OBJECTS!

(MAKING THEM)

REMINDERS

- Exam 2 on monday
  - In this room, during class time
  - 1 hour exam, on paper
- Next homework will be released next week :)

A TURTLE SQUARE SOLUTION

```
red_racer = turtle.Turtle()

red_racer.color("red")
red_racer.shape("turtle")
red_racer.penup()
red_racer.goto(-100, 50) # Note: I changed the starting point
red_racer.pendown() # so our turtle draws a line as it moves

steps = 0
while red_racer.xcor() < 200: # Note: this will never be reached
    steps += 1
    if steps % 100 == 0:
      red_racer.right(90)
    red_racer.forward(1)
```

ANOTHER TURTLE SQUARE SOLUTION

```
red_racer = turtle.Turtle()

red_racer.color("red")
red_racer.shape("turtle")
red_racer.penup()
red_racer.goto(-100, 50) # Note: I changed the starting point
red_racer.pendown() # so our turtle draws a line as it moves

for i in range(4): # Note: this will move very fast
  red_racer.forward(100)
  redracer.right(90)
```

CLASSES

A class in Python is a construct that allows us to "bundle data and functionality together." *

- A class defines a new data type!
- Allows instances of that class to be created.

* *From the Python documentation on classes*

A class consists of:

- Some attributes (also called fields) that store data
- Some functions that operate with these fields
  These allow us to create abstractions that are easier to wrap your head around.

CLASSES

So far we've talked about how to **use** classes: creating objects, using attributes/fields, and calling methods inside of a class on a specific instance

Today, we're going to talk about how we **make** classes

__INIT__

__init__ is a special function name that is used for the *intializer*. That is, the function that tells a class how to make a new object.

So previously....

```
class Song:
    def __init__(self, name: str, artist: str, length: int):
        self.name = name
        self.artist = artist
        self.length = length
```

```
my_song = Song("Hello", "Adele", 295) # <-- calls __init__
```

But that doesn't make any sense! You pass in THREE parameters but __init__ takes FOUR! 😱😱

But that doesn't make any sense! You pass in THREE parameters but __init__ takes FOUR! 😱😱

That's because classes work a bit differently, methods in a class should have `self` as a parameter, so every object can reference it *self*!

WHAT CAN WE DO IN __INIT__?

Suppose we have a Ball class...

```
# When we create an instance of a class like this, call __init__
my_ball = Ball(0.5, 0.25, 0.1, (10, 25, 216))
```

```
class Ball:
  def __init__(self, radius, center_x, center_y, color):
    self.radius = radius
    self.center_x = center_x
    self.center_y = center_y
    self.color = color
```

WHAT CAN WE DO IN __INIT__?

What if we slightly modify our class `Ball` to randomly generate the colors?

```
class Ball:
    def __init__(self, radius, center_x, center_y): # no more color
        self.radius = radius
        self.center_x = center_x
        self.center_y = center_y

        red = random.randint(0, 255)
        green = random.randint(0, 255)
        blue = random.randint(0, 255)
        self.color = (red, green, blue)
```

```python
@dataclass
class Ball:
  radius: int
  center_x: float
  center_y: float
  color: tuple[int, int, int]
```

This is also something that makes a lot more sense to do in a general class rather than a dataclass!

Let's try to use objects to make drawing in penndraw easier

Here we have the `Square` class defined with the method `draw`

```
class Square:
    def __init__(self, half_length, center_x, center_y):
        self.half_length = half_length
        self.center_x = center_x
        self.center_y = center_y
        red = random.randint(0, 255)
        green = random.randint(0, 255)
        blue = random.randint(0, 255)
        self.color = (red, green, blue)

    def draw(self):
        penndraw.set_pen_color(self.color) # we use self for attrs.
        penndraw.filled_square(self.center_x, self.center_y,
                               self.half_length)
```

PREDICT WHAT HAPPENS!

`change_color()` method that we'd call to replace the color of a `Square` object with a new one, e.g. `my_square.change_color((155, 78, 300))`.

```
class Square:
  def __init__(self, half_length, center_x, center_y, color):
    self.half_length = half_length
    self.center_x = center_x
    self.center_y = center_y
    self.color = color
  def change_color(new_color):
    color = new_color
```

Can you spot the bug & predict what would happen if we tried to call `change_color`?

PREDICT WHAT HAPPENS!

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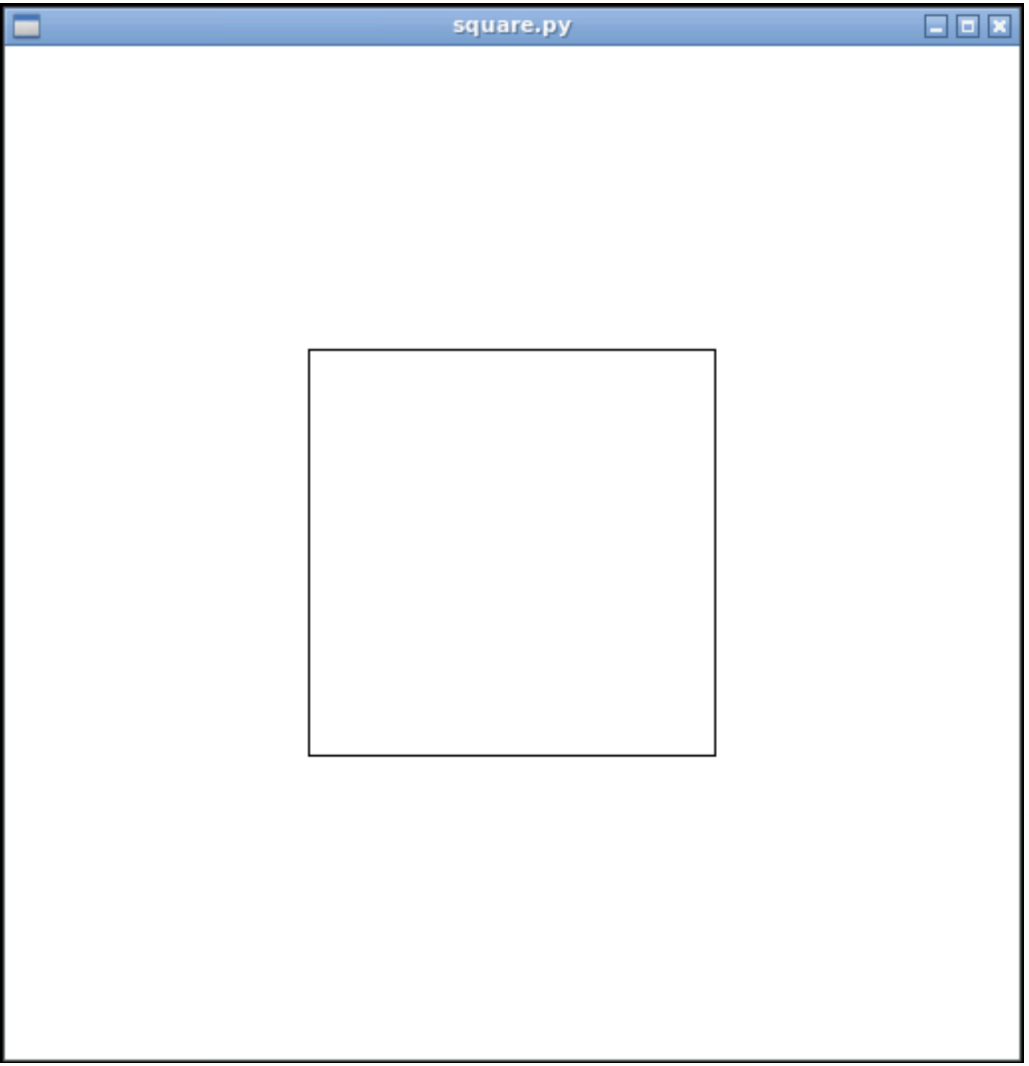
```
class Square:
  def __init__(self, half_length, center_x, center_y, color):
    self.half_length = half_length
    self.center_x = center_x
    self.center_y = center_y
    self.color = color
  def change_color(new_color): # <-- missing self!
    color = new_color          # <-- sets a new variable called color
```

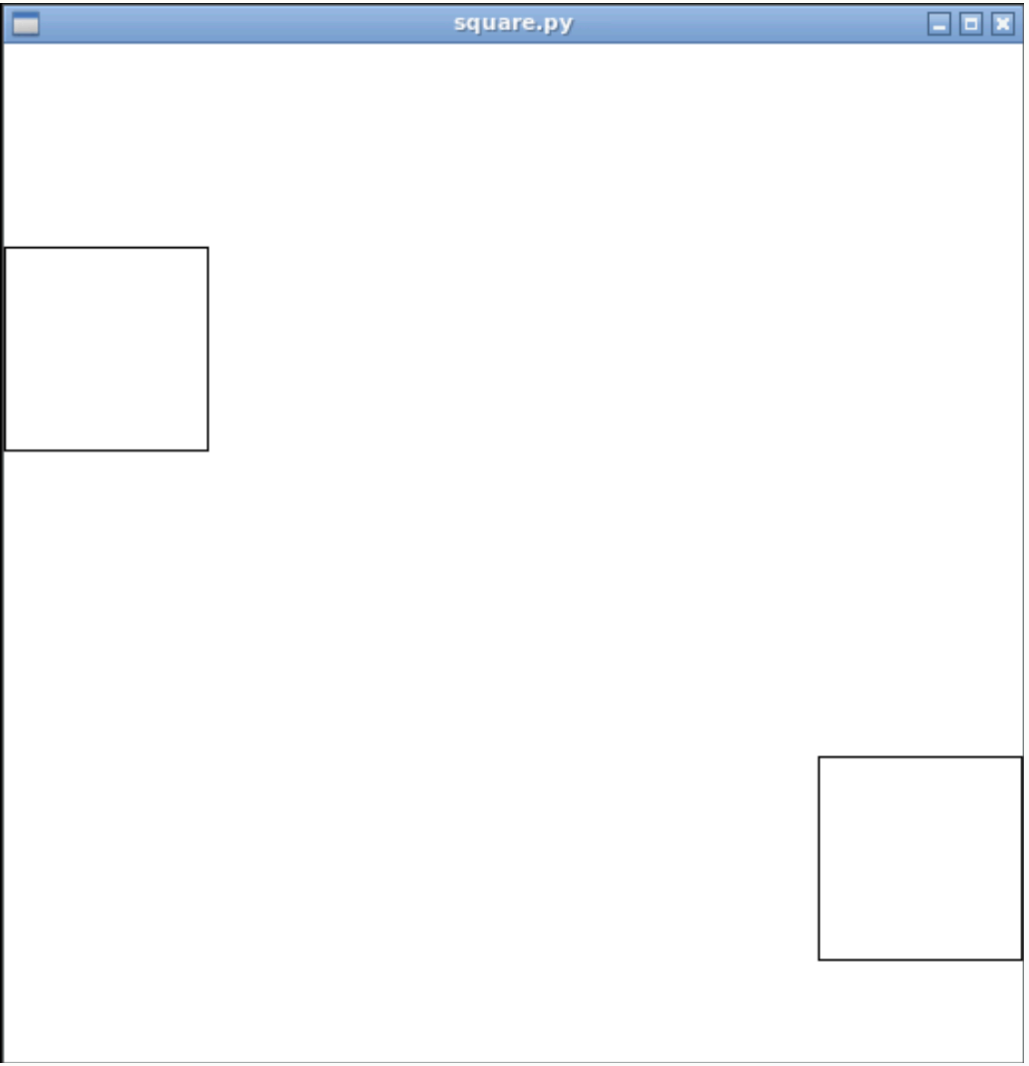


REVIEW: USING METHODS

Methods are functions that belong to an object, so they are called (mostly) like any function

- Call by name and pass in arguments within parentheses
- Make sure to call the method *on the object* that you want to perform that behavior!

```
my_square = Square(0.5, 0.5, 0.2)
my_square.draw()
```



You might have several instances of a class in your program.

- A method called on an object should *modify/use just that object.*
- Other objects will be unchanged by another object's method call.

```
left_square = Square(0.1, 0.2, 0.1)
right_square = Square(0.9, 0.2, 0.1)
left_square.move_by(0, 0.5)
left_square.draw()
right_square.draw()
```

PRACTICE: CONTAINS POINT [C1]

Write the method `contains_point` for the `Square` class that checks to see if a point is contained within the square.
Returns `True` if the point is in the square, or `False` if it is not in the square.

```
def contains_point(self, other_x: float, other_y: float) --> bool:
    # TODO: probably use half_length, center_x and center_y
```

Can you do this without writing an `if`?

BOUNCING BALL SIMULATION

Ingredients:

- `ball.py`, a class that defines how a 2D ball moves & bounces on a screen
- `bouncing_balls.py`:
  - contains a main method so that the simulation is runnable
  - creates a `list[Ball]` in which to store the objects to be simulated
  - defines a "physics" (animation) loop

A BIT OF PHYSICS

To simulate an object's motion in 2D space over time, we need to keep track of its:

- position (p_x, p_y)
  - where the object is **right now**
- velocity/speed (v_x, v_y)
  - how much the object **should move** from where it is right now to where it will be next time we look
- acceleration (a_x, a_y)
  - how much the object's velocity should change from what it is right now to what it will be next time we look (always a constant)

A BIT OF PHYSICS

Since our simulation is run using a loop, we do our calculations in *discrete steps*.

- We denote the step number using superscripts, so p_x^t means "x position at step t"
- We'll assume a constant unit timestep, meaning that we don't have to account for the length of the timestep in our equations
  - *(ignore this point if the details of physical simulations are not interesting to you)*

A BIT OF PHYSICS

EQUATION	MEANING	CODE
$p_x^{t+1} = p_x^t + v_x^t$	x position in the next iteration is equal to the x position now plus the x speed now	px = px + vx
$p_y^{t+1} = p_y^t + v_x^t$	y position in the next iteration is equal to the y position now plus the y speed now	py = py + vy
$v_x^{t+1} = v_x^t + a_x^t$	x speed in the next iteration is equal to the x speed now plus the x acceleration	vx = vx + ax
$v_y^{t+1} = v_y^t + a_y^t$	y speed in the next iteration is equal to the y speed now plus the y acceleration	vy = vy + ay

SOME MATH THAT WILL HELP YOU NEXT WEEK [L1]

Assume at time t we have a Ball $(0.5, 0.5)$ with $v_x^t = 0.1, v_y^t = 0.2$ and $a_x^t = 0$, $a_y^t = -0.05$.

What's the position after one time step (at time $t + 1$)?
What's the x velocity after one time step, v_x^{t+1}?
What's the y velocity after one time step, v_y^{t+1}?
Recall:

- $p_x^{t+1} = p_x^t + v_x^t$
- $p_y^{t+1} = p_y^t + v_x^t$
- $v_x^{t+1} = v_x^t + a_x^t$
- $v_y^{t+1} = v_y^t + a_y^t$

IMPLEMENTING BALL.PY

What behaviors does a `Ball` object need to exhibit as part of a simple physics simulation?

- Needs to be drawable so that we can see the simulation
- Needs to move & bounce pursuant to the previous equations

Methods:

`def draw(self)`, `def update(self)`

IMPLEMENTING BALL.PY

What properties does a `Ball` object need to store in order to perform these operations?

- position, x and y
- velocity, x and y
- acceleration, x and y
  - we'll ignore x acceleration, and y acceleration is just gravity
- radius
  - used for drawing
  - used for deciding when to bounce

THE SIMULATOR

The simulator will be responsible for initializing and keeping track of all of the balls in the simulation.

- How will we store all of the objects being simulated?
  - Create an `list[Ball]`
- How will we draw each of the objects being simulated?
  - Iterate through the list and call the `draw()` method on each of the `Ball` objects.
- How will we get each of the objects to move and bounce?
  - Iterate through the list and call the `update()` method on each of the `Ball` objects

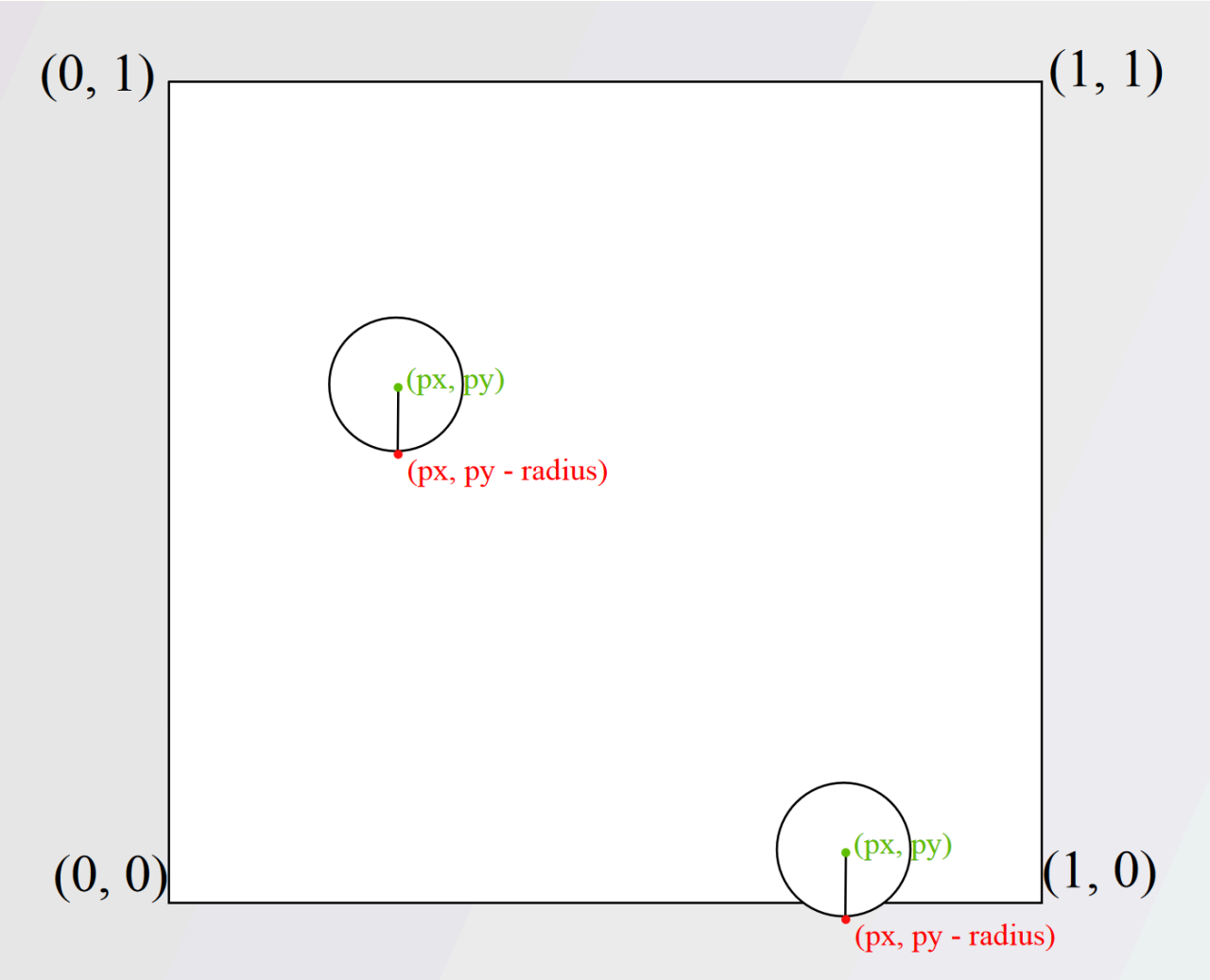
```
import penndraw
import ball
def main():
    N = 10
    all_balls = []

    for _ in range(N):
        all_balls.append(ball.Ball())

    penndraw.set_canvas_size(600, 600)
    while True:
        penndraw.clear()
        for current_ball in all_balls:
            current_ball.draw()
            current_ball.update()
        penndraw.advance()
    penndraw.run()
```

```
class Ball:
    def __init__(self):
        self.px = random.random()
        self.py = random.random()
        self.vx = -0.005 + (random.random() * 0.01) # [-0.005, 0.005]
        self.vy = -0.005 + (random.random() * 0.01)
        self.gravity = -0.0001
        self.radius = 0.02 + random.random() * 0.04 # [0.02, 0.06]

    def draw(self):
        penndraw.filled_circle(self.px, self.py, self.radius)

    def update(self): # No bouncing yet!
        self.px = self.px + self.vx
        self.py = self.py + self.vy
        self.vy = self.vy + self.gravity
```

PROBLEM: NO BOUNCING!

Currently, the balls just drop off the sides or bottom of the screen. How can we get them to bounce?

- Check if the ball has gone past the left, right, or bottom of the screen
- Simulate a bounce by inverting the velocity for the next update step



A BOUNCE [L2]

On the left, we have a sketch of the canvas with two balls.

- Which one should "bounce"?
- How can you formalize (write an equation for or just describe) how we can decide when a ball should bounce off the bottom of the screen (in terms of ball attributes)

CHECKING A BOUNCE

A ball should bounce off the bottom of the screen when, at time step t:

- The ball is traveling downwards ($v_y^t < 0$)
- The bottom of the ball is at or below the bottom of the screen ($p_y^t - \text{radius} \leq 0$)

MODELING A BOUNCE

What happens when an object bounces off of a surface?

- The object should change direction
- The object should lose a bit of momentum

The Bounce:

$$v_y = -0.9 * v_y$$

A BETTER UPDATE()

```
def update(self):
    self.px = self.px + self.vx
    self.py = self.py + self.vy
    self.vy = self.vy + self.gravity

    if (self.vy < 0 and self.py - self.radius <= 0):
        self.vy = -0.9 * self.vy
```

COLLISION PRACTICE: [C2]

What if we want to make the balls bounce off of the walls?

A ball should bounce off the side of the screen when, at time step t:

- The ball is traveling in the direction of the wall
  - $v_x^t < 0$ for the left wall
  - $v_x^t > 0$ for the right wall
- The bottom of the ball is at or past the wall
  - $p_x^t - \text{radius} \leq 0$ for the left wall
  - $p_x^t - \text{radius} \geq 1$ for the right wall

What can we add to the update method to support bouncing off of the walls?

A BEST UPDATE()

```
def update(self):
    self.px = self.px + self.vx
    self.py = self.py + self.vy
    self.vy = self.vy + self.gravity

    if (self.vy < 0 and self.py - self.radius <= 0):
        self.vy = -0.9 * self.vy

    if ((self.vx < 0 and self.px - self.radius <= 0) or
            (self.vx > 0 and self.px + self.radius >= 1)):
        self.vx = -0.9 * self.vx
```