

Recycling Methods:

- **Mechanical**: Physical separation and size reduction
- **Pyrometallurgy**: High-temperature metal recovery
- **Hydrometallurgy**: Chemical leaching processes
- **Biotechnology**: Microbial metal extraction

Benefits:

- **Resource conservation**: Recovery of precious metals
- **Environmental protection**: Prevents soil and water contamination
- **Economic value**: Job creation and revenue generation
- **Energy savings**: Less energy than primary production

Mnemonic

"CDSPR" - Collection, Dismantling, Shredding, Separation, Refining

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Question 2(c OR) [07 marks]

Define pollution and its source. Explain the classification of pollutants.

Solution

Definition: Pollution is the introduction of harmful substances or energy into the environment, causing adverse changes to air, water, soil, or living organisms.

Table 19: Sources of Pollution

Source Type	Examples	Pollutants Released
Point Sources	Industrial chimneys, sewage outfalls	Specific location discharge
Non-point Sources	Agricultural runoff, urban stormwater	Diffuse area pollution
Mobile Sources	Vehicles, ships, aircraft	Exhaust emissions
Stationary Sources	Power plants, factories	Stack emissions

Classification of Pollutants:
1. By Nature:

Table 21: Pollutant Classification by Nature

Type	Characteristics	Examples
Biodegradable	Decompose naturally	Organic waste, sewage
Non-biodegradable	Persist in environment	Plastics, heavy metals
Slowly degradable	Decompose over years	Pesticides, radioactive materials

2. By Form:
- **Primary**: Directly emitted ($SO_2, CO, particulates$)
- **Secondary**: Formed by reactions ($O_3, acidrain, smog$)

3. By Source:
- **Natural**: Volcanic eruptions, forest fires
- **Anthropogenic**: Human activities, industrial processes

Diagram: Pollution Classification

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Pollutants] {-{-}{} B[By Nature]}
    A {-{-}{} C[By Form]}
    A {-{-}{} D[By Source]}
    B {-{-}{} E[Biodegradable]}
    B {-{-}{} F[Non{-}biodegradable]}
    C {-{-}{} G[Primary]}
    C {-{-}{} H[Secondary]}
    D {-{-}{} I[Natural]}
    D {-{-}{} J[Anthropogenic]}
{Highlighting}
{Shaded}
```

Effects of Pollution:
- **Environmental**: Ecosystem disruption, species extinction
- **Health**: Respiratory diseases, cancer, genetic disorders
- **Economic**: Healthcare costs, reduced productivity
- **Social**: Quality of life degradation

Mnemonic

"BNS-PFC" - Biodegradable, Non-biodegradable, Slowly degradable - Primary, Form, Classification

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Question 3(a) [03 marks]

State the working of solar cell.

Solution

Solar cell converts light energy directly into electrical energy through photovoltaic effect using semiconductor materials.

Table 23: Solar Cell Working Process

Step	Process	Result
Photon Absorption	Light hits semiconductor	Electron excitation

Electron-Hole Generation	Energy breaks bonds	Free charge carriers
Charge Separation	Built-in electric field	Electrons to n-side, holes to p-side
Current Collection	External circuit connection	Electrical current flow

- **p-n junction**: Creates internal electric field
- **Depletion region**: Area with charge separation
- **External load**: Completes electrical circuit

Mnemonic

"PECS" - Photon, Electron, Charge, Separation

Question 3(b) [04 marks]

Give the comparison between Horizontal Axis and Vertical Axis wind mills.

Solution

Table 25: HAWT vs VAWT Comparison

Parameter	Horizontal Axis (HAWT)	Vertical Axis (VAWT)
Blade Orientation	Horizontal rotation	Vertical rotation
Wind Direction	Must face wind	Accepts from any direction
Efficiency	Higher (35-45%)	Lower (20-35%)
Height	Tower mounted, high	Ground level installation
Maintenance	Difficult, high altitude	Easy, ground accessible
Noise	Moderate	Lower
Cost	Higher initial	Lower installation
Power Output	Higher for large scale	Suitable for small scale

Advantages: **HAWT**: Higher efficiency, proven technology, better power-to-weight ratio **VAWT**: Omnidirectional, easier maintenance, quieter operation, urban friendly
Applications: **HAWT**: Large wind farms, utility-scale power generation **VAWT**: Urban areas, small-scale applications, distributed generation

Mnemonic

"HEAVEN" - Height, Efficiency, Accessibility, Versatility, Economics, Noise

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Question 3(c) [07 marks]

Explain construction and working of Biogas plant with sketch.

Solution

Biogas plant produces methane-rich gas through anaerobic digestion of organic waste materials by methanogenic bacteria.
Diagram: Biogas Plant

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                Gas Outlet
                    ↑
Feed Inlet   [Digester]   Slurry Outlet
                    ↓
               Gas Holder
                    ↑
```

```
Underground Chamber
```

Table 27: Biogas Plant Components

Component	Function	Material
Digester	Anaerobic fermentation chamber	Concrete/steel
Gas Holder	Gas storage and pressure regulation	Steel/plastic
Inlet Chamber	Feed material entry	Masonry
Outlet Chamber	Slurry discharge	Masonry
Mixing Tank	Raw material preparation	Concrete

Construction Details:
Underground Digester:

- **Shape**: Cylindrical or dome-shaped
- **Capacity**: 10-100 $m^3 for household plants$
- **Wall thickness**: 10-15 cm concrete
- **Insulation**: Prevents heat loss

Working Process:

Table 29: Biogas Production Stages

Stage	Process	Duration	Products
Hydrolysis	Large molecules breakdown	1-3 days	Simple sugars, amino acids
Acidogenesis	Acid formation	3-7 days	Organic acids, alcohols
Methanogenesis	Methane production	15-30 days	$CH_4(60\%), CO_2(40\%)$

Operating Conditions:

- **Temperature**: 30-40$^{(}mesophilic$)
- **pH**: 6.8-7.2 (neutral)
- **C:N ratio**: 25-30:1 optimal
- **Retention time**: 20-30 days

Applications:

- **Cooking**: Clean burning fuel
- **Lighting**: Gas lamps
- **Heating**: Space and water heating
- **Electricity**: Generator sets

Advantages:

- **Renewable energy**: Sustainable fuel source
- **Waste management**: Organic waste disposal
- **Fertilizer production**: Nutrient-rich slurry
- **Environmental benefits**: Reduces greenhouse gases

Mnemonic

"BIGHM" - Biological, Input, Gas, Holder, Methane

Question 3(a OR) [03 marks]

List the advantages of flat plate collector.

Solution

Table 31: Flat Plate Collector Advantages

Category	Advantages
Technical	Simple design, no moving parts, low maintenance
Economic	Low cost, mass production possible

Operational	Works with diffuse light, handles both direct and indirect radiation
Durability	Long life (15-20 years), weather resistant
Versatility	Multiple applications, modular installation

Key Benefits:
- **Reliability**: No complex mechanisms or controls required
- **Efficiency**: 40-60% thermal efficiency in optimal conditions
- **Installation**: Easy mounting on roofs or ground

Mnemonic

"TEODV" - Technical, Economic, Operational, Durability, Versatility

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Question 3(b OR) [04 marks]

What is wind farm? List its advantages.

Solution

Definition: Wind farm is a group of wind turbines installed in the same location for commercial electricity generation, connected to electrical grid through transmission lines.

Table 33: Wind Farm Advantages

Category	Advantages
Environmental	Clean energy, zero emissions, reduces carbon footprint
Economic	Job creation, low operating costs, revenue for landowners
Technical	Scalable capacity, grid stability, energy independence
Social	Rural development, community benefits, educational opportunities

Specific Benefits:
- **Land use efficiency**: Farming can continue between turbines
- **Quick installation**: Faster than conventional power plants
- **Predictable costs**: Fixed fuel cost (wind is free)
- **Modular expansion**: Capacity can be increased incrementally

Applications:
- **Onshore**: Land-based installations
- **Offshore**: Ocean-based for higher wind speeds
- **Distributed**: Small-scale community projects

Mnemonic

"ECTS" - Environmental, Economic, Technical, Social benefits

Question 3(c OR) [07 marks]

Explain in brief (1) Geothermal energy (2) Tidal energy

Solution

(1) Geothermal Energy:
Geothermal energy harnesses heat from Earth's interior for electricity generation and direct heating applications.

Table 35: Geothermal Energy Systems

Type	Temperature	Applications
High Temperature	>150	Electricity generation
Medium Temperature	90-150	Direct heating, cooling
Low Temperature	<90	Heat pumps, agriculture

Working Principle:

- **Heat source**: Radioactive decay in Earth's core
- **Extraction**: Wells drilled to access hot water/steam
- **Conversion**: Steam drives turbines for electricity
- **Reinjection**: Water returned to reservoir

(2) Tidal Energy:

Tidal energy converts kinetic and potential energy of ocean tides into electricity using predictable tidal movements.

Table 37: Tidal Energy Technologies

Technology	Principle	Installation
Tidal Barrage	Potential energy of tidal range	Dam across estuary
Tidal Stream	Kinetic energy of tidal currents	Underwater turbines
Tidal Lagoon	Artificial impoundment	Breakwater construction

Advantages: Geothermal: Baseload power, low emissions, small footprint, reliable **Tidal**: Predictable, high energy density, long lifespan, no fuel costs

Challenges: Geothermal: Location specific, high initial cost, induced seismicity **Tidal**: High capital cost, environmental impact, limited locations

Mnemonic

"GT-POWER" - Geothermal Temperature, Tidal Predictable Ocean Water Energy Resource

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Question 4(a) [03 marks]

Explain Need of Renewable energy.

Solution

Table 39: Need for Renewable Energy

Driver	Reasons
Environmental	Climate change mitigation, reduced pollution
Economic	Energy security, price stability, job creation
Technical	Depleting fossil fuels, technological advancement
Social	Rural development, health benefits, energy access

Key Needs:

- **Climate commitments**: Meet Paris Agreement targets
- **Energy independence**: Reduce import dependence
- **Sustainable development**: Long-term energy security

Mnemonic

"EETS" - Environmental, Economic, Technical, Social needs
