MODULE 3 – Answers (10 points each)

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1. Explain why e-waste is classified as post-consumer waste in the e-waste management framework.

1. E-waste refers to electrical and electronic products that have reached the end of their useful life.
2. Once a consumer discards an electronic product, it becomes *post-consumer* waste.
3. It is generated after complete usage by households, institutions, or businesses.
4. The waste originates from end users, not manufacturers, hence classified as post-consumer.
5. It includes discarded phones, computers, appliances, etc., after full consumption.
6. Its composition is complex (plastics, metals, toxins), making it different from pre-consumer waste.
7. Post-consumer waste is tracked to ensure accountability in collection and recycling.
8. E-waste contains harmful substances like lead, mercury, cadmium that require regulated disposal.
9. It also contains valuable materials like gold, copper, and aluminium, making recovery necessary.
10. Classification helps develop policies for consumer take-back, recycling, and safe processing.

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2. Describe the major stages of the e-waste value chain from generation to recycling.

1. **Generation:** Consumers discard electronic products after end-of-life.
2. **Collection:** Waste is gathered by formal centres, informal collectors, or buy-back systems.
3. **Segregation:** Items are sorted based on type – phones, computers, appliances, etc.
4. **Transportation:** E-waste is moved safely to dismantling or recycling facilities.
5. **Dismantling:** Manual or mechanical separation of components like motherboards, batteries, plastics.
6. **Pre-processing:** Shredding, crushing, and separation of metals, plastics, and glass.
7. **Hazardous material removal:** Toxic components (CRT glass, batteries) are separated carefully.
8. **Material recovery:** Metals like copper, gold, aluminium are extracted through refining.
9. **Recycling:** Recovered materials are processed for reuse in manufacturing.
10. **Final disposal:** Residual hazardous waste is disposed in secure landfill or treated as per rules.

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3. Differentiate between formal and informal e-waste collection systems with suitable points.

1. **Ownership:** Formal systems are government-authorized; informal systems are unregulated.
2. **Training:** Formal collectors are trained; informal workers lack safety training.
3. **Safety:** Formal collection uses PPE and safe tools; informal handling involves unsafe practices.
4. **Environmental impact:** Formal systems ensure eco-friendly processing; informal causes pollution.
5. **Process:** Formal follows strict segregation; informal uses manual crude techniques.
6. **Documentation:** Formal systems maintain records; informal systems have no documentation.
7. **Compliance:** Formal centres follow E-waste Rules; informal workers do not comply.

8. **Efficiency:** Formal systems recover materials scientifically; informal systems have lower recovery rates.
9. **Health:** Informal workers suffer health risks like toxic exposure; formal systems minimize risks.
10. **Integration:** Governments aim to integrate informal workers into formal systems through training.

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4. Summarize the role of authorized collection centres in improving the e-waste value chain.

1. They serve as official drop-off points for safe e-waste disposal.
2. Ensure proper segregation of different types of electronics.
3. Prevent illegal dumping and reduce environmental pollution.
4. Create awareness and encourage consumers to return devices responsibly.
5. Collect e-waste in bulk from households, businesses, and institutions.
6. Safely store waste following approved guidelines.
7. Act as intermediaries between consumers and recyclers.
8. Support Extended Producer Responsibility (EPR) compliance for companies.
9. Improve traceability and tracking of waste throughout the value chain.
10. Strengthen the overall recycling ecosystem by enabling a steady supply of waste.

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5. Explain how consumer awareness affects the effectiveness of e-waste collection systems.

1. Awareness encourages consumers to avoid throwing e-waste in regular garbage.
2. Educated consumers participate in recycling and take-back programs.
3. Knowledge helps them identify nearest collection centres.
4. Prevents harmful dumping, leading to safer environmental conditions.
5. Increases return rates of devices, strengthening recycling industries.
6. Reduces e-waste given to informal recyclers.
7. Consumers learn harmful impacts of toxins like lead and mercury.
8. Awareness drives responsible purchasing (eco-friendly products).
9. Helps companies meet EPR targets due to higher collection volumes.
10. Leads to a shift towards responsible behaviour and sustainable waste management.

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6. Explain the concept of Extended Producer Responsibility (EPR) in the context of e-waste management.

1. EPR is a policy approach assigning producers responsibility for post-consumer waste.
2. Manufacturers must collect and recycle their products after consumer use.
3. Ensures producers design products that are easier to recycle.

4. Encourages eco-friendly packaging and material selection.
5. Producers must set up collection centres or partner with PROs.
6. They must meet recycling and recovery targets set by regulations.
7. EPR shifts financial burden from government to producers.
8. Helps reduce illegal dumping and improves recycling rates.
9. Fosters circular economy practices in electronics manufacturing.
10. Ensures safe handling, transportation, and disposal of e-waste by producers.

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7. Describe how Collective Responsibility supports effective implementation of EPR.

1. EPR works best when all stakeholders participate collectively.
2. Producers, recyclers, distributors, and consumers share responsibilities.
3. Promotes cooperation between government agencies and industry.
4. Retailers help collect old devices at purchase points.
5. Consumers return old products instead of discarding them.
6. Recyclers process waste safely according to regulations.
7. Municipal bodies support awareness programs.
8. Shared responsibility increases collection efficiency.
9. Prevents burden falling only on producers.
10. Ensures a holistic, sustainable e-waste management ecosystem.

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8. Explain the role of a Producer Responsibility Organization (PRO) in assisting producers to meet EPR obligations.

1. PROs are third-party agencies authorized to manage e-waste on behalf of producers.
2. They help producers achieve annual collection and recycling targets.
3. Set up collection mechanisms across regions.
4. Partner with recyclers to ensure safe processing.
5. Conduct consumer awareness programs.
6. Maintain documentation and submit compliance reports.
7. Help track material flow from collection to recycling.
8. Reduce operational burden on individual producers.
9. Ensure transparency and legal compliance.
10. Facilitate large-scale, efficient e-waste management.

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9. Differentiate between Individual Producer Responsibility (IPR) and Collective Producer Responsibility (CPR).

1. **Definition:**
    - IPR: Each producer handles waste from their own products.
    - CPR: Multiple producers share waste management responsibilities.
2. **System:**
    - IPR is brand-specific; CPR is group-based.
3. **Cost:**
    - IPR involves higher individual costs; CPR reduces costs through sharing.
4. **Collection:**
    - IPR requires separate collection channels; CPR uses common facilities.
5. **Flexibility:**
    - IPR gives full control to the producer; CPR offers shared control.
6. **Management:**
    - IPR managed individually; CPR often managed via PROs.
7. **Efficiency:**
    - CPR is more efficient for small producers; IPR suits large brands.
8. **Compliance:**
    - IPR focuses on producer-specific reporting; CPR provides group reporting.
9. **Accountability:**
    - IPR has higher accountability; CPR distributes accountability.
10. **Scalability:**
    - CPR scales easily through pooling of resources.

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10. Summarize the key functions performed by PROs in the e-waste collection and recycling value chain.

1. Set up authorized e-waste collection points.
2. Coordinate with waste collectors and logistics providers.
3. Ensure safe transportation of collected waste.
4. Partner with certified recyclers for processing.
5. Monitor dismantling and material recovery operations.
6. Maintain databases on collection, segregation, and recycling activities.
7. Conduct awareness and consumer education programs.
8. Assist producers in meeting government-mandated EPR targets.
9. Submit compliance documentation to regulatory authorities.

10. Improve overall efficiency and transparency in the e-waste value chain.

MODULE 4 – Answers (10 Points Each)

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1. Classify e-waste into hazardous and non-hazardous categories for a given device.

Hazardous e-waste:

1. Components containing heavy metals like lead (CRT glass, solder).
2. Mercury-containing lamps and switches in LCD screens.
3. Cadmium in rechargeable Ni-Cd batteries.
4. Lithium-ion batteries with fire and explosion risks.
5. Printed circuit boards containing toxic flame retardants.
6. Refrigerants and coolants in refrigerators and AC units.
7. Toner and ink cartridges containing chemical powder.
8. Cathode Ray Tube (CRT) glass with toxic phosphor coating.
9. Capacitors and transformers containing PCB oils.
10. Electronic components contaminated with chemical residues.

Non-hazardous e-waste:

1. Plastics from casings, keyboards, and mouse bodies.
2. Metals like aluminium and steel from frames or bodies.
3. Glass from non-CRT screens.
4. Rubber components such as gaskets and insulation.
5. Packaging materials like thermocol and cardboard.
6. Copper wires (if insulation intact).
7. Speakers and small motors.
8. Screws, nuts, bolts and metallic joints.
9. Re-usable adapters and cables.
10. Non-toxic electronic accessories.

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2. Apply characterization steps to identify materials in discarded electronics.

1. **Visual inspection:** Identify plastics, metals, batteries, cables, etc.
2. **Disassembly:** Carefully open the device to separate internal parts.
3. **Categorization:** Sort parts into plastic, glass, metal, PCB, and battery groups.
4. **Material testing:** Use magnets to detect ferrous metals.
5. **Density test:** Identify plastic types by float/sink test.
6. **XRF analysis:** Detect hazardous elements like Pb, Hg, Cd.

7. **Electrical test:** Determine if the battery retains charge.
8. **Weight measurement:** Quantify quantity of each material category.
9. **Label checking:** Identify material information printed on components.
10. **Documentation:** Record materials for recycling or safe disposal.

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3. Suggest suitable packaging for safe transport of e-waste.

1. Use sturdy corrugated cardboard boxes for general electronics.
2. Wrap fragile components in bubble wrap or foam padding.
3. Use anti-static bags for PCBs, chips, and processors.
4. Seal batteries in insulated, leak-proof containers.
5. Use plastic bins with cushioning for loose components.
6. Pack items tightly to prevent movement during transport.
7. Label boxes with "E-WASTE – HANDLE WITH CARE."
8. Keep chemicals or toner cartridges in sealed packets.
9. Use pallets for stacking large appliances.
10. Ensure moisture-proof protection to avoid short-circuit or corrosion.

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4. Prepare a proper label for an e-waste container.

A proper label must include:

1. **Title:** "E-WASTE COLLECTION BIN / CONTAINER."
2. **Hazard symbol:** Display e-waste or toxic material icons.
3. **Type of waste:** Example – electronics, batteries, PCBs.
4. **Name of generator:** Company/household/department name.
5. **Date of storage:** When the waste was placed in the bin.
6. **Handling warning:** "DO NOT OPEN / DO NOT MIX."
7. **Safety instructions:** Wear PPE, avoid wet conditions.
8. **Transport instructions:** "For authorized transporter only."
9. **Contact details:** Phone number of responsible person.
10. **Regulatory references:** "As per E-Waste Management Rules."

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5. Recommend correct packaging and labelling for mixed e-waste items.

1. Separate hazardous and non-hazardous components before packing.
2. Use strong boxes for mixed small e-waste pieces.
3. Provide cushioning to prevent breakage.

4. Place batteries in individual insulated covers.
5. Seal chemical cartridges properly before packing.
6. Use anti-static pouches for electronics.
7. Label package as “Mixed E-Waste – Contains Hazardous Material.”
8. Indicate type of items inside the package clearly.
9. Add handling instructions like “Do Not Drop / Keep Dry.”
10. Attach transporter and recycler details for tracking.

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6. Apply safe transportation guidelines to suggest how e-waste should be moved from a collection centre to a recycler.

1. Use only approved transport vehicles for e-waste movement.
2. Ensure drivers are trained in handling hazardous loads.
3. Items must be packed securely to avoid spillage or breakage.
4. Transport batteries separately in fire-resistant containers.
5. Use tie-downs or straps for large appliances.
6. Maintain proper documentation (manifest) during transport.
7. Vehicle must display “Hazardous / E-Waste Transport” sign.
8. Avoid overloading to prevent accidents.
9. Ensure no open handling of waste during transport.
10. Deliver directly to authorized recycler without intermediate dumping.

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7. Recommend proper storage methods for hazardous e-waste items in a lab.

1. Store hazardous items in a separate designated area.
2. Use fire-proof cabinets for batteries and flammable components.
3. Keep chemicals and toner cartridges in sealed containers.
4. Label all materials clearly as hazardous.
5. Maintain proper ventilation in storage areas.
6. Avoid high temperatures to prevent battery leakage or explosion.
7. Prevent moisture entry to avoid corrosion or short circuits.
8. Follow FIFO (First In First Out) for moving materials.
9. Restrict access to trained personnel only.
10. Keep spill kits and fire extinguishers nearby.

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8. Identify suitable personal protective equipment (PPE) for workers handling mixed e-waste.

1. Safety gloves (rubber, nitrile, or anti-cut).
2. Safety goggles to protect from solder or metal particles.
3. Dust masks or respirators for harmful fumes.
4. Safety shoes with anti-slip soles.
5. Protective aprons or lab coats.
6. Ear protection near shredding machines.
7. Face shields during dismantling.
8. Static wristbands for handling sensitive electronics.
9. Helmets for heavy equipment areas.
10. Insulated gloves for handling batteries or live wires.

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9. Suggest precautionary steps to prevent accidents during manual e-waste handling.

1. Wear PPE at all times.
2. Disconnect power supply before dismantling.
3. Avoid breaking CRTs, fluorescent lamps, and batteries by force.
4. Handle sharp components carefully to prevent cuts.
5. Keep work area clean and dry.
6. Use proper tools instead of makeshift instruments.
7. Avoid touching chemical residues without gloves.
8. Do not inhale fumes from soldering or burning.
9. Maintain good ventilation indoors.
10. Follow training and safety instructions strictly.

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10. Propose a safe handling procedure for transporting lithium-ion battery waste.

1. Inspect batteries for leaks, swelling, or damage.
2. Store each battery in an individual insulated pouch.
3. Use non-metallic, fireproof containers for packing.
4. Apply terminal tape to prevent short circuits.
5. Maintain cool temperature during storage and transport.
6. Do not crush, drop, or expose batteries to force.
7. Transport separately from other e-waste categories.
8. Use vehicles approved for hazardous materials.
9. Label packages with “Lithium-Ion Battery Waste – Flammable.”
10. Deliver only to certified battery recycling facilities.

MODULE 5 – Answers (10 Points Each)

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1. Identify hazardous substances present in a discarded mobile phone using ROHS guidelines.

1. **Lead (Pb):** Found in solder, PCB joints, and glass components.
2. **Mercury (Hg):** Present in backlights of some older displays.
3. **Cadmium (Cd):** Found in certain batteries and chip resistors.
4. **Hexavalent Chromium (Cr^{6+}):** Used for corrosion protection in metal parts.
5. **Polybrominated Biphenyls (PBB):** Flame retardants in plastic casings.
6. **Polybrominated Diphenyl Ethers (PBDE):** Used as flame retardants on PCBs.
7. **Lithium and electrolytes:** Hazardous chemicals in Li-ion batteries.
8. **Arsenic traces:** Found in microchips and semiconductors.
9. **Nickel:** Present in connectors and battery components, can cause allergies.
10. **Beryllium:** Found in connectors and springs, toxic when inhaled.

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2. Apply ROHS Directive 84 restrictions to evaluate whether a given electronic device is compliant.

1. Check if levels of **Lead (Pb)** do not exceed *0.1%* by weight.
2. Confirm **Mercury (Hg)** presence is below *0.1%*.
3. Verify **Cadmium (Cd)** content is below *0.01%*.
4. Ensure **Hexavalent Chromium (Cr^{6+})** is under *0.1%*.
5. Examine if **PBB** flame retardants are less than *0.1%*.
6. Ensure **PBDE** flame retardants are also below *0.1%*.
7. Request a material declaration report from the manufacturer.
8. Cross-check test certificates like XRF or chemical analysis reports.
9. Check product labels for ROHS compliance marks.
10. Confirm that supplier components used in assembling the device are also ROHS certified.

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3. Suggest design changes to reduce lead or mercury content in electronics as per ROHS standards.

1. Replace **lead-based solder** with **lead-free solder** (Sn-Ag-Cu alloys).
2. Use **mercury-free LEDs** instead of fluorescent backlights.
3. Adopt **halogen-free flame retardants** for plastics.
4. Use **nickel-silver connectors** instead of leaded components.
5. Replace **cadmium coatings** with organic coatings.
6. Redesign PCBs to use **lead-free surface finishes** (ENIG, OSP).

7. Introduce **modular design** to reduce hazardous components.
8. Use **eco-friendly adhesives** and non-toxic laminates.
9. Employ **automated soldering** to ensure precise material control.
10. Choose suppliers offering components certified under ROHS.

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4. Examine an electronic product label and determine if it meets ROHS compliance requirements in India.

To determine ROHS compliance:

1. Check for a **"ROHS" or "ROHS Compliant"** marking.
2. Look for the **WEEE crossed-bin symbol** indicating safe disposal.
3. Confirm the manufacturer's **declaration of conformity** is printed or attached.
4. Verify that restricted substances are mentioned as below threshold.
5. Check for **product serial number** and traceability information.
6. Ensure the brand name and importer address are present.
7. Look for **IS standards** followed in India (if applicable).
8. Confirm that the RoHS label is not misleading or outdated.
9. Review if a **self-declaration** is provided as per Indian E-Waste Rules.
10. Validate with online databases if the model is officially listed as compliant.

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5. Apply Indian ROHS rules to check whether a small manufacturer's product can be sold in the market.

1. Ensure lead, mercury, cadmium, Cr^{6+}, PBB, and PBDE are within permissible limits.
2. Check if the manufacturer has issued a **self-declaration certificate**.
3. Verify ROHS compliance tests or lab reports for materials.
4. Ensure the product follows **E-Waste Management Rules, 2022**.
5. Confirm the presence of **ROHS and WEEE symbols** on labels.
6. Check manufacturing processes for use of hazardous substances.
7. Validate supplier components for ROHS compliance.
8. Make sure there is documentation on safe disposal instructions.
9. Ensure traceability records are maintained for audits.
10. If all rules are satisfied, the product can legally be sold in India.

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6. Apply dismantling steps to separate major components from a discarded desktop CPU.

1. Remove outer casing using screwdrivers.
2. Disconnect and remove power supply unit (PSU).

3. Take out hard disk and SSD drives.
4. Remove RAM modules from slots.
5. Detach motherboard carefully from mounting screws.
6. Disconnect CPU fan and heat sink assembly.
7. Remove CPU chip from socket if possible.
8. Separate graphic cards and additional expansion cards.
9. Sort cables, connectors, screws, and metal parts.
10. Segregate components into metal, PCB, plastic, and hazardous categories.

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7. Suggest a segregation method for separating plastics, metals, and PCBs from mixed e-waste.

1. **Manual dismantling** to remove large components.
2. **Magnetic separation** to isolate ferrous metals.
3. **Eddy current separation** for non-ferrous metals like aluminium and copper.
4. **Density-based separation** to float/sink different materials.
5. **Air classification** to remove light plastics.
6. **Optical sorting** using sensors for plastic identification.
7. **Shredding** to break components into smaller pieces.
8. **Sieving or screening** to separate particle sizes.
9. **Hand-sorting** for final quality control.
10. **Chemical extraction** for metals from PCBs.

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8. Identify the suitable recycling technology (mechanical/chemical/pyro/ metallurgical) for recovering copper from cables.

1. **Mechanical stripping** to remove insulation manually.
2. **Cable granulation** where cables are shredded into small granules.
3. **Air separation** to separate copper granules from plastic.
4. **Cryogenic processing** to freeze and break insulation.
5. **Electrolytic refining** to purify recovered copper.
6. **Pyrolysis** to burn off insulation in controlled conditions.
7. **Hydrometallurgical leaching** to dissolve copper in chemical solutions.
8. **Magnetic separation** for cleaning metallic fractions.
9. **Hammer mill crushing** to free copper strands.
10. **Final melting** and casting of copper into reusable form.

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9. Propose a simple recovery process to extract reusable metals from printed circuit boards (PCBs).

1. Manual removal of components using soldering tools.
2. Shredding PCB boards into fine particles.
3. Magnetic separation to remove iron-based metals.
4. Eddy current separation for aluminium and copper.
5. Density separation to remove lighter plastics.
6. Chemical leaching using acids to dissolve metals like copper and gold.
7. Electro-winning to recover pure copper from solution.
8. Precipitation to extract other metals.
9. Refining of recovered metals to improve purity.
10. Safe disposal of chemical residues in compliance with regulations.

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10. Apply standard recycling operations to design a basic flow for processing mobile phone e-waste.

Basic Recycling Flow:

1. **Collection:** Gather discarded mobile phones from consumers or centres.
2. **Sorting:** Separate phones based on type, condition, and battery presence.
3. **Battery removal:** Extract Li-ion batteries for separate processing.
4. **Dismantling:** Manually remove PCBs, screens, casings, and cameras.
5. **Shredding:** Mechanically shred plastic and metal components.
6. **Metal recovery:** Use magnetic & eddy-current separation for metals.
7. **PCB processing:** Apply chemical or pyro methods for gold and copper extraction.
8. **Plastic segregation:** Identify and recycle plastics by type (ABS, polycarbonate).
9. **Refining:** Purify recovered metals like gold, silver, copper.
10. **Final disposal:** Dispose hazardous waste safely as per e-waste rules.

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