Object-oriented programming

International Baccalaureate · IB Diploma · Computer Science · SL

Scope and prerequisites

This handout teaches Theme B3, Object-oriented programming, for the course first assessed in 2027, using Python, with Java shown where its syntax differs.

Prerequisites: B2 Programming (variables, selection, loops, functions and parameters). The examples are fictional models, not real bank systems.

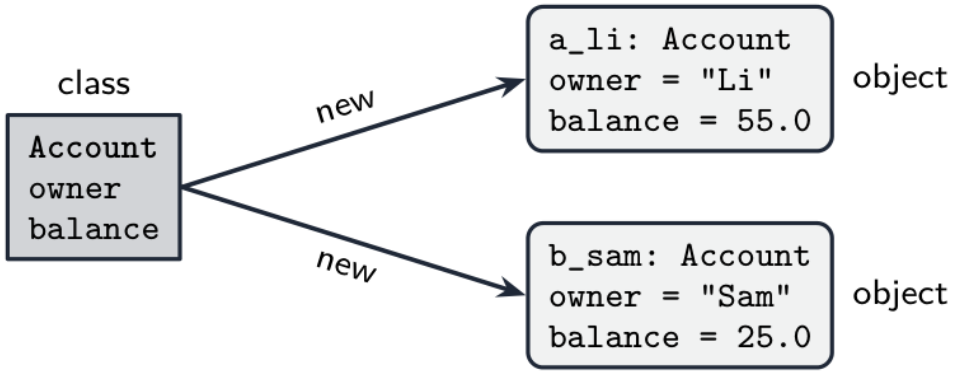
Classes and objects

Why model the world as objects?

A school app tracks thousands of students. Each one has a name, a year group and a list of grades, and each can enrol on a course or receive a grade. Writing separate variables for every student is impossible. Instead we write the design once, as a class, and make one object per student.

Class, object and instance

A **class** is a blueprint: it defines the **attributes** (the data each object holds) and the **methods** (what each object can do). An **object** is one thing built from that blueprint, an **instance** of the class. Making an object is **instantiation**.



One class, many objects: the same attributes, each with its own values

- An object's **state** is the current values of its attributes; its **behaviour** is what its methods do.
- Objects of a class normally share its defined interface and may hold different instance values; Python also allows instance attributes to be added dynamically.

Writing a class in Python

```python
class Account:
    def __init__(self, owner, balance):   # the constructor
        self.owner = owner                 # instance attributes
        self.balance = balance

    def deposit(self, amount):
        self.balance = self.balance + amount

    def get_balance(self):
        return self.balance

a_li = Account("Li", 40.0)      # instantiation
b_sam = Account("Sam", 20.0)
a_li.deposit(15.0)
print(a_li.get_balance(), b_sam.get_balance())   # 55.0 20.0
```

- The object-initialisation step is often taught with the **constructor**. In normal Python construction, `__new__` creates the instance and `__init__` initialises its state. In Java it is a method with the class's name: `public Account(String owner, double balance)`.
- `self` is the object the method is working on: `a_li.deposit(15.0)` changes `a_li`'s balance only.
- A variable holds a **reference** to an object. After `c = a_li`, both names refer to the **same** object: a deposit through `c` is seen through `a_li`.

Instance and static members

An **instance attribute** belongs to one object. A **static** (class) attribute belongs to the class and is shared by every object.

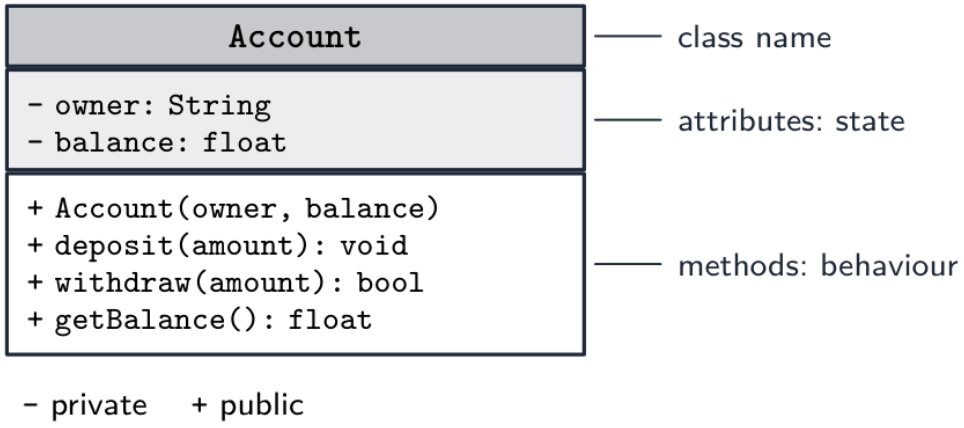
```python
class Account:
    count = 0                          # static: one value for the whole
    ↪ class
    def __init__(self, owner, balance):
        self.owner = owner
        self.balance = balance
        Account.count = Account.count + 1
```

After two accounts are made, `Account.count` is 2. In Java a static member is marked `static` and is called on the class, such as `Math.sqrt(9)`.

Encapsulation

Hiding the state

Encapsulation bundles the data and the methods that act on it into one class, and hides the data so it can be changed only through those methods. The class then protects its own rules, such as "the balance is never negative".



A UML class diagram: name, attributes, methods; - private, + public

Access	Java	Python convention	Who can use it
private	`private`	leading _ marks non-public use by convention	Java restricts access; Python's single underscore does not enforce privacy
public	`public`	plain name	any code

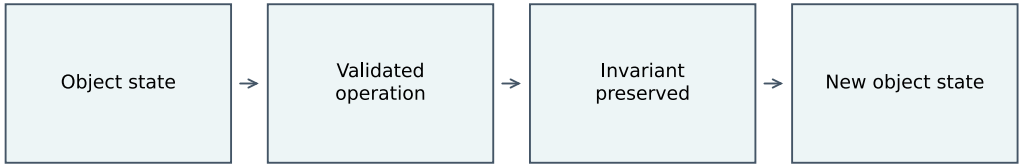
Accessors and mutators

Private attributes are read through an **accessor** (getter) and changed through a **mutator** (setter), which can check the new value first.

```
class Account:
    def __init__(self, owner, balance):
        self._owner = owner
        self._balance = max(0.0, balance)

    def get_balance(self):              # accessor
        return self._balance

    def withdraw(self, amount):         # mutator with validation
        if amount <= 0 or amount > self._balance:
            return False
        self._balance = self._balance - amount
        return True
```



A validated operation keeps the rule true: a rejected withdrawal leaves the state unchanged

Trace: `acc = Account("Li", 15.0)`; `acc.withdraw(30.0)` returns `False` and the balance stays 15.0; `acc.withdraw(15.0)` returns `True` and the balance becomes 0.0.

Advantages of encapsulation:

- **Data integrity**: invalid values are rejected in one place.
- **Maintenance**: the inside of a class can change without breaking code that uses only its public methods.
- **Teamwork**: a programmer can use a class from its public interface alone.

Designing with classes

Choosing attributes and methods

To design a class from a scenario, pick out the **nouns** that are data (attributes) and the **verbs** that are actions (methods).

> A library lends books. Each book has a title, an ISBN and whether it is on loan. A book can be lent and returned.

Attributes (private)	Methods (public)
`title: String`	`lend(): bool`
`isbn: String`	`give_back(): void`
`on_loan: bool`	`is_on_loan(): bool`

`lend` returns `False` if the book is already on loan, so the rule "a book cannot be lent twice" lives inside the class.

Advantages and limits of OOP

Advantages	Disadvantages
models real things, so designs are easy to discuss	more code and planning for a small program
classes are reused in other programs	objects can use more memory
encapsulation protects data	a poor class design is hard to change later

Practice

1. Explain the difference between a class and an object, using a phone model as an example.
2. For the `Account` class with `deposit`, state the output of: `x = Account("Ana", 10.0)`, `y = Account("Bo", 10.0)`, `x.deposit(5.0)`, `print(x.get_balance(), y.get_balance())`.
3. `p = Account("Kai", 30.0)`, `q = p`, `q.deposit(20.0)`. State `p.get_balance()` and explain.
4. Explain why `balance` is made private and changed only through `withdraw`.
5. Draw the UML class diagram for a `Thermostat` with a private `target` (an integer), a constructor, and public methods `raise_by(d)`, `lower_by(d)` and `get_target()`.
6. From the scenario "A cinema has screens. Each screen has a number and a number of seats; seats can be booked and cancelled", identify two attributes and two methods of `Screen`.
7. State **one** advantage and **one** disadvantage of OOP.

Answers.

1. The class is the design (the phone model): it says what every phone has and can do. An object is one actual phone built from it, with its own state, such as its own battery level.
2. `15.0 10.0`: each object has its own balance.
3. **50.0**: `q = p` copies the reference, so `p` and `q` are the same object.
4. Encapsulation: no code outside the class can set the balance to an invalid value; `withdraw` checks every change, so the rule "never negative" always holds.
5. Three compartments: `Thermostat`; `- target: int`; `+ Thermostat(target)`, `+ raise_by(d): void`, `+ lower_by(d): void`, `+ get_target(): int`.
6. Attributes: `number`, `seats` (or `booked`). Methods: `book()`, `cancel()`.
7. Advantage: e.g. classes can be reused, or data is protected by encapsulation. Disadvantage: e.g. more planning and code for a small program.
8. Each subclass overrides `speak()`. The loop calls `a.speak()` on each `Animal`; at run time each object runs its own class's version, so dogs bark and cats meow without the loop testing the type.
9. Overriding: a subclass redefines a superclass method with the same name and parameters. Overloading: methods in one class share a name but take different parameters.
10. (a) composition; (b) inheritance (a truck **is a** vehicle); (c) aggregation.

Exam tips

- Use the words exactly: a **class** is the blueprint, an **object** is an instance, **instantiation** makes it.
- In a UML class diagram, keep three compartments and mark each member `-` private or `+` public, with types.
- When you "explain encapsulation", say both parts: data and methods bundled together, and the data hidden behind methods that validate it.
- In code questions, remember that assigning an object variable copies the reference, not the object.
- Mutators normally return nothing (`void`); accessors return a value and change nothing.