Subject Name Solutions

4311101 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Define Power & Energy.

Solution

- **Power**: Rate of doing work or energy consumption per unit time. Measured in Watts (W).
- **Energy**: Ability to do work or the work done. Measured in Joules (J) or Watt-hours (Wh).

Table 1: Power vs Energy

Parameter	Definition	Formula	Unit
Power	Rate of energy transfer	P = W/t	Watt (W)
Energy	Capacity to do work	E = P $\times t$	Joule (J) or Watt-hour (Wh)

Mnemonic

"Power Performs, Energy Endures"

Question 1(b) [4 marks]

Define current and electrical potential.

Solution

Diagram:

```
flowchart LR
    A[Electron Flow] {-{-}|Rate of Flow| B[Current]}
    C[Potential Energy] {-{-}|Per Unit Charge| D[Voltage]}
```

- **Current**: Flow of electric charge per unit time. Measured in Amperes (A).
- **Electrical Potential**: Work done per unit charge to move a charge from one point to another. Measured in Volts (V).

Mnemonic

"Current Charges, Potential Pushes"

Question 1(c) [7 marks]

Explain KCL and KVL with examples.

Solution

Diagram:

```
+{-{-}{-}{-}{-}+        i1}
      |        ↓
      |    R1
      +{-{-}{-}{-}{-}///{-}{-}{-}{-}+}
      |               |
```

```
      |               |
     +++              |
     | | V1       R2  |
     +++          /{//}
      |               |
      |               |
      +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
         i2 ↑    ↑ i3
            {    /}
             {  /}
              {/}
              R3
               |
               |
             {-{-}{-}}
              {-}
```

Kirchhoff's Current Law (KCL):

- Sum of currents entering a node equals sum of currents leaving it.
- Example: At node X, i1 + i2 = i3

Kirchhoff's Voltage Law (KVL):

- Sum of voltage drops around any closed loop equals zero.
- Example: V1 - V(R1) - V(R2) = 0

Mnemonic

"Currents Come-Leave, Voltages Voyage-Loop"

Question 1(c) OR [7 marks]

Explain different types of connections for Resistors.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Series Connection"
    A[R1] {-{-}{-} B[R2] {-}{-}{-} C[R3]}
    end
    subgraph "Parallel Connection"
    D[R1]
    E[R2]
    F[R3]
    G {-{-}{-} D \& E \& F {-}{-}{-} H}
    end
{Highlighting}
{Shaded}
```

Table 2: Series vs Parallel Connection

Parameter	Series Connection	Parallel Connection
Total Resistance	Req = R1 + R2 + R3 + ...	1/Req = 1/R1 + 1/R2 + 1/R3 + ...
Current	Same through all resistors	Divides through each path
Voltage	Divides across resistors	Same across all resistors
Application	Voltage dividers	Current division

Mnemonic

"Series Sum, Parallel Parts"

Question 2(a) [3 marks]

Define Resistance and Resistivity. Also state their unit of measurement.

Solution

- **Resistance**: Opposition to current flow, measured in Ohms (Ω). R = V/I.
- **Resistivity**: Material property indicating resistance per unit dimension, measured in Ohm-meter ($\Omega \cdot$ m).   = RA/L.

Mnemonic

"Resistance Restricts, Resistivity Relates to material"

Question 2(b) [4 marks]

Define cell and write names of different types of cell.

Solution

Diagram:

```
+{-{-}{-}{-}{-}{-}{-}{-}+}
|         |
| +    {- |}
|  {  /   |}
|   {/    |}
|         |
+{-{-}{-}{-}{-}{-}{-}{-}+}
  Battery
```

- **Cell**: Device that converts chemical energy into electrical energy creating a voltage.

Types of Cells:

1. **Primary cells**: Dry cell, Alkaline cell, Mercury cell
2. **Secondary cells**: Lead-acid, Nickel-Cadmium, Lithium-ion

Mnemonic

"Primary Produces once, Secondary Serves repeatedly"

Question 2(c) [7 marks]

Calculate total equivalent resistance of the above circuit if R1=5Ω, R2=3Ω, R3=4Ω, R4=1Ω, R5=2Ω.

Solution

Diagram:

```
               R1
             /{//}
     +{-{-}{-}{-}{-}{-}{-}+      +{-}{-}{-}{-}{-}{-}+}
     |                     |
     |                     |
     |                     |
  R2 /{          R3       / R5}
     {/         ///    /}
     |       +{-{-}+      +{-}{-}+}
     |       |            |
```

```
+{-{-}{-}{-}{-}{-}{-}+           |}
                      |
         R4           |
        /{//        |}
+{-{-}{-}{-}{-}{-}{-}+      +{-}{-}{-}{-}{-}+}
|                     |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

Step-by-step solution:

1. R2 and R3 are in series: R23 = R2 + R3 = 3Ω + 4Ω = 7Ω
2. R23 and R4 are in parallel: 1/R234 = 1/7 + 1/1 = (1+7)/7 = 8/7 Therefore, R234 = 7/8 = 0.875Ω
3. R1, R234, and R5 are in series: Req = R1 + R234 + R5 = 5Ω + 0.875Ω + 2Ω = 7.875Ω

Therefore, equivalent resistance = 7.875Ω

Mnemonic

"Series-Sum, Parallel-Product over Sum"

Question 2(a) OR [3 marks]

Find the cost of energy if 100W bulb operated 10 hours daily for 30 days. Rate of energy is Rupees 5/unit.

Solution

Table 3: Energy Calculation

Parameter	Value	Calculation
Power	100W = 0.1kW	Given
Operating hours	10 hours/day $\times 30 days = 300 hours$	Given
Energy consumed	0.1kW $\times 300h = 30kWh = 30 units$	E = P $\times t$
Rate	Rs. 5/unit	Given
Total cost	30 units $\times Rs.5/unit = Rs.150$	Cost = Units $\times Rate$

Therefore, cost of energy = Rs. 150

Mnemonic

"Energy $\times Rate = Electric bill fate''$

Question 2(b) OR [4 marks]

State ohm's law and explain the use ohm's law to calculate current in any circuit.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Voltage] {-{-}{}|"V = IR"| B[Current]}
    C[Resistance] {-{-}{} B}
{Highlighting}
{Shaded}
```

Ohm's Law: Current flowing through a conductor is directly proportional to voltage and inversely proportional to resistance.
Formula: V = IR or I = V/R or R = V/I

Application: To find current in a circuit, measure voltage across a component and divide by its resistance (I = V/R).

Mnemonic

"Volts Invite current, Resistance Restricts"

Question 2(c) OR [7 marks]

Show that the current in a purely capacitive circuit leads the applied voltage by 90°$andthecurrentinapurelyinductive$

Solution

Diagrams:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Capacitive Circuit"
    A[Voltage] {-{-}{-} B["Voltage = V sin( t)"]}
    C[Current] {-{-}{-} D["Current = I sin( t + 90^)"]}
    end
    subgraph "Inductive Circuit"
    E[Voltage] {-{-}{-} F["Voltage = V sin( t)"]}
    G[Current] {-{-}{-} H["Current = I sin( t {-} 90^)"]}
    end
{Highlighting}
{Shaded}
```

For Capacitive Circuit:

- **Voltage equation: v = V sin(t)**
- **Current:**
  i = C $\times dv/dt = CVcos(t) = Isin(t + 90°)$

- **Current leads voltage by 90°**

For Inductive Circuit:

- **Voltage equation:**
  v = L $\times di/dt = LIcos(t) = Vsin(t + 90°)$

- **Current: i = I sin(t)**
- **Current lags voltage by 90°**

Mnemonic

"ELI the ICE man" - In EL (inductor), I lags E; in ICE (capacitor), I leads E

Question 3(a) [3 marks]

Define cycle, form factor and amplitude.

Solution

Diagram:

```
    \^{}
    |    /{      /}
    |   /  {    /  }
A{-{-}{-}|{-}{-}/{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}}
    | /      {/      }
    |/                {}
    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}
        |{-{-}{-}{-}{-}|}
```

```
cycle
```

- **Cycle:** One complete repetition of a waveform.
- **Form Factor:** Ratio of RMS value to average value. For sine wave = 1.11.
- **Amplitude:** Maximum displacement of a waveform from its mean position.

Mnemonic

"Cycles Complete, Form Factors Find ratio, Amplitude Achieves maximum"

Question 3(b) [4 marks]

Define RMS and Average value. Write expression of RMS and average value of sinusoidal waveform.

Solution

Table 4: RMS vs Average Value

Parameter	Definition	Formula for Sine Wave
RMS Value	Square root of mean of squared values	Vrms = Vm/$\sqrt{2} = 0.707Vm$
Average Value	Mean of all instantaneous values over half cycle	Vavg = 2Vm/ = 0.637 Vm

- **RMS (Root Mean Square):** Equivalent DC value that produces same heating effect.
- **Average Value:** Mean of all instantaneous values over a half cycle.

Mnemonic

"RMS Relates to heating, Average Adds and divides"

Question 3(c) [7 marks]

Explain the terms Apparent power, True Power and Reactive power. State their unit of measurement.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Power Triangle"
    A[True Power P] {-{-}{-} B[Apparent Power S]}
    C[Reactive Power Q] {-{-}{-} B}
    end
{Highlighting}
{Shaded}
```

Table 5: Types of Power

Power Type	Definition	Formula	Unit
Apparent Power (S)	Total power supplied	S = VI	VA (Volt-Ampere)
True Power (P)	Actual power consumed	P = VI cos	W (Watt)
Reactive Power (Q)	Power oscillating between source and load	Q = VI sin	VAR (Volt-Ampere Reactive)

Power Triangle: $S^2 = P^2 + Q^2$

Mnemonic

“Active Performs work, Reactive Returns energy, Apparent Adds vectors”

Question 3(a) OR [3 marks]

Write mathematical expressions of 3-phase voltages.

Solution

Three-phase voltage expressions:

Table 6: 3-Phase Voltages

Phase	Expression
R-phase	VR = Vm sin(t)
Y-phase	VY = Vm sin(t - 120°)
B-phase	VB = Vm sin(t - 240°)

Where Vm is the maximum voltage and is the angular frequency.

Mnemonic

“Red phase Reference, Yellow lags 120°, $Bluebringsup240°''$

Question 3(b) OR [4 marks]

Define crest factor and state value of crest factor for sine wave.

Solution

Diagram:

```
    \^{}
    |    /{      /}
    |   /  {    /  }
{-{-}{-}{-}|{-}{-}/{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}}
    | /      {/      }
    |/               {}
    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}

    Peak value
    |{-{-}{-}{-}{-}{-}{-}{-}|}
    |   RMS  |
    |   value|
```

- **Crest Factor:** Ratio of peak value to RMS value of a waveform.
- **Formula:** Crest Factor = Peak Value / RMS Value
- **For sine wave:** Crest Factor = 1/0.707 = 1.414

Mnemonic

“Crest Compares peak to RMS”

Question 3(c) OR [7 marks]

Describe different three phase electrical connections.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Star Connection"
    A1[R] {-{-}{-} D[Neutral]}
    B1[Y] {-{-}{-} D}
    C1[B] {-{-}{-} D}
    end

    subgraph "Delta Connection"
    A2[R] {-{-}{-} B2[Y]}
    B2 {-{-}{-} C2[B]}
    C2 {-{-}{-} A2}
    end
{Highlighting}
{Shaded}
```

Table 7: Star vs Delta Connection

Parameter	Star (Y) Connection	Delta (Δ) Connection
Line Voltage (VL)	$\sqrt{3} \times PhaseVoltage$	Same as Phase Voltage
Line Current (IL)	Same as Phase Current	$\sqrt{3} \times PhaseCurrent$
Neutral Wire	Present	Absent
Application	Unbalanced loads, Residential	Balanced loads, Industrial

Mnemonic

"Star Shows neutral, Delta Delivers higher current"

Question 4(a) [3 marks]

Calculate the peak to peak value of a sinusoidal voltage if RMS value is 230V.

Solution

Table 8: Calculation Steps

Parameter	Formula	Calculation
RMS Value	Given	230V
Peak Value	Vm = $\sqrt{2} \times Vrms$	Vm = $\sqrt{2} \times 230 = 325.27V$
Peak-to-Peak Value	Vp-p = 2 $\times Vm$	Vp-p = 2 $\times 325.27 = 650.54V$

Therefore, peak-to-peak value = 650.54V

Mnemonic

"RMS to Peak - multiply by $\sqrt{2}, PeaktoPeak - doubleit''$

Question 4(b) [4 marks]

An alternating current is given by i=142.14sin628t find frequency and time period.

Solution

Table 9: Calculation Steps

Parameter	Formula	Calculation
Given equation	i = 142.14 sin(628t)	= 628 rad/s
Frequency	f = /(2)	f = 628/(2) = 100 Hz
Time Period	T = 1/f	T = 1/100 = 0.01 s = 10 ms

Therefore, frequency = 100 Hz and time period = 0.01 s

Mnemonic

"Frequency From omega divide 2 , Time takes inverse"

Question 4(c) [7 marks]

State and explain Fleming's left hand rule and right hand rule.

Solution

Diagram:

```
Left Hand Rule           Right Hand Rule
    F                        F
    \^{                        \^{}}
    |                        |
    |                        |
    +{-{-}B                    +{-}{-}B}
   /                        /
  /                        /
 I                        I
```

Fleming's Left Hand Rule (Motor):
- **Used to determine direction of force on a current-carrying conductor in a magnetic field.**
- **Hold left hand with thumb, fore and middle fingers at right angles.**
- **Thumb: Motion (Force)**
- **Forefinger: Magnetic field**
- **Middle finger: Current**

Fleming's Right Hand Rule (Generator):
- **Used to determine direction of induced current when a conductor moves in a magnetic field.**
- **Hold right hand with thumb, fore and middle fingers at right angles.**
- **Thumb: Motion of conductor**
- **Forefinger: Magnetic field**
- **Middle finger: Induced current**

Mnemonic

"Left Lifts motors, Right Raises generators"

Question 4(a) OR [3 marks]

A conductor of length 1 metre moves with speed of 30m/s in magnetic field of 0.6 Tesla making angle of 30$^\circ withthefield.CalculatedynamicallyEMFinducedinit.(usesin30^\circ = 0.5)$

Solution

Table 10: Given Parameters

Parameter	Value
Length (l)	1 meter
Speed (v)	30 m/s
Magnetic Field (B)	0.6 Tesla
Angle ( )	30°

Formula: E = Blv sin
Calculation: E = 0.6 $\times 1 \times 30 \times 0.5 = 9 volts$
Therefore, induced EMF = 9 volts

Mnemonic

"EMF Emerges from Field, velocity and Length with angle"

Question 4(b) OR [4 marks]

State & explain Lenz's law.

Solution

Diagram:

```
+{-{-}{-}{-}{-}{-}{-}{-}+}
|   N    |  Moving
|   |    |  Magnet
|   v    |
+{-{-}{-}{-}{-}{-}{-}{-}+}
    |
    v
+{-{-}{-}{-}{-}{-}{-}{-}+}
|        |  Induced
|       |  Current
|        |
+{-{-}{-}{-}{-}{-}{-}{-}+}
  Coil
```

Lenz's Law: The direction of induced EMF or current is always such that it opposes the cause that produces it.
Application: When a magnet approaches a coil, induced current creates a magnetic field that repels the approaching magnet.

Mnemonic

"Lenz Likes to Oppose"

Question 4(c) OR [7 marks]

Explain Statically and dynamically induced EMF.

Solution

Table 11: Statically vs Dynamically Induced EMF

Parameter	Statically Induced EMF	Dynamically Induced EMF
Definition	EMF induced due to change in current/flux	EMF induced due to movement of conductor in magnetic field
Physical action	Fixed conductor, changing field	Moving conductor in fixed field
Example	Transformer	Generator
Formula	e = -N dΦ/dt	e = Blv sin

Mnemonic

"Static Stays but flux Changes, Dynamic Drives through field"

Question 5(a) [3 marks]

Explain PV Cell.

Solution

Diagram:

```
    Sun Rays
       |||
       vvv
    +{-{-}{-}{-}{-}{-}{-}+}
    |  N    |
    |{-{-}{-}{-}{-}{-}{-}| {-} P{-}N Junction}
    |  P    |
    +{-{-}{-}{-}{-}{-}{-}+}
       | |
       | |
       Load
```

- **PV Cell: Device that converts sunlight directly into electricity using photovoltaic effect.**
- **Working: Sunlight excites electrons in semiconductor material, creating voltage difference.**
- **Material: Typically made from silicon with P-N junction.**

Mnemonic

"Photons Visit, Current Created"

Question 5(b) [4 marks]

Explain the solar PV panel and arrays.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Solar Cell] {-{-}{}|"Multiple cells in series"| B[Solar Panel]}
    B {-{-}{}|"Multiple panels connected"| C[Solar Array]}
{Highlighting}
{Shaded}
```

Table 12: Solar System Hierarchy

Component	Description
PV Cell	**Basic unit that converts sunlight to electricity (0.5V - 0.6V)**
PV Panel	**Multiple cells connected in series/parallel (typically 12V, 24V)**
PV Array	**Multiple panels connected to achieve required voltage/current**

Mnemonic

"Cells Combine into Panels, Panels Produce Arrays"

Question 5(c) [7 marks]

Draw and explain block diagram of wind power system.

Solution

Diagram:

```
flowchart LR
    A[Wind Turbine] {-{-}|"Mechanical energy"| B[Gearbox]}
    B {-{-}|"High speed rotation"| C[Generator]}
    C {-{-}|"AC power"| D[Power Electronics]}
    D {-{-}|"Controlled output"| E[Transformer]}
    E {-{-}|"Grid{-}compatible power"| F[Grid/Load]}
    G[Control System] {-.{-} A \& C \& D}
```

Components of Wind Power System:

1. **Wind Turbine:** Converts wind energy to mechanical energy
2. **Gearbox:** Increases rotational speed for generator
3. **Generator:** Converts mechanical energy to electrical energy
4. **Power Electronics:** Controls and regulates electrical output
5. **Transformer:** Steps up/down voltage for transmission/distribution
6. **Control System:** Monitors and optimizes overall operation

Mnemonic

"Wind Turns Gears, Generating Electrical Returns"

Question 5(a) OR [3 marks]

State the benefits of green energy.

Solution

Table 13: Benefits of Green Energy

Benefit Category	Examples
Environmental	Reduces pollution, Minimizes carbon footprint
Economic	Creates jobs, Reduces energy dependency
Health	Improves air quality, Reduces health issues
Sustainability	Renewable, Inexhaustible sources

Mnemonic

"Clean Energy Creates Economic Salvation"

Question 5(b) OR [4 marks]

Explain Solar PV applications in brief.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
```

```
graph TD
    A[Solar PV Applications] {-{-}{} B[Residential]}
    A {-{-}{} C[Commercial]}
    A {-{-}{} D[Industrial]}
    A {-{-}{} E[Utility Scale]}
    A {-{-}{} F[Off{-}grid]}
{Highlighting}
{Shaded}
```

Solar PV Applications:

1. **Residential: Rooftop systems, Solar water heaters**
2. **Commercial: Building integrated PV, Solar parking**
3. **Industrial: Process heating, Power generation**
4. **Utility Scale: Solar farms, Grid support**
5. **Off-grid: Rural electrification, Remote applications**

Mnemonic

"Residences, Commerce, Industry Utilize Solar"

Question 5(c) OR [7 marks]

Explain different types of Green energy.

Solution

Table 14: Types of Green Energy

Type	Source	Applications
Solar	Sun	PV systems, Thermal plants
Wind	Moving air	Wind turbines, Windmills
Hydro	Flowing water	Dams, Run-of-river systems
Biomass	Organic matter	Combustion, Biogas production
Geothermal	Earth's heat	Direct heating, Power plants
Tidal	Ocean tides	Barrage systems, Tidal turbines

Diagram:

```
pie title "Green Energy Sources"
    "Solar" : 30
    "Wind" : 25
    "Hydro" : 20
    "Biomass" : 15
    "Geothermal" : 7
    "Tidal" : 3
```

Mnemonic

"Sun, Wind, Hydro, Biomass, Geothermal, Tidal - Simple Ways Humans Build Green Tomorrow"