Turtle graphics was first developed as part of the children’s programming language Logo in the late 1960’s. It exemplifies OOP extremely well. You will be using classes already defined for you.

Turtles are just Python objects, so you can use any Python constructs in turtle programs: selection, loops, recursion, etc.

Turtles are objects that move about on a screen (window).

Various methods allow you to direct the turtle’s movement.

The turtle’s tail can be up or down. When it is down, the turtle draws on the screen as it moves.

You can draw some pretty awesome images!
A Turtle Drawing

A Turtle Drawing: I Drew This One


Coordinate Grid

The Turtle’s Data

Like all Python classes, the `turtle` class defines data and methods. The data (attributes) of the turtle consists of:

- **Position**: denoted by its current x and y coordinates; the units are pixels.
- **Heading**: denoted by an angle in degrees. East is 0 degrees, north is 90 degrees, west is 180 degrees, south is 270 degrees.
- **Color**: the color can be set to $2^{24}$ (≈ 16.8 million) colors.
- **Width**: the width of the line drawn as the turtle moves (initially 2 pixels).
- **Down**: a Boolean attribute indicating whether the turtle’s tail is down.
Turtle Methods

Many turtle methods are listed in your textbook (pages 81, 83) and online; Google “python turtle graphics.”

- `t = Turtle()` create a new Turtle object and open its window
- `t.home()` move the turtle to (0, 0), pointing east
- `t.pendown()` lower the tail (`t.down()` also works)
- `t.penup()` raise the tail (`t.up()` also works)
- `t.pensize(k)` set linewidth to k pixels
- `t.setheading(d)` change heading to direction d
- `t.left(d)` turn left d degrees
- `t.right(d)` turn right d degrees
- `t.speed(n)` set how fast the turtle moves (0 .. 10)
- `t.setx(n)` set the turtle’s x coordinate, leave y unchanged
- `t.sety(n)` set the turtle’s y coordinate, leave x unchanged

Turtle Methods

- `t.forward(n)` move in the current direction n pixels
- `t.backward(n)` move in the reverse direction n pixels
- `t.goto(x, y)` move to coordinates (x, y)
- `t.position()` return the current position as a tuple (x, y)
- `t.heading()` return the current direction (angle)
- `t.isdown()` return True if the pen is down
- `t.pencolor(r, g, b)` change the color to the specified RGB value or named color
- `t.write(s, font)` write a message to the screen (you can specify font and size, e.g., “font=('Arial', 8, normal)”

Keeping it On Screen

Because the window goes away immediately after the program terminates, it may be hard to see the result unless you delay things. You can use `turtle.done()` for that. Note that this is a class method rather than an instance method; that means that you need to use the class name `turtle.done()`, not the instance `leonardo.done()`.

- `turtle.done()` make the screen persist until you close it

The turtle itself will appear on your screen as a small arrowhead. You can decide whether to show or hide the turtle.

- `t.hideturtle()` make the turtle invisible
- `t.showturtle()` make the turtle visible
- `t.isvisible()` return True if the turtle is visible

```python
import turtle
def drawSquare(ttl, x, y, length):
    """ Draws a square using turtle ttl, with upper left corner at (x, y), and side of length""
    ttl.penup()
    ttl.goto(x, y)
    ttl.setheading(0)
    ttl.pendown()
    for count in range(4):
        ttl.forward(length)
        ttl.right(90)
    ttl.penup()
    Bob = turtle.Turtle()
    Bob.speed(10)
    Bob.pensize(3)
    drawSquare(Bob, 0, 0, 100)
turtle.done()
```
```python
import turtle

def drawTriangle(turtle, x1, y1, x2, y2, x3, y3):
    turtle.penup()
    turtle.goto(x1, y1)
    turtle.pendown()
    turtle.goto(x2, y2)
    turtle.goto(x3, y3)
    turtle.goto(x1, y1)
    turtle.penup()

Tom = turtle.Turtle()  # our turtle is named Tom
Tom.speed(10)  # make Tom crawl fast
Tom.pensize(3)  # line width of 3 pixels

Tom.pencolor(1, 0, 0)  # set pen to red
drawTriangle(Tom, 0, 0, 50, 100, 100, 0)
Tom.pencolor(0, 1, 0)  # set pen to green
drawTriangle(Tom, 0, 0, 50, -100, 100, 0)
Tom.hideturtle()
```
Colors

I'm not sure this works on all versions of turtle graphics.

Colors are in the RGB system, using a triple: \((R, G, B)\). Each element in the triple is an intensity from 0 to 255, indicating the contribution of R (red), G (green), and B (blue). For example:

<table>
<thead>
<tr>
<th>Color</th>
<th>RGB</th>
</tr>
</thead>
<tbody>
<tr>
<td>black</td>
<td>(0,0,0)</td>
</tr>
<tr>
<td>red</td>
<td>(255,0, 0)</td>
</tr>
<tr>
<td>green</td>
<td>(0, 255, 0)</td>
</tr>
<tr>
<td>blue</td>
<td>(0, 0, 255)</td>
</tr>
<tr>
<td>gray</td>
<td>(127, 127, 127)</td>
</tr>
<tr>
<td>white</td>
<td>(255, 255, 255)</td>
</tr>
<tr>
<td>burnt orange</td>
<td>(255, 125, 25)</td>
</tr>
</tbody>
</table>

This is a nice website that allows you to find the RGB values for various colors: www.colorschemer.com/color-picker.

The named Python colors can be found here: https://python-graph-gallery.com/python-colors/.

Circles

Turtles have two “colormodes” and you’ll get an error if you try to do some things in the wrong mode. The modes are 1.0 and 255. In mode 255, use triples of range \(0 \leq c \leq 255\). In mode 1, use triples (percentages) in range \(0 \ldots 1\).

```python
>>> t = Turtle()
>>> t.pencolor(127, 127, 127)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
     raise TurtleGraphicsError("bad color sequence: %s" % str(color))
```

```python
>>> t.pencolor(0.5, 0.5, 0.5)
>>> t.screen.colormode(255)
>>> print(t.screen.colormode())
255
>>> t.pencolor(127, 127, 127)
>>> t.screen.colormode(1)
```

You can draw circles, arcs, and dots using these functions:

- `t.circle(r, ext, step)` draw a circle with radius \(r\), ext (arc of circle drawn; 360 is entire circle), step (number of segments).
- `t.dot(d, color)` draw a filled circle with diameter \(r\) and color

Note: the circle is not centered at the starting point. If you want that you could write:

```python
def centeredCircle(ttl, r, x, y):
    """ Draw a circle with radius \(r\) centered at \((x, y)\). ""
    ttl.up()  # raise the pen
    angle = ttl.heading()  # save the current heading
    ttl.setheading(0)  # set heading east
    ttl.goto(x, y - r)  # move to bottom of circle
    ttl.down()  # pen down
    ttl.circle(r)  # draw the circle
    ttl.up()  # pen up
    ttl.setheading(angle)  # restore the heading
```
Circles

def drawSomeCircles(ttl):
    ttl.speed(10)
ttl.pensize(3) # line is 3 pixels
ttl.up()
ttl.home() # go to (0, 0)
ttl.down()
ttl.pencolor('Green')
ttl.circle(25) # rad. 25 pixels
ttl.up()
ttl.goto(0, 0)
ttl.pencolor('Red ')
ttl.down()
ttl.circle(50, 180) # arc 180 deg.
ttl.up()
ttl.goto(0, 0)
ttl.pencolor('Blue ')
ttl.down()
ttl.circle(75, 360, 8) # octogon
ttl.up()
Sam = turtle.Turtle()
drawSomeCircles(Sam)

More with Circles

def tangentCircles(ttl):
    """ Print 10 tangent circles. """
r = 10 # initial radius
n = 10 # count of circles
for i in range(1, n + 1, 1):
    ttl.circle(r * i)

def concentricCircles(ttl):
    """ Print 10 concentric circles. """
r = 10 # initial radius
for i in range(10):
    ttl.circle(r * i)
ttl.up()
ttl.sety((r * i) * (-1))
ttl.down()
Ben = turtle.Turtle()
Ben.up(); Ben.goto(0, 150)
Ben.down(); Ben.pencolor('Blue ')
tangentCircles(Ben)
Ben.up(); Ben.goto(0, -150)
Ben.down(); Ben.pencolor('Red ')
concentricCircles(Ben)

Fill Areas

If you draw a closed region, you can fill it with a specified color:

t.fillcolor() sets the pen fill color
t.begin_fill() call this before filling a shape
t.end_fill() call to no longer keep filling
t.filling() return True if filling, False otherwise

Drawing a Chessboard

def maybeFillSquare(ttl, x, y, lngth, fill, color):
    """ Boolean parameter fill says whether to fill. """
    if fill:
        ttl.fillcolor( color )
ttl.begin_fill()
drawSquare( ttl, x, y, lngth )
ttl.end_fill()
    else:
        drawSquare( ttl, x, y, lngth )

def drawChessboard(ttl, x, y, squaresize):
    """ Draw a teal and white chessboard. """
    fill = True
    for j in range(8):
        for i in range(8):
            x1 = x + i*squaresize
            y1 = y - j*squaresize
            maybeFillSquare( ttl, x1, y1, squaresize, fill, 'teal' )
            fill = not fill
            fill = not fill
Matt = turtle.Turtle()
drawChessboard( Matt, 0, 0, 20 )
Our Chessboard

I don’t know why those weird lines are in there. They don’t show up on the screen.

Some Complex Stuff: Sierpinski Curve

```python
def oneSide(ttl, s, diag, level):
    if (level == 0):
        return
    else:
        oneSide(ttl, s, diag, level - 1)
        ttl.right(45); ttl.forward(diag); ttl.right(45)
        oneSide(ttl, s, diag, level - 1)
        ttl.left(90); ttl.forward(s); ttl.left(90)
        oneSide(ttl, s, diag, level - 1)
        ttl.right(45); ttl.forward(diag); ttl.right(45)
        oneSide(ttl, s, diag, level - 1)

def sierpinski(ttl, s, level):
    diag = s / math.sqrt(2)
    for i in range(4):
        oneSide(ttl, s, diag, level)
        ttl.right(45)
        ttl.forward(diag)
        ttl.right(45)
```

Some Complex Stuff: Fractal Triangles
def drawOutwardTriangles( ttl, size):
    if size < 10:
        return
    for i in range(3):
        ttl.forward( size / 2 )
        insert( ttl, size )
        ttl.forward( size / 2 )
        ttl.right( 120 )

def insert( ttl, size ):
    ttl.left( 120 )
    drawOutwardTriangles( ttl, size / 2 )
    ttl.right( 120 )

Ken = turtle.Turtle()
Ken.color("blue")
drawOutwardTriangles( Ken, 200 )

---

Python saves your picture as a postscript file, but you can convert it. To save your picture as a jpeg, do the following:

```python
from PIL import Image

def save_as_jpg(canvas,fileName):
    # save postscript image
    canvas.postscript(file = fileName + '.eps')
    # use PIL to convert to JPEG
    img = Image.open(fileName + '.eps')
    img.save(fileName + '.jpeg', 'jpeg')
< Your drawing functions >

ts = turtle.getscreen()
tc = ts.getcanvas()
# creates a postscript image file
# substitute your own filename
tc.postscript(file="filename.eps")
# converts to JPEG
save_as_jpg(tc,"filename")
turtle.done()
```

---

Write Turtle graphics functions that will do the following:
- draw a cube;
- draw a regular polygon with k sides and radius r (distance from center to one of the vertices);
- draw m concentric circles, varying the color as you go outward;
- draw an American flag;
- draw the UT Tower.