Subject Name Solutions

4361106 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

List different types of Renewable Energy Sources and explain any one in detail.

Solution

Table 1: Types of Renewable Energy Sources

Type	Source	Application
Solar	Sun's radiation	Solar panels, heating
Wind	Moving air	Wind turbines
Hydroelectric	Flowing water	Dams, turbines
Biomass	Organic matter	Biofuels, heating
Geothermal	Earth's heat	Power plants, heating

Solar Energy Explanation:

- **Photovoltaic Effect**: Converts sunlight directly into electricity using silicon cells
- **Advantages**: Clean, abundant, renewable
- **Applications**: Rooftop systems, solar farms

Mnemonic

"SWHBG - Sun Wins Hearts By Going"

Question 1(b) [4 marks]

List the different types of Solar Cells and explain any two.

Solution

Table 2: Types of Solar Cells

Type	Efficiency	Cost	Application
Silicon	15-20%	Medium	Residential
Monocrystalline	18-22%	High	Premium systems
Polycrystalline	15-17%	Low	Budget systems
Thin Film	10-12%	Very Low	Large installations
Amorphous Silicon	6-8%	Low	Small devices

Monocrystalline Silicon:

- **Structure**: Single crystal structure with uniform appearance
- **Efficiency**: Highest among silicon cells (18-22%)

Polycrystalline Silicon:

- **Structure**: Multiple crystals with blue speckled appearance
- **Cost**: Lower manufacturing cost than monocrystalline

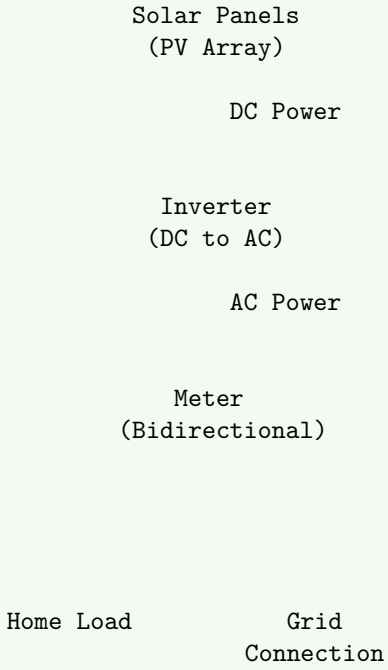
Mnemonic

"My Poly Thin Amp - Most Popular Types Available"

Question 1(c) [7 marks]

Draw and explain Block Diagram of a Home Solar rooftop system.

Solution



Components Explanation:

- **Solar Panels**: Convert sunlight to DC electricity using photovoltaic effect
- **Inverter**: Converts DC power to AC power for home use
- **Bidirectional Meter**: Measures power consumption and excess power fed to grid
- **Home Load**: Electrical appliances and devices
- **Grid Connection**: Connects to utility grid for backup and selling excess power

Working Principle:

- **Day Operation**: Solar panels generate electricity, inverter converts to AC
- **Excess Power**: Fed back to grid through net metering
- **Night Operation**: Power drawn from grid when solar not available

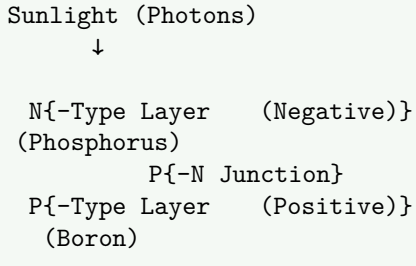
Mnemonic

"Solar Inverter Meter Home Grid - Simple Installation Makes Happy Generation"

Question 1(c) OR [7 marks]

Explain with diagram Solar Photovoltaic effect & Principle of photovoltaic conversion.

Solution



```
External
 Circuit
```

Photovoltaic Effect Process:
- **Photon Absorption**: Solar photons hit silicon atoms
- **Electron Excitation**: Electrons gain energy and move to conduction band
- **Charge Separation**: P-N junction creates electric field
- **Current Flow**: Electrons flow through external circuit

Key Parameters:
- **Band Gap**: Energy difference between valence and conduction bands
- **Open Circuit Voltage**: Maximum voltage when no current flows
- **Short Circuit Current**: Maximum current when terminals are shorted

Conversion Efficiency:
- **Theoretical Maximum**: ~33% for single junction cells
- **Practical Efficiency**: 15-22% for commercial cells

Mnemonic

"Photons Push Electrons Past Junction - Power Production Perfectly Planned"

Question 2(a) [3 marks]

What is Nanotechnology? List its applications.

Solution

Definition: Nanotechnology is the manipulation of matter at atomic and molecular scale (1-100 nanometers).

Table 3: Applications of Nanotechnology

Field	Application	Benefit
Electronics	Transistors, Memory	Miniaturization
Medicine	Drug delivery, Imaging	Targeted treatment
Energy	Solar cells, Batteries	Higher efficiency
Materials	Composites, Coatings	Enhanced properties
Environment	Water purification	Clean technology

Key Features:
- **Scale**: 1 nanometer = $10^{-9} meters$
- **Properties**: Different properties at nanoscale
- **Applications**: Cross-disciplinary technology

Mnemonic

"Nano Makes Everything More Efficient"

Question 2(b) [4 marks]

List the different types of EV technologies and explain any two.

Solution

Table 4: Types of EV Technologies

Type	Full Form	Power Source	Range
BEV	Battery Electric Vehicle	Battery only	150-400 km
HEV	Hybrid Electric Vehicle	Engine + Battery	600+ km
PHEV	Plug-in Hybrid Electric	Engine + Battery	50-80 km electric
FCEV	Fuel Cell Electric Vehicle	Hydrogen fuel cell	400-600 km

Battery Electric Vehicle (BEV):
- **Power Source**: Rechargeable battery pack only
- **Operation**: Pure electric drive with zero emissions
- **Charging**: External charging from grid required

Hybrid Electric Vehicle (HEV):
- **Power Source**: Internal combustion engine + electric motor
- **Operation**: Automatic switching between power sources
- **Efficiency**: Regenerative braking recovers energy

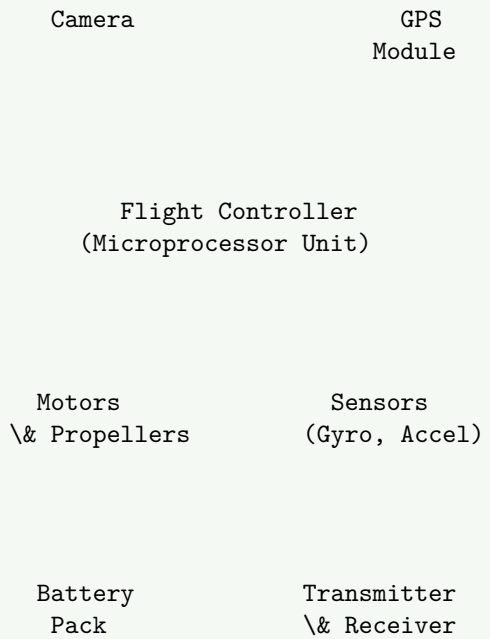
Mnemonic

"Big Hybrid Plug Fuel - Better Transportation Options"

Question 2(c) [7 marks]

Describe the Block diagram of a drone and its major components.

Solution



Major Components:
Flight Controller:
- **Function**: Central processing unit controlling all operations
- **Features**: Stabilization, navigation, autopilot functions

Motors and Propellers:
- **Brushless Motors**: High efficiency, precise speed control
- **Propellers**: Generate thrust for lift and movement

Sensors Package:

- **Gyroscope**: Measures angular velocity for stability
- **Accelerometer**: Detects acceleration and tilt
- **Barometer**: Altitude measurement

Power System:
- **Battery**: Lithium Polymer (LiPo) for high power density
- **ESC**: Electronic Speed Controllers for motor control

Communication:
- **Transmitter/Receiver**: Radio communication with remote controller
- **GPS**: Position tracking and navigation

Mnemonic

"Flying Controllers Motor Sensors Power Communication - Drones Fly Perfectly"

Question 2(a) OR [3 marks]

What is UAV? List its applications.

Solution

Definition: UAV (Unmanned Aerial Vehicle) is an aircraft operated without human pilot onboard.

Table 5: UAV Applications

Sector	Application	Benefit
Agriculture	Crop monitoring, Spraying	Precision farming
Security	Surveillance, Border patrol	Enhanced monitoring
Delivery	Package delivery	Fast transportation
Photography	Aerial photography	New perspectives
Inspection	Infrastructure inspection	Safe access

Key Features:
- **Autonomous**: Self-controlled flight capabilities
- **Remote Control**: Operated from ground station
- **Versatile**: Multiple payload options

Mnemonic

"Unmanned Aircraft Versatile - Applications Are Vast"

Question 2(b) OR [4 marks]

List the different types of EV energy sources and explain any two.

Solution

Table 6: EV Energy Sources

Type	Technology	Storage	Efficiency
Battery	Lithium-ion	Chemical	90-95%
Fuel Cell	Hydrogen	Chemical	50-60%
Ultracapacitor	Electric field	Electrical	95%+
Flywheel	Kinetic energy	Mechanical	85-90%
Regenerative Braking	Motor generator	Kinetic to electrical	70-80%

Battery System:
- **Technology**: Lithium-ion cells with high energy density
- **Advantages**: Mature technology, good energy storage
- **Charging**: External charging infrastructure required

Fuel Cell System:
- **Technology**: Hydrogen combines with oxygen to produce electricity
- **Advantages**: Quick refueling, long range
- **Challenges**: Hydrogen infrastructure limited

Mnemonic

"Battery Fuel Ultra Fly Regen - Energy Sources Enable Vehicles"

Question 2(c) OR [7 marks]

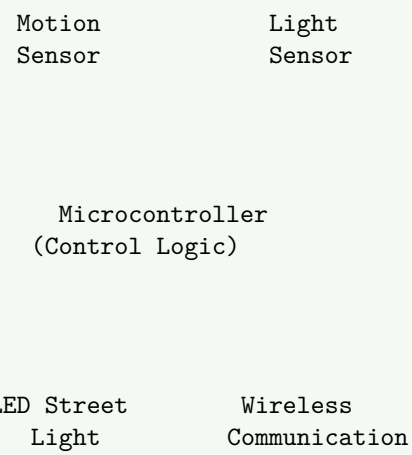
List the different types of Smart Systems. Explain with a diagram any 2 smart systems.

Solution

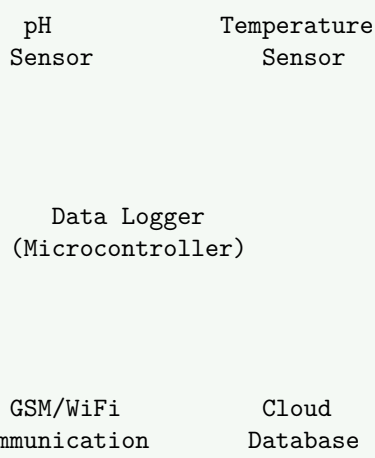
Table 7: Types of Smart Systems

System	Function	Technology
Smart Homes	Home automation	IoT, sensors
Smart Cars	Self-driving	AI, sensors
Smart City	Urban management	IoT, big data
Smart Grid	Power management	Communication
Smart Health	Health monitoring	Wearables, AI

Smart Street Light System:



Smart Water Pollution Monitoring:



Features:

- **Automation**: Intelligent response to environmental conditions
- **Energy Efficiency**: Optimized power consumption
- **Remote Monitoring**: Real-time data collection and analysis

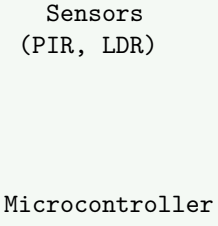
Mnemonic

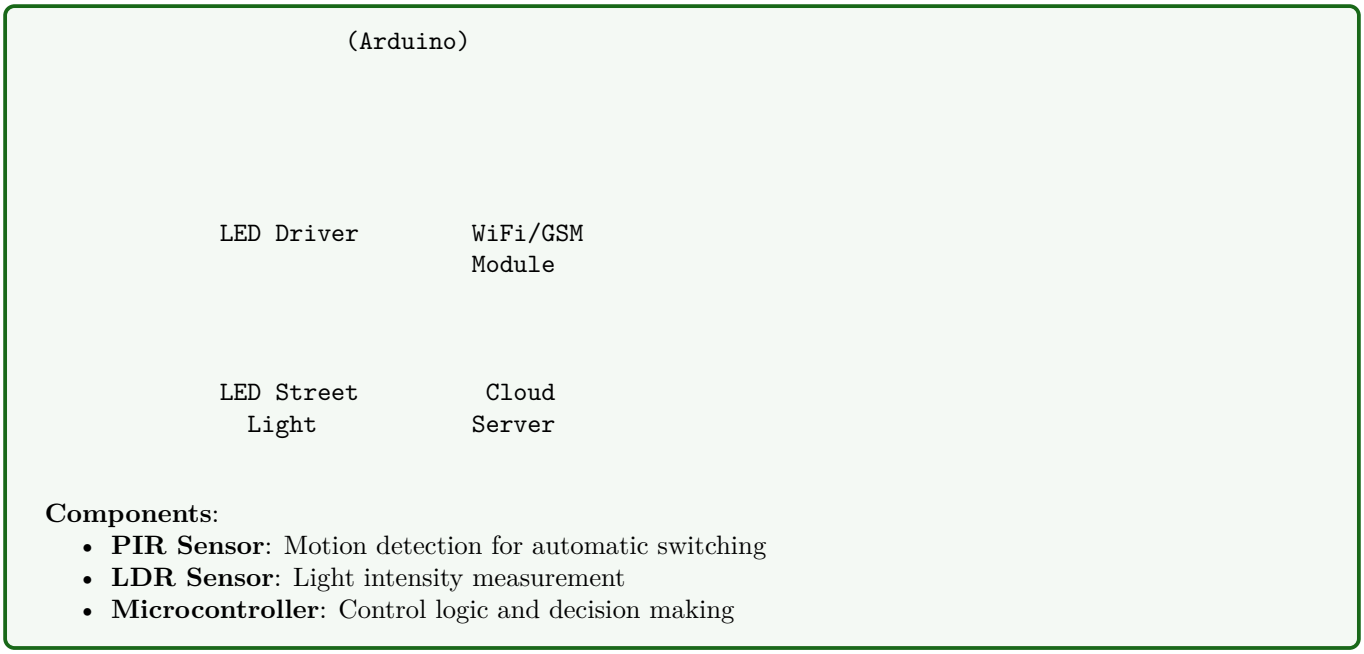
"Smart Systems Save Energy Efficiently"

Question 3(a) [3 marks]

Draw the Block diagram of a Smart Street light control and monitoring system.

Solution





Components:
- **PIR Sensor**: Motion detection for automatic switching
- **LDR Sensor**: Light intensity measurement
- **Microcontroller**: Control logic and decision making

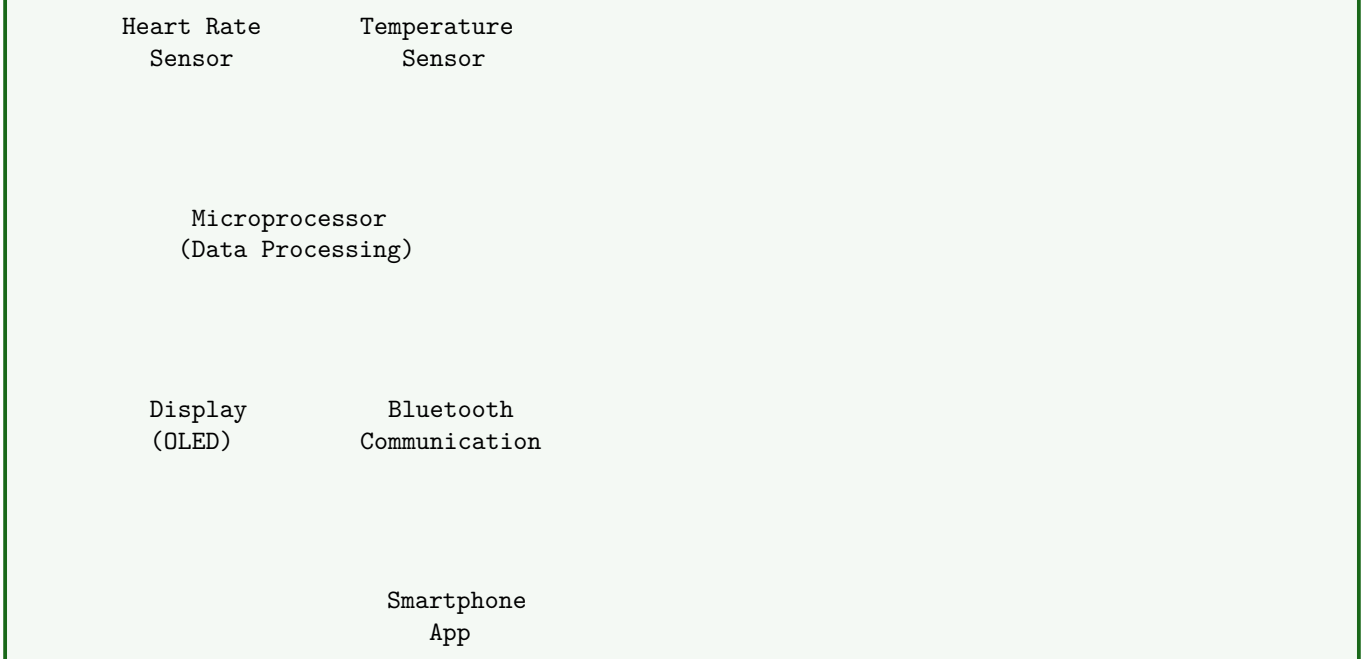
Mnemonic

"Smart Streets Save Power Perfectly"

Question 3(b) [4 marks]

Draw and explain the block diagram of a wearable health monitoring system.

Solution



Explanation:
- **Sensors**: Monitor vital signs continuously
- **Processing**: Analyze data and detect anomalies
- **Communication**: Send data to smartphone via Bluetooth
- **Alerts**: Notify user and emergency contacts if needed

Applications:
- **Fitness Tracking**: Step count, calories burned

- **Health Monitoring**: Heart rate, blood pressure
- **Emergency Alert**: Automatic SOS in critical conditions

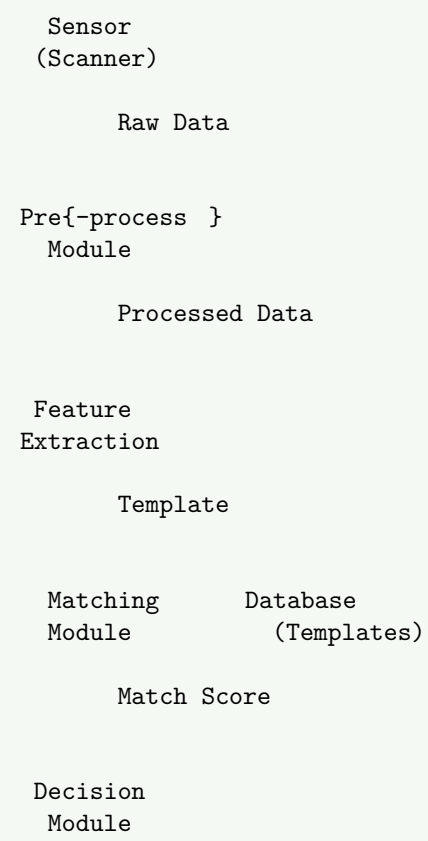
Mnemonic

"Wearable Health Watches Monitor Continuously"

Question 3(c) [7 marks]

Explain Biometric systems and their basic block diagram.

Solution



Components Explanation:
Sensor Module:
- **Function**: Captures biometric data (fingerprint, face, iris)
- **Technology**: Optical, capacitive, or thermal sensors

Pre-processing:
- **Function**: Noise removal and image enhancement
- **Operations**: Filtering, normalization, quality assessment

Feature Extraction:
- **Function**: Extract unique characteristics
- **Output**: Mathematical template representing biometric

Matching Module:
- **Function**: Compare captured template with database
- **Algorithm**: Pattern matching algorithms

Database:
- **Function**: Store enrolled biometric templates
- **Security**: Encrypted storage for privacy

Decision Module:
- **Function**: Accept or reject based on threshold

- **Parameters**: False Accept Rate (FAR), False Reject Rate (FRR)

Types of Biometrics:
- **Physiological**: Fingerprint, face, iris, retina
- **Behavioral**: Voice, signature, gait

Applications:
- **Access Control**: Building security, device unlocking
- **Identification**: Border control, forensics
- **Authentication**: Banking, attendance systems

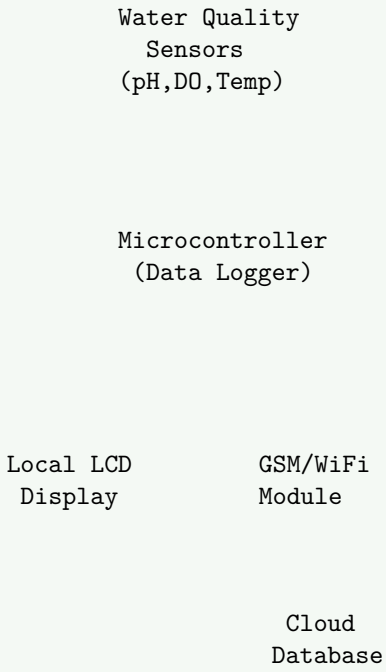
Mnemonic

"Sensors Process Features Match Database Decide - Biometric Security Better Done"

Question 3(a) OR [3 marks]

Draw the Block diagram of a Water pollution monitoring system.

Solution



Sensors:
- **pH Sensor**: Measures water acidity/alkalinity
- **DO Sensor**: Dissolved oxygen measurement
- **Temperature**: Water temperature monitoring

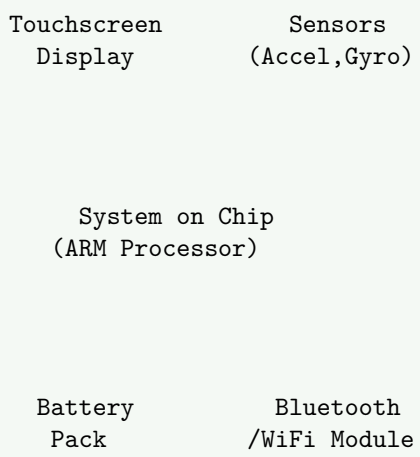
Mnemonic

"Water Quality Monitoring Prevents Pollution"

Question 3(b) OR [4 marks]

Draw and explain the block diagram of a Smart Watch.

Solution



Explanation:

- **Display**: OLED touchscreen for user interface
- **Sensors**: Motion tracking and health monitoring
- **Processor**: Low-power ARM-based SoC
- **Connectivity**: Bluetooth for smartphone pairing

Features:

- **Health Tracking**: Heart rate, steps, sleep
- **Notifications**: Calls, messages, apps
- **Apps**: Weather, music, payments

Mnemonic

"Smart Watches Show Health Information"

Question 3(c) OR [7 marks]

Explain AR/VR core technology and discuss its applications.

Solution

AR/VR Core Technologies:

Table 8: AR vs VR Technology

Aspect	Augmented Reality (AR)	Virtual Reality (VR)
Environment	Real + Digital overlay	Completely virtual
Hardware	Smartphone, AR glasses	VR headset, controllers
Immersion	Partial	Complete
Interaction	Touch, gesture	Controllers, hand tracking

Core Components:
Display Technology:
- **AR**: See-through displays, projection
- **VR**: High-resolution OLED/LCD screens

Tracking Systems:
- **Motion Tracking**: 6-DOF (Degrees of Freedom) tracking
- **Eye Tracking**: Gaze detection for interaction
- **Hand Tracking**: Gesture recognition

Processing Power:
- **Graphics Processing**: Real-time 3D rendering
- **Computer Vision**: Object recognition and tracking
- **AI/ML**: Scene understanding and optimization

Applications:
Education:
- **AR**: Interactive textbooks, 3D models overlay
- **VR**: Virtual classrooms, historical simulations

Healthcare:
- **AR**: Surgery assistance, medical training
- **VR**: Therapy, pain management, training

Entertainment:
- **AR**: Pokemon Go, Snapchat filters
- **VR**: Gaming, virtual concerts, movies

Industry:
- **AR**: Maintenance instructions, quality inspection
- **VR**: Training simulations, design review

Retail:
- **AR**: Virtual try-on, product visualization
- **VR**: Virtual showrooms, immersive shopping

Future Trends:
- **Mixed Reality**: Combining AR and VR
- **Haptic Feedback**: Touch sensation
- **Cloud Rendering**: Remote processing power

Mnemonic

"AR VR Display Track Process Apply - Technology Transforms Reality"

Question 4(a) [3 marks]

Differentiate between Inorganic and Organic electronics.

Solution

Table 9: Inorganic vs Organic Electronics

Parameter	Inorganic Electronics	Organic Electronics
Materials	Silicon, Germanium	Carbon-based compounds
Processing	High temperature	Low temperature
Flexibility	Rigid	Flexible
Cost	High	Low
Performance	High speed, stable	Lower speed, improving

Key Differences:
- **Structure**: Inorganic uses crystalline materials, organic uses polymer chains
- **Manufacturing**: Inorganic requires clean rooms, organic uses printing methods
- **Applications**: Inorganic for high-performance, organic for large-area devices

Mnemonic

"Inorganic Is Rigid, Organic Offers Flexibility"

Question 4(b) [4 marks]

List different types of organic components and explain any two.

Solution

Table 10: Types of Organic Components

Component	Full Form	Application
OLED	Organic Light Emitting Diode	Displays
OFET	Organic Field Effect Transistor	Switching
OPVD	Organic Photovoltaic Device	Solar cells
OECT	Organic Electrochemical Transistor	Biosensors

Organic LED (OLED):
- **Structure**: Organic layers between electrodes
- **Working**: Electroluminescence when current flows
- **Advantages**: Self-illuminating, flexible, wide viewing angle

Organic FET (OFET):
- **Structure**: Organic semiconductor channel
- **Working**: Current controlled by gate voltage
- **Applications**: Flexible circuits, sensors

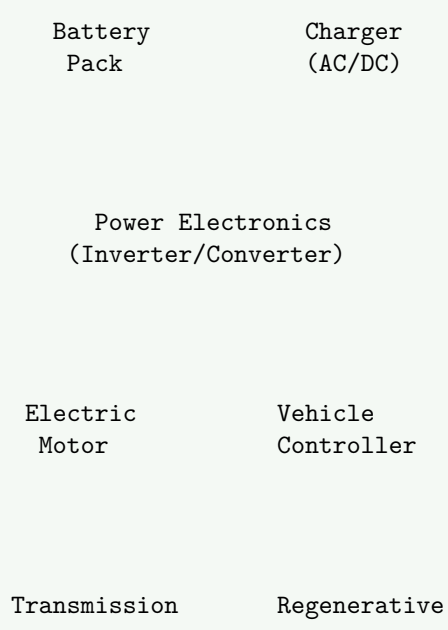
Mnemonic

"Organic Only Offers Outstanding Options"

Question 4(c) [7 marks]

Draw and explain the block diagram of an electric vehicle.

Solution



```
System          Braking



Wheels
```

Component Explanation:
Battery Pack:
- **Technology**: Lithium-ion cells in series/parallel
- **Function**: Energy storage for vehicle propulsion
- **Management**: Battery Management System (BMS) for safety

Power Electronics:
- **Inverter**: Converts DC to AC for motor drive
- **Converter**: DC-DC conversion for auxiliary systems
- **Control**: Precise motor speed and torque control

Electric Motor:
- **Type**: Permanent magnet synchronous or induction motor
- **Advantages**: High efficiency (90-95%), instant torque
- **Control**: Variable frequency drive for speed control

Vehicle Controller:
- **Function**: Central control unit managing all systems
- **Features**: Accelerator input, motor control, safety monitoring
- **Communication**: CAN bus for system integration

Charging System:
- **AC Charging**: Level 1 (120V) and Level 2 (240V)
- **DC Fast Charging**: High-power charging for quick top-up
- **Onboard Charger**: Converts AC grid power to DC

Regenerative Braking:
- **Function**: Converts kinetic energy back to electrical energy
- **Efficiency**: Recovers 15-25% of energy during braking
- **Integration**: Works with mechanical brakes

Advantages:
- **Efficiency**: 3-4 times more efficient than ICE vehicles
- **Emissions**: Zero local emissions
- **Maintenance**: Fewer moving parts, lower maintenance

Mnemonic

"Battery Powers Motor Through Controller - Electric Vehicles Very Efficient"

Question 4(a) OR [3 marks]

Write the Advantages of Organic Electronics.

Solution

Table 11: Advantages of Organic Electronics

Advantage	Description	Application
Flexibility	Bendable, rollable	Flexible displays
Low Cost	Cheap materials, printing	Consumer electronics
Large Area	Easy scaling	Large displays
Light Weight	Thin, lightweight	Wearables
Transparency	See-through devices	Smart windows

Key Benefits:
- **Processing**: Low-temperature manufacturing
- **Energy**: Low-power operation
- **Customization**: Tunable properties
- **Integration**: Compatible with plastics

Mnemonic

"Organic Advantages Are Obviously Outstanding"

Question 4(b) OR [4 marks]

Write about AR/VR Industry perspectives and opportunities.

Solution

Market Perspectives:

Table 12: AR/VR Market Segments

Segment	Market Size	Growth Rate	Key Players
Gaming	$12B	25%	Meta, Sony
Enterprise	$8B	35%	Microsoft, Magic Leap
Healthcare	$3B	40%	Various startups
Education	$2B	30%	Google, Apple

Opportunities:
- **5G Networks**: Enable cloud-based VR/AR
- **AI Integration**: Intelligent content adaptation
- **Hardware Miniaturization**: Lighter, more comfortable devices

Challenges:
- **Motion Sickness**: VR comfort issues
- **Battery Life**: Power consumption optimization
- **Content Creation**: Need for quality immersive content

Future Outlook:
- **Metaverse**: Virtual worlds and social interaction
- **Remote Work**: Virtual collaboration platforms
- **Digital Twins**: Industrial applications

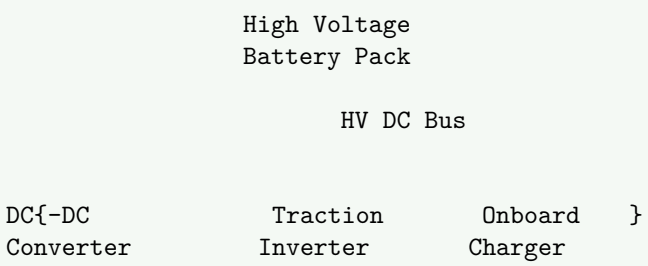
Mnemonic

"AR VR Market Growing Rapidly"

Question 4(c) OR [7 marks]

Draw and explain the EV architecture.

Solution



```
    12V Battery     AC Motor        Charging
    \& Auxiliaries   (Traction)       Port



                    Transmission
                      \& Wheels
```

EV Architecture Components:
High Voltage Battery Pack:
- **Voltage**: 300-800V for modern EVs
- **Capacity**: 40-100+ kWh energy storage
- **Management**: Battery Management System (BMS) for safety and optimization

Traction Inverter:
- **Function**: Converts DC battery power to 3-phase AC for motor
- **Control**: Variable frequency and voltage control
- **Efficiency**: 95-98% power conversion efficiency

AC Traction Motor:
- **Type**: Permanent magnet synchronous motor (PMSM) or induction motor
- **Power**: 100-400+ kW depending on vehicle class
- **Torque**: Instant torque delivery from zero RPM

DC-DC Converter:
- **Function**: Steps down HV battery voltage to 12V for auxiliaries
- **Power**: 2-5 kW typical capacity
- **Isolation**: Galvanic isolation between HV and LV systems

Onboard Charger:
- **Function**: Converts AC grid power to DC for battery charging
- **Power**: 3-22 kW for AC charging
- **Standards**: SAE J1772, CCS, CHAdeMO compatibility

12V Auxiliary Battery:
- **Function**: Powers lights, infotainment, HVAC when vehicle off
- **Type**: Lead-acid or Li-ion auxiliary battery
- **Backup**: Emergency power for safety systems

Vehicle Control Unit:
- **Function**: Central controller coordinating all systems
- **Communication**: CAN bus network integration
- **Safety**: Functional safety (ISO 26262) compliance

Thermal Management:
- **Battery Cooling**: Liquid cooling for temperature control
- **Motor Cooling**: Prevents overheating during high power operation
- **Integration**: Heat pump systems for cabin heating

Safety Systems:
- **HV Isolation**: Insulation monitoring and contactor control
- **Crash Safety**: Automatic HV disconnect in accident
- **Ground Fault**: Detection and protection systems

Mnemonic

"High Voltage Battery Powers Traction Through Control - EV Architecture Efficiently Arranged"

Question 5(a) [3 marks]

Write briefly about Monocrystalline Silicon solar cells.

Solution

Monocrystalline Silicon Solar Cells:

Table 13: Monocrystalline Silicon Characteristics

Parameter	Value	Description
Efficiency	18-22%	Highest among silicon cells
Structure	Single crystal	Uniform crystal lattice
Color	Dark blue/black	Uniform appearance
Lifespan	25+ years	Long-term reliability
Cost	High	Premium pricing

Manufacturing Process:

- **Czochralski Method**: Single crystal growth from molten silicon
- **Wafer Cutting**: Thin slices cut from crystal ingot
- **Doping**: P-type and N-type regions created

Advantages:

- **High Efficiency**: Best power output per area
- **Space Efficient**: Less area needed for same power
- **Durability**: Long operational life

Applications:

- **Residential Systems**: Premium rooftop installations
- **Commercial**: High-efficiency requirements
- **Space Applications**: Where efficiency is critical

Mnemonic

"Mono Means Single Crystal - Maximum Efficiency"

Question 5(b) [4 marks]

Describe the working principle of a drone.

Solution

Drone Working Principle:

Basic Physics:

- **Lift Generation**: Propellers create downward airflow (Newton's 3rd Law)
- **Thrust Control**: Variable propeller speed controls vertical movement
- **Stability**: Gyroscopic effect and active control maintain balance

Flight Control Mechanism:

Table 14: Drone Movement Control

Movement	Control Method	Motor Action
Ascend	Increase all motor speeds	All props faster
Descend	Decrease all motor speeds	All props slower
Forward	Tilt forward	Rear motors faster
Backward	Tilt backward	Front motors faster
Left/Right	Bank left/right	Opposite side faster
Rotation	Torque differential	Diagonal pairs

Control Systems:

- **Gyroscope**: Measures angular velocity for stability
- **Accelerometer**: Detects acceleration and tilt angles
- **Magnetometer**: Compass heading reference
- **Barometer**: Altitude measurement and hold

Flight Modes:

- **Manual**: Direct pilot control
- **Stabilized**: Auto-leveling assistance
- **GPS Hold**: Position holding using GPS
- **Autonomous**: Pre-programmed flight paths

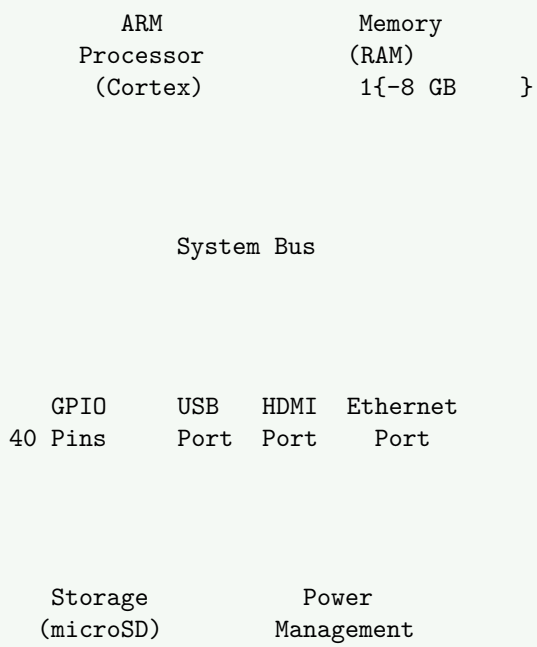
Mnemonic

"Propellers Push Air Down - Drone Flies Up"

Question 5(c) [7 marks]

Explain the Block diagram of Raspberry Pi.

Solution



Core Components:

ARM Processor:

- **Type**: Broadcom SoC (System on Chip)
- **Architecture**: ARM Cortex-A series (32/64-bit)
- **Speed**: 1.2-1.8 GHz depending on model
- **Features**: Built-in GPU for graphics processing

Memory (RAM):

- **Type**: LPDDR4 SDRAM
- **Capacity**: 1GB to 8GB depending on Pi model
- **Shared**: GPU shares system memory
- **Performance**: High-speed memory interface

GPIO (General Purpose Input/Output):

- **Pins**: 40-pin connector for external devices
- **Functions**: Digital I/O, PWM, SPI, I2C, UART
- **Voltage**: 3.3V logic levels
- **Current**: Limited current per pin for safety

Connectivity Options:
- **USB Ports**: 2-4 USB 2.0/3.0 ports for peripherals
- **HDMI**: Digital video and audio output
- **Ethernet**: Wired network connectivity (Gigabit on newer models)
- **WiFi/Bluetooth**: Built-in wireless on newer models

Storage:
- **microSD**: Primary storage for OS and data
- **Boot**: Boots from microSD card
- **Capacity**: 8GB minimum, 32GB+ recommended

Power Management:
- **Supply**: 5V DC via USB-C or micro-USB
- **Current**: 2.5-3A typical requirement
- **Regulation**: On-board voltage regulators for 3.3V and 1.8V rails

Additional Features:
- **Camera Interface**: CSI connector for Pi Camera
- **Display Interface**: DSI connector for official touchscreen
- **Audio**: 3.5mm analog audio output
- **Real-time Clock**: Optional RTC for timekeeping

Software Support:
- **Operating System**: Raspberry Pi OS (Debian-based)
- **Programming**: Python, C++, Scratch, Java support
- **GPIO Control**: Libraries for hardware interfacing

Applications:
- **Education**: Learning programming and electronics
- **IoT Projects**: Sensor monitoring, home automation
- **Media Center**: Video streaming and playback
- **Industrial**: Prototyping and small-scale automation

Advantages:
- **Cost-effective**: Low-cost computing platform
- **Community**: Large community support and resources
- **Flexibility**: General-purpose computing with I/O capabilities
- **Education**: Designed for learning and experimentation

Mnemonic

"Raspberry Pi Processes Everything Through GPIO - Perfect Platform for Projects"

Question 5(a) OR [3 marks]

Write briefly about Polycrystalline Silicon solar cells.

Solution

Polycrystalline Silicon Solar Cells:

Table 15: Polycrystalline Silicon Characteristics

Parameter	Value	Description
Efficiency	15-17%	Good efficiency, lower than mono
Structure	Multiple crystals	Grain boundaries visible
Color	Blue speckled	Non-uniform appearance
Lifespan	25+ years	Reliable performance
Cost	Medium	Cost-effective option

Manufacturing Process:
- **Casting Method**: Molten silicon cooled in square molds
- **Multiple Crystals**: Random crystal orientation forms grains
- **Wafer Production**: Square wafers with less waste

Advantages:
- **Cost-effective**: Lower manufacturing cost than monocrystalline
- **Less Waste**: Square shape reduces material waste
- **Good Performance**: Reasonable efficiency for most applications

Applications:
- **Residential**: Budget-friendly solar installations
- **Utility Scale**: Large solar farms where cost matters
- **Commercial**: Medium-scale installations

Mnemonic

"Poly Means Many Crystals - More Affordable Choice"

Question 5(b) OR [4 marks]

Compare Types of machine learning techniques: supervised and unsupervised.

Solution

Table 16: Supervised vs Unsupervised Learning

Aspect	Supervised Learning	Unsupervised Learning
Data Type	Labeled data	Unlabeled data
Goal	Prediction	Pattern discovery
Examples	Classification, Regression	Clustering, Association
Algorithms	SVM, Decision Trees	K-means, PCA
Evaluation	Accuracy, Precision	Silhouette score

Supervised Learning:
- **Training**: Uses input-output pairs for learning
- **Types**: Classification (categories) and Regression (continuous values)
- **Applications**: Email spam detection, price prediction

Unsupervised Learning:
- **Training**: Finds hidden patterns in data without labels
- **Types**: Clustering (grouping) and Dimensionality reduction
- **Applications**: Customer segmentation, anomaly detection

Key Differences:
- **Guidance**: Supervised has teacher, unsupervised learns independently
- **Complexity**: Supervised is more straightforward, unsupervised more exploratory
- **Validation**: Supervised easier to validate, unsupervised needs domain expertise

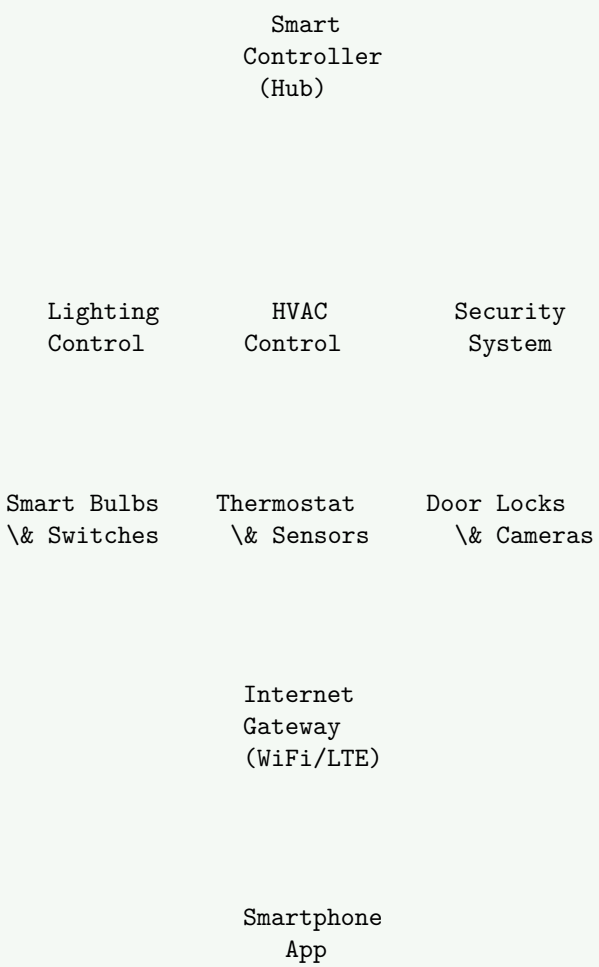
Mnemonic

"Supervised Sees Solutions, Unsupervised Uncovers Secrets"

Question 5(c) OR [7 marks]

Draw and explain the block diagram of a Smart Home.

Solution



Smart Home System Components:
Smart Controller (Hub):

- **Function**: Central control unit coordinating all devices
- **Protocols**: ZigBee, Z-Wave, WiFi, Bluetooth communication
- **Processing**: Local automation rules and remote connectivity
- **Integration**: Works with voice assistants (Alexa, Google)

Lighting Control System:

- **Smart Bulbs**: LED bulbs with wireless connectivity
- **Smart Switches**: Retrofit existing lighting with smart control
- **Features**: Dimming, color changing, scheduling, motion sensing
- **Energy Saving**: Automatic on/off based on occupancy

HVAC Control System:

- **Smart Thermostat**: Programmable temperature control
- **Sensors**: Temperature, humidity, occupancy detection
- **Learning**: Adaptive scheduling based on usage patterns
- **Efficiency**: Energy optimization and remote control

Security System:

- **Smart Locks**: Keyless entry with smartphone control
- **Cameras**: Indoor/outdoor surveillance with recording
- **Sensors**: Door/window, motion, glass break detection
- **Alerts**: Real-time notifications to smartphone

Internet Gateway:

- **Connectivity**: High-speed internet for cloud services
- **Router**: WiFi network for device connectivity
- **Security**: Network firewall and device authentication
- **Backup**: Cellular backup for critical functions

Smartphone Integration:

- **Mobile App**: Remote control and monitoring interface

- **Voice Control**: Integration with voice assistants
- **Automation**: Scene creation and scheduling
- **Notifications**: Security alerts and system status

Smart Home Features:

Automation Scenarios:

- **Good Morning**: Lights on, coffee maker start, thermostat adjust
- **Away Mode**: All lights off, security armed, thermostat setback
- **Good Night**: Doors lock, lights dim, security sensors active
- **Movie Mode**: Lights dim, blinds close, entertainment system on

Energy Management:

- **Load Monitoring**: Track energy usage by device
- **Peak Shaving**: Avoid high electricity rate periods
- **Solar Integration**: Coordinate with solar panels and batteries
- **Smart Appliances**: Dishwasher, washer run during low-cost hours

Security Features:

- **Perimeter Protection**: Door/window sensors, cameras
- **Interior Protection**: Motion sensors, glass break detectors
- **Access Control**: Smart locks, keypad entry, visitor management
- **Emergency Response**: Automatic alerts to security company

Benefits:

- **Convenience**: Remote control and automation
- **Energy Efficiency**: Optimized usage patterns
- **Security**: Enhanced home protection
- **Comfort**: Personalized environment control
- **Property Value**: Increased home value

Communication Protocols:

- **WiFi**: High bandwidth for cameras and streaming
- **ZigBee**: Low power mesh network for sensors
- **Z-Wave**: Reliable mesh for critical devices
- **Bluetooth**: Short-range direct device connection

Future Trends:

- **AI Integration**: Machine learning for better automation
- **Edge Computing**: Local processing for faster response
- **Energy Storage**: Battery backup and grid services
- **Health Monitoring**: Air quality, sleep tracking integration

Mnemonic

"Smart Homes Control Everything Through Internet - Convenience Comfort Security Efficiency"