**Basic Electrical and Electronics Engineering - BE3251**

**UNIT 1 Electrical Circuits**

**PART-B**

**1. Problems Based on Kirchhoff’s Current Law (KCL)**

**Kirchhoff’s Current Law (KCL) – Statement:**

At any **junction (node)** in an electrical circuit, the **sum of currents entering** the node is equal to the **sum of currents leaving** the node.

∑Iin=∑Iout\sum I\_{in} = \sum I\_{out}

This is based on the **law of conservation of charge**.

**Example Problem (KCL):**

**Given:**

At a node:

* I1=5AI\_1 = 5A (entering)
* I2=3AI\_2 = 3A (entering)
* I3=?I\_3 = ? (leaving)
* I4=2AI\_4 = 2A (leaving)

**Solution:**

Using KCL:

I1+I2=I3+I4I\_1 + I\_2 = I\_3 + I\_4 5+3=I3+2⇒I3=6A5 + 3 = I\_3 + 2 \Rightarrow I\_3 = 6A

**Answer:** I3=6AI\_3 = 6A

**2. Problems Based on Kirchhoff’s Voltage Law (KVL)**

**Kirchhoff’s Voltage Law (KVL) – Statement:**

The **algebraic sum** of all voltages in a **closed loop** is **zero**.

∑V=0\sum V = 0

This includes EMFs and voltage drops across resistors.

**Example Problem (KVL):**

**Circuit Description:**

A loop with:

* Battery: 10V
* Resistor R1=2ΩR\_1 = 2\Omega
* Resistor R2=3ΩR\_2 = 3\Omega

Find the current II.

**Solution:**

Using Ohm’s Law:

* Voltage drop across R1=2IR\_1 = 2I
* Voltage drop across R2=3IR\_2 = 3I

Apply KVL:

10−2I−3I=0⇒10=5I⇒I=2A10 - 2I - 3I = 0 \Rightarrow 10 = 5I \Rightarrow I = 2A

**Answer:** I=2AI = 2A

**Another KVL Problem with Direction:**

**Given:**

* R1=4ΩR\_1 = 4\Omega, R2=6ΩR\_2 = 6\Omega
* Battery: 12V

Clockwise current II flows through the loop.

Apply KVL:

12−4I−6I=0⇒12=10I⇒I=1.2A12 - 4I - 6I = 0 \Rightarrow 12 = 10I \Rightarrow I = 1.2A

**Answer:** I=1.2AI = 1.2A

**Conclusion:**

* **KCL** is applied at **junctions** to conserve charge.
* **KVL** is applied in **loops** to conserve energy.
* Both are essential tools in analyzing **DC and AC circuits**.

Here’s a **13-mark level explanation and solved problem** on **Nodal Analysis**, as per your request for **Problem 4**.

**3. Problems Based on Nodal Analysis**

**🔹 What is Nodal Analysis?**

**Nodal Analysis** is a method used to determine the **voltage at different nodes** in an electrical circuit using **Kirchhoff’s Current Law (KCL)**.

It involves:

* Selecting a **reference node** (ground),
* Applying **KCL** at non-reference nodes,
* Using **Ohm’s Law** to express currents in terms of voltages.

**🔹 Step-by-Step Procedure:**

1. **Choose the reference node** (usually the one connected to most elements).
2. Assign **node voltages** to other nodes (let’s say V1,V2,…V\_1, V\_2, \dots).
3. Apply **KCL** at each node (except the reference).
4. Use **Ohm’s Law**:  
   Current through resistor RR = V1−V2R\frac{V\_1 - V\_2}{R}
5. Solve the resulting **simultaneous equations**.

**🔸 Example Problem – Nodal Analysis**

**🔧 Circuit Description:**

R1 = 2Ω R2 = 4Ω

(10V) ---/\/\/\---(Node A)---/\/\/\---(Ground)

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R3 = 2Ω

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(Ground)

* A 10V battery is connected to a resistor R1=2ΩR\_1 = 2\Omega
* Node A connects to two resistors: R2=4ΩR\_2 = 4\Omega and R3=2ΩR\_3 = 2\Omega, both going to ground
* Find the **voltage at Node A**, VAV\_A

**🧮 Solution:**

Let the **ground** be the reference node (0V).

Apply **KCL at Node A**:

* Current from battery to Node A through R1R\_1:  
  10−VA2\frac{10 - V\_A}{2}
* Current from Node A to ground through R2R\_2:  
  VA4\frac{V\_A}{4}
* Current from Node A to ground through R3R\_3:  
  VA2\frac{V\_A}{2}

Now apply KCL:

10−VA2=VA4+VA2\frac{10 - V\_A}{2} = \frac{V\_A}{4} + \frac{V\_A}{2}

Multiply both sides by **4** to eliminate denominators:

2(10−VA)=VA+2VA⇒20−2VA=3VA⇒20=5VA⇒VA=4V2(10 - V\_A) = V\_A + 2V\_A \Rightarrow 20 - 2V\_A = 3V\_A \Rightarrow 20 = 5V\_A \Rightarrow V\_A = 4V

**Answer:**

Voltage at Node A is **4 volts**.

**🔚 Conclusion:**

Nodal analysis is an efficient method to solve circuits with **multiple nodes and resistors**. It simplifies circuit analysis by focusing on **node voltages** rather than individual branch currents.

**UNIT 2 Electrical Machines**

**1.Construction, Working, Types and Torque equation of DC Motor**

**🔹 Construction:**

* **Yoke:** Outer frame made of cast iron or steel for mechanical support.
* **Field Poles:** Carry field windings to produce the magnetic field.
* **Armature Core:** Cylindrical core made of laminated steel, houses armature windings.
* **Commutator:** Converts AC induced in armature to DC at output.
* **Brushes:** Carbon brushes that maintain contact with the commutator to supply current.

**🔹 Working Principle:**

* Based on **Lorentz force law**: A current-carrying conductor placed in a magnetic field experiences a mechanical force.
* The interaction between magnetic field (from stator) and current in armature conductors generates torque, causing rotation.

**🔹 Types of DC Motors:**

1. **Shunt Wound** (field and armature in parallel)
2. **Series Wound** (field and armature in series)
3. **Compound Wound** (combination of series and shunt)

**🔹 Torque Equation:**

Torque TT is given by:

T=P⋅ϕ⋅Z⋅Ia2πAT = \frac{P \cdot \phi \cdot Z \cdot I\_a}{2\pi A}

Where:  
PP = Number of poles  
ϕ\phi = Flux per pole (Wb)  
ZZ = Total number of armature conductors  
IaI\_a = Armature current  
AA = Number of parallel paths

**2.** **Construction, Working, Types and EMF equation of Single phase Transformer**

**Single Phase Transformer**

**🔹 Construction:**

* **Core:** Made of laminated silicon steel to reduce eddy current losses.
* **Windings:** Primary and secondary copper windings placed over the core.
* **Tank:** Encloses the core and windings, filled with oil for cooling.
* **Bushings:** Insulate terminals.

**🔹 Working Principle:**

* Based on **Faraday's Law of Electromagnetic Induction**.
* An alternating current in the **primary winding** produces a varying magnetic flux in the core, which induces EMF in the **secondary winding**.

**🔹 Types:**

1. **Core-type Transformer**
2. **Shell-type Transformer**
3. **Step-up / Step-down Transformers**

**🔹 EMF Equation:**

E=4.44fNϕmE = 4.44 f N \phi\_m

Where:  
EE = RMS value of induced EMF  
ff = Frequency in Hz  
NN = Number of turns  
ϕm\phi\_m = Maximum flux in Wb

**3.** **Construction, Working, Torque equation of Three phase alternator**

**Three-Phase Alternator (Synchronous Generator)**

**🔹 Construction:**

* **Stator:** Stationary part with 3-phase armature winding.
* **Rotor:** Rotating part with DC field winding (either **salient pole** or **non-salient pole**).
* **Slip Rings and Brushes:** Provide DC excitation to rotor.
* **Frame:** Supports the stator and rotor.

**🔹 Working Principle:**

* When rotor is rotated (by prime mover), its magnetic field cuts the stator conductors.
* According to **Faraday’s Law**, an EMF is induced in the stator windings.
* As rotor continues to rotate, a 3-phase alternating EMF is generated.

**🔹 Torque Equation:**

The electromagnetic torque TeT\_e is given by:

Te=3ωsEfIacos⁡(δ)T\_e = \frac{3}{\omega\_s} E\_f I\_a \cos(\delta)

Where:  
EfE\_f = Field EMF  
IaI\_a = Armature current  
ωs\omega\_s = Synchronous speed  
δ\delta = Load angle between EfE\_f and terminal voltage

**UNIT 3 Analog Electronics**

**1. IGBT (Insulated Gate Bipolar Transistor)**

**🔹 Construction:**

* IGBT combines features of **MOSFET (high input impedance)** and **BJT (low conduction loss)**.
* Layers:
  + **Emitter (N+)**
  + **P-base**
  + **N- drift region**
  + **Collector (P+)**
  + **Gate terminal** over an oxide layer (like MOSFET)

**Symbol:** A combination of MOSFET and BJT symbols.

**🔹 Working:**

* Gate is insulated from the channel by an oxide layer.
* When a **positive voltage** is applied to the gate:
  + It creates a conductive channel in the P-base.
  + Electrons flow from **emitter to collector** via N-drift and P+ collector.
* Gate voltage controls switching like a MOSFET, and conduction is like a BJT.

**🔹 VI Characteristics:**

* **Output Characteristics (VCE vs IC):**
  + Like BJT, curves for different **V\_GE** values.
* **Transfer Characteristics (IC vs V\_GE):**
  + Shows threshold voltage.
* **Breakdown Region:** Excess VCE leads to breakdown.

**🔹 Applications:**

* Electric vehicle drives
* SMPS (Switch Mode Power Supplies)
* Induction heating
* Motor control
* Renewable energy inverters

**✅ 2. Rectifier**

**🔹 Construction:**

* Uses **diodes** arranged in specific patterns.
* Types:
  + **Half-wave Rectifier:** Single diode
  + **Full-wave Rectifier (Center-tapped):** Two diodes
  + **Bridge Rectifier:** Four diodes in bridge form

**🔹 Working:**

**➤ Half-Wave:**

* Only allows **positive half** of AC through.
* Negative half is blocked.

**➤ Full-Wave (Bridge):**

* During both positive and negative halves, the diodes conduct in such a way that output is always **positive**.

**🔹 Output Waveforms:**

**➤ Half-Wave:**

Input: Output:

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**➤ Full-Wave:**

Input: Output:

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**✅ 3. Inverter**

**🔹 Construction:**

* Uses **power electronic switches** (like MOSFETs or IGBTs).
* Also includes:
  + **DC source**
  + **Control circuit**
  + **Gate drivers**
* Output is connected to a **load** (like motor, lamp, etc.)

**🔹 Working:**

* Converts **DC to AC** using high-speed switching.
* Switches are turned **ON/OFF alternately** to generate **AC waveform**.
* Uses **PWM (Pulse Width Modulation)** to improve waveform quality.

**🔹 Output Waveforms:**

**➤ Ideal Inverter:**

* Pure sine wave (for high-end inverters)

**➤ Practical Inverter:**

* **Square wave** or **Modified sine wave** (common in low-cost inverters)

Output: \_\_\_ \_\_\_

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(Square Wave Output)

**UNIT 4 Digital Electronics**

**1. Problems Based on Number Conversions**

**🔹 Number System Conversions**

We will cover conversions between the following number systems:

* **Binary to Decimal**
* **Decimal to Binary**
* **Binary to Hexadecimal**
* **Hexadecimal to Binary**

**Example 1: Binary to Decimal**

Convert **1011₂** to Decimal.

**Solution:** We expand the binary number as:

10112=(1×23)+(0×22)+(1×21)+(1×20)1011\_2 = (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) =8+0+2+1=1110= 8 + 0 + 2 + 1 = 11\_{10}

So, **1011₂ = 11₁₀**.

**Example 2: Decimal to Binary**

Convert **13₁₀** to Binary.

**Solution:** Divide the decimal number by 2, keeping track of the remainders:

13÷2=6 remainder 113 \div 2 = 6 \text{ remainder } 1 6÷2=3 remainder 06 \div 2 = 3 \text{ remainder } 0 3÷2=1 remainder 13 \div 2 = 1 \text{ remainder } 1 1÷2=0 remainder 11 \div 2 = 0 \text{ remainder } 1

Now, reading the remainders from bottom to top, we get **1101₂**.

So, **13₁₀ = 1101₂**.

**Example 3: Binary to Hexadecimal**

Convert **11011010₂** to Hexadecimal.

**Solution:** Group the binary digits into 4-bit groups from right to left:

1101 10101101 \, 1010

Convert each group to its hexadecimal equivalent:

11012=D16, 10102=A161101\_2 = D\_{16}, \, 1010\_2 = A\_{16}

So, **11011010₂ = DA₁₆**.

**Example 4: Hexadecimal to Binary**

Convert **3F₁₆** to Binary.

**Solution:** Convert each hexadecimal digit to binary:

316=00112, F16=111123\_{16} = 0011\_2, \, F\_{16} = 1111\_2

So, **3F₁₆ = 00111111₂**.

**2. Adder and Subtractor Circuits**

**🔹 Adder Circuits**

An adder circuit adds two binary numbers. The most common types are:

**➤ Half Adder:**

A **half adder** adds two single-bit binary numbers, producing a sum and a carry output.

**Truth Table:**

| **A** | **B** | **Sum (S)** | **Carry (C)** |
| --- | --- | --- | --- |
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 |

**Logic Equations:**

* **Sum (S)** = A ⊕ B (XOR gate)
* **Carry (C)** = A ⋅ B (AND gate)

**Circuit Diagram of Half Adder:**

* **Inputs:** A, B
* **Outputs:** Sum (S), Carry (C)
  + XOR gate for Sum
  + AND gate for Carry

**➤ Full Adder:**

A **full adder** adds three bits: two significant bits (A, B) and a carry-in (C\_in). It produces a sum (S) and a carry-out (C\_out).

**Truth Table:**

| **A** | **B** | **C\_in** | **Sum (S)** | **Carry (C\_out)** |
| --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 |

**Logic Equations:**

* **Sum (S)** = A ⊕ B ⊕ C\_in
* **Carry-out (C\_out)** = (A ⋅ B) + (B ⋅ C\_in) + (A ⋅ C\_in)

**Circuit Diagram of Full Adder:**

* **Inputs:** A, B, C\_in
* **Outputs:** Sum (S), Carry-out (C\_out)
  + XOR gates for Sum
  + AND gates and OR gate for Carry-out

**🔹 Subtractor Circuits**

Subtraction can be achieved using an adder circuit by using **two's complement**.

**➤ Half Subtractor:**

A **half subtractor** subtracts one single-bit number (B) from another (A), producing a difference and a borrow output.

**Truth Table:**

| **A** | **B** | **Difference (D)** | **Borrow (B\_out)** |
| --- | --- | --- | --- |
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |

**Logic Equations:**

* **Difference (D)** = A ⊕ B (XOR gate)
* **Borrow (B\_out)** = A' ⋅ B (AND gate)

**Circuit Diagram of Half Subtractor:**

* **Inputs:** A, B
* **Outputs:** Difference (D), Borrow (B\_out)
  + XOR gate for Difference
  + AND gate for Borrow

**➤ Full Subtractor:**

A **full subtractor** subtracts three bits: two significant bits (A, B) and a borrow-in (B\_in). It produces a difference (D) and a borrow-out (B\_out).

**Truth Table:**

| **A** | **B** | **B\_in** | **Difference (D)** | **Borrow (B\_out)** |
| --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |

**Logic Equations:**

* **Difference (D)** = A ⊕ B ⊕ B\_in
* **Borrow-out (B\_out)** = (A' ⋅ B) + (A' ⋅ B\_in) + (B ⋅ B\_in)

**Circuit Diagram of Full Subtractor:**

* **Inputs:** A, B, B\_in
* **Outputs:** Difference (D), Borrow-out (B\_out)
  + XOR gates for Difference
  + AND gates and OR gate for Borrow-out

**Conclusion:**

* **Adder Circuits**: Essential for binary addition. Half adders and full adders form the basic building blocks.
* **Subtractor Circuits**: Achieve binary subtraction using two's complement logic in half and full subtractor configurations.

**UNIT 5 Measurements and Instrumentation**

**1. Energy Meter**

**🔹 Definition:**

An **energy meter** (also called watt-hour meter) is a device used to measure the **electrical energy consumed** by a residence, business, or electrical device.

**🔹 Construction:**

* **Voltage coil** (shunt coil): Connected in parallel with the supply.
* **Current coil** (series coil): Connected in series with the load.
* **Aluminum disc**: Rotates due to eddy current effect.
* **Permanent magnet**: Acts as a brake to control the speed.
* **Gear mechanism**: Translates disc rotations to reading on a counter.

**🔹 Working Principle:**

The meter works on the **electromagnetic induction principle**:

* Current coil produces a magnetic field proportional to load current.
* Voltage coil produces another magnetic field based on supply voltage.
* The interaction of these fields produces torque on the aluminum disc.
* The disc’s rotation is proportional to power consumption.
* The total revolutions represent **energy in kWh**.

**🔹 Types:**

* **Electromechanical Induction type** (Traditional)
* **Electronic energy meter** (Digital meters with LCD display)

**🔹 Applications:**

* Domestic and industrial energy billing
* Energy monitoring and management systems

**2. Data Acquisition System (DAS)**

**🔹 Definition:**

A **Data Acquisition System (DAS)** is a system that **collects, processes, and stores real-world data** from physical environments for monitoring, control, or analysis.

**🔹 Basic Components:**

1. **Sensors/Transducers** – Convert physical signals (temperature, pressure, etc.) to electrical signals.
2. **Signal Conditioning Circuit** – Amplifies or filters signals.
3. **Analog-to-Digital Converter (ADC)** – Converts analog signals to digital.
4. **Processor or Computer Interface** – Processes and stores the data.
5. **Software** – Visualizes and analyzes the acquired data.

**🔹 Block Diagram:**

[Sensor] → [Signal Conditioner] → [ADC] → [Processor/Computer] → [Storage/Display]

**🔹 Types of DAS:**

* **Analog DAS**
* **Digital DAS**
* **Hybrid DAS**

**🔹 Applications:**

* Industrial automation
* Weather monitoring
* Biomedical instrumentation
* Automotive systems
* Energy management

**3. Three Phase Power Measurement**

**🔹 Need:**

To measure the **total power consumed** in a 3-phase system, which is widely used in industrial and commercial setups.

**🔹 Methods of Measurement:**

**i) Three Wattmeter Method:**

* Used in **3-phase 4-wire system**
* 3 wattmeters measure each phase's power
* Total power:

Ptotal=W1+W2+W3P\_{total} = W\_1 + W\_2 + W\_3

**ii) Two Wattmeter Method:**

* Used in **3-phase 3-wire system**
* Total power:

Ptotal=W1+W2P\_{total} = W\_1 + W\_2

* Can measure both balanced and unbalanced loads.

**Power factor (pf)** can also be calculated using:

cos⁡ϕ=W1+W23(W1−W2)(for lagging loads)\cos \phi = \frac{W\_1 + W\_2}{\sqrt{3}(W\_1 - W\_2)} \quad \text{(for lagging loads)}

**iii) One Wattmeter Method:**

* Used only for **balanced loads**
* The wattmeter is connected with a switching arrangement.

**🔹 Example Setup: Two Wattmeter Method**

* **W1** is connected between Phase A and B
* **W2** is connected between Phase C and B

If readings are:

* W1 = 5kW
* W2 = 3kW

Then total power:

Ptotal=5+3=8 kWP\_{total} = 5 + 3 = 8\, \text{kW}

**🔹 Applications:**

* Industrial power monitoring
* Load analysis in substations
* Energy audits