

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] --> B[Current]
    C[Potential Energy] --> 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

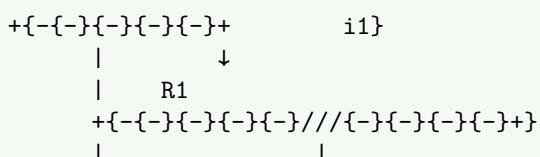
“Current Charges, Potential Pushes”

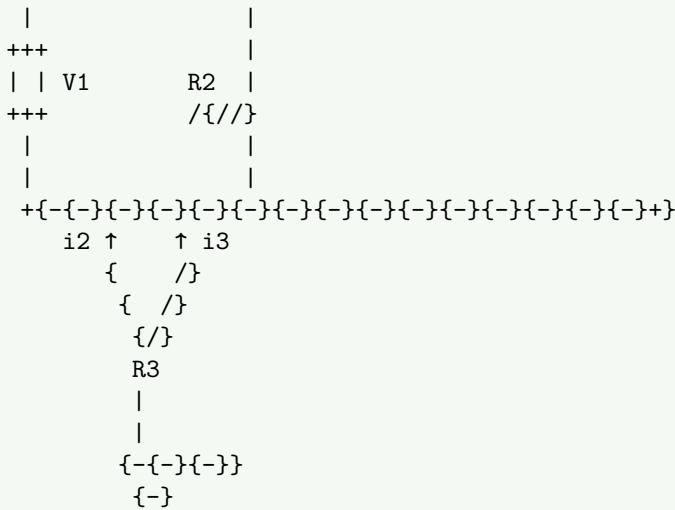
Question 1(c) [7 marks]

Explain KCL and KVL with examples.

Solution

Diagram:





Kirchhoff's Current Law (KCL):

- Sum of currents entering a node equals sum of currents leaving it.
- Example: At node X, $i_1 + i_2 = i_3$

Kirchhoff's Voltage Law (KVL):

- Sum of voltage drops around any closed loop equals zero.
- Example: $V_1 - V(R_1) - V(R_2) = 0$

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 | $Req = R_1 + R_2 + R_3 + \dots$ | $1/Req = 1/R_1 + 1/R_2 + 1/R_3 + \dots$ |
| 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

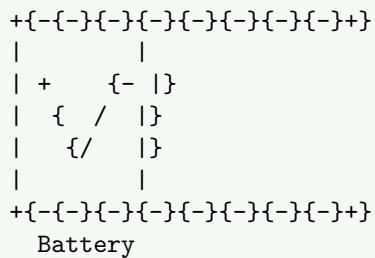
“Resistance Restricts, Resistivity Relates to material”

Question 2(b) [4 marks]

Define cell and write names of different types of cell.

Solution

Diagram:



- **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

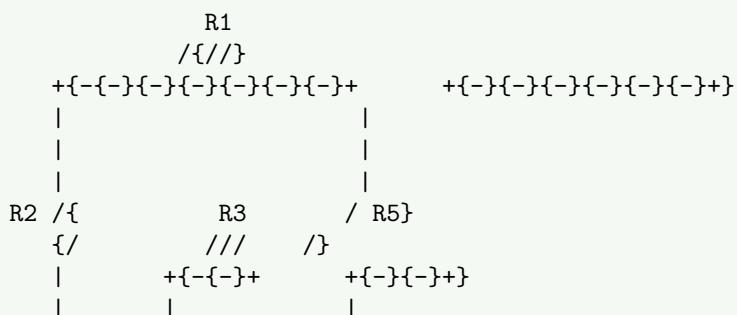
“Primary Produces once, Secondary Serves repeatedly”

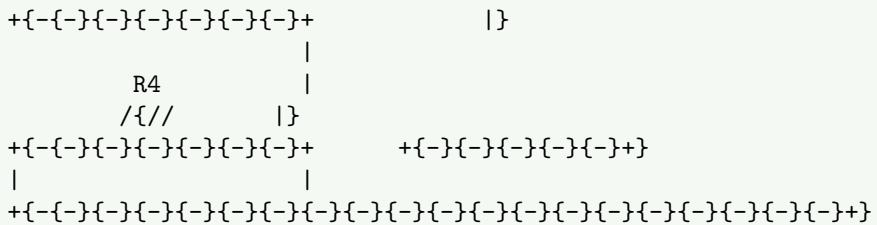
Question 2(c) [7 marks]

Calculate total equivalent resistance of the above circuit if $R_1=5\Omega$, $R_2=3\Omega$, $R_3=4\Omega$, $R_4=1\Omega$, $R_5=2\Omega$.

Solution

Diagram:





Step-by-step solution:

1. R2 and R3 are in series: $R_{23} = R_2 + R_3 = 3\Omega + 4\Omega = 7\Omega$
2. R23 and R4 are in parallel: $\frac{1}{R_{234}} = \frac{1}{7} + \frac{1}{1} = \frac{8}{7}$ Therefore, $R_{234} = \frac{7}{8} = 0.875\Omega$
3. R1, R234, and R5 are in series: $R_{eq} = R_1 + R_{234} + R_5 = 5\Omega + 0.875\Omega + 2\Omega = 7.875\Omega$

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 | $10 \text{ hours/day} \times 30 \text{ days} = 300 \text{ hours}$ | Given |
| Energy consumed | $0.1kW \times 300h = 30kWh = 30 \text{ units}$ | $E = P \times t$ |
| Rate | Rs. 5/unit | Given |
| Total cost | $30 \text{ units} \times \text{Rs.} 5/\text{unit} = \text{Rs.} 150$ | Cost = Units × Rate |

Therefore, cost of energy = **Rs. 150**

Mnemonic

“Energy × Rate = Electric bill rate”

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] --> 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° and the current in a purely inductive circuit lags the applied voltage by 90° .

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:
 $i = C \times dv/dt = CV\cos(t) = I\sin(t + 90^\circ)$
 - Current leads voltage by 90°
- For Inductive Circuit:
- Voltage equation:
 $v = L \times di/dt = LI\cos(t) = V\sin(t + 90^\circ)$
 - 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 | $V_{rms} = V_m/\sqrt{2} = 0.707V_m$ |
| Average Value | Mean of all instantaneous values over half cycle | $V_{avg} = 2V_m/ = 0.637 V_m$ |

- 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 | $P = VI \cos \phi$ | W (Watt) |
| Reactive Power (Q) | Power oscillating between source and load | $Q = VI \sin \phi$ | 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 | $V_R = V_m \sin(t)$ |
| Y-phase | $V_Y = V_m \sin(t - 120^\circ)$ |
| B-phase | $V_B = V_m \sin(t - 240^\circ)$ |

Where V_m is the maximum voltage and ω is the angular frequency.

Mnemonic

“Red phase Reference, Yellow lags 120° , Blue brings up 240° ”

Question 3(b) OR [4 marks]

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

Solution

Diagram:

- 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) | $\sqrt{3} \times \text{PhaseVoltage}$ | Same as Phase Voltage |
| Line Current (IL) | Same as Phase Current | $\sqrt{3} \times \text{PhaseCurrent}$ |
| 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 | $V_m = \sqrt{2} \times V_{rms}$ | $V_m = \sqrt{2} \times 230 = 325.27V$ |
| Peak-to-Peak Value | $V_{p-p} = 2 \times V_m$ | $V_{p-p} = 2 \times 325.27 = 650.54V$ |

Therefore, peak-to-peak value = 650.54V

Mnemonic

“RMS to Peak - multiply by $\sqrt{2}$, Peak to Peak – double it”

Question 4(b) [4 marks]

An alternating current is given by $i=142.14\sin(628t)$ find frequency and time period.

Solution

Table 9: Calculation Steps

| Parameter | Formula | Calculation |
|----------------|-------------------------|--|
| Given equation | $i = 142.14 \sin(628t)$ | $= 628 \text{ rad/s}$ |
| Frequency | $f = / (2\pi)$ | $f = 628 / (2\pi) = 100 \text{ Hz}$ |
| Time Period | $T = 1/f$ | $T = 1/100 = 0.01 \text{ s} = 10 \text{ ms}$ |

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

Mnemonic

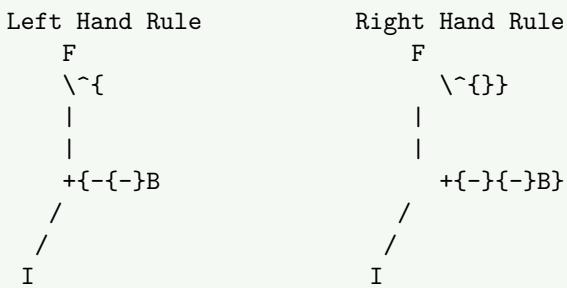
“Frequency From omega divide 2 , Time takes inverse”

Question 4(c) [7 marks]

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

Solution

Diagram:



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° with the field. Calculate dynamically EMF induced in it. (use $\sin 30^\circ = 0.5$)

Solution

Table 10: Given Parameters

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

Formula: $E = Blv \sin \theta$

Calculation: $E = 0.6 \times 1 \times 30 \times 0.5 = 9 \text{ volts}$

Therefore, induced EMF = 9 volts

Mnemonic

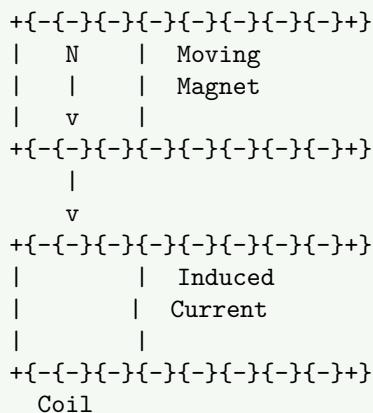
“EMF Emerges from Field, velocity and Length with angle”

Question 4(b) OR [4 marks]

State & explain Lenz's law.

Solution

Diagram:



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 | $e = -N \frac{d\Phi}{dt}$ | $E = Blv \sin \theta$ |

Mnemonic

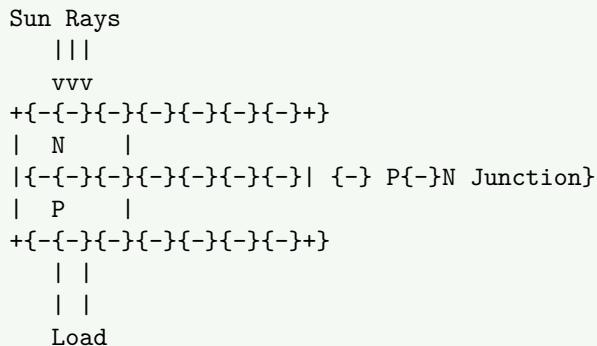
“Static Stays but flux Changes, Dynamic Drives through field”

Question 5(a) [3 marks]

Explain PV Cell.

Solution

Diagram:



- 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] --> B["Mechanical energy"]
    B --> C["High speed rotation"]
    C --> D["AC power"]
    D --> E["Controlled output"]
    E --> F["Grid-compatible power"]
    F --> G[Control System]
    G --> A
    C & D & E & F
```

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”