**Smart HVAC (Heating, Ventilation, and Air Conditioning) System** for a large office building. Our goal is to create an efficient HVAC system that optimizes energy usage, maintains comfort, and adapts to changing conditions. Throughout this case study, we’ll incorporate various design patterns to achieve these objectives.

**Problem Statement: Smart HVAC System for an Office Building**

**Context:**

Our office building houses hundreds of employees and spans multiple floors. The HVAC system needs to regulate temperature, humidity, and air quality while minimizing energy consumption. We’ll design a smart HVAC system that adapts to occupancy, external weather, and time of day.

**Design Patterns Used:**

1. **Builder Pattern**:
   * **Scenario**: Creating complex HVAC configurations.
   * **Use Case**: When setting up HVAC zones (e.g., conference rooms, open workspaces), we need to handle various parameters (temperature setpoints, airflow rates, humidity levels).
   * **Solution**: Use the builder pattern to construct HVACZone objects with flexible configuration options.
2. **Observer Pattern**:
   * **Scenario**: Monitoring environmental changes.
   * **Use Case**: When external weather conditions (e.g., temperature, sunlight) change, we want to adjust HVAC settings accordingly.
   * **Solution**: Implement an observer pattern where weather sensors notify the HVAC controller about changes.
3. **Factory Method Pattern**:
   * **Scenario**: Creating HVAC equipment.
   * **Use Case**: Our system manages various HVAC devices (e.g., air handlers, chillers, thermostats). We need a consistent way to create and manage these devices.
   * **Solution**: Implement an HVACDeviceFactory that produces different types of equipment based on building requirements.
4. **Decorator Pattern**:
   * **Scenario**: Enhancing HVAC functionality.
   * **Use Case**: We want to add features like energy-saving modes, occupancy detection, and adaptive scheduling to HVAC components.
   * **Solution**: Use decorators to dynamically enhance HVACComponent objects without modifying their core behavior.
5. **Singleton Pattern**:
   * **Scenario**: Managing system-wide resources.
   * **Use Case**: We need a single point of control for global settings (e.g., building occupancy, holiday schedules).
   * **Solution**: Create an HVACSystemManager class as a singleton to ensure consistent behavior across the entire system.
6. **Strategy Pattern**:
   * **Scenario**: Energy optimization algorithms.
   * **Use Case**: Our system employs different strategies for energy conservation (e.g., load shedding during peak hours, pre-cooling before occupancy).
   * **Solution**: Define a family of energy-saving strategies and allow runtime selection based on building conditions.
7. **Composite Pattern**:
   * **Scenario**: Representing HVAC zones.
   * **Use Case**: We want to model the building’s layout (floors, rooms, corridors) and their HVAC requirements.
   * **Solution**: Use the composite pattern to treat individual zones and their hierarchies uniformly.

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