1. (a) State True or False of the following (any five):
    - (i) Agarose gel electrophoresis mainly used to separate nucleic acids based on the molecular size.
        - **True**
    - (ii) The median and the mode of the following data is 44, 49, 44, 54, 42 is 42.
        - Data (sorted): 42, 44, 44, 49, 54.
        - Median = 44
        - Mode = 44
        - Therefore, the statement is **False**.
    - (iii) Using a fume hood without ventilation is an example of bio-safety measures.
        - **False** (A fume hood *requires* proper ventilation to function as a biosafety measure).
    - (iv) PCR is a technique to amplify the DNA of a sample.
        - **True**
    - (v) Number of moles of solute present in one liter of the solution is called Molality.
        - **False** (It is called Molarity; Molality is moles of solute per kilogram of solvent).
    - (vi) The goal of fixation is to keep the cells or specimen in the living state for longer duration.
        - **False** (Fixation aims to preserve cellular components and structures, usually by killing the cells and preventing degradation, not keeping them in a living state).

- (vii) Condenser lens collects the electron beam coming out of specimen after interaction and bends them to magnify the image in electron microscope.
    - **False** (The objective lens and projector/intermediate lens are responsible for magnifying the image; the condenser lens focuses the beam onto the specimen).

2. (b) Expand the following (any five):
    - (i) HEPA - **High-Efficiency Particulate Air**
    - (ii) BOD - **Biochemical Oxygen Demand**
    - (iii) SEM - **Scanning Electron Microscope**
    - (iv) PAGE - **Polyacrylamide Gel Electrophoresis**
    - (v) HPLC - **High-Performance Liquid Chromatography**
    - (vi) EDTA - **Ethylenediaminetetraacetic acid**
    - (vii) YEB - **Yeast Extract Broth** (or **Yeast Extract Beef** for some specific formulations)
3. (c) Fill in the blanks (any five):
    - (i) **Pinhole aperture** in confocal microscope blocks out-of-focus light from above and below the focal point.
    - (ii) To prepare 500 mL of a 2% (v/v) ethanol solution, you would need **10** mL of ethanol.
    - (iii) **Standard deviation** or **Variance** (or Range, Interquartile Range) is a measure of data spread or dispersion.
    - (iv) **Herbarium** is a catalogue to collect and preserve plant specimens.
    - (v) **Statistics** is used to analyses and present the data in organized manner.

- (vi) **Laminar flow hood** or **Biosafety cabinet** is a workstation used to create a contamination-free and sterilized environment through filters to capture all the particles entering the cabinet.
- (vii) **BOD incubator** is a specialized equipment used to measure the amount of oxygen consumed by microorganisms in wastewater samples.

4. Differentiate between any five:
   - (i) LR grade and AR grade chemicals
     - **LR (Laboratory Reagent) grade chemicals:**
       - Generally suitable for general laboratory purposes and educational experiments where high purity is not critically required.
       - The purity level is lower than AR grade, and they may contain more impurities.
       - Not typically used for analytical work where precise results are needed.
     - **AR (Analytical Reagent) grade chemicals:**
       - High purity chemicals suitable for analytical work, research, and quality control.
       - Have very low levels of impurities, and their exact composition and maximum impurity limits are usually specified on the label.
       - Used when accurate and reproducible results are essential, such as in quantitative analysis.
   - (ii) Light microscope and Electron Microscope
     - **Light Microscope:**
       - Uses visible light as the illumination source.

- Uses glass lenses to focus light and magnify the specimen.
- Can view living specimens (e.g., bacteria, cells).
- Magnification typically up to ~1500x-2000x.
- Resolution limited by the wavelength of light (~200 nm).
- Specimen preparation is generally simpler.

▪ **Electron Microscope:**

- Uses a beam of electrons as the illumination source.
- Uses electromagnetic lenses to focus the electron beam and magnify the specimen.
- Can only view dead, dehydrated, and often specially prepared specimens, as it operates in a vacuum.
- Much higher magnification, up to millions of times.
- Much higher resolution, down to ~0.1-0.2 nm (SEM) or even sub-ångström (TEM).
- Specimen preparation is complex and often involves fixation, dehydration, embedding, sectioning, and heavy metal staining/coating.

○ (iii) Pour plate and Spread plate technique

▪ **Pour Plate Technique:**

- A known volume of the sample (or diluted sample) is first pipetted into a sterile Petri dish.
- Molten (cooled to ~45-50°C) agar medium is then poured over the sample.

- The sample and agar are gently mixed by swirling the plate.
- The agar solidifies, trapping microorganisms throughout the medium. Colonies grow both on the surface and embedded within the agar.
- Useful for counting viable cells and isolating individual colonies, especially for oxygen-sensitive microorganisms.

- **Spread Plate Technique:**
  - A known volume of the sample (or diluted sample) is pipetted onto the surface of a solidified agar medium in a Petri dish.
  - The sample is then evenly spread over the agar surface using a sterile bent glass rod (spreader).
  - Colonies grow only on the surface of the agar.
  - Useful for counting viable cells and isolating individual colonies, especially for obligate aerobes. It's also easier to pick individual colonies.

- (iv) MS Excel and PowerPoint
  - **MS Excel:**
    - A spreadsheet program primarily designed for data organization, calculation, analysis, and visualization.
    - Uses cells arranged in rows and columns to store and manipulate numerical and text data.
    - Features include formulas, functions, pivot tables, charting tools, and data sorting/filtering.

- Best suited for creating budgets, financial reports, statistical analysis, and managing large datasets.

- **PowerPoint:**
  - A presentation software designed for creating slideshows to convey information visually and verbally.
  - Uses slides that can contain text, images, charts, audio, video, and animations.
  - Features include design templates, transitions, and presenter tools.
  - Best suited for delivering lectures, business presentations, and visual aids for public speaking.

- (v) Micrometer and Hemocytometer

- **Micrometer (or Ocular Micrometer):**
  - A small, circular glass disc with an etched scale (e.g., 100 divisions) that is inserted into the eyepiece of a microscope.
  - It is used for *measuring* the size of microscopic objects.
  - The divisions on the ocular micrometer must be calibrated against a stage micrometer (a slide with a known scale) at each magnification to determine the actual length represented by each division.

- **Hemocytometer:**
  - A specialized, thick glass slide with a precisely ruled counting chamber (a grid of known area and depth).

- Primarily used for *counting* microscopic cells or particles in a liquid suspension (e.g., blood cells, yeast cells, bacteria).
- A known volume of cell suspension is loaded onto the chamber, and cells within specific squares of the grid are counted to determine the cell concentration per unit volume.

- (vi) Agarose and SDS-PAGE gel electrophoresis
  - **Agarose Gel Electrophoresis:**
    - **Principle:** Separates nucleic acids (DNA, RNA) based on their molecular size and conformation. Larger molecules migrate slower through the gel matrix.
    - **Gel Matrix:** Agarose, a polysaccharide derived from seaweed, forms a porous gel.
    - **Application:** Used for DNA/RNA analysis (e.g., DNA fingerprinting, PCR product analysis, plasmid DNA separation), purification of nucleic acids.
    - **Denaturing/Non-denaturing:** Can be run under non-denaturing conditions (for native DNA/RNA) or denaturing conditions (for single-stranded nucleic acids).
  - **SDS-PAGE (Sodium Dodecyl Sulfate Polyacrylamide Gel Electrophoresis):**
    - **Principle:** Separates proteins primarily based on their molecular weight. Proteins are denatured and coated with SDS, giving them a uniform negative charge-to-mass ratio, so migration is predominantly determined by size.

- **Gel Matrix:** Polyacrylamide, a synthetic polymer, forms a more tightly controlled and adjustable pore size gel.
- **Application:** Used for protein analysis (e.g., protein purity, molecular weight determination, quantification), separating complex protein mixtures.
- **Denaturing:** Almost always run under denaturing conditions (SDS denatures proteins).

5. Write short notes on any three:
    - (i) **Disposal of hazardous waste**
        - Disposal of hazardous waste is a critical aspect of laboratory safety and environmental protection. Hazardous waste includes any waste that poses a risk to human health or the environment due to its flammability, corrosivity, reactivity, toxicity, or biological contamination. Proper disposal methods are mandated by regulations and typically involve several steps:
            - **Identification and Segregation:** Wastes must be correctly identified (e.g., chemical, biological, radioactive, sharp) and segregated at the point of generation into appropriate, clearly labeled containers. This prevents dangerous reactions and facilitates proper treatment.
            - **Collection and Storage:** Wastes are collected in designated, leak-proof, and puncture-resistant containers. They should be stored in secure, well-ventilated areas, away from drains, and for limited durations as per regulations. Incompatible wastes must be stored separately.

- **Treatment and Deactivation:** Biological waste (e.g., contaminated cultures, sharps, animal carcasses) often requires sterilization (e.g., autoclaving) before disposal to render it non-infectious. Chemical wastes may require neutralization, precipitation, or oxidation depending on their nature.
- **Packaging and Labeling:** Treated or untreated hazardous wastes must be packaged in specific containers and clearly labeled with their contents, hazard symbols, and emergency contact information as per regulatory guidelines (e.g., DOT, EPA, OSHA standards).
- **Off-site Disposal:** Most hazardous wastes cannot be disposed of with general waste. They require transport by licensed hazardous waste transporters to specialized facilities for treatment, incineration, secure landfilling, or recycling. Documentation (manifests) of waste transfer is crucial.
- **Regulatory Compliance:** Adherence to local, national, and international regulations (e.g., RCRA in the US, biomedical waste rules in India) is paramount to avoid fines and environmental damage. Training of personnel involved in handling and disposal is also essential.

- (ii) **Culture media: types and applications**
  - Culture media are solid or liquid preparations used to grow, transport, and store microorganisms (bacteria, fungi, protists) or cells (animal, plant) in the laboratory. They provide the necessary nutrients, energy sources, buffering agents, and physical conditions (pH, oxygen level) for microbial growth.

- **Types of Culture Media:**
  - **Based on Consistency:**
    - **Liquid (Broth) Media:** Used for growing large quantities of microorganisms, studying fermentation, and biochemical tests. (e.g., Nutrient Broth, Luria-Bertani Broth).
    - **Solid Media:** Contain agar or gelatin to solidify the medium, allowing for isolation of pure cultures and colony morphology studies. (e.g., Nutrient Agar, Blood Agar).
    - **Semi-solid Media:** Have a lower agar concentration, used for motility tests and culturing microaerophilic bacteria. (e.g., SIM medium).
  - **Based on Chemical Composition:**
    - **Chemically Defined (Synthetic) Media:** Exact chemical composition is known, used for nutritional studies and research where precise control of growth conditions is needed. (e.g., Minimal Media).
    - **Complex (Undefined) Media:** Contain ingredients with unknown exact chemical composition (e.g., yeast extract, peptone, beef extract), providing a rich source of nutrients for fastidious organisms. (e.g., Nutrient Broth/Agar, Tryptic Soy Broth/Agar).
  - **Based on Function/Application:**
    - **General Purpose Media:** Support the growth of a wide range of non-fastidious microorganisms. (e.g., Nutrient Agar).

- **Enriched Media:** Contain added nutrients (e.g., blood, serum, vitamins) to support the growth of fastidious organisms. (e.g., Blood Agar, Chocolate Agar).
- **Selective Media:** Contain inhibitors that suppress the growth of unwanted microorganisms while allowing the growth of desired ones. (e.g., MacConkey Agar for Gram-negative bacteria, Mannitol Salt Agar for Staphylococcus).
- **Differential Media:** Allow differentiation between different types of microorganisms based on their biochemical characteristics (e.g., fermentation of sugars, enzyme production), often indicated by color changes. (e.g., MacConkey Agar differentiates lactose fermenters, EMB Agar differentiates E. coli).
- **Transport Media:** Designed to maintain the viability of microorganisms in a clinical sample during transport without allowing significant growth or death. (e.g., Stuart's Medium).
- **Assay Media:** Used for microbiological assays, such as antibiotic sensitivity testing.

- **Applications:**
  - Isolation and identification of microorganisms from various sources (clinical samples, environmental samples, food).
  - Cultivation of specific microorganisms for research, industrial production (e.g., antibiotics, enzymes), or vaccine production.

- Enumeration (counting) of microorganisms in a sample.
- Studying microbial physiology, metabolism, and genetics.
- Antimicrobial susceptibility testing.

- (iii) **Herbarium**
  - A herbarium (plural: herbaria) is a collection of preserved plant specimens, typically dried and mounted on sheets of paper, accompanied by detailed taxonomic and collection information. It serves as a permanent repository for botanical diversity and a fundamental resource for botanical research and education.
  - **Key Features and Components:**
    - **Pressed and Dried Specimens:** Plants are carefully collected, pressed flat, and dried to preserve their morphology and prevent decay.
    - **Mounting:** Dried specimens are meticulously mounted onto archival-quality sheets of paper.
    - **Labels:** Each sheet carries a label providing crucial data: scientific name, family, common name, locality (country, state, district, specific site), habitat, collection date, collector's name and number, and any relevant ecological notes (e.g., flower color, height, associated species).
    - **Arrangement:** Specimens are systematically arranged, usually according to a recognized system of classification (e.g., Bentham & Hooker, APG), facilitating easy retrieval.

- **Fumigation/Pest Control:** Herbaria employ strict measures to protect specimens from insect pests and fungi.

▪ **Importance and Applications:**

- **Taxonomic Research:** Essential for identifying, classifying, and describing new plant species. They serve as reference points for species concepts.
- **Biodiversity Studies:** Provide historical records of plant distribution, allowing tracking of changes in flora over time (e.g., effects of climate change, habitat loss).
- **Ecological Studies:** Data on habitat and associated species can inform ecological research.
- **Conservation:** Help identify rare or endangered species and their historical ranges, guiding conservation efforts.
- **Educational Resource:** Used for teaching botany, plant identification, and taxonomy.
- **Forensic Botany:** Can be used in forensic investigations to identify plant material found at crime scenes.
- **Ethnobotanical Research:** Historical labels may contain information on traditional uses of plants.
- **Source of Genetic Material:** Preserved specimens can be used for DNA extraction and molecular studies, though older specimens may have degraded DNA.

o (iv) **Fire extinguisher**

- A fire extinguisher is an active fire protection device used to extinguish or control small fires, often in emergency situations. It consists of a hand-held cylindrical pressure vessel containing an agent that can be discharged to put out a fire. Understanding their types and proper use is crucial for workplace safety.
- **Working Principle:** Fire extinguishers work by removing one or more elements of the "fire triangle" (heat, fuel, oxygen) or "fire tetrahedron" (adding chain reaction). Different agents achieve this in different ways:
    - **Cooling:** Water-based extinguishers cool the fuel below its ignition temperature.
    - **Smothering:** Agents like CO2 or foam displace oxygen, suffocating the fire.
    - **Starvation:** Separating the fuel from the fire (not common for extinguishers but part of overall fire control).
    - **Breaking Chain Reaction:** Dry chemical agents interrupt the chemical chain reaction of combustion.
- **Types of Fire Extinguishers (by Class of Fire):**
    - **Class A (Ordinary Combustibles):** Involve solid materials like wood, paper, textiles, plastics.
        - **Extinguisher Type:** Water, Foam, ABC Dry Chemical.
    - **Class B (Flammable Liquids):** Involve flammable liquids like petrol, oil, paints, solvents.
        - **Extinguisher Type:** Foam, CO2, Dry Chemical (ABC or BC).

- **Class C (Flammable Gases):** Involve flammable gases like propane, butane, methane.
    - **Extinguisher Type:** Dry Chemical (ABC or BC), CO2.
- **Class D (Combustible Metals):** Involve combustible metals like magnesium, titanium, sodium.
    - **Extinguisher Type:** Special dry powder (e.g., sodium chloride-based, graphite-based). Water or standard chemicals can react violently.
- **Class K (Kitchen/Cooking Oils):** Involve cooking oils and fats (e.g., deep fat fryers) found in commercial kitchens.
    - **Extinguisher Type:** Wet Chemical.

- **Operation (PASS Method):**
    - **P**ull the pin.
    - **A**im the nozzle or hose at the base of the fire.
    - **S**queeze the operating lever slowly and evenly.
    - **S**weep the nozzle from side to side at the base of the fire.
- **Maintenance:** Fire extinguishers must be regularly inspected, maintained, and recharged after use or periodically as per regulations to ensure they are functional when needed.

6. (a) Explain the process of serial dilution and how it is used to estimate the concentration of microorganisms in a sample. Include the steps involved and an example calculation.

- **Serial Dilution:**
    - Serial dilution is a stepwise process of diluting a substance in a solution, typically used to reduce a concentrated sample to a more manageable concentration. In microbiology, it's a fundamental technique to reduce the number of microorganisms in a sample to a countable range (usually 30-300 colonies per plate for bacterial enumeration). Each step in the dilution series reduces the concentration by a constant factor (e.g., 10-fold, 100-fold).
- **How it is used to estimate microorganism concentration:**
    - After performing serial dilutions, a small volume (e.g., 0.1 mL or 1 mL) from one or more of the diluted samples is plated onto a suitable agar medium using either the pour plate or spread plate technique.
    - The plates are then incubated under appropriate conditions for microbial growth.
    - After incubation, the number of colonies that grow on a selected plate (within the countable range) is counted.
    - Each colony is assumed to have originated from a single viable microorganism (colony-forming unit, CFU).
    - By knowing the dilution factor of the plate from which the count was obtained and the volume plated, the original concentration of microorganisms (CFU/mL) in the undiluted sample can be calculated.
- **Steps Involved:**
    i. **Prepare Diluent:** Obtain several tubes containing a sterile diluent (e.g., saline, distilled water, peptone water) of a known volume (e.g., 9 mL for 1:10 dilutions or 99 mL for 1:100 dilutions).

ii. **Initial Dilution:** Take a known small volume of the original (undiluted) sample (e.g., 1 mL) and add it to the first tube of diluent (e.g., 9 mL). This creates the first dilution (e.g., 1:10 or 10^{-1} dilution). Mix thoroughly.

iii. **Subsequent Dilutions:** From the first dilution tube, transfer the same known small volume (e.g., 1 mL) to the next tube of sterile diluent (e.g., 9 mL). Mix thoroughly. Repeat this process for several more tubes, creating a series of dilutions (e.g., $10^{-2}, 10^{-3}, 10^{-4}$, and so on).

iv. **Plating:** From several selected dilutions (e.g., $10^{-4}, 10^{-5}, 10^{-6}$), aseptically transfer a specific volume (e.g., 0.1 mL or 1 mL) onto separate sterile agar plates.

v. **Spreading/Pouring:**

- For spread plate: Spread the liquid evenly over the surface of pre-solidified agar.
- For pour plate: Pour molten agar over the sample in the Petri dish and mix.

vi. **Incubation:** Incubate the plates under optimal conditions (temperature, time, atmosphere) to allow colonies to grow.

vii. **Counting:** Select a plate with a countable number of colonies (typically 30-300 CFU). Count all the colonies on this plate.

viii. **Calculation:** Use the formula to calculate the original concentration.

- **Example Calculation:**
  - Suppose you perform a serial dilution of a bacterial sample.

- You take 1 mL of sample into 9 mL of diluent (10^{-1}).
- Then 1 mL of 10^{-1} into 9 mL of diluent (10^{-2}).
- Then 1 mL of 10^{-2} into 9 mL of diluent (10^{-3}).
- You plate 0.1 mL from the 10^{-3} dilution and count 50 colonies after incubation.
- **Formula:** Original Concentration (CFU/mL) = (Number of colonies counted) / (Volume plated in mL × Dilution factor of the plated sample)
- **Calculation:**
  - Number of colonies = 50
  - Volume plated = 0.1 mL
  - Dilution factor of the plated sample = 10^{-3} (This means the sample was diluted by 1000 times, so the dilution factor is $1/1000 = 0.001$).
  - Original Concentration = $50/(0.1 \text{ mL} \times 10^{-3})$
  - Original Concentration = $50/0.0001$
  - Original Concentration = $500{,}000$ CFU/mL or 5.0×10^5 CFU/mL

7. (b) Detail the working principle of Spectrophotometer and writes its applications.
   - **Working Principle of Spectrophotometer:**
     - A spectrophotometer is an instrument used to measure the intensity of light as a function of wavelength. It quantifies the amount of light that a sample absorbs (absorbance) or transmits (transmittance) at specific wavelengths. The fundamental principle is based on **Beer-Lambert's Law**, which states that the absorbance

of a solution is directly proportional to the concentration of the solute and the path length of the light through the solution.

- **Key Components and their Function:**

    1. **Light Source:** Emits a broad spectrum of electromagnetic radiation (e.g., Tungsten lamp for visible light, Deuterium lamp for UV light).
    2. **Monochromator:** A device (often a prism or diffraction grating) that selects a specific wavelength of light from the broad spectrum emitted by the light source. It disperses the light into its constituent wavelengths and allows only a narrow band of wavelengths to pass through to the sample.
    3. **Slit:** A narrow opening that controls the bandwidth of light reaching the sample.
    4. **Sample Holder (Cuvette):** A transparent container (typically made of glass for visible light, quartz for UV light) designed to hold the liquid sample. It ensures a consistent path length for the light beam through the solution.
    5. **Detector:** A photodetector (e.g., photomultiplier tube, photodiode) measures the intensity of light that passes through the sample. It converts the light energy into an electrical signal.
    6. **Readout Device:** An electronic display or computer software that processes the signal from the detector and displays the absorbance, transmittance, or concentration values.

- **How it Works (Steps):**

    7. **Light Emission:** The light source emits light.

8. **Wavelength Selection:** The monochromator selects a specific wavelength (monochromatic light) to pass through the sample.
9. **Reference (Blank) Measurement:** A blank (e.g., solvent without the analyte) is placed in the cuvette, and the spectrophotometer is "zeroed" or set to 100% transmittance (0 absorbance) for the selected wavelength. This calibrates the instrument and accounts for any light absorbed by the cuvette or solvent.
10. **Sample Measurement:** The sample containing the analyte is placed in the cuvette. The monochromatic light passes through the sample.
11. **Light Absorption/Transmission:** The analyte in the sample absorbs some of the light at the specific wavelength. The remaining light is transmitted through the sample.
12. **Detection and Conversion:** The detector measures the intensity of the transmitted light (I). It also measures the intensity of the incident light (I_0) from the blank.
13. **Calculation:** The instrument calculates Transmittance ($T = I/I_0$) or Absorbance ($A = -\log_{10}T = \log_{10}(I_0/I)$). Higher absorbance means less light transmitted, indicating a higher concentration of the absorbing substance in the sample (according to Beer-Lambert's Law).

- **Applications of Spectrophotometer:**
  - **Quantitative Analysis:**

- **Concentration Determination:** Most common application; used to determine the concentration of various substances (e.g., proteins using Bradford or Lowry assay, DNA/RNA, drugs, metabolites) in solutions by measuring their absorbance at a specific wavelength and comparing it to a standard curve.
- **Enzyme Kinetics:** Monitoring the rate of enzymatic reactions by measuring the appearance or disappearance of colored products or substrates over time.

▪ **Qualitative Analysis:**

- **Identification of Substances:** Different substances absorb light at characteristic wavelengths, creating unique absorption spectra. This can help in identifying unknown compounds.
- **Purity Assessment:** Analyzing the absorbance at multiple wavelengths can indicate the purity of a sample (e.g., A260/A280 ratio for nucleic acid purity).

▪ **Microbiology:**

- **Bacterial Growth Measurement:** Estimating the bacterial population density in a liquid culture by measuring the turbidity (light scattering) at a specific wavelength (e.g., OD600).

▪ **Clinical Chemistry:**

- **Diagnostic Tests:** Used in clinical labs to quantify analytes in blood, urine, or other body fluids for disease diagnosis (e.g., glucose, cholesterol, bilirubin levels).

- **Environmental Monitoring:**
    - **Water Quality Analysis:** Measuring concentrations of pollutants, nutrients (e.g., nitrates, phosphates), or heavy metals in water samples.
- **Food Industry:**
    - **Quality Control:** Assessing color, turbidity, and concentration of components in food and beverage products.
- **Research and Development:**
    - Widely used across various scientific disciplines for fundamental research, drug discovery, and materials science.

8. (a) What is sampling? Briefly describe the different sampling methods?

- **Sampling:**
    - Sampling is the process of selecting a subset of individuals or items from a larger population. The goal of sampling is to obtain a representative subset that can be studied to make inferences and generalize findings about the entire population, without having to examine every single member of that population. Sampling is crucial in research, surveys, and quality control, as studying an entire population is often impractical, costly, or impossible.
- **Different Sampling Methods:**
    - Sampling methods can broadly be categorized into two main types: Probability Sampling and Non-Probability Sampling.
    - **I. Probability Sampling Methods:**

- In these methods, every member of the population has a known, non-zero chance of being selected for the sample. This allows for statistical inference and estimation of sampling error.
- **1. Simple Random Sampling (SRS):**
    - **Description:** Every possible sample of a given size has an equal chance of being selected. This is often done by assigning a number to each member of the population and then using a random number generator to select the sample.
    - **Example:** Drawing names out of a hat, or using a random number table to select 50 students from a list of 500.
    - **Pros:** Highly representative, minimizes bias.
    - **Cons:** Can be difficult or impractical for very large populations; may not guarantee representation of small subgroups.
- **2. Stratified Random Sampling:**
    - **Description:** The population is first divided into homogeneous subgroups (strata) based on certain characteristics (e.g., age, gender, income, geographic region). Then, a simple random sample is drawn from each stratum. Proportional stratification ensures the sample size from each stratum is proportional to its size in the population.
    - **Example:** Dividing a university student population into undergraduate and

postgraduate strata, then randomly sampling from each.

- **Pros:** Ensures representation of key subgroups, can lead to more precise estimates than SRS if strata are homogeneous.
- **Cons:** Requires knowledge of population characteristics to form strata; more complex to implement than SRS.

- **3. Systematic Sampling:**
  - **Description:** Members of the population are selected at regular intervals from a randomly chosen starting point. A sampling interval (k) is determined by dividing the population size (N) by the desired sample size (n) ($k = N/n$). A random number between 1 and k is chosen as the starting point, and every k^{th} member thereafter is selected.
  - **Example:** Selecting every 10th customer entering a store, starting with a randomly chosen first customer.
  - **Pros:** Simple to implement, often more efficient than SRS for large populations.
  - **Cons:** Can be biased if there's a hidden periodicity in the population list that aligns with the sampling interval.
- **4. Cluster Sampling:**
  - **Description:** The population is divided into naturally occurring groups or clusters (e.g., neighborhoods, schools, hospitals). A random

sample of clusters is selected, and *all* individuals within the selected clusters are included in the sample. In multi-stage cluster sampling, further sampling is done within the selected clusters.

- **Example:** Randomly selecting 10 schools in a city, and then surveying all students within those 10 schools.
- **Pros:** Cost-effective and practical for geographically dispersed populations.
- **Cons:** Less precise than SRS or stratified sampling; increased sampling error due to homogeneity within clusters.

- **II. Non-Probability Sampling Methods:**

  - In these methods, the selection of individuals is not based on random chance, and thus, not every member has a known probability of being selected. These methods are often used for qualitative research, exploratory studies, or when probability sampling is not feasible. They are generally not suitable for generalizing findings to the entire population.
  - **1. Convenience Sampling:**
    - **Description:** Individuals are selected based on their easy accessibility and willingness to participate.
    - **Example:** Surveying people walking by on a street corner, or using students in a researcher's own class.
    - **Pros:** Very easy and inexpensive.

- **Cons:** Highly prone to bias; results are rarely generalizable.

- **2. Purposive (Judgmental) Sampling:**
  - **Description:** The researcher deliberately selects individuals based on their expert judgment that these individuals are most likely to provide the desired information or possess specific characteristics relevant to the study.
  - **Example:** Interviewing experts in a particular field, or selecting patients with a specific rare condition.
  - **Pros:** Useful for specific situations, in-depth understanding.
  - **Cons:** Highly subjective and prone to researcher bias; difficult to generalize.

- **3. Quota Sampling:**
  - **Description:** Similar to stratified sampling, but selection within strata is non-random (often convenience or judgmental). The researcher sets quotas for each subgroup to ensure proportional representation of certain characteristics, but then fills these quotas with easily accessible individuals.
  - **Example:** Ensuring a sample includes 50 males and 50 females by stopping people until the quotas are met.
  - **Pros:** Ensures representation of certain groups; relatively quick.

- **Cons:** Still prone to selection bias within quotas.

- **4. Snowball Sampling:**
  - **Description:** Used when studying hard-to-reach or hidden populations. Initial participants are identified and then asked to refer other potential participants who fit the study criteria. The sample "snowballs" as more referrals are made.
  - **Example:** Interviewing drug users, then asking them to refer other drug users.
  - **Pros:** Effective for sensitive topics or rare populations.
  - **Cons:** High potential for bias (participants are often socially connected); difficult to determine representativeness.

9. (b) What is standard error? Compute the mean, standard deviation, standard error and coefficient of variation of the following data that showed increase in the length of pods of a plant after treatment with a hormone.

   - **What is Standard Error?**
     - The **Standard Error of the Mean (SEM)** is a measure of the statistical accuracy of an estimate, specifically how much the sample mean is likely to vary from the true population mean. It quantifies the precision of the sample mean as an estimate of the population mean.
     - A smaller standard error indicates that the sample mean is a more precise estimate of the population mean, meaning that different samples drawn from the same

population would likely have means that are closer to each other and to the true population mean.

- It is calculated as the sample standard deviation divided by the square root of the sample size (SEM $= s/\sqrt{n}$).

- **Data:** 4.25, 4.20, 4.15, 3.35, 3.25, 4.70, 3.25, 3.75, 3.70, 3.90
- **Number of observations (n) = 10**
- **1. Compute the Mean ($\bar{x}$):**
  - Sum of data (Σx) = $4.25 + 4.20 + 4.15 + 3.35 + 3.25 + 4.70 + 3.25 + 3.75 + 3.70 + 3.90 = 38.50$
  - $\bar{x} = \Sigma x/n = 38.50/10 = 3.85$
- **2. Compute the Standard Deviation (s):**
  - First, calculate $\Sigma(x_i - \bar{x})^2$:
    - $(4.25 - 3.85)^2 = (0.40)^2 = 0.1600$
    - $(4.20 - 3.85)^2 = (0.35)^2 = 0.1225$
    - $(4.15 - 3.85)^2 = (0.30)^2 = 0.0900$
    - $(3.35 - 3.85)^2 = (-0.50)^2 = 0.2500$
    - $(3.25 - 3.85)^2 = (-0.60)^2 = 0.3600$ (appears twice)
    - $(4.70 - 3.85)^2 = (0.85)^2 = 0.7225$
    - $(3.75 - 3.85)^2 = (-0.10)^2 = 0.0100$
    - $(3.70 - 3.85)^2 = (-0.15)^2 = 0.0225$
    - $(3.90 - 3.85)^2 = (0.05)^2 = 0.0025$
  - Sum of squared differences ($\Sigma(x_i - \bar{x})^2$) = $0.1600 + 0.1225 + 0.0900 + 0.2500 + 0.3600 + 0.7225 + 0.3600 + 0.0100 + 0.0225 + 0.0025 = 2.1000$

- Variance (s^2) = $\Sigma(x_i - \bar{x})^2/(n-1) = 2.1000/(10-1) = 2.1000/9 \approx 0.2333$
- Standard Deviation (s) = $\sqrt{s^2} = \sqrt{0.2333} \approx 0.4830$

- **3. Compute the Standard Error of the Mean (SEM):**
  - SEM $= s/\sqrt{n} = 0.4830/\sqrt{10} = 0.4830/3.1623 \approx 0.1527$
- **4. Compute the Coefficient of Variation (CV):**
  - CV $= (s/\bar{x}) \times 100\%$
  - CV $= (0.4830/3.85) \times 100\% \approx 0.12545 \times 100\% \approx 12.55\%$
- **Summary of Results:**
  - **Mean:** 3.85
  - **Standard Deviation:** 0.4830
  - **Standard Error of the Mean (SEM):** 0.1527
  - **Coefficient of Variation (CV):** 12.55%