Tic Tac Toe

Write a program that allows two players to play a game of Tic Tac Toe.

Here's everything we'll need to do for this program:

- Represent the board
- Display the board
- Keep track of who's turn it is
- Allow players to make moves
- Prevent players from making impossible/illegal moves
- Detect when the game has ended

Most of these items will be accomplished without much trouble. Our biggest challenge will be writing code to detect when the game has ended. Let's build up the game then see what it takes to detect end-game conditions.

If you want to skip to the complete version, go right to repl repl.it!

Two-Dimensional Array Coordinates

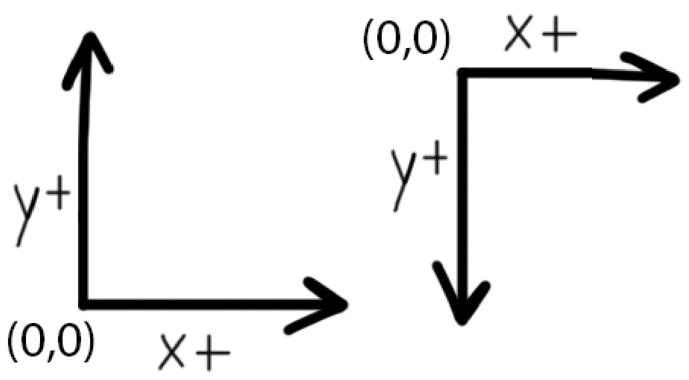
Let's start with the board representation. A two-dimensional array is a great choice for this grid game. Here's a 3x3 grid filled with `None` values to represent an empty board. Let's practice accessing different spots on the board to make sure we've got our coordinates all figured out.

```
board = [
  [None, None, None],
  [None, None, None],
  [None, None, None],
]
```

We're saving the entire two-dimensional grid in to a variable called `board`. The board has three rows going from top to bottom, and three columns going from left to right.

To access the top-left corner of the board we access `board[0][0]`. It's in the first row, in the first column. The grid is an array of arrays. That is to say, the `board` variable itself refers to one array. That array contains three things. Each of those things is an array itself. Each of the inner arrays has three empty spots.

- The top left corner is at index `board[0][0]`
- The middle spot is at index `board[1][1]`
- The bottom left corner is at index `board[2][0]`
- The middle bottom spot is at index `board[2][1]`
- The bottom right corner is at index `board[2][2]`



If you come from a background dealing with (x,y) coordinates with lines and graphs like in a math class you might notice something odd here. In math classes we draw a graph with the origin `(0,0)` in the bottom left corner. The graph has two axes: one for `x` extending to the right, and one for `y` extending up. In a math graph y values start at zero at the bottom and increase as they go up. In our Tic Tac Toe grid our "y" row indexes go up in the opposite direction. Our vertical row coordinates start at zero at the top of the grid, and they increase as they go toward the bottom.

Often in computer graphics the top of the screen is where y-coordinates start. They start at the top as zero and increase as they move down the screen. Think of it like the way you read a book. You start at the top left corner of a page and read left-to-right, then top-to-bottom.

Since I'm personally used to y-coordinates increasing as they go up I strive to refer to array indexes with the words "row" and "column," especially in strictly grid-like structures. It makes it easier for me to reason about where things are located.

Game Engine

Now that we've determined how to represent the state of the board we can think about what sort of interactions we need to have with the game. Let's make a class that represents a game of Tic Tac Toe. The class needs methods to determine if the game is over, allow players to make moves, and keep track of who wins at the end of the game.

Here's a simplified version of how the main program will use this class. The most important methods here are `is_game_over`, and `make_move`. The class will have more methods used by itself internally.

```
game = TicTacToeGame()
while not game.is_game_over():
  row, col = prompt_player(game)
  game.make_move(row, col)
  display_board(game)
display_winner(game)
```

Most of the complexity of this main program has been abstracted away with the methods `prompt_player`, `display_board` and `display_winner`. You can assume those methods access properties on the `TicTacToeGame` class, and perform sufficient input and output.

Here's an outline of the whole `TicTacToeGame` class:

```
class TicTacToeGame:
  winner = None
  is_game_over = false

  turn = 0
  players = ['X', 'O']
```

```
    board = [
      [None, None, None],
      [None, None, None],
      [None, None, None]
    ]

    reset_game()
    make_move(row, col)

    get_current_player()
    is_game_over()
    get_winner()

    is_valid_move(row, col)
    check_game_over()
  }
```

The class has state for if the game is over and who won. It has an integer variable `turn` to count what turn number it is. It will use the `turn` number to determine which player's turn it is. The `players` array stores the two players in the game, represented as the strings `"X"` and `"O"` .

The class has a `board` property referring to the 3x3 two-dimensional array, and it has methods to manipulate everything when moves are made.

Notice there's more methods in the class than there are used in the miniature main concept program above. Specifically, the `is_valid_move` and `check_game_over` will never be called from the main program. These are internal methods that will only be called from other methods inside the class. These will be called from inside `make_move()` which is called from the main program.

Programming languages often call the different between externally-used and internally-used methods `public` and `private` methods.

Read more about encapsulation.

Making Moves and Taking Turns

Let's implement `make_move(row, col)` . This method accepts a position on the board and marks the spot with an `"X"` or an `"O"` . It depends on knowing which player is currently making the move. It should only count the move if the player has chosen a legitimate row and column on the board, and it should prevent the player from overwriting a move already made at a position. If the move is legitimate then the board is marked, and the next time the method is called it is the next player's turn.

In summary:

- Have the current player attempt to make a move
- Double-check to make sure the move is legitimate
- Manipulate the state of the game as per the move
- Advance the state of the game to the next player

How do we keep track of what player's turn it is? Use the `turn` number to constantly cycle through the array of `players` whenever a legitimate turn is complete. There's a nice pattern we can use with the modulus operator to achieve this cleanly.

If we always increment the `turn` number and take the modulo of it and the length of the `players` array then we will get a number that cycles through each of the array indexes, starting at zero, going to the end and repeating over and over.

Check out this example:

```
# referring to a Star Trek TNG poker scene
# https://www.youtube.com/watch?v=XRE9HNUmdtA
players = ['Beverly', 'Riker', 'Geordie', 'Worf', 'Data']
```

```
turn = 0
while turn < 42:
  index = turn % players.length
  player = players[index]
  print('current player:', player)

  turn += 1
```

Takeaway: You can always use an integer, an array, and the modulus operator to proceed through player turns in an orderly fashion until a game is over. When you take the turn number "modulo" the length of the array you end up with a number sequence that cycles through indexes of the array.

Here's an example using modulus in a two player game, and a five player game. No matter how many players are in the game this will always work.

(Well, technically there's one specific thing that could cause this to hiccup. Read more about Integer Overflow. Practically it would only happen if your game lasted many, many, many turns.)

Turn	turn % 2	Two Players	turn % 5	Five Players
0	0 % 2 == 0	Alice	0 % 5 == 0	Beverly
1	1 % 2 == 1	Bob	1 % 5 == 1	Riker
2	2 % 2 == 0	Alice	2 % 5 == 2	Geordie
3	3 % 2 == 1	Bob	3 % 5 == 3	Worf
4	4 % 2 == 0	Alice	4 % 5 == 4	Data
5	5 % 2 == 1	Bob	5 % 5 == 0	Beverly
6	6 % 2 == 0	Alice	6 % 5 == 1	Riker
7	7 % 2 == 1	Bob	7 % 5 == 2	Geordie
8	8 % 2 == 0	Alice	8 % 5 == 3	Worf
9	9 % 2 == 1	Bob	9 % 5 == 4	Data
10	10 % 2 == 0	Alice	10 % 5 == 0	Beverly
11	11 % 2 == 1	Bob	11 % 5 == 1	Riker
12	12 % 2 == 0	Alice	12 % 5 == 2	Geordie
13	13 % 2 == 1	Bob	13 % 5 == 3	Worf

Make one method `get_current_player` that uses modulus with `turn` and the `players` array to return either `"X"` or `"O"` for the current player.

Create a method `is_valid_move(row, col)` that checks the bounds of the row and column indexes, and checks to make sure no one has played at that position before. To check the row and column indexes just make sure the numbers are no less than zero and no greater than two. Check to see make sure the place on the board is empty by verifying it's value is `None` .

Now we can use these two helper methods inside the `make_move(row, col)` method. First, use `is_valid_move(row, col)` to pass the row and column coordinates through to make sure the move is possible. If the move is not possible simply return from the method without having changed the state of the game at all. The main program outside this class will need to detect that it is still the same players turn and prompt them to make a legal move.

If the move is valid then it's save to mark the board. The `get_current_player()` method retrieves either an `"X"` or an `"O"` and saves that value to the position on the board.

After a legitimate move has been made and a mark has been left the `make_move` method should increment the `turn` number and run logic to see if the game has ended.

Here's the code all together. We'll look more at creating the `check_game_over` method next.

```
def get_current_player(self):
  index = self.turn % self.players.length
  return self.players[index]

def is_valid_move(row, col):
  # make sure indexes are legitimate array indexes within the grid
  if (row < 0 or col < 0 or row >= 3 or col >= 3) {
    return False

  # make sure the spot on the grid hasn't already been taken
  if (board[row][col] is not None) {
    return False
  return True

def make_move(row, col):
  if self.is_valid_move(row, col):
    # mark the board with the current player ("X" or "O")
    self.board[row][col] = self.get_current_player()
    self.turn += 1

    # check to see if the move ended the game
    self.check_game_over()
```

Checking For Game Over

OK, now we've got a class set up to represent the whole Tic Tac Toe game. The class uses a two-dimensional array to represent the board. It's got methods that allow players to make moves, it increments through player turns smoothly, and makes sure players only make legitimate moves. Let's figure out when this thing ends!

When does Tic Tac Toe end?

- A player wins when a player gets three in a row.
- Players tie when the board fills up no threes-in-a-row

I apologize for having explained end-game conditions for Tic Tac Toe. If you've seriously never played Tic Tac Toe, welcome to the game!

Now let's translate our end-game conditions into code.

Detecting the "cat's games" as the end-game tie condition is easier than looking everywhere on the board for three-in-a-rows. Since our game only increments the `turn` counter when legitimate moves are made we know that ties will always occur at the end of turn nine if there's not a three-in-a-row (or is it eight because we start at zero? Watch out for off-by-one-errors!).

Detecting three things in a row on our grid requires looking at lots of different places on the board. This seems like a job for for-loops. Let's write code using for-loops first, then we'll explore a simpler solution.

Asserting Three-in-a-row

Let's consider the logic to check if there's three things in a row. We need to account for mixtures of three values: `Nones`, `Xs` and `Os`.

We know there's three in a row if the first one matches the second, and if the second matches the third. We don't need to check to see if the first matches the third because we're already comparing both the first and the third to the second.

We could get false positive in our program if we accidentally counted three `Nones` in a row as winning. Let's add one more piece of logic to make sure that the first spot is not empty, `None`.

Let's see how this logic holds up against some examples. It's nice to be thorough and really write out all these variations to make sure our logic is correct.

- `[X, X, X]` #1 is not None, #1 matches #2, #2 matches #3. X wins.
- `[X, X, O]` #1 is not None, #1 matches #2, #2 does not match #3. No win due to a not-match.
- `[X, X, None]` #1 is not None, #1 matches #2, #2 does not match #3. No win due to a not-match.
- `[X, None, X]` #1 is not None, #1 does not match #2, #2 matches #3. No win due to a not-match.
- `[None, X, X]` #1 is None, #1 does not match #2, #2 matches #3. No win due to a not-match.
- `[None, None, None]` #1 is None, #1 matches #2, #2 matches #3. No win due to #1 being None.

Here is logic checking to see if there's three-in-a-row across the top row:

```
is_not_none = board[0][0] is not None
three_in_a_row = board[0][0] == board[0][1] and board[0][1] == board[0][2]
return is_not_none and three_in_a_row
```

Traversing Arrays

Now that we have the logic to detect three-in-a-row we need to check for three-in-a-row everywhere on the board. Three-in-a-rows appear in three (or four?) different patterns:

1. From left to right across a row (on the top, middle, or bottom rows)
2. From top to bottom along a column (along the left, middle, or right columns)
3. From top-left to bottom-right in a diagonal
4. From bottom-left to top-right in a diagonal

First we write a for-loop to check each row. The loops needs to move across all three rows and check to see if the three spots all match each other.

Checking for three-in-a-row across columns is (exactly) similar, so there's a for-loop that moves across columns in the same way too.

```
# check each row for three-in-a-row across
for row in range(3):
  is_not_none = board[row][0] is not None
  three_in_a_row = board[row][0] == board[row][1] and board[row][1] == board[row][2]

  if is_not_none and three_in_a_row:
    return True

# check each column for three-in-a-row down
for col in range(3):
  is_not_none = board[0][col] is not None
  three_in_a_row = board[0][col] == board[1][col] and board[1][col] == board[2][col]

  if is_not_none and three_in_a_row:
    return True
```

Ah, but there's redundant logic inside the for-loops! It's annoying to have to write the same code inside the two for-loops twice. We can write a function to capture this logic.

This function checks three spots on the board and returns `true` or `false` if all the spots match each other, and they are not `None`.

Read more about Reducing Redundant Redundancy and why it can be a great thing.

```
def check_three(row1, col1, row2, col2, row3, col3):
  is_not_none = board[row1][col1] is not None
  three_in_a_row = board[row1][col1] == board[row2][col2] and board[row2][col2] == board[row3][col3]

  if is_not_none and three_in_a_row:
    return True
  return False
```

False Optimization

An astute reader will notice that the `check_three` function above can be "optimized," specifically around condensing the if-statement that takes up four whole lines.

```
def check_three(row1, col1, row2, col2, row3, col3):
  is_not_none = board[row1][col1] is not None
  three_in_a_row = board[row1][col1] == board[row2][col2] and board[row2][col2] == board[row3][col3]
  return is_not_none and three_in_a_row
```

The astute reader will realize the code can be "optimized" even further.

```
def check_three(a,b,c,d,e,f):
  return board[a][b] is not None and board[a][b] == board[c][d] and board[c][d] == board[e][f]
```

This reader is a dolt, a coward, they are missing the forest for the trees, seeing a finger for the moon, and prioritizing having less lines-of-code over striving for clarity, investigatibility, and maintainability. This is a false optimization, a bad habit, and no one wants to talk to these people at parties.

Basically squishing code together like this just makes things harder to understand and much harder to debug and log and interact with in the future.

Spreading code out across multiple lines (especially the hard-coded `true` and `false` individual return statements) make it easy to observe what path your program takes if you watch it execute it line-by-line with a debugger.

Saving boolean values into variables like `is_not_none` and `three_in_a_row` is a great way simply to describe what logic check your performing. The next person that reads the code (especially future-you) can quickly see what you're trying to determine just by the name of the variable. Good debuggers will let you see the value of the variable too, so it's nice to be able to pause the program and see the result of those logics.

You're probably going to extend the program in the future and rewrite this code anyway. Breaking code across many variable and across many lines will give you more "contact points" in the future. More places to "hook up wires" or "weld stuff on."

Read more about One-Liners Suck

And another one thing!! Tiny variable names are absolutely terrible. Imagine searching through a code-base to see everywhere a variable, or a function is called. If you named something `a` you're going to get a lot of useless search results like "banana," "banana," "banana," "bandanna," "bandanna," "bandanna," "a = 78", "search," and so on.

All Together

Here's all the win checks together. There's a for loop to check across the rows, a for-loop to check all the columns, and two one-offs to check the two diagonal lines across the board.

It's correct and it totally works. Still, something about it doesn't feel like the best way to do things. I especially don't like the repetitive if-statements that happen over and over.

In the next section we will see how to abstract all these line checks together into one simple for-loop that checks totally everything.

```
# check each row for three-in-a-row across
for row in range(3):
  if check_three(row, 0, row, 1, row, 2):
    return True

# check each column for three-in-a-row down
for col in range(3):
  if check_three(0, col, 1, col, 2, col):
    return True

# check diaganols
# top-left to bottom-right
if check_three(0, 0, 1, 1, 2, 2):
  return True

# bottom-left to top-right
if check_three(2, 0, 1, 1, 0, 3):
  return True

return False
```

A More Complex Simple Solution

The problem with the last approach is that we're over-solving the problem. We did a great job writing for-loops to check across all the rows, and all the columns, but the truth of the matter is there's not many rows or columns to check! There's not much bang-for-our-buck in those two for loops that each execute exactly three times.

Instead of trying to capture the redundancy of checking the three rows and the three columns with for-loops let's bite the bullet and hard code every line of three-in-a-row as an array of three coordinates.

Make a list of all three-in-a-row positions, then use the `check_three` function to see if any of those lines are winners. Since there's only eight lines it isn't too bad to hard-code this all in to our program.

We'll look at more complicated grid-assessments when we look at Connect Four in the next game.

If our Tic Tac Toe board was very tall or very narrow it would make sense to write those for-loops to iterate over many of them to check for three-in-a-rows. Here we can see that's it is not totally bad to hard code all the lines out because there's not many of them.

Standardizing all of the lines in the same format (an array of coordinates) allows us to put all of the lines in one array and iterate through them all identically so we only need to write one if-statement to see if that line is a winner.

```
def has_winner():
  lines = [
    # horizontal lines
    [0, 0, 0, 1, 0, 2],
    [1, 0, 1, 1, 1, 2],
    [2, 0, 2, 1, 2, 2],

    # vertical lines
    [0, 0, 1, 0, 2, 0],
    [0, 1, 1, 1, 2, 1],
    [0, 2, 1, 2, 2, 2],

    # top-left to bottom-right
    [0, 0, 1, 1, 2, 2],

    # bottom-left to top-right
    [2, 0, 1, 1, 0, 2]
  ]

  for line in lines:
    if check_three(line[0], line[1], line[2], line[3], line[4], line[5]):
      return True
  return False
```

Detecting End-Game vs Detecting A Winner

We've done a great job writing code checking for three-in-a-rows. We can totally find out when the game ends. One thing we haven't really accounted for is finding out *who* the winner was when the game is done!

We could change the `check_three` function so that instead of returning `true` or `false` it could also return a string representing the winner like `"X"` , `"O"` , or `"tie"` . This isn't the best idea, just because it involves the function returning sometimes boolean values, and sometimes string values. It's generally good practice to have a function only return one type of value (in fact more-strict languages don't even allow a function to possibly return mixed types!)

In the case of Tic Tac Toe we can take advantage of the nature of the game to determine the winner. That is, the winner will always be the last player to make a move. There's never going to be a situation when `"X"` plays and then `"O"` somehow gets three-in-a-row.

Let's add logic to the `make_move` method to check for wins immediately after a player makes a move and set that player as the winner if the game is won.

Pay attentions to where the `turn` number is incremented. We're only incrementing it if there's not three-in-a-row and if there's not a tie. It could be too easy to make a silly order-which-things-occur mistake and somehow mark an incorrect player as the winner if we mixed up the order of incrementing the `turn` number and the call to `get_current_player()` .

When we detect that there's a win we update the state of the game so `winner` stores the winning player, and the `is_game_over` flag is set to true. Notice that I added another small if-statement to the beginning of the `make_move()` function that checks to see if the game is over. This is a small idiot-check I like to leave in to prevent the game from getting in to a corrupt state after a game has ended. Why should anyone be allowed to make a move if the game is over?

```
  make_move(row, col):
    if self.is_game_over:
      return

    if self.is_valid_move(row, col):
      # mark the board with the current player ("X" or "O")
      player = self.get_current_player()
      self.board[row][col] = player

      # check to see if the move ended the game
      if self.has_winner():
        self.is_game_over = True
        self.winner = player
      else if self.turn == 9:
        self.is_game_over = True
        self.winner = 'tie'
      else:
        self.turn += 1
```

Wiring Our Engine to Input/Output

We have a working Tic Tac Toe game engine! Let's hook it up so we can play!

First let's decide how we want the game to appear. I'm going to continue using an ASCII terminal environment. The main program will print out the board and ask the user to type in something and press enter to make their moves.

I don't want the user to have to enter something like `0,0` to make a move on the top left of the board, so I'm coming up with a scheme to make their life a bit easier. I'm labeling each spot on the board with a letter the user can type in to make their moves. I'll write a function in the program maps each letter to row column indexes. (Sorry if you're not using a US keyboard. These letters are all together on the left-hand side of a US keyboard.)

Using a dictionary to create this mapping is the perfect tool for the job.

```
 q | w | e
---+---+---
 a | s | d
---+---+---
 z | x | c
```

```python
def letter_to_coordinate(letter):
    mapping = {
        "q": (0, 0), "w": (0, 1), "e": (0, 2),
        "a": (1, 0), "s": (1, 1), "d": (1, 2),
        "z": (2, 0), "x": (2, 1), "c": (2, 2),
    }
    return mapping[letter]
```

Overall I want the game to look like this. The program shows the board, it shows the keys to enter next to the board, it shows who's turn it is (either X or O) and prompts the user to enter a letter.

```
   |   |     q w e
---+---+---
   |   |     a s d
---+---+---
   |   |     z x c

X: enter your move:
```

The main program needs a function `display_board` to read each spot on the board from the 2D array and print it out properly. It needs to print Xs and Os when spots are filled in.

```
 X | X | O   q w e
---+---+---
   | O |     a s d
---+---+---
 X |   |     z x c

O: enter your move:
```

Printing the board out is rarely pretty code. I'm taking advantage of Python's ability to unpack an array into variables, and using Python's string formatting to render the value of variables into a string template.

I'm taking advantage of Python's list comprehensions too. Python list comprehensions allow you to take one list and generate another list on the fly. Let's look at what's happening line by line.

First, the program accesses the first row at `game.board[0]`. There are three things in that row. Python unpacks the array of three things into the three variables `q, w, e`. `q` gets the first item, `w` gets the second item, `e` gets the third item.

```
q, w, e = game.board[0]
```

The first time I rendered these values into the board I ended up getting a board that looks like this. I forgot that the board contains `None` values initially.

```
 None | None | None   q w e
 ---+---+---
 None | None | None   a s d
 ---+---+---
 None | None | None   z x c
```

I need to write code that detects if each variable is equal to `None` and replaces it with an empty string `" "` instead.

```
if q is None:
    q = " "
if w is None:
    w = " "
if e is None:
    e = " "
```

This gets repetitive, especially because I have to do it for every single one of the nine variables. The list comprehension is a fancy way Python allows us to write this all extremely succinctly.

This basic list comprehension iterates over the three-item list in `game.board[0]` and adds an exclamation mark at the end of each string. This is just a small example to show you what a simple list comprehension looks like.

```
[mark + "!" for mark in game.board[0]]
```

The whole list comprehension I use include an if-else statement. The if else statement will return an empty string `" "` if the `mark` on the board is equal to `None`, otherwise it will return the value of `mark`, which will be either `"X"` or `"O"`.

So. `game.board[0]` accesses the first row for three things. The list comprehension iterates over that list of three things and creates a new list of three things. The new list is equal to the old list, but it has empty strings where `None` values were in the original list. Finally, Python unpacks the list of three things into the three variables. Then they're all ready to render into the string templates that make up the whole board.

I could have done this all with more simple code and that would have been totally fine. The program would have behaved exactly correctly. It just that sometimes it's fun and satisfying to take advantage of special features like these!

```
def display_board(game):
    # [f(x) if condition else g(x) for x in sequence]
    q, w, e = [' ' if mark is None else mark for mark in game.board[0]]
    a, s, d = [' ' if mark is None else mark for mark in game.board[1]]
    z, x, c = [' ' if mark is None else mark for mark in game.board[2]]

    lines = [
        "",
        " %s | %s | %s   q w e" % (q, w, e),
        "---+---+---",
        " %s | %s | %s   a s d" % (a, s, d),
        "---+---+---",
        " %s | %s | %s   z x c" % (z, x, c)
    ]
    for line in lines:
        print(line)
```

Source Code

View it on repl.it

main.py

```
from tic_tac_toe_game import TicTacToeGame


def display_board(game):
    # [f(x) if condition else g(x) for x in sequence]
    q, w, e = [' ' if mark is None else mark for mark in game.board[0]]
    a, s, d = [' ' if mark is None else mark for mark in game.board[1]]
    z, x, c = [' ' if mark is None else mark for mark in game.board[2]]

    lines = [
        "",
        " %s | %s | %s    q w e" % (q, w, e),
        "---+---+---",
        " %s | %s | %s    a s d" % (a, s, d),
        "---+---+---",
        " %s | %s | %s    z x c" % (z, x, c)
    ]

    for line in lines:
        print(line)


def letter_to_coordinate(letter):
    mapping = {
        "q": (0, 0), "w": (0, 1), "e": (0, 2),
        "a": (1, 0), "s": (1, 1), "d": (1, 2),
        "z": (2, 0), "x": (2, 1), "c": (2, 2),
    }
    return mapping[letter]


def prompt_player(game):
    player = game.get_current_player()

    prompt = "%s: enter your move: " % player
    print(prompt, end="")

    letter = input()
    coordinate = letter_to_coordinate(letter)
    return coordinate


def display_winner(game):
    display_board(game)
    if game.winner in game.players:
        print("%s wins!" % game.winner)
    else:
        print("CATS! The game ended in a tie.")


def main():
    game = TicTacToeGame()

    while not game.is_game_over:
        display_board(game)
        row, col = prompt_player(game)
        game.make_move(row, col)

    display_winner(game)


main()
```

Tic Tac Toe Class

tic_tac_toe_game.py

```
class TicTacToeGame:
    def __init__(self):
        self.reset_game()

    def reset_game(self):
        self.winner = None
        self.is_game_over = False

        self.turn = 0
        self.players = ["X", "O"]

        self.board = [
            [None, None, None],
            [None, None, None],
            [None, None, None],
        ]

    def get_current_player(self):
        index = self.turn % len(self.players)
        player = self.players[index]
        return player

    def is_valid_move(self, row, col):
        if row < 0 or col < 0 or row > 2 or col > 2:
            return False

        if self.board[row][col] is not None:
            return False

        return True

    def make_move(self, row, col):
        if self.is_game_over:
            return

        if not self.is_valid_move(row, col):
            return

        # mark the board with the current player X or O
        player = self.get_current_player()
        self.board[row][col] = player

        # check to see if the move ended the game
        if self.has_winner():
            self.is_game_over = True
            self.winner = player
        elif self.turn == 8:
            self.is_game_over = True
            self.winner = "tie"
        else:
            self.turn += 1
```

```python
def check_three(self, row1, col1, row2, col2, row3, col3):
    board = self.board

    is_not_none = board[row1][col1] is not None
    oneMatchesTwo = board[row1][col1] is board[row2][col2]
    twoMatchesThree = board[row2][col2] is board[row3][col3]
    three_in_a_row = oneMatchesTwo and twoMatchesThree

    if is_not_none and three_in_a_row:
        return True
    return False

def has_winner(self):
    lines = [
        # horizontal lines
        [0, 0, 0, 1, 0, 2],
        [1, 0, 1, 1, 1, 2],
        [2, 0, 2, 1, 2, 2],

        # vertical lines
        [0, 0, 1, 0, 2, 0],
        [0, 1, 1, 1, 2, 1],
        [0, 2, 1, 2, 2, 2],

        # top-left to bottom-right
        [0, 0, 1, 1, 2, 2],

        # bottom-left to top-right
        [2, 0, 1, 1, 0, 2]
    ]

    for line in lines:
        if self.check_three(line[0], line[1], line[2], line[3], line[4], line[5]):
            return True
    return False
```