Electrical Wiring and Estimation$1cm]**DI03009011**$2cm]

Previous Year Question Papers

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Contents

S2026

1(a)List any six electrical wiring tools and explain their use.3

Electrical Wiring Tools and Their Uses:

1. **Combination Pliers**: Used for cutting, twisting, and gripping electrical wires.
2. **Wire Stripper**: Used for removing the insulation from electrical wires without damaging the copper conductor.
3. **Screwdrivers (Flat/Cross/Star)**: Used for tightening or loosening screws in electrical accessories like switches, sockets, and distribution boards.
4. **Neon Tester (Line Tester)**: Used to check the presence of electrical supply or live phase in the circuit.
5. **Crimping Tool**: Used for attaching lugs or terminals to the ends of electrical wires securely.
6. **Hacksaw**: Used for cutting PVC pipes, metallic conduits, and sometimes heavy cables during wiring installation.

1(b)Explain different safety accessories in electrical wiring system.4

Safety accessories in an electrical wiring system are designed to protect human life from electrical shocks and safeguard equipment from short circuits and overloads.

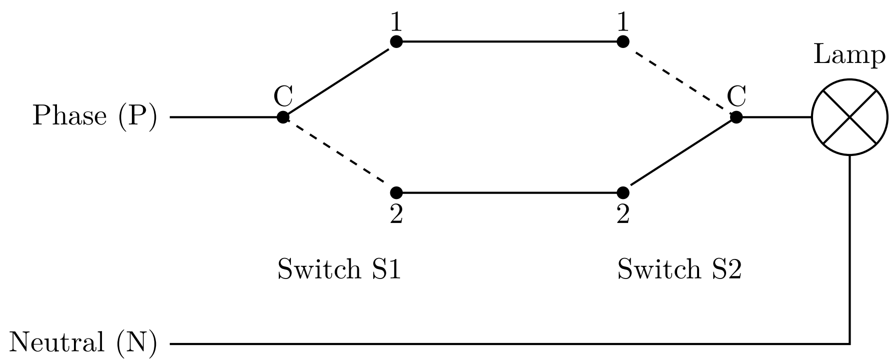
1. **Fuse**: It is the simplest and most common over-current protection device. It consists of a metallic wire with a low melting point. When excessive current flows due to an overload or short circuit, the fuse wire melts and breaks the circuit.
2. **Miniature Circuit Breaker (MCB)**: An electromechanical device that automatically switches off the electrical circuit during an abnormal condition (overload or short circuit). Unlike a fuse, an MCB does not need to be replaced and can simply be reset by switching it back ON.
3. **Earth Leakage Circuit Breaker (ELCB)**: A safety device used to detect small stray voltages on the metal enclosures of electrical equipment and interrupt the circuit if a dangerous voltage is detected, protecting against electric shock.
4. **Residual Current Circuit Breaker (RCCB)**: It is designed to protect against earth fault currents. It continuously monitors the residual current (difference between phase and neutral currents). If a leakage current is detected (e.g., someone getting a shock), it trips the circuit instantly.
5. **Earthing/Grounding System**: The process of connecting the metallic body of electrical equipment to the earth using a low-resistance wire. It provides a safe path for leakage current to flow to the ground, preventing electric shock.

1(c)Illustrate staircase wiring and godown wiring with neat sketches.7

1. Staircase Wiring: Staircase wiring is used to control a single lamp from two different locations independently. It is commonly used in staircases, corridors, and large rooms. It requires two **Two-Way Switches**.

Staircase Wiring Logic

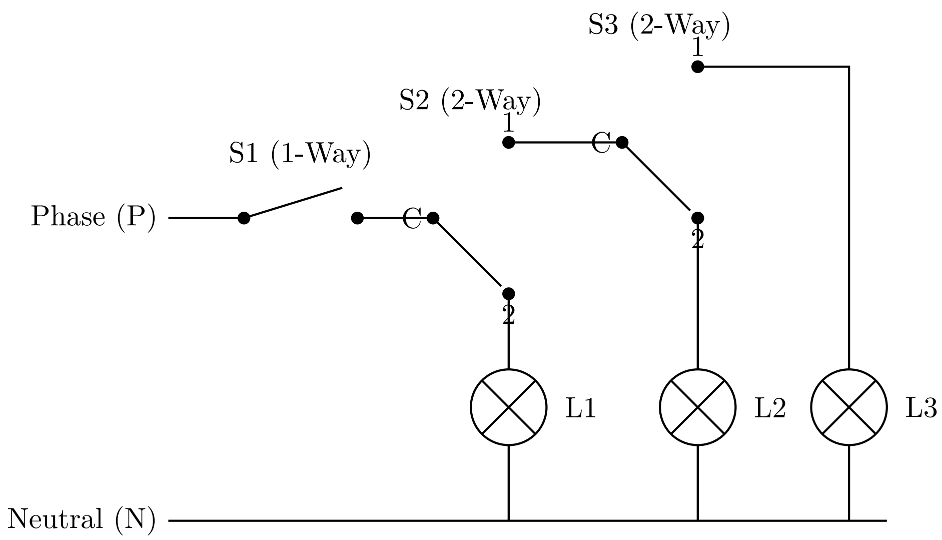
A two-way switch has three terminals. The phase wire is connected to the common terminal of the first switch, and the lamp is connected to the common terminal of the second switch. The other two terminals of both switches are cross-connected. The lamp glows only when both switches are in opposite positions or depending on the cross-connection logic.



Operation:

- A person entering the staircase at the bottom can turn ON the light using switch S1.
- After reaching the top, they can turn OFF the light using switch S2 without having to come back down.
- The process works in reverse as well.

2. Godown Wiring: Godown wiring is designed to control a sequence of lamps such that only one lamp is turned ON at a time as a person moves through a long godown or tunnel. It saves energy by automatically switching off the previous lamp when the next one is switched ON. It requires one One-Way Switch and multiple Two-Way Switches.



Operation:

- When entering the godown, the first switch (One-Way Switch S1) is turned ON, lighting up Lamp L1.
- Moving further, turning ON Two-Way Switch S2 will turn OFF L1 and turn ON L2.

- Similarly, turning ON Two-Way Switch S3 will turn OFF L2 and turn ON L3.
- While returning, switching them back turns the current lamp OFF and the previous lamp ON, until S1 is turned OFF at the exit.

1(c) ORWhat is estimation? List abilities of a good estimator. Compare between approximate and scientific estimation.7

Estimation: Estimation is the process of predicting or calculating the probable cost, quantities of materials, labor required, and time needed to complete a specific electrical project before the actual work begins.

Abilities of a Good Estimator:

1. **Technical Knowledge**: Should have sound knowledge of electrical drawing, wiring rules, and standard practices.
2. **Market Awareness**: Must be up-to-date with current market prices of electrical materials and labor rates.
3. **Analytical Skills**: Ability to carefully read and interpret project drawings and specifications.
4. **Mathematical Skills**: Should be proficient in performing calculations quickly and accurately.
5. **Foresight**: Ability to anticipate hidden costs, site conditions, and potential problems during execution.
6. **Organization**: Must prepare estimates in a clear, logical, and structured manner.

Comparison Between Approximate and Scientific Estimation:

Approximate (Rough) Estimation	**Scientific (Detailed) Estimation**
It is a quick calculation to find out the rough cost of the project.	It is an accurate and detailed calculation of the exact cost of the project.
Calculated based on past experience or per-point basis (e.g., cost per light point).	Calculated based on a detailed bill of materials, exact lengths of wires, and labor hours.
Takes very less time to prepare.	Takes significant time and effort to prepare.
Accuracy is low; it gives a general idea for budget planning.	Accuracy is high; it is used for financial approval and contract bidding.
Detailed drawings and specifications are not required.	Complete layout drawings, circuit diagrams, and specifications are strictly required.
Cannot be used for tender documentation or legal agreements.	Highly reliable and forms the basis for tender documents and contracts.

1 Question 2

Question 2(a) [3 marks]

List any six general rules for domestic wiring estimation.

Here are six general rules to be followed for domestic wiring estimation:

1. **Load per Lighting Sub-circuit:** A lighting and fan sub-circuit should not have a total connected load exceeding 800 W or a maximum of 10 points.

2. **Load per Power Sub-circuit:** A power sub-circuit (for heavy appliances like ACs, geysers) should not have a total connected load exceeding 3000 W or a maximum of 2 points.

3. **Position of Switches:** All single-pole switches must strictly be connected to the live (phase) wire, not the neutral wire.

4. **Standard Height Guidelines:** The main switchboard and distribution board should be installed at a height of 1.5 m from the floor level. Ceiling fans must have a minimum clearance of 2.75 m from the floor.

5. **Assumed Wattage Rating:** If power ratings are not explicitly specified, standard wattages should be assumed: Light = 60 W, Fan = 60 W, 5A socket = 100 W, and 15A socket = 1000 W.

6. **Earthing:** The earth pin of all 3-pin sockets and the metallic body of all heavy appliances must be connected to a solid earth wire for safety.

Question 2(b) [4 marks]

A residential flat consists of following electrical points: (1) light points-10 nos. (2) fan points-05 nos. (3) 3 pin socket (5 Amp) - 03 nos. (4) 3 pin socket (15 Amp) - 02 nos. Calculate: (1) Total electrical load (2) Number of sub circuits (3) Total current (4) Size of main switch.

Assumption of Standard Wattages

If power ratings are not given, assume standard domestic load ratings: Light = 60 W, Fan = 60 W, 5A Socket = 100 W, 15A Socket = 1000 W. Standard domestic voltage $V = 230$ V.

1) Total Electrical Load:

- Light load $= 10 \times 60$ W $= 600$ W
- Fan load $= 5 \times 60$ W $= 300$ W
- 5A socket load $= 3 \times 100$ W $= 300$ W
- 15A socket load $= 2 \times 1000$ W $= 2000$ W

Total Electrical Load $= 600 + 300 + 300 + 2000 = \mathbf{3200}$ W

2) Number of Sub-circuits:

- **Lighting & Fan Sub-circuits:** Total L&F load $= 600 + 300 + 300 = 1200$ W. Total points $= 10 + 5 + 3 = 18$ points. Since one sub-circuit allows a max of 800 W or 10 points, we require: $18/10 = 1.8 \approx \mathbf{2}$ sub-circuits. (Also required due to 1200 W > 800 W).
- **Power Sub-circuits:** Total power load = 2000 W. Total power points = 2. Since one power sub-circuit allows a max of 3000 W or 2 points, we require **1** power sub-circuit.

Total Number of Sub-circuits $= 2 + 1 = \mathbf{3}$ sub-circuits.

3) Total Current: Assuming single-phase AC supply with Voltage $V = 230$ V and power factor $\cos\phi = 1$ (resistive load assumption): $I = \frac{P}{V} = \frac{3200}{230} = \mathbf{13.91}$ A

4) Size of Main Switch: The total calculated current is 13.91 A. The standard rating of the main switch available in the market that is greater than the full load current is 16 A or 32 A. Considering future expansion margin, a **32A, 240V DPIC** (Double Pole Iron Clad) main switch or **32A DP MCB** should be selected. (A 16A rating is theoretically sufficient but practically 32A is preferred).

Question 2(c) [7 marks]

Explain various tests performed after completion of domestic electrical installation.

After completing a domestic electrical wiring installation, it is mandatory to perform certain tests before connecting the main power supply to ensure safety and compliance with IE rules. The main tests are:

1. **Insulation Resistance Test between Conductors:** This test verifies that there is no short circuit or current leakage between the phase and neutral conductors.
    - **Method:** Using a Megger (500V DC), connect one terminal to the phase wire and the other to the neutral wire. All switches must be ON, and all lamps/appliances must be removed.
    - **Standard:** The insulation resistance should not be less than 1 MΩ.
2. **Insulation Resistance Test between Conductor and Earth:** This test ensures there is no leakage of current from live conductors to the earth.
    - **Method:** Connect one terminal of the Megger to the earth continuity conductor (or water pipe) and the other to the phase and neutral conductors tied together.
    - **Standard:** The insulation resistance should be $\geq \frac{50}{\text{Number of points}}$ MΩ, and never less than 1 MΩ.
3. **Polarity Test of Single-Pole Switches:** This test ensures that all single-pole switches are correctly connected to the live (phase) wire and not the neutral wire.
    - **Importance:** If a switch is connected to the neutral wire, the appliance will remain "live" even when the switch is OFF, posing a severe shock hazard.
    - **Method:** Conducted using a test lamp or continuity tester. One end is connected to earth and the other to the switch terminal.
4. **Earth Continuity Path Test:** This test ensures that the earth wire provides a continuous, unbroken path with very low resistance from the appliance's metallic body to the main earth electrode.
    - **Standard:** The resistance of the earth continuity path from any point in the installation to the main earth electrode should not exceed 1 Ω.
5. **Earth Resistance Test:** This checks the resistance of the earth electrode itself in the soil.
    - **Method:** Measured using an Earth Tester using the fall-of-potential method.
    - **Standard:** The resistance of the earth electrode for domestic installations should ideally be less than 5 Ω.

Question 2(a) OR [3 marks]

Explain selection of conductor size based on load requirement in domestic wiring.

The selection of the proper conductor (wire) size for domestic wiring depends on the total connected load and involves the following steps:

1. **Calculate Total Current (I):** Determine the total connected load in watts (P). Calculate the maximum full load current using the formula $I = \frac{P}{V \cos\phi}$ for single-phase systems (assuming $V = 230$ V).
2. **Consider Future Expansion:** Add a margin of 20% to 25% to the calculated full load current to accommodate any future appliances.
3. **Current Carrying Capacity:** Refer to standard cable manufacturer tables to select a conductor size whose safe current-carrying capacity is greater than the total expected current.
4. **Permissible Voltage Drop:** Ensure the selected conductor size does not cause a voltage drop exceeding 3% to 5% of the supply voltage ($230\text{ V} \times 0.03 = 6.9\text{ V}$) from the meter board to the farthest point in the installation.
5. **IE Rules for Minimum Size:** Regardless of the calculated current, the minimum conductor size must adhere to IE rules:
   - For **Lighting & Fan circuits**: Minimum 1.0 mm^2 or 1.5 mm^2 Copper.
   - For **Power circuits**: Minimum 2.5 mm^2 or 4.0 mm^2 Copper.

Question 2(b) OR [4 marks]

Illustrate format of electrical test report for domestic installation.

An electrical test report certifies that the newly installed wiring is safe and complies with IE rules. Below is a standard format for an electrical test report:

Question 2(c) OR [7 marks]

A two bedroom hall kitchen flat has following load.
1) Hall:- Two light, Two fan, one 5 Amp socket.
2) Bedroom 1:- One light, One fan, one 5 Amp socket.
3) Bedroom 2:- One light, One fan, one 5 Amp socket, one AC of 2000 Watt.
4) Kitchen:- One light, One fan, one 15 Amp socket of 1500 Watt.
5) Bathroom:- One light, one 5 Amp socket.
Calculate: 1) Total connected load 2) Total current 3) Total light and fan sub circuits 4) Total power sub circuits 5) Size of main MCB 6) Size of sub circuit MCB

Load Assumption and Rules

Standard Wattages: Light = 60 W, Fan = 60 W, 5A Socket = 100 W. Supply Voltage $V = 230$ V.
Rule 1: L&F Sub-circuit max limit = 800 W or 10 points.
Rule 2: Power Sub-circuit max limit = 3000 W or 2 points.

ELECTRICAL INSTALLATION TEST REPORT	
Name of Consumer:	....
Address of Premises:	....
Date of Testing:	....
1. Insulation Resistance Test	
a) Between Phase and Neutral:	.... MΩ
b) Between Phase/Neutral and Earth:	.... MΩ
2. Polarity Test	
Are all single-pole switches on the phase wire?	.... (Yes/No)
3. Earth Continuity Test	
Maximum resistance of earth continuity path:	.... Ω (Must be < 1 Ω)
4. Earth Electrode Resistance Test	
Resistance of the main earth electrode:	.... Ω (Must be < 5 Ω)
Declaration:	
I/We certify that the installation has been tested and complies with IE rules.	
Signature of Licensed Wireman/Tester	**Signature of Electrical Contractor**
License No:	License No: ....

Room	Light (60W)	Fan (60W)	5A Socket (100W)	Power Load	Total Load
Hall	2 (120W)	2 (120W)	1 (100W)	-	340 W
Bedroom 1	1 (60W)	1 (60W)	1 (100W)	-	220 W
Bedroom 2	1 (60W)	1 (60W)	1 (100W)	AC (2000W)	2220 W
Kitchen	1 (60W)	1 (60W)	-	15A Sock (1500W)	1620 W
Bathroom	1 (60W)	-	1 (100W)	-	160 W
Total	**6 (360W)**	**5 (300W)**	**4 (400W)**	**2 Points (3500W)**	**4560 W**

Step 1: Room-wise Load Calculation Table

1) Total connected load: Total L&F Load $= 360 + 300 + 400 = 1060$ W (Total 15 points) Total Power Load $= 2000 + 1500 = 3500$ W (Total 2 points) Total Load $= 1060$ W $+ 3500$ W $=$ **4560** W

2) Total current: Assuming $V = 230$ V and $\cos\phi = 1$: $I = \frac{P}{V} = \frac{4560}{230} = \mathbf{19.82}$ A

3) Total light and fan sub-circuits: Total L&F points = 15, Total L&F load = 1060 W. Since max points per circuit is 10 and max load is 800 W, we need: Number of sub-circuits $= 15/10 = 1.5 \implies$ **2** L&F Sub-circuits.

4) Total power sub-circuits: Total power points = 2, Total power load = 3500 W. Since max load per power circuit is 3000 W, and our load is 3500 W > 3000 W, we must separate them: Number of sub-circuits $= 3500/3000 = 1.16 \implies$ **2** Power Sub-circuits (One for AC, one for Kitchen).

5) Size of main MCB: Total full load current is 19.82 A. Standard available ratings are 20A, 32A, 40A. A 20A MCB is too close to the rated current and may trip due to the starting surge of the AC. Therefore, a **32A Double Pole (DP) MCB** is the correct size.

6) Size of sub-circuit MCBs:

- **L&F Sub-circuit 1 & 2:** Load is approx 530 W each (2.3 A). Size = **6A** SP MCB.
- **Power Sub-circuit 1 (AC 2000W):** Current = $\frac{2000}{230}$ = 8.69 A. Size = **16A** SP MCB.
- **Power Sub-circuit 2 (Kitchen 1500W):** Current = $\frac{1500}{230}$ = 6.52 A. Size = **16A** SP MCB.
- **Question 3(a) [3 marks]**
  Calculate full load current and starting current of 10 H.P., 415 Volt, 3-phase Induction motor. Assume power factor=0.8 lag, efficiency=80%.

  Answer:

  Calculation of Motor Currents

  The Full Load Current (I_{FL}) of a 3-phase induction motor is calculated as: $I_{FL} = \frac{P_{out}}{\sqrt{3} \times V \times \cos\phi \times \eta}$
  For estimation of switchgear and cable rating, the starting current (I_{st}) is considered as 1.5 times the Full Load Current: $I_{st} = 1.5 \times I_{FL}$

  Given data:

  - Output Power (P_{out}) = 10 H.P. = 10×735.5 W = 7355 W (Assuming metric H.P.)
  - Voltage (V) = 415 V
  - Power factor ($\cos\phi$) = 0.8
  - Efficiency (η) = 80% = 0.8

  1. Full Load Current (I_{FL}):

  $$I_{FL} = \frac{7355}{\sqrt{3} \times 415 \times 0.8 \times 0.8}$$
  $$I_{FL} = \frac{7355}{1.732 \times 415 \times 0.64}$$
  $$I_{FL} = \frac{7355}{459.99} \approx 15.99 \text{ A}$$

  2. Starting Current (I_{st}): For the purpose of estimating cable sizes and switch ratings, the starting current is taken as 1.5 times the full load current:

  $$I_{st} = 1.5 \times I_{FL} = 1.5 \times 15.99 = 23.99 \text{ A}$$

  (Note: The actual starting current of the motor during Direct-On-Line (DOL) starting is approximately 6 times the FLC, i.e., $6 \times 15.99 \approx 96$ A. However, for wiring design purposes, 1.5 times FLC is standard.)

- **Question 3(b) [4 marks]**
  Explain IE rules for Industrial wiring.

  Answer: The important Indian Electricity (IE) rules to be followed for industrial wiring are:

  1. **Equipment Enclosures:** All electrical equipment must be enclosed in iron-clad casings or suitable enclosures to protect them from mechanical damage, dust, and moisture.

2. **Earthing of Motors:** The frames of all motors, metallic casings, and control gears must be connected to the earth system by two separate and distinct earthing connections.
3. **Motor Switches and Starters:** A separate, properly rated motor switch and starter must be provided for every individual motor. They should be installed close to the motor and be easily accessible.
4. **Protection Devices:** The starter must be equipped with necessary protection devices, such as thermal overload relays and under-voltage (no-volt) releases.
5. **Wiring Method:** Industrial wiring should generally be done using metal conduit wiring or armoured cables to ensure strong mechanical protection.
6. **Main Switchboard:** The main switchboard and distribution boards must be located in an accessible, well-ventilated, and dry area. Appropriate clearance space must be maintained around the panels.
7. **Voltage Drop Limitation:** The size of the cables should be chosen such that the voltage drop at the motor terminals does not exceed 5% of the declared supply voltage at full load.

- **Question 3(c) [7 marks]**

  In a workshop 20 m X 10 m x 5 m, Two squirrel cage Induction Motor are to be installed. a) 3 HP, 415 Volt, 3-phase, 50 Hz and b) 1 HP, 415 Volt, 3-phase, 50 Hz. Calculate rating of main switch and motor switch. Draw single line diagram for the whole installation. Assume efficiency = 85% and COS Ø = 0.85.

  Answer: Given general data for both motors: $V = 415$ V, $\eta = 0.85$, $\cos\phi = 0.85$

  Step 1: Calculate Full Load Current (FLC) for each motor The formula for FLC is: $I_{FL} = \frac{\text{HP}\times 735.5}{\sqrt{3}\times V\times\cos\phi\times\eta}$ Denominator $D = \sqrt{3}\times 415\times 0.85\times 0.85 = 1.732\times 415\times 0.7225 = 519.32$

  Motor M1 (3 HP):

  $$I_{FL1} = \frac{3\times 735.5}{519.32} = \frac{2206.5}{519.32} = 4.25 \text{ A}$$

  Motor M2 (1 HP):

  $$I_{FL2} = \frac{1\times 735.5}{519.32} = \frac{735.5}{519.32} = 1.42 \text{ A}$$

  Step 2: Calculate Rating of Motor Switches For motor switches, the current rating is calculated based on the starting current (taken as 1.5 times FLC).

  - **Motor Switch for M1:** $I_{SM1} = 1.5\times I_{FL1} = 1.5\times 4.25 = 6.375$ A.
    Selection: Select a 16 A, 415 V, ICTP (Iron Clad Triple Pole) switch.
  - **Motor Switch for M2:** $I_{SM2} = 1.5\times I_{FL2} = 1.5\times 1.42 = 2.13$ A.
    Selection: Select a 16 A, 415 V, ICTP switch.

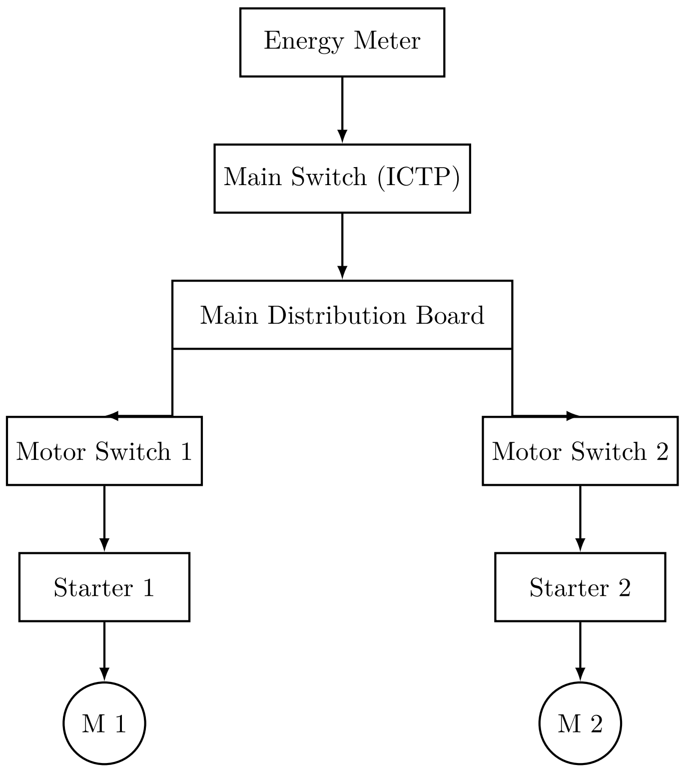
  Step 3: Calculate Rating of Main Switch The current for the main switch is calculated by taking the starting current of the largest motor and adding the full load current of the remaining motors.

  $$I_{Main} = (1.5\times I_{FL1}) + I_{FL2} = (1.5\times 4.25) + 1.42 = 6.375 + 1.42 = 7.795 \text{ A}$$

  Selection: Select a 16 A, 415 V, ICTP main switch with a neutral link.

  Step 4: Single Line Diagram (SLD)

  Below is the Single Line Diagram for the installation:



- **Question 3(a) OR [3 marks]**
  Calculate full load current and starting current of 20 H.P, 415 Volt, 3-phase Induction motor. Assume power factor=0.85 lag, efficiency=85%

  Answer: Given data:

  - Output Power (P_{out}) = 20 H.P. = 20×735.5 W = 14710 W
  - Voltage (V) = 415 V
  - Power factor ($\cos\phi$) = 0.85
  - Efficiency (η) = 85% = 0.85

  1. Full Load Current (I_{FL}): Using the formula $I_{FL} = \frac{P_{out}}{\sqrt{3} \times V \times \cos\phi \times \eta}$

  $$I_{FL} = \frac{14710}{\sqrt{3} \times 415 \times 0.85 \times 0.85}$$

  $$I_{FL} = \frac{14710}{1.732 \times 415 \times 0.7225} = \frac{14710}{519.32} \approx 28.33 \text{ A}$$

  2. Starting Current (I_{st}): For switchgear and cable sizing, the starting current is taken as 1.5 times the full load current:

  $$I_{st} = 1.5 \times I_{FL} = 1.5 \times 28.33 = 42.49 \text{ A}$$

- **Question 3(b) OR [4 marks]**
  Explain the formula for finding full load current of single phase and three phase Induction Motor.

  Answer:

Full Load Current Formulas

The Full Load Current (FLC) of an induction motor represents the current it draws from the supply when operating at its rated mechanical output power.

1. Single Phase Induction Motor: The input electrical power to a single-phase motor is given by:

$$P_{in} = V \times I_{FL} \times \cos\phi$$

The relationship between output mechanical power (P_{out}) and input power is:

$$P_{out} = P_{in} \times \eta$$

$$P_{out} = V \times I_{FL} \times \cos\phi \times \eta$$

Rearranging for I_{FL}:

$$I_{FL} = \frac{P_{out}}{V \times \cos\phi \times \eta}$$

2. Three Phase Induction Motor: The input electrical power to a three-phase motor is given by:

$$P_{in} = \sqrt{3} \times V_L \times I_{FL} \times \cos\phi$$

Using the efficiency relationship ($P_{out} = P_{in} \times \eta$):

$$P_{out} = \sqrt{3} \times V_L \times I_{FL} \times \cos\phi \times \eta$$

Rearranging for I_{FL}:

$$I_{FL} = \frac{P_{out}}{\sqrt{3} \times V_L \times \cos\phi \times \eta}$$

Where in both formulas:

- I_{FL} = Full Load Current in Amperes (A)
- P_{out} = Rated output power in Watts (W). If given in HP, convert it as 1 HP = 735.5 W (metric) or 746 W (British).
- V = Supply voltage for 1-phase (e.g., 230 V)
- V_L = Line-to-line supply voltage for 3-phase (e.g., 415 V)
- $\cos\phi$ = Power factor of the motor at full load
- η = Efficiency of the motor at full load (expressed as a decimal, e.g., 85% = 0.85)

- **Question 3(c) OR [7 marks]**

  In a workshop 20 m X 10 m x 5 m, Two squirrel cage Induction Motor are to be installed. a) 10 HP, 415 Volt, 3-phase, 50 Hz and b) 20 HP, 415 Volt, 3-phase, 50 Hz. Calculate rating of main switch and motor switch. Draw single line diagram for the whole installation. Assume efficiency = 80% and COS Ø = 0.80.

  Answer: Given general data for both motors: $V = 415$ V, $\eta = 0.80$, $\cos\phi = 0.80$

Step 1: Calculate Full Load Current (FLC) for each motor The formula for FLC is: $I_{FL} = \frac{\text{HP}\times 735.5}{\sqrt{3}\times V\times \cos\phi\times\eta}$
Denominator $D = \sqrt{3}\times 415\times 0.80\times 0.80 = 1.732\times 415\times 0.64 = 459.99 \approx 460$

Motor M1 (10 HP):

$$I_{FL1} = \frac{10\times 735.5}{460} = \frac{7355}{460} = 15.99\text{ A}$$

Motor M2 (20 HP):

$$I_{FL2} = \frac{20\times 735.5}{460} = \frac{14710}{460} = 31.98\text{ A}$$

Step 2: Calculate Rating of Motor Switches For motor switches, the current rating is calculated based on 1.5 times FLC.

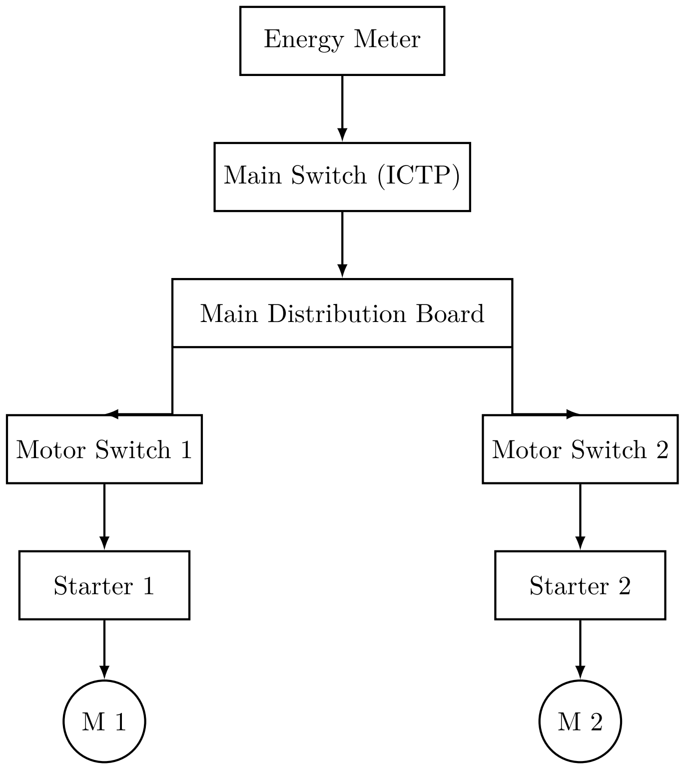
- **Motor Switch for M1:** $I_{SM1} = 1.5\times I_{FL1} = 1.5\times 15.99 = 23.985$ A.
  Selection: Select a 32 A, 415 V, ICTP switch.
- **Motor Switch for M2:** $I_{SM2} = 1.5\times I_{FL2} = 1.5\times 31.98 = 47.97$ A.
  Selection: Select a 63 A, 415 V, ICTP switch.

Step 3: Calculate Rating of Main Switch The main switch rating is based on the starting current of the largest motor plus the full load current of the remaining motors. Largest motor is M2 (20 HP).

$$I_{Main} = (1.5\times I_{FL2}) + I_{FL1} = 47.97 + 15.99 = 63.96\text{ A}$$

Selection: Since the required current is 63.96 A, which is slightly more than the standard 63 A rating, it is safer to select the next standard size. Select a 100 A, 415 V, ICTP main switch.

Step 4: Single Line Diagram (SLD)
Below is the Single Line Diagram for the installation:



Explain reasons for failure of line insulators. 3 4(a)

Line insulators can fail due to various electrical and mechanical reasons. The main reasons for the failure of line insulators are as follows:

- **Mechanical Stress:** Insulators can break or get damaged due to excessive mechanical stress caused by high wind loads, ice loading on conductors, or uneven tension.
- **Puncture:** An electrical puncture occurs when a high voltage surge (like a lightning strike) causes the insulation material to break down internally. The arc passes through the body of the insulator.
- **Flashover:** A flashover happens when an electric arc jumps across the air surrounding the insulator, typically caused by moisture, dust, or pollution on the insulator's surface.
- **Cracking of Insulator:** Rapid temperature changes can cause unequal expansion and contraction of porcelain, cement, and steel parts, leading to cracks in the insulator.
- **Porosity of Material:** If the insulator is not properly glazed during manufacturing, it becomes porous and absorbs moisture from the atmosphere, which decreases its insulation resistance.
- **Short Circuits by Animals/Birds:** Birds or animals bridging the gap between the live conductor and grounded hardware can cause short circuits and subsequent failure.

Compare between overhead and underground distribution system. 4 4(b)

Comparison of Distribution Systems

Distribution systems can be implemented either via overhead lines or underground cables. Each has its specific advantages and disadvantages.

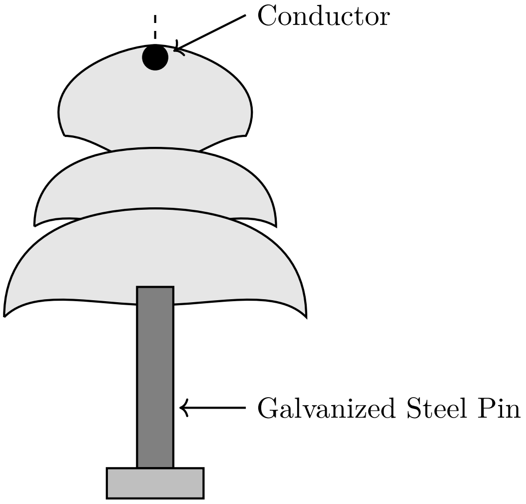
Sr. No.	Parameter	Overhead System	Underground System
1	**Initial Cost**	Less expensive.	Much more expensive.
2	**Maintenance Cost**	Higher due to exposure to environment.	Very low.
3	**Fault Location**	Easy to locate and repair faults.	Difficult to locate and repair faul
4	**Public Safety**	Less safe, risk of live wire snapping.	More safe as wires are buried.
5	**Appearance**	Poor visual appearance (cluttered).	Good appearance (neat, hidden).
6	**Voltage Drop**	Higher voltage drop (more inductance).	Lower voltage drop.
7	**Effect of Lightning**	Highly susceptible to lightning strikes.	Safe from lightning strikes.
8	**Working Life**	Shorter life span (around 25 years).	Longer life span (around 50 years

Explain different types of insulators with neat sketches. 7 4(c)

Insulators used in overhead distribution lines are made of porcelain, glass, or composite materials. The main types of insulators are:

1. Pin Type Insulator:

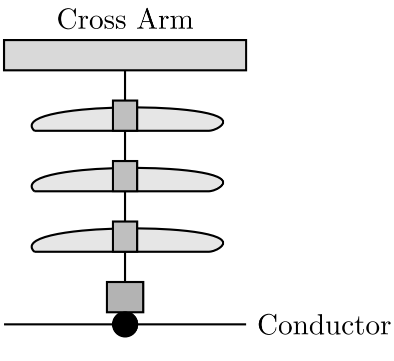
- It is mounted on a pin which is secured to the cross arm of the pole.
- The conductor passes through a groove on the top of the insulator and is tied with binding wire.
- They are generally used up to 33 kV line voltage. Beyond 33 kV, they become bulky and uneconomical.



Pin Type Insulator

2. Suspension Type Insulator:

- Used for high voltages (>33 kV). It consists of a number of porcelain discs connected in series by metal links to form a string.
- The conductor is suspended at the bottom end of this string.
- If one disc gets damaged, only that disc needs to be replaced, not the entire string.



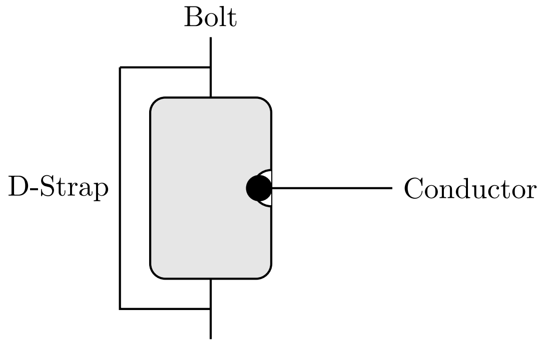
Suspension Type Insulator

3. Strain Type Insulator:

- Used at dead ends, sharp curves, or where the line crosses a river/road, where the line is subjected to high mechanical tension.
- For higher voltages, strain insulators are essentially suspension insulators used in a horizontal plane.

4. Shackle Type Insulator:

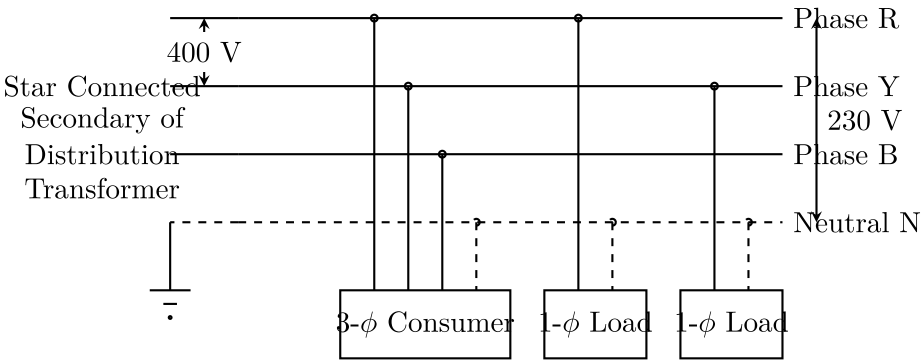
- Primarily used for low voltage (LT) distribution lines.
- They can be used either in a horizontal or vertical position. They are fixed to the pole using a D-clamp.



Shackle Type Insulator

Draw main components of three phase four wire distribution system. 3 4(a) OR

A three-phase, four-wire distribution system is commonly used for secondary distribution to supply both 3-phase and 1-phase loads. The secondary of the distribution transformer is star-connected, and the neutral point is solidly grounded.

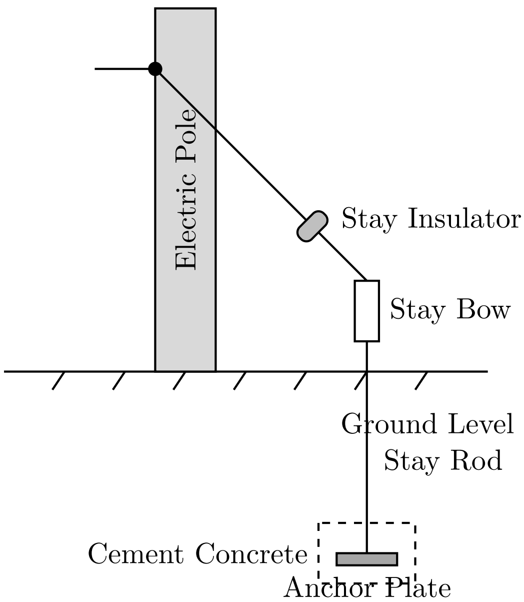


Main Components:

- **Distribution Transformer:** Steps down the voltage (e.g., 11 kV to 400 V) and has a Star-connected secondary.
- **Phase Wires (R, Y, B):** Provide 3-phase supply (400 V between phases).
- **Neutral Wire (N):** Grounded at the transformer. Provides single-phase supply (230 V) when used with any one phase.

Draw sketch of stay set for overhead distribution system. 4 4(b) OR

A stay set (or guy wire) is used to balance the tension on an electric pole, especially at dead ends, angle poles, or junction poles, to prevent the pole from leaning or bending.



Main Parts of Stay Set:

- **Stay Wire:** A galvanized steel wire that provides the pulling force.
- **Stay Insulator (Guy Insulator):** Inserted in the stay wire to prevent any leakage current from reaching the lower part of the stay, ensuring safety for humans and animals.
- **Stay Bow & Turnbuckle:** Used to adjust the tension of the stay wire.
- **Stay Rod & Anchor Plate:** Buried deep in the ground with cement concrete to anchor the stay system firmly.

One 400-Volt, 3-phase, 4 wire, 50 Hz, overhead distribution line is 720 meter long. Take 60-meter span between two poles. Use AAC 3/3.66 mm as line conductor and 8 SWG G.I. as neutral and earth wire. Take PCC pole and estimate total material required. 7 4(c) OR

Estimation of Material for Overhead Line

To estimate the material, we first calculate the number of poles and the length of the conductors required, accounting for sag and wastage.

1. Calculation of Number of Poles:

- Total Line Length = 720 m
- Span = 60 m
- Number of Poles = $\frac{\text{Total Length}}{\text{Span}} + 1 = \frac{720}{60} + 1 = 12 + 1 = 13$ Poles.

2. Calculation of Conductor Length:

- Line Conductor (3 phases) = 3 wires of AAC 3/3.66 mm.
- Length of AAC = 3×720 m = 2160 m. Adding 2% for sag and wastage, total length = $2160 \times 1.02 \approx 2204$ m.
- Neutral and Earth Wire = 2 wires of 8 SWG G.I.

- Length of G.I. Wire = 2×720 m = 1440 m. Adding 2% for sag and wastage, total length = $1440 \times 1.02 \approx 1469$ m.

3. Insulators and Other Hardware:

- Shackle Insulators for 3 phases + 1 Neutral = 4 wires $\times$ 13 poles = 52 Nos.
- Earth wire knobs (reels) for Earth wire = 13 Nos.

Material Estimation Table:

Sr. No.	Particulars of Material with Specifications	Unit	Quantity
1	PCC Pole (8 or 9 meters long)	Nos.	13
2	AAC 3/3.66 mm line conductor	Meters	2204
3	8 SWG G.I. Wire (for neutral and earth)	Meters	1469
4	Shackle Insulators (with D-clamps & bolts)	Nos.	52
5	Earth wire C.I. Knob / Reel Insulator	Nos.	13
6	Stay Set complete (rod, bow, anchor plate)	Sets	4
7	Stay Insulators (Guy Insulators)	Nos.	4
8	Stay Wire (7/8 SWG G.I.)	kg	40
9	Pipe / Coil Earthing sets	Nos.	3
10	Danger Plates	Nos.	13
11	Aluminium Binding Wire	kg	3
12	Cement Concrete (for poles and stays)	L.S.	1