Subject Name Solutions

4311101 – Summer 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Define the following term (1) Resistance (2) Electrical energy (3) Electrical Power

Solution

Term	Definition
Resistance	The property of a material that opposes the flow of electric current, measured in ohms (Ω)
Electrical Energy	The ability to do work by electrical means, measured in joules (J) or kilowatt-hours (kWh)
Electrical Power	The rate at which electrical energy is transferred or converted, measured in watts (W)

Mnemonic

"RIP" - Resistance Impedes Path, Energy Is Potential, Power Is Performance

Question 1(b) [4 marks]

State and Explain Ohm's Law & write limitations of it.

Solution

Ohm's Law: The current flowing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to its resistance.

Mathematically: V = IR, where:

- V = Voltage (volts)
- I = Current (amperes)
- R = Resistance (ohms)

```
flowchart LR
    V[Voltage] {-{-} I[Current]}
    R[Resistance] {-{-}Limits{-}{-} I}
```

Limitations of Ohm's Law:

- Not applicable to non-linear devices (semiconductors, gas discharge tubes)
- Doesn't hold at high temperatures
- Not valid for unilateral elements (diodes)
- Fails for time-varying currents

Mnemonic

"VIRO" - Voltage Is Resistance times Output current

Question 1(c) [7 marks]

Explain series and parallel connection of batteries.

Solution

Series Connection of Batteries:

```
flowchart LR
    B1[Battery 1] {-{-} B2[Battery 2] {-}{-} B3[Battery 3] {-}{-} L[Load]}
    L {-{-} B1}
```

Characteristics of Series Connection:

- **Total Voltage** = Sum of individual voltages ($V = V_1 + V_2 + \ldots + V_n$)
- **Current** = Same through all batteries
- **Applications**: Higher voltage requirements
- **Internal Resistance**: Increases ($R_s = r_1 + r_2 + \ldots + r_n$)

Parallel Connection of Batteries:

```
flowchart LR
    B1[Battery 1] {-{-} L[Load]}
    B2[Battery 2] {-{-} L}
    B3[Battery 3] {-{-} L}
    L {-{-} B1}
    L {-{-} B2}
    L {-{-} B3}
```

Characteristics of Parallel Connection:

- **Voltage** = Same as individual battery (if identical)
- **Total Current** = Sum of individual currents ($I = I_1 + I_2 + \ldots + I_n$)
- **Applications**: Higher current capacity required
- **Internal Resistance**: Decreases ($1/R_p = 1/r_1 + 1/r_2 + \ldots + 1/r_n$)

Mnemonic

"VSCP" - Voltage Sums in Series, Current Parallels

Question 1(c) OR [7 marks]

Explain series and parallel connection of Resistors.

Solution

Series Connection of Resistors:

```
flowchart LR
    S[Source] {-{-} R1[R1] {-}{-} R2[R2] {-}{-} R3[R3] {-}{-} S}
```

Characteristics of Series Connection:

- **Equivalent Resistance** = Sum of individual resistances ($R_s = R_1 + R_2 + \ldots + R_n$)
- **Current** = Same through all resistors
- **Voltage** = Divided across resistors proportional to resistance values
- **Power** divided as per voltage distribution

Parallel Connection of Resistors:

```
flowchart LR
    S[Source] {-{-} R1[R1]}
    S {-{-} R2[R2]}
    S {-{-} R3[R3]}
    R1 {-{-} S}
    R2 {-{-} S}
    R3 {-{-} S}
```

Characteristics of Parallel Connection:

- **Equivalent Resistance**: $1/R_p = 1/R_1 + 1/R_2 + \ldots + 1/R_n$
- **Voltage** = Same across all resistors
- **Current** = Divided inverse-proportionally to resistance values
- **Total Current** = Sum of individual currents

Mnemonic

"RISE-VICE" - Resistance Increases in Series, Voltage Is Constant in Every parallel

Question 2(a) [3 marks]

Define: (1) Amplitude (2) Frequency (3) Time period

Solution

Term	Definition
Amplitude	Maximum displacement of a waveform from its mean position, measured in volts or amperes
Frequency	Number of complete cycles occurring in one second, measured in hertz (Hz)
Time Period	Time taken to complete one cycle of waveform, measured in seconds (s)

Mnemonic

"AFT" - Amplitude is the Full height, Time period is the Total cycle

Question 2(b) [4 marks]

10Ω, 20Ω and 30Ω resistors are connected in series and 100V supply is given to them. Find (1) Equivalent resistance (2) Circuit current (3) Voltage drop across each Resistor (4) Power loss in each resistor.

Solution

Diagram:

```
  +{-{-}[10Ω]{-}{-}[20Ω]{-}{-}[30Ω]{-}{-}+}
  |                          |
(100V)                       |
  |                          |
  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

Solution:

Parameter	Calculation	Result
Equivalent Resistance	R = 10Ω + 20Ω + 30Ω	60Ω
Circuit Current	I = 100V/60Ω	1.67A
Voltage across 10Ω	$V_1 = 1.67A \times 10$	16.7V
Voltage across 20Ω	$V_2 = 1.67A \times 20$	33.3V
Voltage across 30Ω	$V_3 = 1.67A \times 30$	50.0V
Power in 10Ω	$P_1 = 1.67^2 \times 10$	27.8W
Power in 20Ω	$P_2 = 1.67^2 \times 20$	55.6W
Power in 30Ω	$P_3 = 1.67^2 \times 30$	83.4W

Mnemonic

"REÇVP" - Resistances Equivalent Causes Voltage and Power division

Question 2(c) [7 marks]

Explain A.C Through pure Resistor with wave form & vector diagram.

Solution

In a pure resistive circuit with AC supply:

Key Characteristics:

- Current and voltage are **in phase** with each other
- Circuit follows Ohm's Law: V = IR
- Power is always positive (P = VI)
- No reactive power consumed
- Power factor = 1 (cos
  = 1)

Waveform:

```
          V     V     V

   V      V      V        V

   {-{-}{-} Voltage waveform}
   {-{-}{-} Current waveform (identical phase)}
```

Vector Diagram:

```
       V (voltage)

              I (current)
```

Mnemonic

"PARVIP" - Pure AC Resistor has Voltage In Phase with current

Question 2(a) OR [3 marks]

Define: (1) cycle (2) Form factor (3) Peak factor

Solution

Term	Definition
Cycle	One complete repetition of a periodic waveform from start point to same point again
Form Factor	Ratio of RMS value to average value of AC waveform (For sine wave = 1.11)
Peak Factor	Ratio of maximum value to RMS value of AC waveform (For sine wave = 1.414)

Mnemonic

"CFP" - Cycle Finishes a Pattern, Form Factor = Vrms/Vavg, Peak Factor = Vmax/Vrms

Question 2(b) OR [4 marks]

20Ω, 30Ω and 50Ω resistors are connected in parallel and 60V supply is given to them. Find (1) Current in each Resistor. (2) Total current (3) Equivalent resistance (4) Power loss in each resistor.

Solution

Diagram:

```
       [20Ω]

   +         +

  (60V)   [30Ω]

       [50Ω]

   +         +
```

Solution:

Parameter	Calculation	Result
Current in 20Ω	$I_1 = 60V/20$	3A
Current in 30Ω	$I_2 = 60V/30$	2A
Current in 50Ω	$I_3 = 60V/50$	1.2A
Total Current	I = 3A + 2A + 1.2A	6.2A
Equivalent Resistance	1/Req = 1/20 + 1/30 + 1/50	9.68Ω
Power in 20Ω	$P_1 = 60V \times 3A$	180W
Power in 30Ω	$P_2 = 60V \times 2A$	120W
Power in 50Ω	$P_3 = 60V \times 1.2A$	72W

Mnemonic

"VICTIM" - Voltage Is Constant, Total current Is the Measure (in parallel)

Question 2(c) OR [7 marks]

Explain A.C Through pure capacitor with wave form & vector diagram.

Solution

In a pure capacitive circuit with AC supply:
Key Characteristics:

- Current **leads** voltage by 90°
- Capacitive reactance Xc = 1/(2 fC)
- Only reactive power (no active power)
- Power factor = 0 (lagging)
- Average power over complete cycle = 0

Waveform:

```
         Current



       V    V    V



   V



                    V       V       V
```

```
                    Voltage



Vector Diagram:

        I (current)






       V V (voltage)
```

Mnemonic

"CLEAR-90" - Capacitive Load has Electrical Angle Reaching 90°$(current leads voltage)$

Question 3(a) [3 marks]

Define RMS value and average value related to alternating waveform write formula of it.

Solution

Term	Definition	Formula
RMS Value	Root Mean Square value - equivalent DC value producing the same heating effect	Vrms = 0.707 $\times Vmax for sine wave$
Average Value	Mean value of all instantaneous values over half cycle	Vavg = 0.637 $\times Vmax for sine wave$

Mnemonic

"RAM" - RMS Averages the Mean square (RMS = 0.707, AVG = 0.637)

Question 3(b) [4 marks]

If A.C. current is represented by equation i=25 sin(314t). Calculate (1) R.m.s. value (2) Average value (3) Frequency (4) Time period

Solution

Given equation: i = 25 sin(314t)

Parameter	Calculation	Result
Maximum value	Imax = 25 A	25 A
RMS value	Irms = Imax/$\sqrt{2}$ = 25/1.414	17.68 A
Average value	Iavg = 2Imax/ = 2×25/3.14	15.92 A
Angular frequency	= 314 rad/s	314 rad/s
Frequency	f = /2 = 314/6.28	50 Hz
Time period	T = 1/f = 1/50	0.02 s

Mnemonic

"SMART" - Sine's Maximum divided by root 2 equals RMS Then 2/ for Average

Question 3(c) [7 marks]

Explain star connection of resistors and Derive equation shows relationship between voltage and current in star connection.

Solution

Star (Y) Connection:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    N((N)) {-{-}{-} R1[R1] {-}{-}{-} L1((L1))}
    N {-{-}{-} R2[R2] {-}{-}{-} L2((L2))}
    N {-{-}{-} R3[R3] {-}{-}{-} L3((L3))}
    N((Neutral))
{Highlighting}
{Shaded}
```

Characteristics of Star Connection:

- Three resistors connected at common point (neutral)
- Line voltage (VL) = $\sqrt{3} \times Phasevoltage(Vph)$
- Line current (IL) = Phase current (Iph)
- For balanced load: IL = Iph
- Total power = 3 $\times Phasepower$

Mathematical Relationship:

- Phase voltage: Vph = VL/$\sqrt{3}$
- Phase current: Iph = IL
- For balanced resistive load: Iph = Vph/R
- Therefore: IL = VL/($\sqrt{3}$)

Mnemonic

"SLIP-3" - Star Line current Is Phase current, Line voltage is Phase voltage times root-3

Question 3(a) OR [3 marks]

Explain generation of alternating E.M.F.

Solution

Generation of Alternating EMF:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    subgraph "Rotating Coil in Magnetic Field"
    N[N] {-{-}{-} M((Magnet)) {-}{-}{-} S[S]}
    end
    M {-{-}{-} R[Rotating Coil]}
    R {-{-}{-} EMF[EMF Output]}
{Highlighting}
{Shaded}
```

Process:

- Coil rotates in uniform magnetic field
- Flux linkage changes with angle of rotation
- Rate of change of flux induces EMF
- EMF follows sinusoidal pattern: e = Emax sin(t)
- Frequency depends on rotation speed

Mnemonic

"FRAME" - Flux Rotation Alternates Magnetic EMF

Question 3(b) OR [4 marks]

An alternating EMF is expressed by e= 100 sin2 50t. Find out (1) Max value of EMF (2) Frequency (3) Time period (4) Angular Frequency

Solution

Given equation: e = 100 sin2 50t

Parameter	Calculation	Result
Maximum EMF	Emax = 100 V	100 V
Angular Frequency	= 2 50 = 314 rad/s	314 rad/s
Frequency	f = 50 Hz (directly from equation)	50 Hz
Time Period	T = 1/f = 1/50	0.02 s

Mnemonic

"FAST" - Frequency And period are reciprocals, Sin's Top value is maximum

Question 3(c) OR [7 marks]

Explain star connection and Derive equation shows relationship between voltage and current in delta connection.

Solution

Delta (Δ) Connection:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    L1((L1)) {-{-}{-} R1[R1] {-}{-}{-} L2((L2))}
    L2 {-{-}{-} R2[R2] {-}{-}{-} L3((L3))}
    L3 {-{-}{-} R3[R3] {-}{-}{-} L1}
{Highlighting}
{Shaded}
```

Characteristics of Delta Connection:

- Three resistors connected in closed loop
- Line voltage (VL) = Phase voltage (Vph)
- Line current (IL) = $\sqrt{3} \times Phasecurrent(Iph)$
- For balanced load: Vph = VL
- Total power = 3 $\times Phasepower$

Mathematical Relationship:

- Phase voltage: Vph = VL
- Phase current: Iph = Vph/R
- Line current: IL = $\sqrt{3} \times Iph$
- Therefore: IL = $\sqrt{3} \times VL/R$

Mnemonic

"DELVIr3" - Delta Equal Line Voltage, Its line current equals phase current times root-3

Question 4(a) [3 marks]

Define (1) M.M.F. (2) Reluctance (3) flux

Solution

Term	Definition
M.M.F. (Magnetomotive Force)	The force that produces magnetic flux in a magnetic circuit, measured in ampere-turns (AT)
Reluctance	The magnetic equivalent of resistance, opposition to magnetic flux, measured in AT/Wb
Flux	The total magnetic field passing through a surface, measured in webers (Wb)

Mnemonic

"MFR" - MMF Flows against Reluctance like current flows against resistance

Question 4(b) [4 marks]

Explain Apparent, Active and Reactive power in A.C circuits.

Solution

Power Type	Symbol & Unit	Definition
Apparent Power	S (VA)	Vector sum of active and reactive power
Active Power	P (W)	Actual work-producing power consumed by the load
Reactive Power	Q (VAR)	Power that oscillates between source and load

Power Triangle:

```
        \^{ Q (Reactive Power)}




                   S (Apparent Power)
                 /
                /
               /
              /
             /

           /
         /      {}
           P (Active Power)
```

Relationships:

- S = $\sqrt{(P^2 + Q^2)}$
- P = S $\times cos$
- Q = S $\times sin$
- Power factor = cos
  = P/S

Mnemonic

"SPARQ" - S is Power Apparent, Real is P, Q is reactive

Question 4(c) [7 marks]

Compare electric and magnetic circuit.

Solution

Parameter	Electric Circuit	Magnetic Circuit
Force	EMF (V)	MMF (AT)
Opposition	Resistance (Ω)	Reluctance (AT/Wb)
Flow	Current (A)	Flux (Wb)
Ohm's Law	V = IR	MMF = $\Phi \times S$
Medium	Conductor	Ferromagnetic material
Energy	Stored in electric field	Stored in magnetic field
Leakage	Negligible	Significant
Path	Conductors	Usually closed loop
Material Property	Conductivity	Permeability
Current Flow	Electron flow	No particle flow

Mnemonic

"VIRO-MSΦS" - Voltage Is to Resistance as MMF is to Reluctance, Our flows Similar

Question 4(a) OR [3 marks]

State and explain Fleming's left hand rule.

Solution

Fleming's Left Hand Rule: Used to find the direction of the force experienced by a current-carrying conductor placed in a magnetic field.

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Fleming{s Left Hand Rule"}
    T[Thumb: Force] {-{-}{-} F[Forefinger: Field] {-}{-}{-} M[Middle finger: Current]}
    end
{Highlighting}
{Shaded}
```

Application:

- Thumb → $Direction of Force(F)$
- Forefinger → $Direction of magnetic Field(B)$
- Middle finger → $Direction of Current(I)$
- Only works when fingers are perpendicular to each other

Mnemonic

"FBI-Left" - Force, B-field, and I-current directions are shown by the Left hand

Question 4(b) OR [4 marks]

Draw power triangle and explain each component of it.

Solution

Power Triangle:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    O {-{-}{-} P[Active Power P]}
    O {-{-}{-} S[Hypotenuse: Apparent Power S]}
    P {-{-}{-} Q[Reactive Power Q]}
    P {-.{-} A[Power Factor Angle  ]}
{Highlighting}
{Shaded}
```

Components:

Component	Symbol	Unit	Meaning
Active Power	P	Watt (W)	Real power doing useful work
Reactive Power	Q	VAR	Power oscillating between source and load
Apparent Power	S	VA	Vector sum of P and Q
Power Factor	cos	-	Ratio of active to apparent power (P/S)

Relationships:

- S$^2 = P^2 + Q^2$
- P = S $\times cos$
- Q = S $\times sin$

Mnemonic

"SPQR" - S is Pythagoras of P and Q, Ratio of P/S is power factor

Question 4(c) OR [7 marks]

Differentiate statically and dynamically induced E.M.F.

Solution

Parameter	Statically Induced EMF	Dynamically Induced EMF
Definition	EMF induced due to change in current in the primary coil	EMF induced due to relative motion between conductor and magnetic field
Mechanism	Change in linkage flux	Cutting of magnetic flux
Movement	No physical movement required	Requires relative motion
Examples	Transformer, inductor	Generator, motor
Faraday's Law	e = -N(dΦ/dt)	e = Blv
Application	Power transfer without motion	Power generation through motion
Energy Conversion	Electrical to magnetic and back	Mechanical to electrical or vice versa

Mnemonic

"STIM-DMOV" - STatically Induced needs Magnetic flux change, Dynamically needs MOVement

Question 5(a) [3 marks]

Define (1) solar cell (2) solar panel (3) solar array

Solution

Term	Definition
Solar Cell	Basic photovoltaic unit that converts sunlight directly into electricity through semiconductor material
Solar Panel	Collection of solar cells connected in series/parallel in a frame
Solar Array	Multiple solar panels connected together to form a larger electricity-generating unit

Mnemonic

"CPA" - Cell Produces electricity, Panel Arrays cells, Array is collection of panels

Question 5(b) [4 marks]

Differentiate HAWT and VAWT.

Solution

Parameter	Horizontal Axis Wind Turbine (HAWT)	Vertical Axis Wind Turbine (VAWT)
Axis Orientation	Parallel to ground	Perpendicular to ground
Efficiency	Higher (35-45%)	Lower (15-30%)
Wind Direction	Needs to face the wind	Works with wind from any direction
Generator Location	At the top of tower	Can be placed at ground level
Space Required	More	Less
Noise	Higher	Lower
Examples	Propeller-type, widely used commercially	Darrieus, Savonius designs

Mnemonic

"HAVE" - Horizontal Aligns with wind, Vertical Enjoys omnidirectional wind

Question 5(c) [7 marks]

Draw and explain the Block diagram of solar power system.

Solution

Solar Power System Block Diagram:

```
flowchart LR
    S[Solar Panel] {-{-} C[Charge Controller]}
    C {-{-} B[Battery Bank]}
    B {-{-} I[Inverter]}
    I {-{-} L[AC Load]}
    B {-{-} D[DC Load]}
```

Components:

1. **Solar Panels**: Convert sunlight to DC electricity
2. **Charge Controller**: Regulates battery charging, prevents overcharging
3. **Battery Bank**: Stores energy for use when sunlight isn't available

4. **Inverter**: Converts DC to AC power for household appliances
5. **Loads**: AC loads (appliances) and DC loads (LED lights, etc.)

Optional Components:

- **Monitoring System**: Tracks power generation/consumption
- **Grid Connection**: Allows selling excess electricity

Mnemonic

"SCBIL" - Solar Collects, Battery Inverts for Loads

Question 5(a) OR [3 marks]

Explain the need of green energy for our planet.

Solution

Need for Green Energy:

1. **Sustainability**: Renewable sources won't deplete unlike fossil fuels
2. **Pollution Reduction**: Minimizes air and water pollution from burning fossil fuels
3. **Climate Change**: Reduces greenhouse gas emissions that cause global warming
4. **Energy Security**: Decreases dependence on imported fuels
5. **Economic Benefits**: Creates jobs and reduces health costs related to pollution

Mnemonic

"SPECS" - Sustainable, Pollution-free, Economic, Climate-friendly, Secure

Question 5(b) OR [4 marks]

Classify green energy and explain any one in detail.

Solution

Classification of Green Energy Sources:

```
mindmap
  root((Green Energy))
    Solar
    Wind
    Hydro
    Biomass
    Geothermal
    Tidal
```

Solar Energy in Detail:

- **Working Principle**: Photovoltaic effect converts sunlight to electricity
- **Components**: Solar cells, panels, inverters, batteries
- **Applications**: Residential power, industrial use, transportation
- **Advantages**: No pollution, abundant source, low maintenance
- **Limitations**: Weather dependent, requires storage, initial cost

Mnemonic

"SWHBGT" - Sun Wind Hydro Biomass Geothermal Tidal are green energy types

Question 5(c) OR [7 marks]

Explain block diagram of wind power system and explain the operation of wind power system.

Solution

Wind Power System Block Diagram:

```
flowchart LR
    W[Wind Turbine] {-{-} G[Generator]}
    G {-{-} C[Controller]}
    C {-{-} B[Battery Storage]}
    C {-{-} I[Inverter]}
    I {-{-} L[Load]}
    C {-{-} GR[Grid Connection]}
```

Operation:

1. **Wind Turbine**: Converts wind's kinetic energy to mechanical energy
2. **Generator**: Transforms mechanical rotation to electrical energy
3. **Controller**: Regulates power output and protects from high winds
4. **Battery**: Stores excess energy (for off-grid systems)
5. **Inverter**: Converts DC to AC for consumption
6. **Grid Connection**: Feeds excess power to grid or draws when needed

Types of Wind Turbines:

- Horizontal Axis (HAWT): Main commercial type
- Vertical Axis (VAWT): Better for urban settings

Wind Speed Requirements:

- Cut-in speed: 3-5 m/s
- Rated output: 12-15 m/s
- Cut-out speed: 25 m/s (for safety)

Mnemonic

"WGCBIL" - Wind Generates, Controller Balances, Inverter Loads