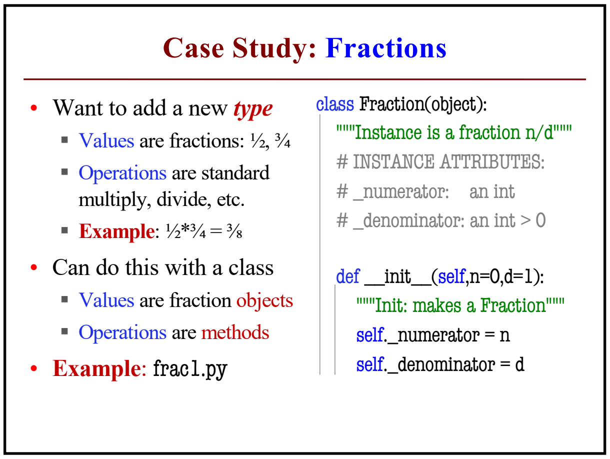


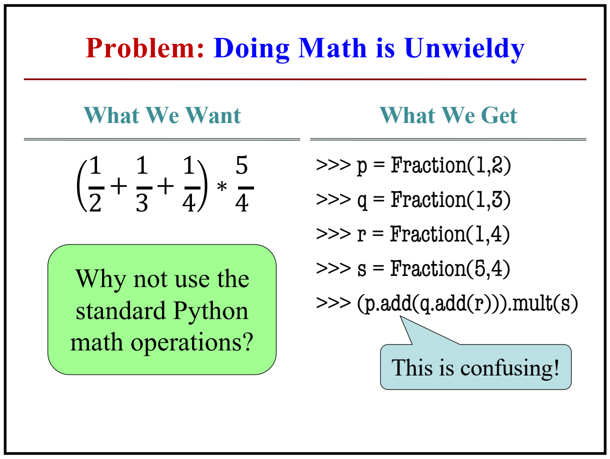
Case Study: Fractions

- Want to add a new *type*
  - Values are fractions: ½, ¾
  - Operations are standard multiply, divide, etc.
  - **Example**: ½*¾ = ⅜
- Can do this with a class
  - Values are fraction objects
  - Operations are methods
- **Example**: frac1.py

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # INSTANCE ATTRIBUTES:
    # _numerator:    an int
    # _denominator: an int > 0

    def __init__(self,n=0,d=1):
        """Init: makes a Fraction"""
        self._numerator = n
        self._denominator = d
```

1



Problem: Doing Math is Unwieldy

What We Want

$$\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{4}\right)*\frac{5}{4}$$

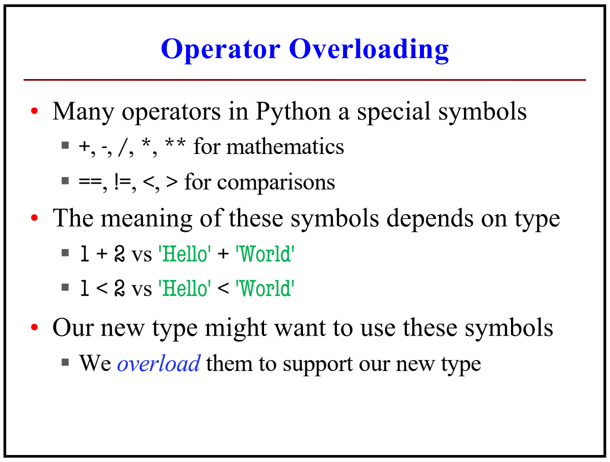
Why not use the standard Python math operations?

What We Get

```
>>> p = Fraction(1,2)
>>> q = Fraction(1,3)
>>> r = Fraction(1,4)
>>> s = Fraction(5,4)
>>> (p.add(q.add(r))).mult(s)
```

This is confusing!

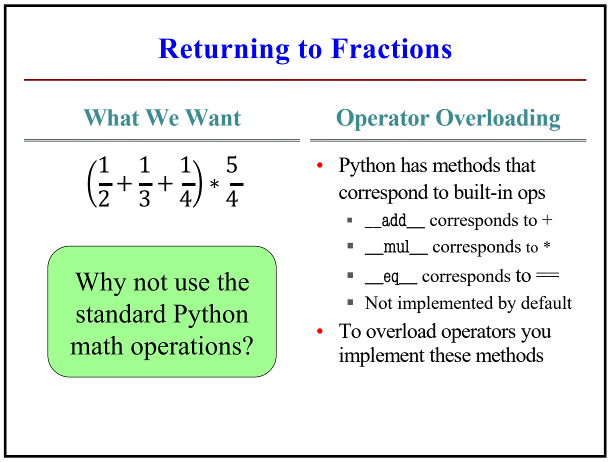
2



Operator Overloading

- Many operators in Python a special symbols
  - +, -, /, *, ** for mathematics
  - ==, !=, <, > for comparisons
- The meaning of these symbols depends on type
  - 1 + 2 vs 'Hello' + 'World'
  - 1 < 2 vs 'Hello' < 'World'
- Our new type might want to use these symbols
  - We *overload* them to support our new type

3



Returning to Fractions

What We Want

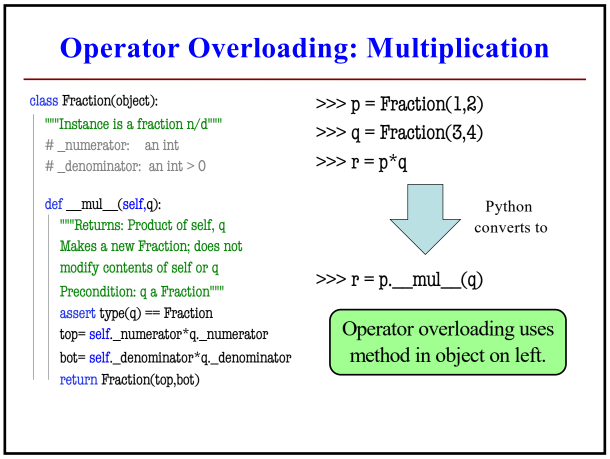
$$\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{4}\right)*\frac{5}{4}$$

Why not use the standard Python math operations?

Operator Overloading

- Python has methods that correspond to built-in ops
  - __add__ corresponds to +
  - __mul__ corresponds to *
  - __eq__ corresponds to ==
  - Not implemented by default
- To overload operators you implement these methods

4



Operator Overloading: Multiplication

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __mul__(self,q):
        """Returns: Product of self, q
        Makes a new Fraction; does not
        modify contents of self or q
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        top= self._numerator*q._numerator
        bot= self._denominator*q._denominator
        return Fraction(top,bot)
```

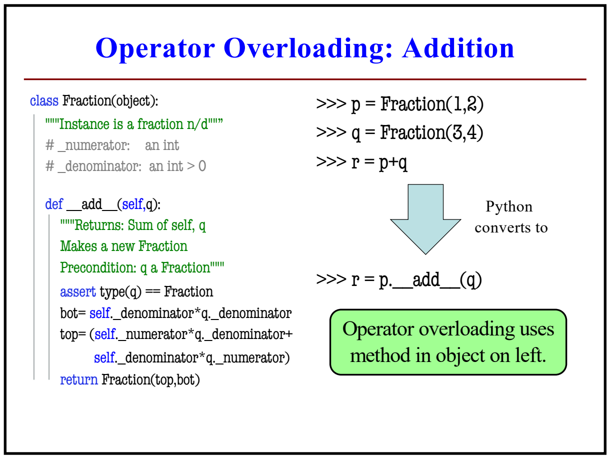
```
>>> p = Fraction(1,2)
>>> q = Fraction(3,4)
>>> r = p*q
```

Python converts to

```
>>> r = p.__mul__(q)
```

Operator overloading uses method in object on left.

5



Operator Overloading: Addition

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __add__(self,q):
        """Returns: Sum of self, q
        Makes a new Fraction
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        bot= self._denominator*q._denominator
        top= (self._numerator*q._denominator+
              self._denominator*q._numerator)
        return Fraction(top,bot)
```

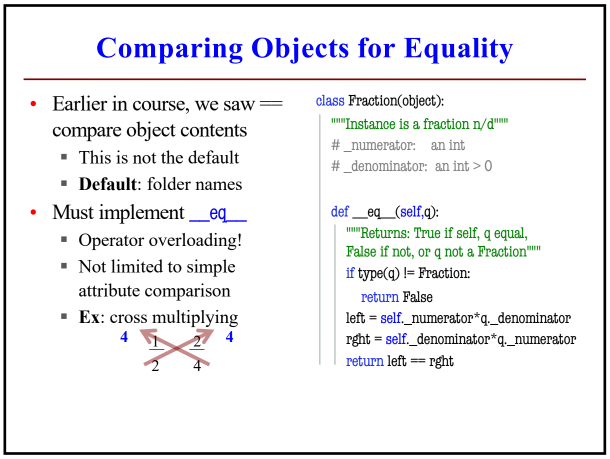
```
>>> p = Fraction(1,2)
>>> q = Fraction(3,4)
>>> r = p+q
```

Python converts to

```
>>> r = p.__add__(q)
```

Operator overloading uses method in object on left.

6



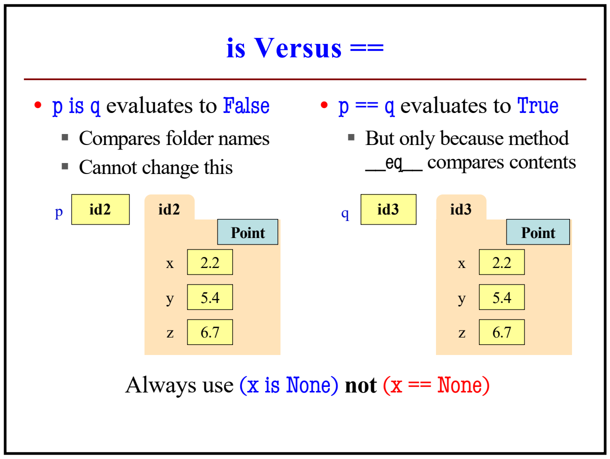
Comparing Objects for Equality

- Earlier in course, we saw == compare object contents
  - This is not the default
  - **Default**: folder names
- Must implement __eq__
  - Operator overloading!
  - Not limited to simple attribute comparison
  - **Ex**: cross multiplying

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __eq__(self,q):
        """Returns: True if self, q equal,
        False if not, or q not a Fraction"""
        if type(q) != Fraction:
            return False
        left = self._numerator*q._denominator
        rght = self._denominator*q._numerator
        return left == rght
```

7



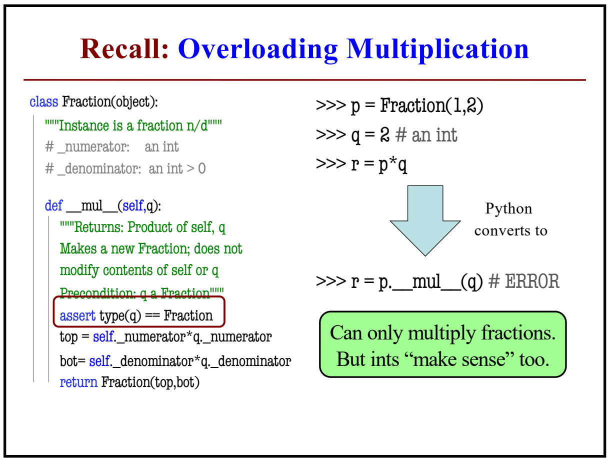
is Versus ==

- p is q evaluates to False
  - Compares folder names
  - Cannot change this
- p == q evaluates to True
  - But only because method __eq__ compares contents

p
id2
id2
Point
x
2.2
y
5.4
z
6.7
q
id3
id3
Point
x
2.2
y
5.4
z
6.7

Always use (x is None) **not** (x == None)

8



Recall: Overloading Multiplication

```
class Fraction(object):
    """Instance is a fraction n/d"""
    # _numerator:    an int
    # _denominator:  an int > 0

    def __mul__(self,q):
        """Returns: Product of self, q
        Makes a new Fraction; does not
        modify contents of self or q
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        top = self._numerator*q._numerator
        bot= self._denominator*q._denominator
        return Fraction(top,bot)
```

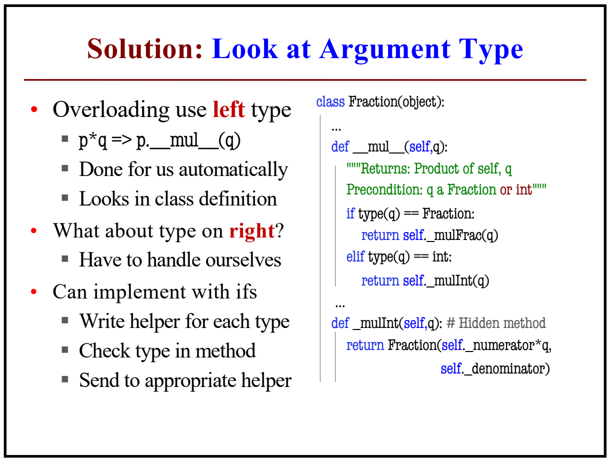
```
>>> p = Fraction(1,2)
>>> q = 2 # an int
>>> r = p*q
```

Python converts to

```
>>> r = p.__mul__(q) # ERROR
```

Can only multiply fractions. But ints "make sense" too.

9

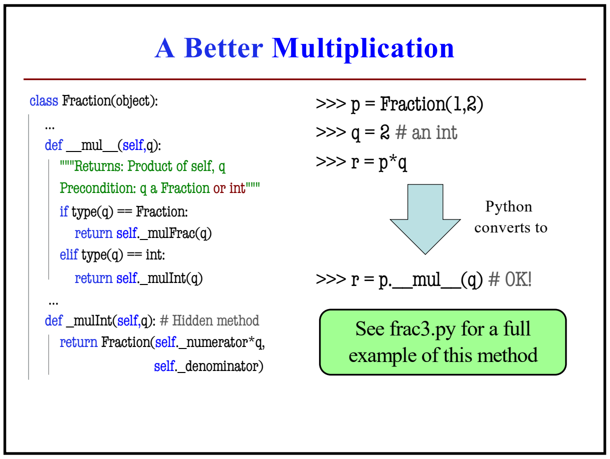


Solution: Look at Argument Type

- Overloading use **left** type
  - p*q => p.__mul__(q)
  - Done for us automatically
  - Looks in class definition
- What about type on **right**?
  - Have to handle ourselves
- Can implement with ifs
  - Write helper for each type
  - Check type in method
  - Send to appropriate helper

```
class Fraction(object):
    ...
    def __mul__(self,q):
        """Returns: Product of self, q
        Precondition: q a Fraction or int"""
        if type(q) == Fraction:
            return self._mulFrac(q)
        elif type(q) == int:
            return self._mulInt(q)
    ...
    def _mulInt(self,q): # Hidden method
        return Fraction(self._numerator*q,
                        self._denominator)
```

10



A Better Multiplication

```
class Fraction(object):
    ...
    def __mul__(self,q):
        """Returns: Product of self, q
        Precondition: q a Fraction or int"""
        if type(q) == Fraction:
            return self._mulFrac(q)
        elif type(q) == int:
            return self._mulInt(q)
    ...
    def _mulInt(self,q): # Hidden method
        return Fraction(self._numerator*q,
                        self._denominator)
```

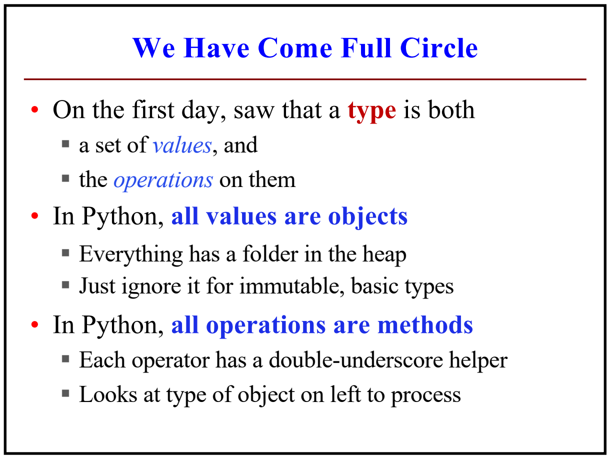
```
>>> p = Fraction(1,2)
>>> q = 2 # an int
>>> r = p*q
```

Python converts to

```
>>> r = p.__mul__(q) # OK!
```

See frac3.py for a full example of this method

11



We Have Come Full Circle

- On the first day, saw that a **type** is both
  - a set of *values*, and
  - the *operations* on them
- In Python, **all values are objects**
  - Everything has a folder in the heap
  - Just ignore it for immutable, basic types
- In Python, **all operations are methods**
  - Each operator has a double-underscore helper
  - Looks at type of object on left to process

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