Design Principles

Coupling : It defines how dependent one object on another object.

- Coupling is a measure of strength of connection between any two system components.
- The more any one components knows about other components, the tighter the coupling (worse) is between those components.

Tight coupling (worse)

```
class Traveler {
    Car c = new Car();
    void startJourney(){
        c.move();
    }}
class Car {
    void move() {
        // logic
    }}
```

Here, Traveler cannot use anything other tha car, because components are highly dependent on each

Low/Loose Coupling

```
class Traveler {
    Vehicle v;
    public void setV(Vechile v)
        this.v = v;
    }
    void startJourney() {
        v.move();
    }
}
Interface Vehicle {
    void move(); }
class Car implements Vehicle
    public void move(){
        // logic
}}
class Bike implements Vehicle
{ public void move(){
        // logic
    }
}
```

On the other hand, Loose coupling – Traveler can work with any Vehicle (Car, Bike etc) without changes.

Design Principles

- **Cohesion:** It measures how closely related the responsibilities of a single module or class are to each other. The more logically related the parts are higher (better) the cohesion is.
  - Cohesion defines how logically and strongly objects are related.

Low coupling + Tight cohesion is good OOD.

- **DRY Principle**
  - Don't Repeat Yourself

Problem (caused by repeating):
- Code for same functionality in multiple places.
- It causes redundancy and it is hard to maintain code.

Benefits: Improve maintainability, Readability, Reduce bugs.

Principles of OOP

SOLID Principle :-

S → Single responsibility Principle

A class should have only one reason to change. Each module, class or method should handle a single part of the system's functionality. The responsibility should be fully encapsulated within the class.

Problem:

```
public class Invoice {
    public void addInvoice(){
        //logic
    }
    pubic void deleteInvoice(){
        // logic
    }
    public void generateReport(){
        //logic
    }
    public void emailReport(){
        //logic
    }
}
```

Soln:

```
public class Invoice{
public void addInvoice()
 { //logic }
 public void deleteInvoice
 { //logic }
}
public class Report {
public void generateReport()
 { //logic
 }
} public class email {
    public void emailReport()
    { //logic }}
```

Now, each class is responsible to take care of one responsibility and only one reason to change. Code is now smaller and manageable for each functionality.

O → Open-Closed Principle :-

"Software entities (class, modules, functions etc.) should be open for extension but closed for modification".

- We can add new behaviour or feature to the system but don't change existing source code.
- It reduces risk of introducing bugs.

Problem:

```
class Car {
public void startEngine(String engineType)
 if (engineType.equals ("Petrol")){
     sout ("start petrol engine");
}else if (engineType.equals("Diesel")){
     sout ("start....");
}else if (engineType.equals("Turbo"){
     sout ("Start....");
}}}
```

If we add a new enginetype, every time we have to modify the Car class. So, we will use abstract class / interface to control where to change. In the solution, the Car class doesn't need to change. We only extend the system by creating new classes. Now code is stable, managable and flexible.

Soln:

```
abstract class Engine{
abstract void start();
}
class petrolEngine
  extends Engine {
@override
  void start() {
 sout ("Start...");
}
}
class DieselEngine extends
Engine {
-------- }
```

Strategic Closure:

"No significant program can be 100% closed".
— R. Martin, 1996

- Use abstract classes/interfaces
- Keep volatile logic separate.

This will minimize future modification points.

L → Liskov Substitution Principle:

Object of a superclass should be replacable with object of its subclasses without breaking the application.

- A subclass must behave like its superclass.
- Redesign inheritence hierarchy or use interfaces properly.

"Inheritence should ensure that any property proved about supertype objects also holds for subtype objects."
— B. Liskov, 1987

Rules:
- Method input parameters must accept same range of values as the superclass.
- Return values must follow same expectations as the superclass.
- subclass must not contradict superclass's expected behaviour.

Problem:

```
Class Bird {
    public void fly(){
    sout("Fly in the sky...");
    }
}
class Ostrich extends Bird{
  @override
    public void fly(){
    throw new Exception("can't..")
    }
}
```

Here, Ostrich can't fly. So, It breaks the expected behaviour.

In the solution, Ostrich is no longer inherits from a class that requires flying. So, we can substitute subclass safely without breaking behaviour.

Soln:

```
abstract class Bird {
public abstract void eat();
}
abstract class FlyingBird
    extends Bird {
  public abstract void fly();
}
class Sparrow extends
        FlyingBird {
@override
  pubic void eat(){

  }@override
pubic void fly(){

  }
}
class Ostrich extends Bird{
  @override
  pubic void eat(){
  }
```

- Square 'IS-A' Rectangle? Should I inherit Square from Rectangle?

Square doesn't behave like a rectangle. It violates LSP. Substituting Square break expected behaviour of Rectangle.

Here, IS-A relationship must refer to behaviour consistency, not just definition or structure.

Problem:

```
class Rectangle {
    int width, height;
  public int getArea(){
    return width * height;
  }
}
class Square extends Rectangle{
    - - - - - -
}
public class main {
    psvm {
      Rectangle s = new Squre();
      s.getArea();
      Rectangle r = new Rectangle();
      r.getArea();
}}
```

Soln ① : Separate classes

```
class Rectangle{
    int width, height;
}
class Square{
    int side;
}
```

Soln ② : Use interface

```
interface Shape {
    double getArea();
}
class Square implements
                Shape {
public double getArea(){ }
}
class Square implements
                Shape {
public double getArea(){ }
}
```

Now, both share the same contract, without one breaking the other's behaviour.

I → Interface Segregation Principle:

"No client should be forced to depend on methods it doesn't use." – Robert. C. Martin

- Don't make one big interface that does everything.
- Split it into smaller, more specific interfaces.
- Classes should implement only what they actually need.

Problem:

```
interface Worker {
    void work();
    void eat();
}
class Human implements
                Worker {
  public void work() {...}
  public void eat() {...}
}
class Robot implements
                Worker {
  public void work() {...}
  "    "  eat() {
    throw new Exception("....");
  }
}
```

Soln:

```
interface Workable {
   void work();
}
interface Eatable {
   void eat();
}
class Human implements
      Workable, Eatable {
  public void work() { }
  public void eat() { }
}
class Robot implements
                Workable {
  public void work() { }
}
```

fat interfaces leads to tight coupling. Here, Robot is forced to implement eat(), it violates ISP. Now, after solution each class depends only on it uses. The design is now clean, flexible, decoupled. It promote high cohesion.

D→ Dependency Inversion Principle:

- High level modules should not depend on low-level modules. Both shauld depend on abstractions.
- Abstraction should not depend on details. Details should depend on abstraction.

Problem:

```
class MySQLDatabase {
    void connect() {
        sout("Connected to MySQL");
    }
}
class UserService {
    MySQLDatabase db = new
                MySQLDatabase();
    void saveUser() {
        db.connect();
        sout(" User saved");
    }
}
```

Here, UserService depends directly on MySQLDatabase. If we want to switch to PostgreSQL we must change UserService. After solution, UserService depends on abstraction (Database), not a concrete class. We can pass any database implementation (MySQL, PostgreSQL etc) without changing

Soln:

```
interface Database {
    void connect();
}
class MySQLDatabase
    implements Database {
    public void connect() {
        sout("connect to SQL");
    }
}
class UserService {
    private Database db;
public UserService(Database
                    db) {
        this.db = db;
    }
    void saveUser() {db.connect()
}}
```

How to solve?

- Create an interface or abstract class
- Make low level modules implement the abstraction.
- Refactor high-level module to depend on the abstraction. Use dependency injection (constructor, setter) to provide the implementation.

```
class UserService {
    private Database db;
    public UserService(Database db){
        this.db = db;
    }
    void saveUser(){
        db.connect();
        Sout("User saved");
    }
}
```

Here, UserService no longer depends on a specific database.

Refactoring and code smell

- Refactoring improves the internal design of the code while keeping its functionality the same
- Make code cleaner, maintainable, readable
- Remove duplication, simplify complex logic and improve structure.
- Verify no change in external behaviour by
  → testing, code analysis, carefulness.

□ Why do we refactor?

→ Deliver more business value faster
→ ease to maintainance and understanding
→ Improve software design.
→ Facilitate change and flexibility
→ Increase Reusability
→ Combat 'Bit Rot'
→ Minimize Technical debt.
→ Fix broken Windows
→ Help find bugs
→ Maintain development speed
→ Write for people, not for compiler.

Refactoring and code smell

- When should we Refactor?
  - → To add new functionality
  - → When existing code is not understandable
  - → When we have to improve the design
  - → To find bugs, remove duplicacy
  - → During code reviews (improve readability.)
- Differentiate between adding a function in a code and refactoring a function :-

Adding Function	Refactoring Function
To add new capabilities or features to the system	To improve internal structure of existing code without changing its behaviour.
Introduces new functionality to the program.	Only structure and readabil are improved.
New tests are written for new feature.	Existing test should still pass.
Goal is to get the test working	Goal is to restructure code to remove redundancy

- How do we refactor?
  - → Look for Code smells (duplicated code, long methods, large ~~meth~~ classes, poor naming etc)
  - → Apply refactoring techniques, when it stinks (renaming variables, simplyfying logic, etc).

Common Code smells:

① Inappropriate Naming:

→ Names given to variables and methods should be clear, descriptive and meaningful.

Bad Naming	Good Naming
private string s;	private string salary;
public double cde(double s)	public double calculateTax(double salary)
✗ hard to read and understand	✓ makes code maintable and self-explanatory
✗ Increase risk of misuse, bugs	

② Comments:

Try to refactor so the the code itself make the code self-documenting / intention-revealing because too many comments reduce the readability and maintainability.

Soln: ① Extract method: move block of code in a well-named method

② Rename method / variable that describe intent.

③ Introduce Assertion to state assumptions instead of comenting them.

Example:

Smelly code:

```
def process_items(items):
    // items should not be empty
    total = 0
    for item in items:
        total += item
```

Refactored code (with Assertion)

```
def process_items(items):
    assert len(items) > 0, "items should
    not be empty"
    total = 0
    return total
```

✱ Introduce Parameter Object: All related parameter are grouped into a single object

Customer
amountInvoice(start:Date, end:Date) amountReceived(" " " ") amountOverdue(" " " ")

⇒

customer
amountInvoic(DateRange) amountReceived(") amountOverdue(")

Example:

Smelly:

```
Public double calculate Price
 (int quantity, double itemPrice,
  double taxRate, double discount){
  double basePrice = quantity * itemPrice;
double discount = basePrice *(1-discount);
return discount*(1+taxRate);
}
```

Refactor:

```
class PriceData {
  int quantity;
  double itemPrice, taxRate,
   discount;
PriceData(int quantity,
double item Price ....){
 this.quantity = quantity;
 - - - - - - - }
public double
calculatePrice (PriceData
                 data){
double basePrice = data.quantity
     * data.itemPrice;
double discount = basePrice*
(1-data.discount);
return discount*(1+data..
                 taxRate;
}
```

When a method has many parameter, combine them into a single object to simplify method calls and make the code cleaner and safer.

✱ Preserve Whole Object: (so the method can handle it in details)

Instead of passing parts of obj, pass entire object

Smelly:

```
int low = daysTempRange().getLoco();
 int high = daysTempRange().getHigh();
withinPlan = plan.withinRange(low, high);
```

Refactor:

```
withinPlan = plan.withinRange(daysTempRange());
```

⊛ Replace Method with Method Object:

Smelly:

```
//class Order
double price(){
   double primaryBasePrice;
   double secondaryBasePrice;
   double teritaryBasePrice;
   ... //long computation
   return totalPrice;
}
```

The method is long and uses many local variable, so it is hard to maintain / extend.

Refactored

```
//class Order
double price(){
   return new PriceCalculator(this).
                                compute();
} //New Method object
class PriceCalculator {
   Order order;
   double primaryBasePrice, seco...;
PriceCalculator(Order order) {
   this.order = order; }
double compute() {
   ----//long computation
   return totalPrice; }
}
```

After refactoring, the long computation is now in its own class, all local variables become fields of the object. Original price() method is, short, clean, readable.

∴ long, complex method ⟶ Separate class

⊛ Decompose Conditional:

Find long or complicated if-then-else that mix multiple condition and extract them

Smelly:

```
if (date.before(SUMMER_START) || date.after(SUMMER_END))
    charge = quantity * _winterRate + _winterServiceCharge;
else
    charge = quantity * _summerRate;
```

Refactor:

```
if (notSummer(date))
    charge = winterCharge(quantity);
else
    charge = summerCharge(quantity);
```

✓ (4) **Long Parameter List:** Methods that take too many parameters produce code that is awkward and difficult to work with.

Soln: ✓ Preserve Whole Object
✓ Introduce Parameter Object
✓ Replace Parameter with Method

* **Replace Parameter with Method:**

Smelly:

```
public double getPrice(){
  int basePrice = quantity* itemPrice;
  int discount = getDiscout();
  double finalPrice = discountPrice(basePrice, discountPrice);
  return finalPrice;
}
private int getDiscount(){
  if (quantity>100) return 2;
  else return 1;
}
private double discountPrice
        (int basePrice, int discount){
  if (getDiscount == 2)
      return basePrice*0.1;
  else
      return basePrice*0.05;
}
```

In the code discountPrice takes the discount as a parameter but it can get itself using getDiscount. which is redundant

Refactor:

```
public double getPrice()
{
int basePrice=q*itemPrice
double finalPrice;
finalPrice=discountPrice
        (basePrice);
return finalPrice;
}
private int getDiscount(){
 if(quantity>100)
   return 2
 else return 1; }
private double
 discountPrice(int basePrice){
//get discountLevel directly
if (getDiscount()==2)
   return basePrice*0.1;
else return basePrice*0.05;
}
```

✓ (5) **Feature Envy:** A method that seems more interested in some other classes than its own class.

- It happens when a method uses more data or methods from another class than its own class.

Problem:

→ frequently calls getters of another class
→ perform calculations mostly on another class data
→ It could logically belong to other classes.

Soln:

✓ Move Field → move the field where it is used mostly
✓ Move Method → move the method to the class where it envies
✓ Extract Method

Smell:

```
class Order {
    privat Customer customer;
public String getCustomerAddress(){
  return customer.getName()+"\n"+
         customer.getStreet()+"\n"+
         customer.getCity()+"\n"+
         customer.getZip();
} }
class Customer {
    private String name, street,
    city, zip ;
// getters of all fields
}
```

Refactor:

```
class Customer {
 private String name,
   street , city, zip;
 public String
   getAdress() {
 return name+"\n"+
 street+"\n"+city+zip;
}}
class Order {
  private customer customer;
public String getCustomerAddress
{ return customer.getAddress();
}
```

⑥ **Dead code:** Code that is no longer used in a system or related system is Dead code.

Problem:	Soln:
✗ Increase complexity, readability	✓ Delete
✗ Accidental changes → bugs	
✗ More dead code	

⑦ **Duplicated Code:**

- It occurs when same/similar code exist in multiple places.

Problem: ① **Obvious/blatant duplication:** Copy and Paste

② **Subtle/non-obvious duplication:** Similar logic or algorithms accross classes with small variation.

Soln: ✓ Extract Method
✓ Pull Up Field
✓ Substitute Algorithm
✓ Form Template Method.

Levels of Duplication:

① **Literal Duplication:** Exact same code in multiple places.

② **Semantic Duplication:** Similar code/logic, not exactly identical

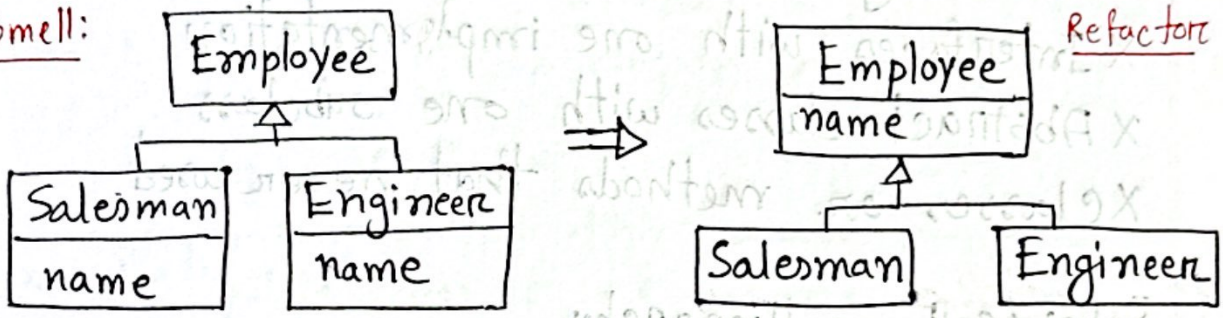
③ **Data Duplication:** Same data or constants appear in multiple places.

④ **Conceptual Duplication:** Different algorithms achieve same goal (example - BubbleSort and QuickSort)

⑤ Logical Steps - Duplication: Same sequence of logical steps is repeated in multiple scenarios. Repeated steps of validation in various points.

✱ Pull up Field: move common field from subclass to superclass. It simplifies inheritence hierarchy.

Smell:



✓ Removes duplication
✓ Make inheritence clear, simplify maintenance
✓ Increase cohesion of superclass

✱ Form Template Method: When we have two or more methods in different subclasses that perform same thing, we can create template method in saperclass to define the common structure.

✱ Substitute Algorithm: When method's logic is too complex, duplicated or in efficient, we can replace it with a simpler or clearer algorithm.

Example: Replace manual loop with buit-in method

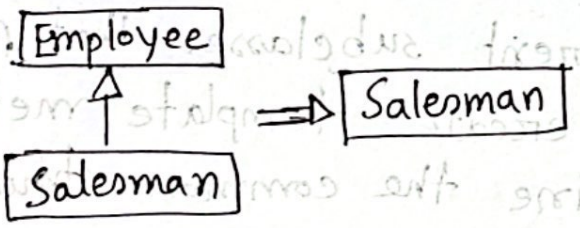
```
int findLargest(int[] numbers){
    return Arrays.stream(numbers).max().getAsInt();
}
```

⑥ **Speculative Generality:** It happens when developers add flexibility or generally "just in case" for future needs that don't exist yet.

Problem: X Parameters for future extension but never used.
X Over-engineed inheritence hierarchies
X Interfaces : with one implementation
X Abstract classes with one subclass
X Classes or methods that never used.

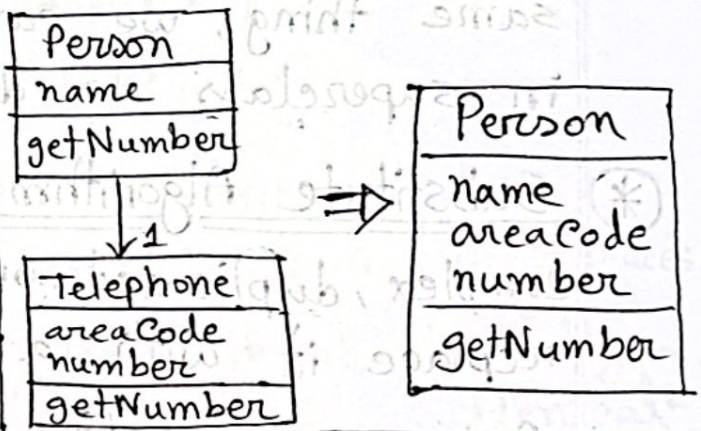
Soln: √Collapse Hierarchy
✓ Inline Class
✓ Remove Parameter.

⊛ **Collapse Hierarchy:**



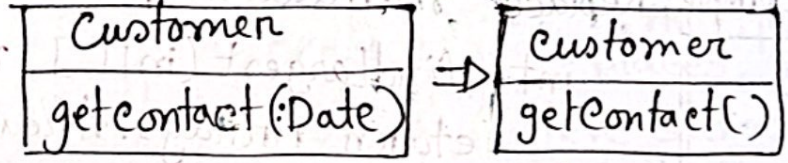
: Remove unnecessary inheritence when superclass or subclass duplication adds no value.

⊛ **Inline Class:** Merge class that is not pulling its weight into another class



⊛ **Remove Parameter:**

: Delete parameters that are not used.



✓(7) **Lazy class**: A class that does not do enough work to justify its existence.

In good OOD, each class should have clear purpose and responsibility.

Soln: ✓Inline Class → Move its functionality into another related class, then delete it.

✓Collapse Hierarchy

Example:
Smelly:

```
public class Letter {
    private final String content;
    public Letter (String content){
        this.content = content;
    }
    public String getContent (){
        return content;
    }
}
```

Soln:
Here, Letter does nothing, just holds a string. If other classes only use it to access a string, it's better to inline it into those class.

✓(8) **Refused Bequest**: It occures when a subclass inherits ↑methods or fields from a superclass but doesn't need them.

Problem:
- X Sub class overrides inherited methods with empty bodies
- X subclass throws exception, for inherited methods; it violates Liskov SP
- X Subclass doesn't use fields/methods it inherits
- X Hierarchy doesn't make sense.

Solution:
- ✓ Push down Method
- ✓ Push down Field

✓ (9) **Black Sheep:** a subclass / method that doesn't fit well with its family.

A subclass that is noticably different from other methods in the class.

```
public class StringUtil {
    ps String pascalCase(String string){
        return ....;
    }
    public static String camelCase(String string){
        return ....
    }
    public static String numberAndNoun(int Number, String noun)
{ return ....}
```

Blacksheep

```
    public static string extractCommand (Map parameter){
        return ((String [] parameter.get("command"))[0];
    }
}
```

Here, Every method is string formatting but extractCommand is not about String manupulation

✓ (10) **Primitive Obsession:** It occurs when primitive data types (like int, float, double, String etc) are used to represent higher level concept that should be modeled as object or classes.

Soln: ✓ Extract Class
✓ Replace Data with Object
✓ Replace code with Class
✓ Replace Array with Obj
✓ Introduce Parameter Object

Refactored:

Smelly:

```
public class CompositeShape
{
  IShape[] arr = new IShape[100];
  int count = 0;
  public void Add(Ishape shape){
    arr[count++] = shape;
  }
public void Remove(IShape Shape){
  for(int i=0; i<100; i++){
    if(shape==arr[i]){
      //code to remove
    }
}}}
```

Refactored:

```
public class CompositeShape
{
  List<IShape> shapeList
    = new List<IShape>();
  public void Add(IShape shape)
{
  ShapList.Add(shape);
}
public void Remove(IShape
                   shape)
{
  shapeList.Remove(shape);
}
}
```

It uses a fixed-size primitive array, manual index tracking (count), manual logic to remove. After fixing, no manual counting, looping. Uses List, which abstracts away low-level array operations.

(*) Replace Array with Object:

Smelly:

```
String[] row = new String[2];
row[0] = "Liverpool";
row[1] = "15";
```

↓

Refactor: `performance row = new Performance("Liverpool","15");`

Arrays used to hold mixed (Liverpool, 15 etc) or unrelated data. After fixing by creating a class (performance) with name field, methods, code become cleaner.

(11) **Odd Ball Solution:** • subtly duplicate code

• same problem is solved in different ways in different parts of the system.

• It leads to — Inconsistent code behaviour, harder maintenance, hidden duplication.

Smelly:

```
String LoadUserProfileAction::process()
{  //some code
   return process("ViewAction");
}
String UploadAction:: process(){
   //code
   return process("ViewAction");
}
String ShowLoginAction:: process(){
   //code
   Action* viewAction = actionProcessor().get("ViewAction");
   return viewAction->process();
}
```

different mechanism to call "ViewAction" method which is inconsistent

Refactor:

```
String BaseAction::processView(
{  return process("ViewAction");
}
String LoadUserProfileAction{
   return processView();
}
" UploadAction::proces(
{   return processView();
}
String ShowLoginAction()
   return processView();
```

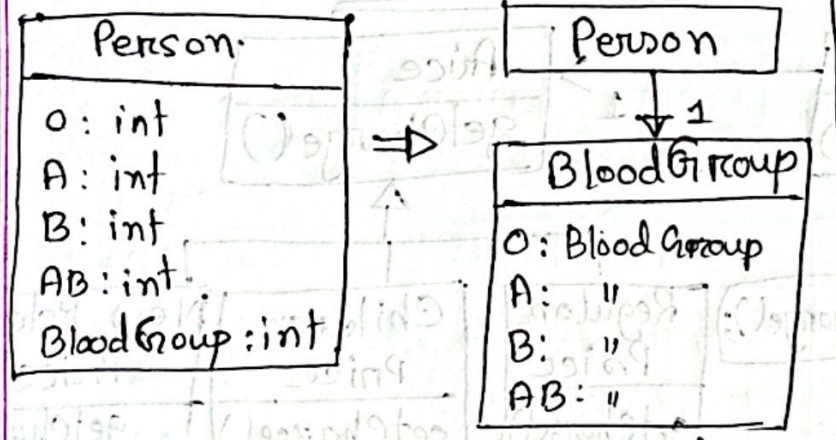
√Another Soln: Substitute Algorithm.

(12) **Large Class:** Class who suffer when they have too long responsibilities.

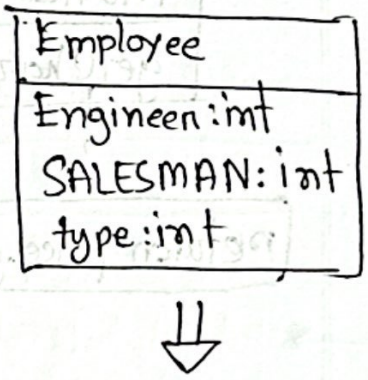
It allso violates SRP, hard to maintain, understand.

Soln:
- ✓ Extract class
- ✓ Replace type code with class
- ✓ " " " subclasses
- ✓ " " " State/Strategy
- ✓ " Conditional " Polymorphism

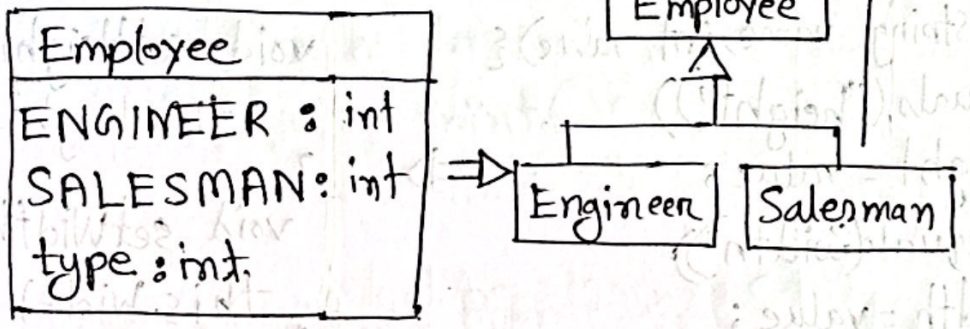
(*) **Replace type code with class:**

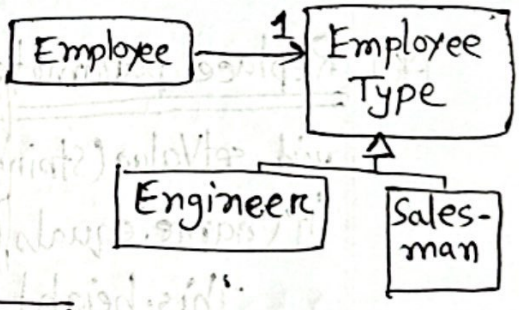


Replace Type with State/Strategy:



(*) **Replace type code with subclasses:**

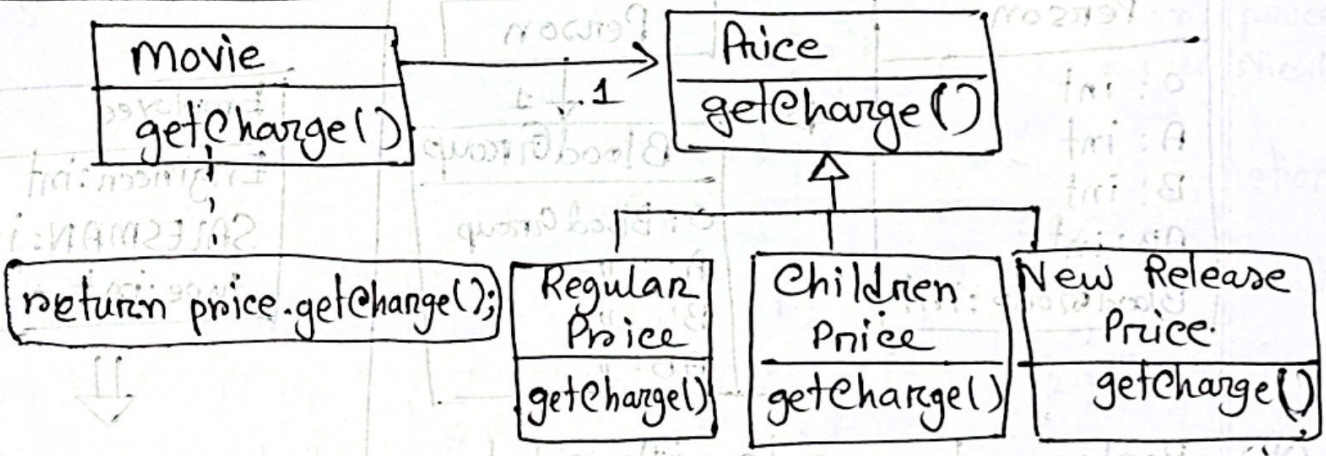




(13) **Switch Statement:** When code contains repeated switch statements (if..else if... else) duplicated across the system.

Soln: ✓ Replace Type code With Polymorphism
✓ " " " " State/Strategy
✓ " Parameter " Explicit Methods
✓ Introduce null object

(*) **Replace Type with Polymorphism:**



(*) **Replace parameters with Method:**

```
void setValue(String name, int value){
if(name.equals("height"))
    this.height = value;
else if(name.equals("width"))
    this.width = value;
}
```

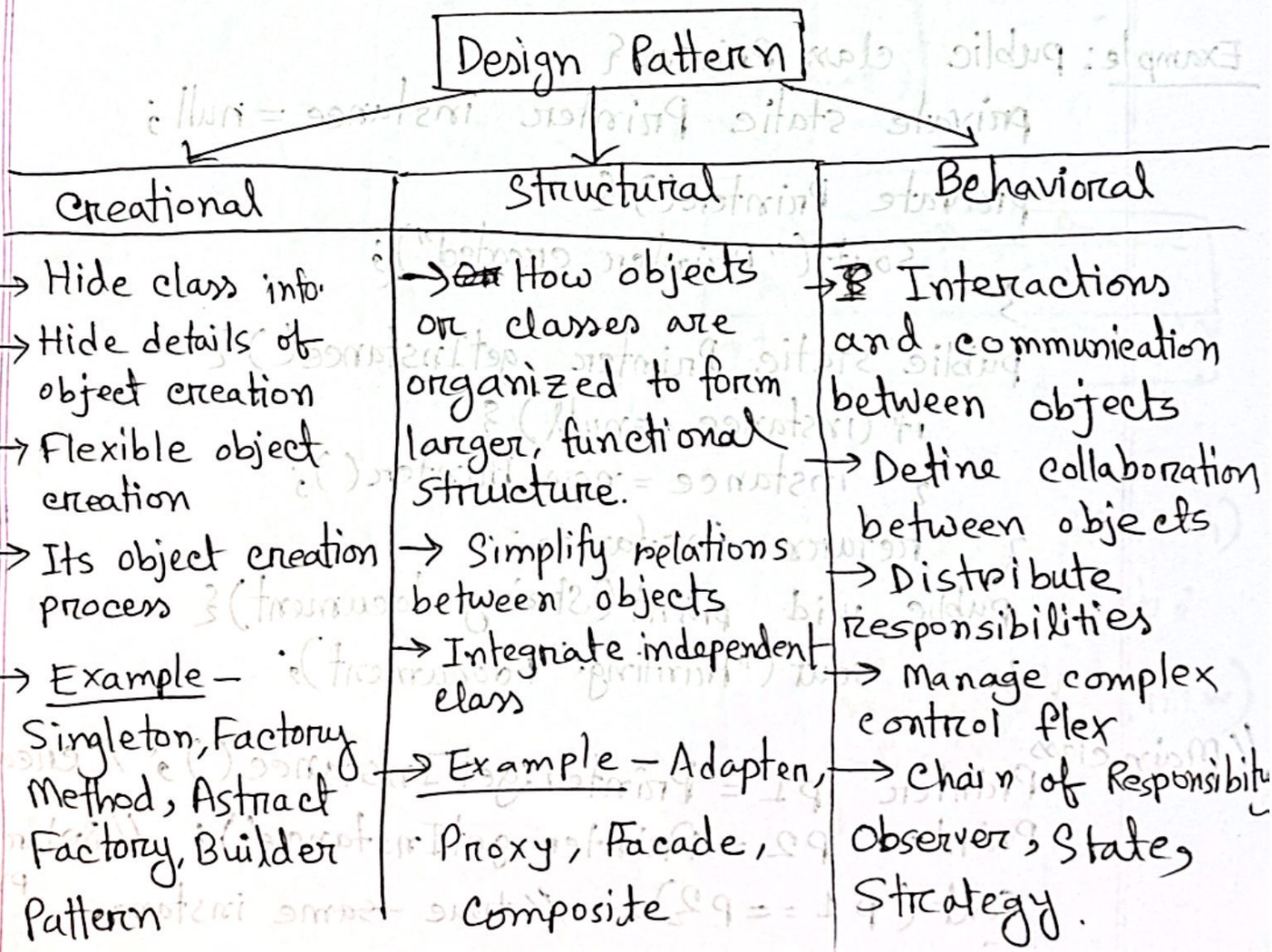
⇒

```
void setHeight(int h)
  this.height=h;
}
void setWidth(int w)
  this.width=w;
}
```

Design Pattern :-

Typical solutions of commonly occuring problems in software design

- ✓ Solves common, recurring software problems
- ✓ Improve code readability, maintainability, flexity.
- ✓ Reduces development time
- ✓ Promotes cleaner solution, reusability
- ✓ Improves collaboration, helps managing complex architecture



Singleton Pattern:

- Ensure that class has only one instance, while providing global access point to this instance

Steps:

1. Make default constructor private, to prevent other objects from using the new operator with the Singleton class.
2. Create a static creation method that acts as a constructor.

Example:

```
public class Printer {
    private static Printer instance = null;
    private Printer() {
        Sout("Printer created");
    }
    public static Printer getInstance() {
        if (instance == null) {
            instance = new Printer();
        }
        return instance;
    }
    public void print(String document) {
        sout("Printing:" + document);
    }
}
```

```
// Main class
Printer p1 = Printer.getInstance(); // create printer
Printer p2 = Printer.getInstance(); // Returns same printer
Sout(p1 == p2); // true - same instance
```