Lecture 18

Using Classes Effectively

Announcements for Today

Exam Time

- **Prelim, Nov 9th 5:15 or 7:30**
  - Same break-up as last time
  - But will swap times assigned
- **Material up to November 1**
  - Review posted this weekend
  - Recursion + Loops + Classes
- **Conflict with Prelim time?**
  - Prelim 2 Conflict on CMS
  - Submit by next Thursday
  - SDS students must submit!

Assignments

- A4 is due tonight!
  - Survey is still open
- A5 was posted yesterday
  - Shorter written assignment
  - Due Wednesday at Midnight
- A6 to be posted tomorrow
  - Due a **week after** prelim
  - Designed to take two weeks
  - Finish Task 3 before exam

Recall: The __init__ Method

two underscores

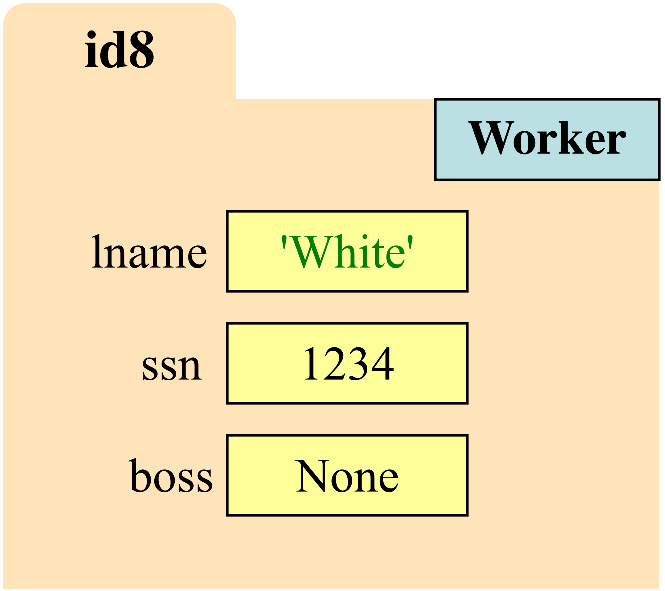
```
w = Worker('Obama', 1234, None)
```

```
def __init__(self, n, s, b):
    """Initializer: creates a Worker

    Has last name n, SSN s, and boss b

    Precondition: n a string, s an int in
    range 0..999999999, and b either
    a Worker or None.
    self.lname = n
    self.ssn  = s
    self.boss = b
```

Called by the constructor



id8

Worker

lname	'White'
ssn	1234
boss	None

Recall: The __init__ Method

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```

Are there other special methods that we can use?

Example: Converting Values to Strings

str() Function

- **Usage**: str(<expression>)
  - Evaluates the expression
  - Converts it into a string
- How does it convert?
  - str(2) → '2'
  - str(True) → 'True'
  - str('True') → 'True'
  - str(Point3()) → '(0.0,0.0,0.0)'

repr() Function

- **Usage**: repr(<expression>)
  - Evaluates the expression
  - Converts it into a string
- How does it convert?
  - repr(2) → '2'
  - repr(True) → 'True'
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  - repr(Point3()) → "<class 'Point3'> (0.0,0.0,0.0)"

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What type is this value?

repr() Function

repr() is for *unambigious* representation

- How does it co
  - repr(2) → '2'
  - repr(True) →
  - repr('True') → "'True'"
  - repr(Point3()) → "<class 'Point3'> (0.0,0.0,0.0)"

The value's type is clear

What Does str() Do On Objects?

- Does **NOT** display contents

  ```
  >>> p = Point3(1,2,3)
  >>> str(p)
  '<Point3 object at 0x1007a90>'
  ```

- Must add a special method
  - __str__ for str()
  - __repr__ for repr()
- Could get away with just one
  - repr() requires __repr__
  - str() can use __repr__ (if __str__ is not there)

```
class Point3(object):
    """Class for points in 3d space"""
    …
    def __str__(self):
        """Returns: string with contents"""
        return '('+self.x + ',' +
                    self.y + ',' +
                    self.z + ')'

    def __repr__(self):
        """Returns: unambiguous string"""
        return str(self.__class__)+
                str(self)
```

What Does str() Do On Objects?

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```

Gives the class name

__repr__ using __str__ as helper

Designing Types

From first day of class!

- **Type**: set of values and the operations on them
  - int: (**set**: integers; **ops**: +, –, *, //, …)
  - Time (**set**: times of day; **ops**: time span, before/after, …)
  - Worker (**set**: all possible workers; **ops**: hire,pay,promote,…)
  - Rectangle (**set**: all axis-aligned rectangles in 2D;
    ops: contains, intersect, …)
- To define a class, think of a *real type* you want to make
  - Python gives you the tools, but does not do it for you
  - Physically, any object can take on any value
  - Discipline is required to get what you want

Making a Class into a Type

1. Think about what values you want in the set
   - What are the attributes? What values can they have?
2. Think about what operations you want
   - This often influences the previous question

- To make (1) precise: write a *class invariant*
  - Statement we promise to keep true **after every method call**
- To make (2) precise: write *method specifications*
  - Statement of what method does/what it expects (preconditions)
- Write your code to make these statements true!

Planning out a Class

```
class Time(object):
    """Class to represent times of day.
    INSTANCE ATTRIBUTES:
        hour: hour of day [int in 0..23]
        min:  minute of hour [int in 0..59]"""

    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""

    def increment(self, hours, mins):
        """Move this time <hours> hours
        and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59"""

    def isPM(self):
        """Returns: this time is noon or later."""
```

Class Invariant

States what attributes are present and what values they can have.

A statement that will always be true of any Time instance.

Method Specification

States what the method does.

Gives preconditions stating what is assumed true of the arguments.

Planning out a Class

```
class Rectangle(object):
    """Class to represent rectangular region
    INSTANCE ATTRIBUTES:
        t:  y coordinate of top edge      [float]
        l:  x coordinate of left edge     [float]
        b: y coordinate of bottom edge [float]
        r: x coordinate of right edge    [float]
    For all Rectangles, l <= r and b <= t."""

    def __init__(self, t, l, b, r):
        """The rectangle [l, r] x [t, b]
        Pre: args are floats; l <= r; b <= t"""

    def area(self):
        """Return: area of the rectangle."""

    def intersection(self, other):
        """Return: new Rectangle describing
            intersection of self with other."""
```

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A statement that will always be true of any Rectangle instance.

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Class Invariant

States what attributes are present and what values they can have.

A statement that will always be true of any Rectangle instance.

Special invariant **relating** attributes to each other

Method Specification

States what the method does.

Gives preconditions stating what is assumed true of the arguments.

Planning out a Class

```
class Hand(object):
    """Instances represent a hand in cards.
    INSTANCE ATTRIBUTES:
        cards: cards in the hand [list of card]
    This list is sorted according to the
    ordering defined by the Card class."""

    def __init__(self, deck, n):
        """Draw a hand of n cards.
        Pre: deck is a list of >= n cards"""


    def isFullHouse(self):
        """Return: True if this hand is a full
        house; False otherwise"""

    def discard(self, k):
        """Discard the k-th card."""
```

Class Invariant

States what attributes are present and what values they can have.

A statement that will always be true of any Rectangle instance.

Method Specification

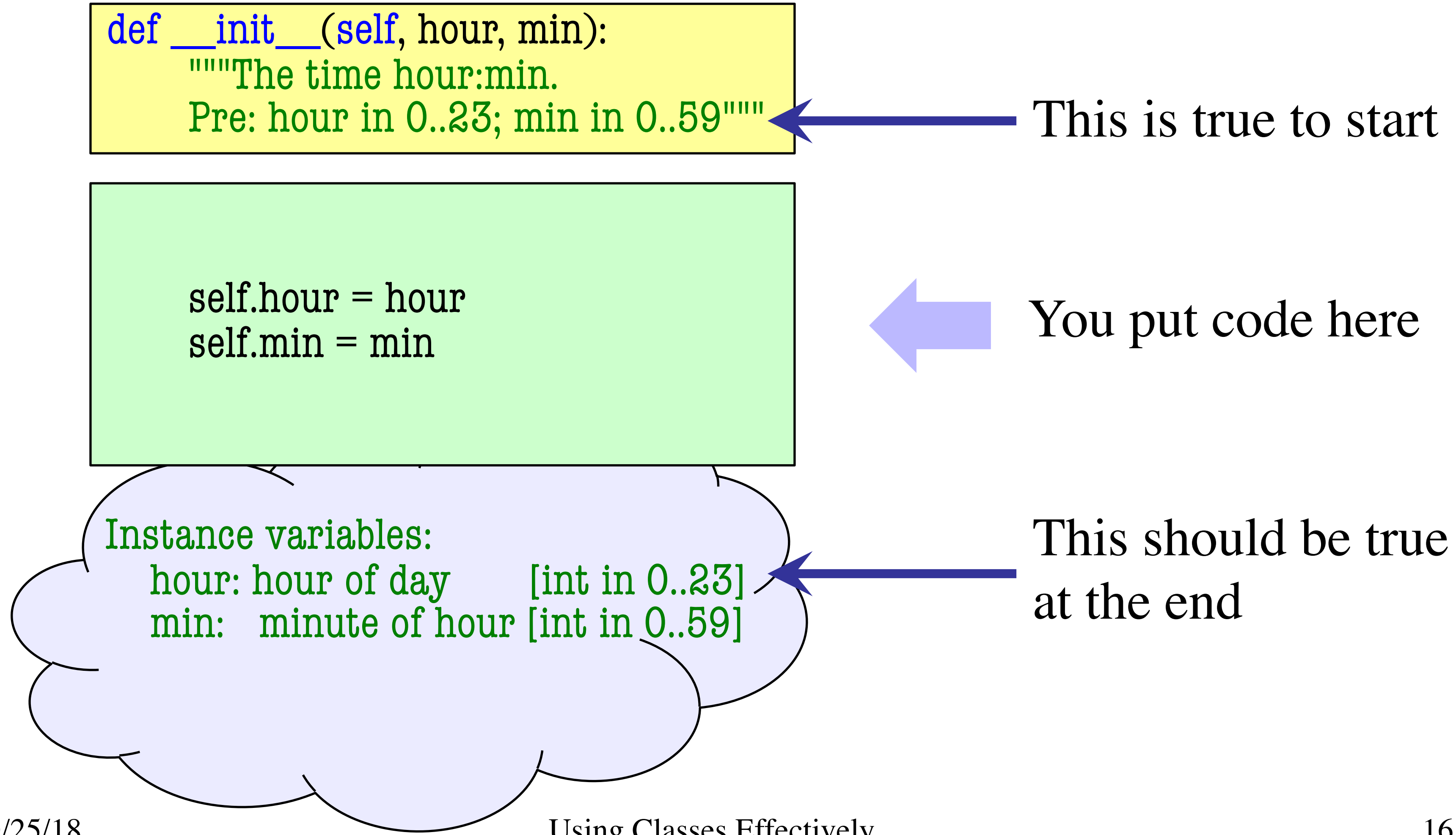
States what the method does.

Gives preconditions stating what is assumed true of the arguments.

Implementing a Class

- All that remains is to fill in the methods. (All?!)
- When implementing methods:
  1. Assume preconditions are true
  2. Assume class invariant is true to start
  3. Ensure method specification is fulfilled
  4. Ensure class invariant is true when done
- Later, when using the class:
  - When calling methods, ensure preconditions are true
  - If attributes are altered, ensure class invariant is true

Implementing an Initializer



```
def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
```

This is true to start

```
        self.hour = hour
        self.min = min
```

You put code here

```
Instance variables:
    hour: hour of day        [int in 0..23]
    min:   minute of hour [int in 0..59]
```

This should be true at the end

Implementing a Method

```
Instance variables:
   hour: hour of day       [int in 0..23]
   min:   minute of hour [int in 0..59]
```

This is true to start

```
def increment(self, hours, mins):
      """Move this time <hours> hours
      and <mins> minutes into the future.
      Pre: hours [int] >= 0; mins in 0..59"""
```

What we are supposed to accomplish

This is also true to start

```
      self.min  = self.min + mins
      self.hour = self.hour + hours
```

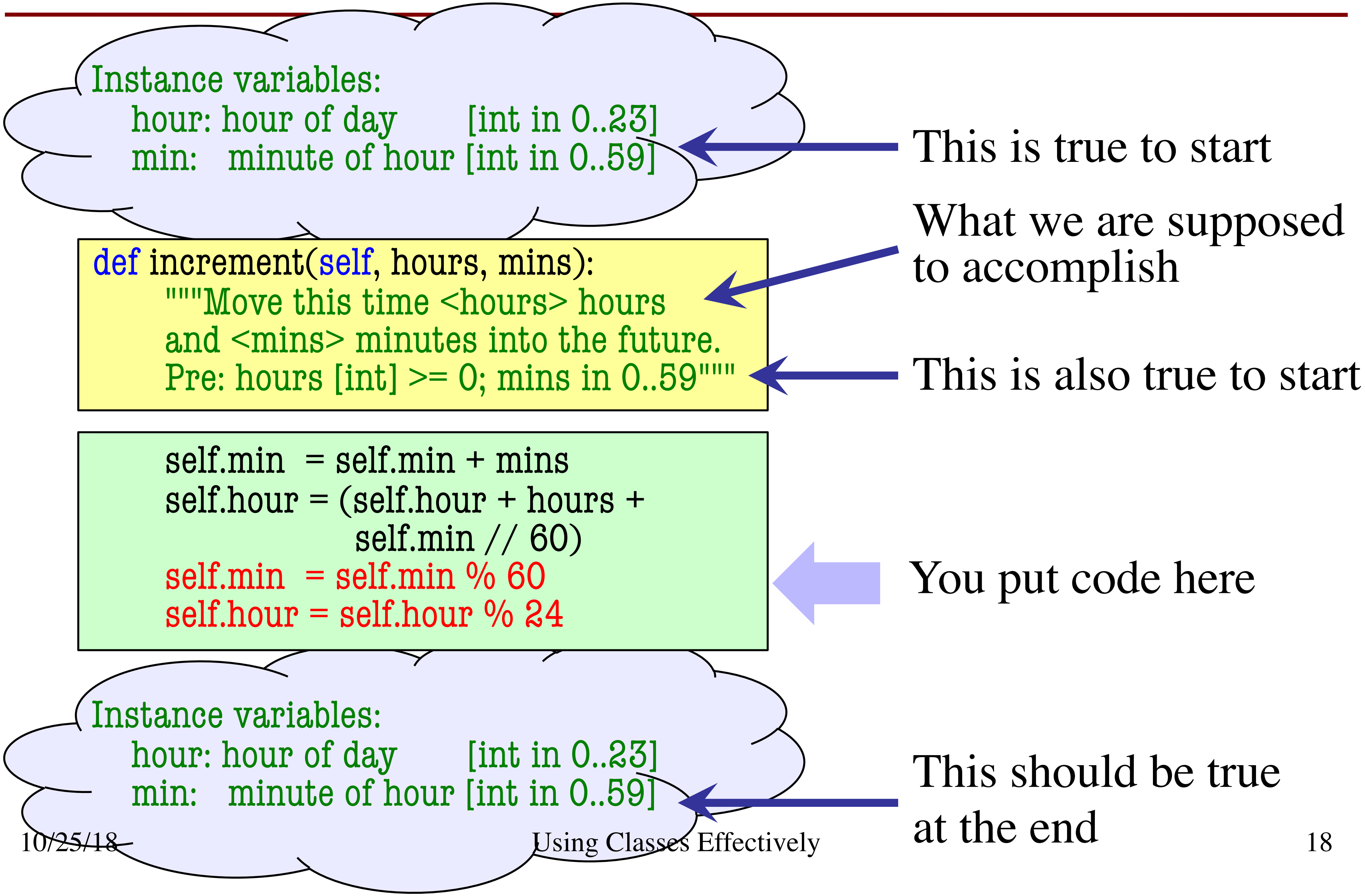
?

You put code here

```
Instance variables:
   hour: hour of day       [int in 0..23]
   min:   minute of hour [int in 0..59]
```

This should be true at the end

Implementing a Method



```
Instance variables:
   hour: hour of day       [int in 0..23]
   min:   minute of hour [int in 0..59]
```

This is true to start

```
def increment(self, hours, mins):
      """Move this time <hours> hours
      and <mins> minutes into the future.
      Pre: hours [int] >= 0; mins in 0..59"""
```

What we are supposed to accomplish

This is also true to start

```
      self.min  = self.min + mins
      self.hour = (self.hour + hours +
                      self.min // 60)
      self.min  = self.min % 60
      self.hour = self.hour % 24
```

You put code here

```
Instance variables:
   hour: hour of day       [int in 0..23]
   min:   minute of hour [int in 0..59]
```

This should be true at the end

Role of Invariants and Preconditions

- They both serve two purposes
  - Help you think through your plans in a disciplined way
  - Communicate to the user* how they are allowed to use the class
- Provide the *interface* of the class
  - interface btw two programmers
  - interface btw parts of an app
- Important concept for making large software systems

*** …who might well be you!**

in•ter•face |ˈintərˌfās| noun

1. point where two systems, subjects, organizations, etc., meet and interact : the interface between accountancy and the law.

   - *chiefly Physics* a surface forming a common boundary between two portions of matter or space, e.g., between two immiscible liquids : the surface tension of a liquid at its air/liquid interface.

2. *Computing* a device or program enabling a user to communicate with a computer.

   - a device or program for connecting two items of hardware or software so that they can be operated jointly or communicate with each other.

—The Oxford American Dictionary

Implementing a Class

- All that remains is to fill in the methods. (All?!)
- When implementing methods:
  1. Assume preconditions are true
  2. Assume class inv
  3. Ensure method sp
  4. Ensure class invariant ue when done

Easy(ish) if we are the user.

But what if we aren't?

- Later, when using the class:
  - When calling methods, ensure preconditions are true
  - If attributes are altered, ensure class invariant is true

Recall: Enforce Preconditions with assert

```
def anglicize(n):
    """Returns: the anglicization of int n.

    Precondition: n an int, 0 < n < 1,000,000"""
    assert type(n) == int, str(n)+' is not an int'
    assert 0 < n and n < 1000000, str(n)+' is out of range'
    # Implement method here...
```

Check (part of) the precondition

(Optional) Error message when precondition violated

Enforce Method Preconditions with assert

```
class Time(object):
    """Class to represent times of day."""

    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
        assert type(hour) == int
        assert 0 <= hour and hour < 24
        assert type(min) == int
        assert 0 <= min and min < 60

    def increment(self, hours, mins):
        """Move this time <hours> hours
        and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59""”
        assert type(hour) == int
        assert type (min) == int
        assert hour >= 0
        assert 0 <= min and min < 60
```

Instance Attributes:
  hour: hour of day [int in 0..23]
  min: minute of hour [int in 0..59]

Initializer creates/initializes all of the instance attributes.

Asserts in initializer guarantee the initial values satisfy the invariant.

Asserts in other methods enforce the method preconditions.

Hiding Methods From Access

- Put underscore in front of a method will make it **hidden**
  - Will not show up in help()
  - But it is still there…
- Hidden methods
  - Can be used as **helpers** inside of the same class
  - But it is bad style to use them outside of this class
- Can do same for attributes
  - Underscore makes it hidden
  - Do not use outside of class

```
class Time(object):
    """INSTANCE ATTRIBUTES:
        hour: the hour   [int in 0..23]
        min: the minute [int in 0..59]"""
```

HIDDEN

```
    def _is_minute(self,m):
        """Return: True if m valid minute"""
        return (type(m) == int and
                    m >= 0 and m < 60)

    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
        assert self._is_minute(m)
        ...
```

Helper method

Enforcing Invariants

```
class Time(object):
    """INSTANCE ATTRIBUTES:
      hour: the hour    [int in 0..23]
      min: the minute   [int in 0..59]
    """
```

Invariants: Properties that are always true.

- These are just comments!

```
>>> t = Time(2,30)
>>> t.hour = 'Hello'
```

- How do we prevent this?

- **Idea**: Restrict direct access
  - Only access via methods
  - Use asserts to enforce them
- **Example**:

```
def getHour(self):
    """Returns: the hour"""
    return self.hour

def setHour (self,value):
    """Sets hour to value"""
    assert type(value) == int
    assert value >= 0 and value < 24
    self.numerator = value
```

Data Encapsulation

- **Idea**: Force the user to only use methods
- Do not allow direct access of attributes

Setter Method

- Used to change an attribute
- Replaces all assignment statements to the attribute
- **Bad**:

```
>>> t.hour = 5
```

- **Good**:

```
>>> f.setHour(5)
```

Getter Method

- Used to access an attribute
- Replaces all usage of attribute in an expression
- **Bad**:

```
>>> x = 3*t.hour
```

- **Good**:

```
>>> x = 3*t.getHour()
```

Data Encapsulation

```
class Time(object):
    """INSTANCE ATTRIBUTES:
        _hour: the hour   [int in 0..23]
        _min: the minute [int in 0..59]"""

    def getHour (self):
        """Returns: hour attribute"""
        return self._hour

    def setHour(self, h):
        """ Sets hour to h
        Pre: h is an int in 0..23"""
        assert type(h) == int
        assert 0 <= h and h < 24
        self._hour = d
```

Do this for all of your attributes

Getter

Setter

Naming Convention

The underscore means "should not access the attribute directly."

Precondition is same as attribute invariant.

Mutable vs. Immutable Attributes

Mutable

- Can change value directly
  - If class invariant met
  - **Example**: turtle.color
- Has both getters and setters
  - Setters allow you to change
  - Enforce invariants w/ asserts

Immutable

- Can’t change value directly
  - May change “behind scenes”
  - **Example**: turtle.x
- Has only a getter
  - No setter means no change
  - Getter allows limited access

May ask you to differetiate on the exam

Mutable vs. Immutable Attributes

Mutable

- Can change value directly
  - If class invariant met
  - **Example**: turtle.color
- Has both getters and setters
  - Setters allow
  - Enforce invar

Where?
Next time.

Immutable

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  - **Example**: turtle.x
- Has only a getter
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Exercise: Design a (2D) Circle

- What are the **attributes**?
  - What is the bare minimum we need?
  - What are some extras we might want?
  - What are the invariants?
- What are the **methods**?
  - With just the one circle?
  - With more than one circle?