Final Project Report

- Class: DS 5100
- Student Name: Jack Burke
- Student Net ID: jpb2uj
- This URL: https://github.com/jackburke12/ds5100_final_project/blob/4541410ff554e9b18553555d02d

Instructions

Follow the instructions in the Final Project isntructions notebook and put evidence of your work in this notebook.

Total points for each subsection under **Deliverables** and **Scenarios** are given in parentheses.

Breakdowns of points within subsections are specified within subsection instructions as bulleted lists.

This project is worth **50 points**.

Deliverables

The Monte Carlo Module (10)

- URL included, appropriately named (1).
- Includes all three specified classes (3).
- Includes at least all 12 specified methods (6; .5 each).

Put the URL to your GitHub repo here.

Repo URL: https://github.com/jackburke12/ds5100_final_project.git

Paste a copy of your module here.

NOTE: Paste as text, not as code. Use triple backticks to wrap your code blocks.

```
import numpy as np
import pandas as pd
```

```
class Die:
    '''
    A class to create a die with customizable faces and weights.
This die can be rolled, and each face has a weight
    that affects the likelihood of it appearing in a roll. Faces
can be strings or numbers, and weights can be positive
    numbers, including zero. Weights default to 1 if not specified.
    '''
    def __init__(self, faces):
        '''
        PURPOSE: Create a die object with any number of faces.
        INPUTS:
        faces: numpy array containing strings or numpy array
containing numbers

        OUTPUTS:
        face_weights: dataframe containing the weight for each face
on the die.

        RETURNS:
        none
        '''
        if not isinstance(faces, np.ndarray):
            raise TypeError("Expected a numpy array for 'faces',
but received something else.")
        if not (np.issubdtype(faces.dtype, np.str_) or
np.issubdtype(faces.dtype, np.number)):
            raise TypeError("The faces array must contain all
strings or all integers. Your array is of type "+str(faces.dtype))
        if len(faces) != len(np.unique(faces)):
            raise ValueError("All faces must be unique.")

        self.face_weights = pd.DataFrame({'faces': faces,
'weights': 1.0})
        self.face_weights.set_index('faces', inplace=True)

    def change_face_weight(self, face, weight):
        '''
        PURPOSE: Customize the weights of the faces on an existing
die object.

        INPUTS:
        face: string or int. Will raise IndexError if the face
provided is not present in the die's index of faces.
        weight: float or int. Must be positive.

        OUTPUTS:
        Changes the face_weights attribute to reflect the inputted
weight.

        RETURNS:
        none
```

```
        '''
        if face not in self.face_weights.index:
            raise IndexError("The face whose weight you wish to
change is not on the die. Valid faces are: "+
str(self.face_weights.index.to_list()))
        if not isinstance(weight, (int, float)):
            raise TypeError("Only integers or floats can be used as
face weights.")
        if weight < 0:
            raise ValueError("Face weights must be positive.")
        self.face_weights.loc[face,'weights'] = weight

    def roll_die(self, num_rolls = 1):
        '''
        PURPOSE: Roll the die the specified number of times and
return the results of the rolls. For example, if a standard six-
sided die was rolled 3 times, the output could look like this:
[2,4,3].

        INPUTS:
        num_rolls: int

        RETURNS:
        rolls: list of strings or integers
        '''
        rolls = []
        for i in range(num_rolls):
            rolls.append(self.face_weights.sample(n = 1, weights =
'weights').index[0])
        return rolls

    def show_face_weights(self):
        '''
        PURPOSE: Show the weights for each face on the die.

        INPUTS:
        none

        RETURNS:
        face_weights: Dataframe with 'faces' as the index and
'weights' as a column of floats
        '''
        return self.face_weights

class Game:
    '''Represents a game played with multiple dice. Each die is
rolled simultaneously for a specified
    number of rolls. The results are stored and can be presented in
either a wide or narrow format.'''

    game = pd.DataFrame()
```

```
    def __init__(self, dice):
        '''
        PURPOSE: Create a game object with a list of dice.

        INPUTS:
        dice: list of dice objects

        RETURNS:
        none
        '''
        if not isinstance(dice, list):
            raise ValueError("Please create a game using a list of
Die objects.")
        if not isinstance(dice[0], Die):
            raise ValueError("Your list must contain Die objects
only.")

        self.dice = dice

    def play(self, num_rolls = 1):
        '''
        PURPOSE: Simulate a game by rolling all dice simultaneously
for a specified number of times.

        INPUTS:
        num_rolls: int specifying number of times to roll the dice

        OUTPUTS:
        game: attribute containing a dataframe of the last played
game. The dataframe has roll number as the named index, columns for
each die number, and the face rolled in that instance in each cell.

        RETURNS:
        none
        '''
        self.current_game = {}
        for index, die in enumerate(self.dice):
            self.current_game[index] = die.roll_die(num_rolls =
num_rolls)
        roll_num = range(1, num_rolls + 1)
        self.game = pd.DataFrame(self.current_game, index =
roll_num)

    def show_result(self, form = 'wide'):
        '''
        PURPOSE: show the result of the last game played in either
a 'wide' (default) or 'narrow' format as specified by the user.

        INPUT:
        form: string. Defaults to 'wide', accepts either 'narrow'
or 'wide'.
```

```
        RETURNS:
        game: dataframe of the last game played in wide (default)
or narrow format.
        '''
        if form == 'wide':
            return self.game
        elif form == 'narrow':
            return self.game.stack()
        else:
            raise ValueError('Please specify how to return results
using either "narrow" or "wide".')

class Analyzer:
    '''
    Used to analyze the results of a Game. It provides methods to
calculate the number of jackpots,
    count occurrences of each face, and count combinations and
permutations of the game results.
    '''

    def __init__(self, game):
        '''
        PUPROSE: create an analyzer object from a game.

        INPUTS: game object

        RETURNS:
        none
        '''
        if not isinstance(game, Game):
            raise ValueError("Please include a 'Game' object in
your constructor.")

        self.game = game

    def jackpot(self):
        '''
        PURPOSE: Calculate the number of 'jackpots' that occurred
in the last game. A jackpot is a result in which all faces are the
same, e.g. all ones for a six-sided die.

        INPUTS: none

        RETURNS:
        total number of jackpots as an integer
        '''
        jackpots = self.game.show_result().nunique(axis = 1)
        return (jackpots == 1).sum()

    def face_counts(self):
        '''
```

```
        PURPOSE: Compute how many times a given face is rolled for
each event. For example, if a roll of five dice has all sixes, then
the counts for this roll would be 5 for the face value '6' and 0
for the other faces.

        INPUTS: none

        RETURNS:
        counts: dataframe with roll number as the index, face
values as columns, and count values in the cells
        '''
        counts =
self.game.show_result().stack().groupby(level=0).value_counts().unstack(fi
        return counts

    def combination_count(self):
        '''
        PURPOSE: Compute the distinct combination of faces rolled
along with their counts. Combinations are order-independent.

        INPUTS: none

        RETURNS:
        dataframe with multiindex of distinct combinations and a
column totaling each combinations' counts.
        '''
        combo_df =
pd.DataFrame(np.sort(self.game.show_result().values, axis = 1),
columns = self.game.show_result().columns)
        return combo_df.value_counts().to_frame()

    def permutation_count(self):
        '''
        PURPOSE: Compute the distinct permutations of faces rolled
along with their counts. Permutations are order-dependent.

        INPUTS: none

        RETURNS:
        dataframe with multiindex of distinct permutations and a
colum totaling each permutations' counts.
        '''
        return self.game.show_result().value_counts().to_frame()
```

Unitest Module (2)

Paste a copy of your test module below.

NOTE: Paste as text, not as code. Use triple backticks to wrap your code blocks.

- All methods have at least one test method (1).
- Each method employs one of Unittest's Assert methods (1).

```
import unittest
import numpy as np
import pandas as pd
from monte_carlo_simulator import Die
from monte_carlo_simulator import Game
from monte_carlo_simulator import Analyzer

class MonteCarloTestSuite(unittest.TestCase):

    def test_die_constructor(self):

        self.assertRaises(TypeError, Die, ['one','two'])
        self.assertRaises(TypeError, Die,
np.array([True,True,False]))
        self.assertRaises(ValueError, Die,
np.array(['one','one','two']))

        die1 = Die(np.array([1,2,3,4,5,6]))

        self.assertEqual(die1.face_weights.shape,(6,1))
        self.assertIsInstance(die1.face_weights, pd.DataFrame)

    def test_change_face_weight(self):
        die1 = Die(np.array([1,2,3,4,5,6]))

        self.assertRaises(IndexError, die1.change_face_weight,
10,4.1)
        self.assertRaises(TypeError, die1.change_face_weight, 2,
'two')
        self.assertRaises(ValueError, die1.change_face_weight,
2,-1)

        die1.change_face_weight(1,10.0)

        self.assertEqual(die1.face_weights.iloc[0,0], 10.0)

    def test_roll_die(self):
        die1 = Die(np.array([1,2,3,4,5,6]))

        results = die1.roll_die(5)

        self.assertTrue(len(results) == 5)
        self.assertIn(results[4],[1,2,3,4,5,6])

    def test_show_face_weights(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
```

```
        self.assertEqual(die1.show_face_weights().shape,(6,1))
        self.assertIsInstance(die1.show_face_weights(),
pd.DataFrame)

    def test_game_constructor(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        die2 = Die(np.array(['red','blue','yellow']))

        self.assertRaises(ValueError, Game, 'not a list')
        self.assertRaises(ValueError, Game, ['something',die1])

        newgame = Game([die1,die2])

        self.assertIsInstance(newgame, Game)

    def test_play(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        die2 = Die(np.array(['red','blue','yellow']))
        newgame = Game([die1,die2])
        newgame.play(5)

        self.assertEqual(newgame.game.shape, (5,2))
        self.assertIsInstance(newgame.game, pd.DataFrame)
        self.assertIn(newgame.game.iloc[0,1],
['red','blue','yellow'])

    def test_show_results(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        die2 = Die(np.array(['red','blue','yellow']))
        newgame = Game([die1,die2])
        newgame.play(5)

        self.assertRaises(ValueError, newgame.show_result,
'either')

        wide = newgame.show_result()
        narrow = newgame.show_result('narrow')

        self.assertIsInstance(wide, pd.DataFrame)
        self.assertEqual(wide.shape, (5,2))
        self.assertEqual(narrow.shape, (10,))

    def test_analyzer_constructor(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        die2 = Die(np.array(['red','blue','yellow']))
        newgame = Game([die1,die2])
        newgame.play(5)

        self.assertRaises(ValueError, Analyzer, die1)

        a1 = Analyzer(newgame)
```

```
        self.assertIsInstance(a1, Analyzer)

    def test_jackpot(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        die2 = Die(np.array([1,2,3,4,5,6]))
        newgame = Game([die1,die2])
        newgame.play(5)
        a1 = Analyzer(newgame)

        self.assertIsInstance(a1.jackpot(), np.number)
        self.assertLessEqual(a1.jackpot(), 5)

        die3 = Die(np.array([1]))
        newgame2 = Game([die3,die3])
        newgame2.play(10)
        a2 = Analyzer(newgame2)

        self.assertEqual(a2.jackpot(), 10)

        die4 = Die(np.array([2,3]))
        newgame3 = Game([die3, die4])
        newgame3.play(4)
        a3 = Analyzer(newgame3)

        self.assertEqual(a3.jackpot(), 0)

    def test_face_counts(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        newgame = Game([die1,die1])
        newgame.play(100)

        a1 = Analyzer(newgame)

        self.assertIsInstance(a1.face_counts(), pd.DataFrame)
        self.assertEqual(a1.face_counts().shape, (100,6))

    def test_combination_count(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        newgame = Game([die1,die1])
        newgame.play(1000)

        a1 = Analyzer(newgame)
        combos = a1.combination_count()

        self.assertIsInstance(combos, pd.DataFrame)
        self.assertLessEqual(len(combos), 21)

    def test_permutation_count(self):
        die1 = Die(np.array([1,2,3,4,5,6]))
        newgame = Game([die1,die1])
        newgame.play(1000)
```

```
        a1 = Analyzer(newgame)
        permos = a1.permutation_count()

        self.assertIsInstance(permos, pd.DataFrame)
        self.assertLessEqual(len(permos), 36)

if __name__ == '__main__':
    unittest.main(verbosity=3)
```

Unittest Results (3)

Put a copy of the results of running your tests from the command line here.

Again, paste as text using triple backticks.

- All 12 specified methods return OK (3; .25 each).

```
PS C:\Users\jburk\Documents\GitHub\ds5100_final_project> python
.\monte_carlo_test.py
test_analyzer_constructor
(__main__.MonteCarloTestSuite.test_analyzer_constructor) ... ok
test_change_face_weight
(__main__.MonteCarloTestSuite.test_change_face_weight) ... ok
test_combination_count
(__main__.MonteCarloTestSuite.test_combination_count) ... ok
test_die_constructor
(__main__.MonteCarloTestSuite.test_die_constructor) ... ok
test_face_counts (__main__.MonteCarloTestSuite.test_face_counts)
... ok
test_game_constructor
(__main__.MonteCarloTestSuite.test_game_constructor) ... ok
test_jackpot (__main__.MonteCarloTestSuite.test_jackpot) ... ok
test_permutation_count
(__main__.MonteCarloTestSuite.test_permutation_count) ... ok
test_play (__main__.MonteCarloTestSuite.test_play) ... ok
test_roll_die (__main__.MonteCarloTestSuite.test_roll_die) ... ok
test_show_face_weights
(__main__.MonteCarloTestSuite.test_show_face_weights) ... ok
test_show_results (__main__.MonteCarloTestSuite.test_show_results)
... ok

----------------------------------------------------------------------
---
Ran 12 tests in 0.775s

OK
```

Import (1)

Import your module here. This import should refer to the code in your package directory.

- Module successuflly imported (1).

In [7]:
```
from monte_carlo import monte_carlo_simulator
```

Help Docs (4)

Show your docstring documentation by applying `help()` to your imported module.

- All methods have a docstring (3; .25 each).
- All classes have a docstring (1; .33 each).

In [8]:
```
help(monte_carlo_simulator)
```

```
Help on module monte_carlo.monte_carlo_simulator in monte_carlo:

NAME
    monte_carlo.monte_carlo_simulator

CLASSES
    builtins.object
        Analyzer
        Die
        Game

    class Analyzer(builtins.object)
     |  Analyzer(game)
     |
     |  Used to analyze the results of a Game. It provides methods to calculate the
number of jackpots,
     |  count occurrences of each face, and count combinations and permutations of t
he game results.
     |
     |  Methods defined here:
     |
     |  __init__(self, game)
     |      PUPROSE: create an analyzer object from a game.
     |
     |      INPUTS: game object
     |
     |      RETURNS:
     |      none
     |
     |  combination_count(self)
     |      PURPOSE: Compute the distinct combination of faces rolled along with the
ir counts. Combinations are order-independent.
     |
     |      INPUTS: none
     |
     |      RETURNS:
     |      dataframe with multiindex of distinct combinations and a column totaling
each combinations' counts.
     |
     |  face_counts(self)
     |      PURPOSE: Compute how many times a given face is rolled for each event. F
or example, if a roll of five dice has all sixes, then the counts for this roll woul
d be 5 for the face value '6' and 0 for the other faces.
     |
     |      INPUTS: none
     |
     |      RETURNS:
     |      counts: dataframe with roll number as the index, face values as columns,
and count values in the cells
     |
     |  jackpot(self)
     |      PURPOSE: Calculate the number of 'jackpots' that occurred in the last ga
me. A jackpot is a result in which all faces are the same, e.g. all ones for a six-s
ided die.
     |
     |      INPUTS: none
```

```
     |
     |      RETURNS:
     |      total number of jackpots as an integer
     |
     |  permutation_count(self)
     |      PURPOSE: Compute the distinct permutations of faces rolled along with th
eir counts. Permutations are order-dependent.
     |
     |      INPUTS: none
     |
     |      RETURNS:
     |      dataframe with multiindex of distinct permutations and a colum totaling
each permutations' counts.
     |
     |  ----------------------------------------------------------------------
     |  Data descriptors defined here:
     |
     |  __dict__
     |      dictionary for instance variables
     |
     |  __weakref__
     |      list of weak references to the object

    class Die(builtins.object)
     |  Die(faces)
     |
     |  A class to create a die with customizable faces and weights. This die can be
rolled, and each face has a weight
     |  that affects the likelihood of it appearing in a roll. Faces can be strings
or numbers, and weights can be positive
     |  numbers, including zero. Weights default to 1 if not specified.
     |
     |  Methods defined here:
     |
     |  __init__(self, faces)
     |      PURPOSE: Create a die object with any number of faces.
     |      INPUTS:
     |      faces: numpy array containing strings or numpy array containing numbers
     |
     |      OUTPUTS:
     |      face_weights: dataframe containing the weight for each face on the die.
     |
     |      RETURNS:
     |      none
     |
     |  change_face_weight(self, face, weight)
     |      PURPOSE: Customize the weights of the faces on an existing die object.
     |
     |      INPUTS:
     |      face: string or int. Will raise IndexError if the face provided is not p
resent in the die's index of faces.
     |      weight: float or int. Must be positive.
     |
     |      OUTPUTS:
     |      Changes the face_weights attribute to reflect the inputted weight.
     |
```

```
 |      RETURNS:
 |      none
 |
 |  roll_die(self, num_rolls=1)
 |      PURPOSE: Roll the die the specified number of times and return the resul
ts of the rolls. For example, if a standard six-sided die was rolled 3 times, the ou
tput could look like this: [2,4,3].
 |
 |      INPUTS:
 |      num_rolls: int
 |
 |      RETURNS:
 |      rolls: list of strings or integers
 |
 |  show_face_weights(self)
 |      PURPOSE: Show the weights for each face on the die.
 |
 |      INPUTS:
 |      none
 |
 |      RETURNS:
 |      face_weights: Dataframe with 'faces' as the index and 'weights' as a col
umn of floats
 |
 |  ----------------------------------------------------------------------
 |  Data descriptors defined here:
 |
 |  __dict__
 |      dictionary for instance variables
 |
 |  __weakref__
 |      list of weak references to the object

class Game(builtins.object)
 |  Game(dice)
 |
 |  Represents a game played with multiple dice. Each die is rolled simultaneous
ly for a specified
 |  number of rolls. The results are stored and can be presented in either a wid
e or narrow format.
 |
 |  Methods defined here:
 |
 |  __init__(self, dice)
 |      PURPOSE: Create a game object with a list of dice.
 |
 |      INPUTS:
 |      dice: list of dice objects
 |
 |      RETURNS:
 |      none
 |
 |  play(self, num_rolls=1)
 |      PURPOSE: Simulate a game by rolling all dice simultaneously for a specif
ied number of times.
 |
```

```
 |      INPUTS:
 |      num_rolls: int specifying number of times to roll the dice
 |
 |      OUTPUTS:
 |      game: attribute containing a dataframe of the last played game. The data
frame has roll number as the named index, columns for each die number, and the face
rolled in that instance in each cell.
 |
 |      RETURNS:
 |      none
 |
 |  show_result(self, form='wide')
 |      PURPOSE: show the result of the last game played in either a 'wide' (def
ault) or 'narrow' format as specified by the user.
 |
 |      INPUT:
 |      form: string. Defaults to 'wide', accepts either 'narrow' or 'wide'.
 |
 |      RETURNS:
 |      game: dataframe of the last game played in wide (default) or narrow form
at.
 |
 |  ----------------------------------------------------------------------
 |  Data descriptors defined here:
 |
 |  __dict__
 |      dictionary for instance variables
 |
 |  __weakref__
 |      list of weak references to the object
 |
 |  ----------------------------------------------------------------------
 |  Data and other attributes defined here:
 |
 |  game = Empty DataFrame
 |  Columns: []
 |  Index: []

FILE
    c:\users\jburk\documents\github\ds5100_final_project\monte_carlo\monte_carlo_sim
ulator.py
```

`README.md` File (3)

Provide link to the README.md file of your project's repo.

- Metadata section or info present (1).
- Synopsis section showing how each class is called (1). (All must be included.)
- API section listing all classes and methods (1). (All must be included.)

URL: https://github.com/jackburke12/ds5100_final_project/blob/main/README.md

Successful installation (2)

Put a screenshot or paste a copy of a terminal session where you successfully install your module with pip.

If pasting text, use a preformatted text block to show the results.

- Installed with `pip` (1).
- Successfully installed message appears (1).

```
PS C:\Users\jburk\Documents\GitHub\ds5100_final_project> pip
install .
Processing c:\users\jburk\documents\github\ds5100_final_project
  Preparing metadata (setup.py) ... done
Requirement already satisfied: numpy in
c:\users\jburk\anaconda3\lib\site-packages (from Monte-Carlo-
Simulator==1.0.0) (1.26.4)
Requirement already satisfied: pandas in
c:\users\jburk\anaconda3\lib\site-packages (from Monte-Carlo-
Simulator==1.0.0) (2.2.2)
Building wheels for collected packages: Monte-Carlo-Simulator
  Building wheel for Monte-Carlo-Simulator (setup.py) ... done
  Created wheel for Monte-Carlo-Simulator:
filename=Monte_Carlo_Simulator-1.0.0-py3-none-any.whl size=7276
sha256=d7c810d7c28a1a4c0291f34bc1b206ce1df96055715f02f1f1dcda7aeb403e4d
  Stored in directory: C:\Users\jburk\AppData\Local\Temp\pip-ephem-
wheel-cache-
mu5h_let\wheels\86\53\c8\f70666a0c2241adb0b45e52e08b83c64540e41c8c3c1ebd5a
Successfully built Monte-Carlo-Simulator
Installing collected packages: Monte-Carlo-Simulator
  Attempting uninstall: Monte-Carlo-Simulator
    Found existing installation: Monte-Carlo-Simulator 1.0.0
    Uninstalling Monte-Carlo-Simulator-1.0.0:
      Successfully uninstalled Monte-Carlo-Simulator-1.0.0
Successfully installed Monte-Carlo-Simulator-1.0.0
PS C:\Users\jburk\Documents\GitHub\ds5100_final_project>
```

Scenarios

Use code blocks to perform the tasks for each scenario.

Be sure the outputs are visible before submitting.

Scenario 1: A 2-headed Coin (9)

Task 1. Create a fair coin (with faces H and T) and one unfair coin in which one of the faces has a weight of 5 and the others 1.

- Fair coin created (1).
- Unfair coin created with weight as specified (1).

In [9]:
```
from monte_carlo.monte_carlo_simulator import Die, Game, Analyzer
import numpy as np
import pandas as pd

fair_coin = Die(np.array(['H','T']))

unfair_coin = Die(np.array(['H','T']))
unfair_coin.change_face_weight('H',5)

unfair_coin.show_face_weights()
```

Out[9]:

faces	weights
H	5.0
T	1.0

In [10]:
```
fair_coin.show_face_weights()
```

Out[10]:

faces	weights
H	1.0
T	1.0

Task 2. Play a game of 1000 flips with two fair dice.

- Play method called correclty and without error (1).

In [11]:
```
fair_game = Game([fair_coin,fair_coin])

fair_game.play(1000)

fair_game.show_result()
```

Out[11]:

	0	1
1	T	T
2	H	H
3	H	T
4	T	T
5	H	T
...	...	...
996	H	H
997	H	H
998	T	H
999	H	T
1000	T	H

1000 rows × 2 columns

Task 3. Play another game (using a new Game object) of 1000 flips, this time using two unfair dice and one fair die. For the second unfair die, you can use the same die object twice in the list of dice you pass to the Game object.

- New game object created (1).
- Play method called correclty and without error (1).

In [12]:
```
unfair_game = Game([fair_coin, unfair_coin, unfair_coin])

unfair_game.play(1000)
unfair_game.show_result()
```

Out[12]:

	0	1	2
1	H	T	H
2	H	H	H
3	T	H	T
4	H	H	H
5	H	H	H
...	...	...	...
996	T	H	H
997	T	H	H
998	H	H	H
999	T	H	H
1000	H	H	H

1000 rows × 3 columns

Task 4. For each game, use an Analyzer object to determine the raw frequency of jackpots — i.e. getting either all Hs or all Ts.

- Analyzer objecs instantiated for both games (1).
- Raw frequencies reported for both (1).

In [13]:
```
fair_a = Analyzer(fair_game)
unfair_a = Analyzer(unfair_game)

print(f'Number of jackpots after 1000 tosses of two fair coins: {fair_a.jackpot()}'
print(f'Number of jackpots after 1000 tosses of one fair coin and two unfair coins:
```

```
Number of jackpots after 1000 tosses of two fair coins: 512
Number of jackpots after 1000 tosses of one fair coin and two unfair coins: 366
```

Task 5. For each analyzer, compute relative frequency as the number of jackpots over the total number of rolls.

- Both relative frequencies computed (1).

In [14]:
```
print(f'Relative frequency of jackpots in fair game: {fair_a.jackpot() / 1000}')
print(f'Relative frequency of jackpots in unfair game: {unfair_a.jackpot() / 1000}'
```

```
Relative frequency of jackpots in fair game: 0.512
Relative frequency of jackpots in unfair game: 0.366
```

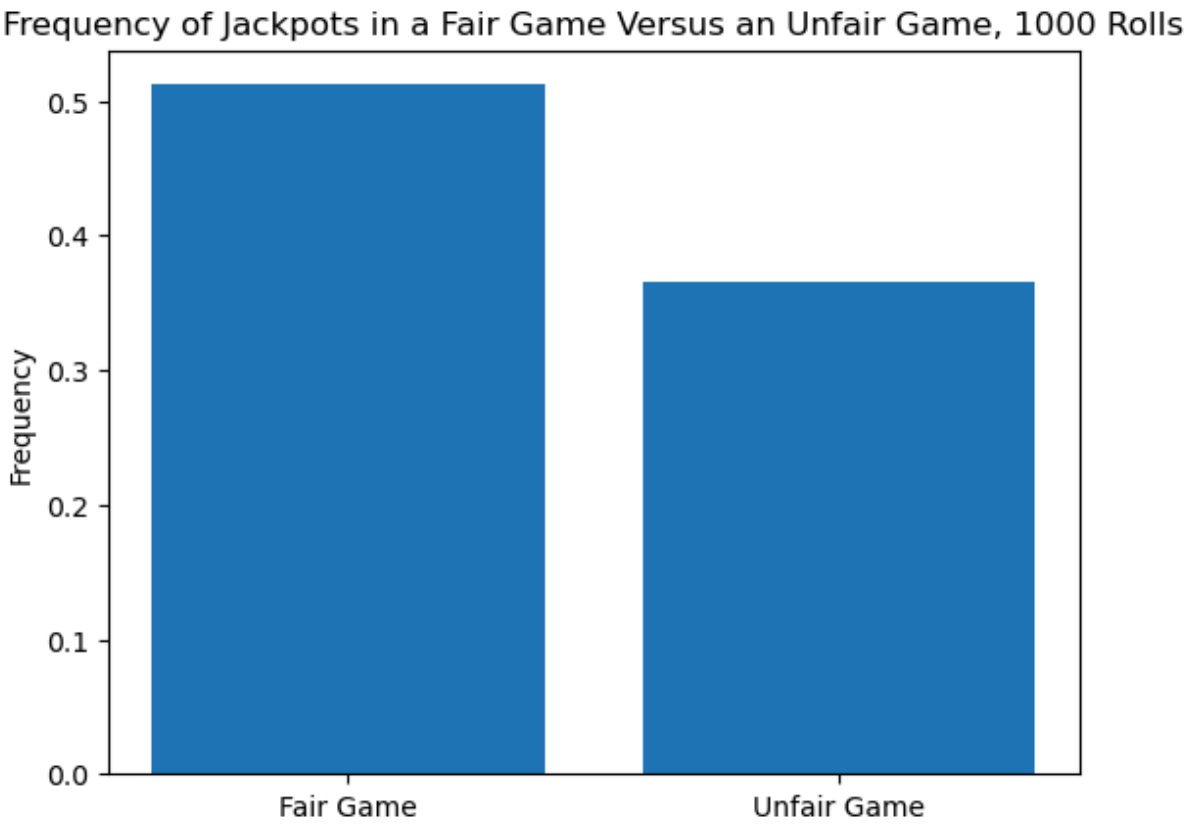
Task 6. Show your results, comparing the two relative frequencies, in a simple bar chart.

- Bar chart plotted and correct (1).

In [15]:
```
import matplotlib.pyplot as plt

plt.bar(['Fair Game','Unfair Game'], [fair_a.jackpot()/1000, unfair_a.jackpot()/100
plt.ylabel('Frequency')
plt.title('Frequency of Jackpots in a Fair Game Versus an Unfair Game, 1000 Rolls')

plt.show()
```



Scenario 2: A 6-sided Die (9)

Task 1. Create three dice, each with six sides having the faces 1 through 6.

- Three die objects created (1).

In [16]:
```
die1 = Die(np.array([1,2,3,4,5,6]))
die2 = Die(np.array([1,2,3,4,5,6]))
die3 = Die(np.array([1,2,3,4,5,6]))

die1.show_face_weights()
```

Out[16]:

faces	weights
1	1.0
2	1.0
3	1.0
4	1.0
5	1.0
6	1.0

Task 2. Convert one of the dice to an unfair one by weighting the face 6 five times more than the other weights (i.e. it has weight of 5 and the others a weight of 1 each).

- Unfair die created with proper call to weight change method (1).

In [17]:
```
die1.change_face_weight(6,5)
die1.show_face_weights()
```

Out[17]:

faces	weights
1	1.0
2	1.0
3	1.0
4	1.0
5	1.0
6	5.0

Task 3. Convert another of the dice to be unfair by weighting the face 1 five times more than the others.

- Unfair die created with proper call to weight change method (1).

In [18]:
```
die2.change_face_weight(1,5)
die2.show_face_weights()
```

Out[18]:

faces	weights
1	5.0
2	1.0
3	1.0
4	1.0
5	1.0
6	1.0

Task 4. Play a game of 10000 rolls with 5 fair dice.

- Game class properly instantiated (1).
- Play method called properly (1).

In [19]:
```
fair_game = Game([die3,die3,die3,die3,die3])

fair_game.play(10000)

fair_game.show_result()
```

Out[19]:

	0	1	2	3	4
1	3	1	6	5	5
2	4	6	5	1	3
3	5	2	2	5	5
4	1	4	1	1	1
5	3	1	5	4	6
...	...	...	...	...	...
9996	3	2	2	6	5
9997	2	1	4	5	3
9998	4	2	1	6	3
9999	1	2	3	5	5
10000	6	3	3	3	6

10000 rows × 5 columns

Task 5. Play another game of 10000 rolls, this time with 2 unfair dice, one as defined in steps #2 and #3 respectively, and 3 fair dice.

- Game class properly instantiated (1).
- Play method called properly (1).

In [20]:
```
unfair_game = Game([die1,die2,die3,die3,die3])

unfair_game.play(10000)

unfair_game.show_result()
```

Out[20]:

	0	1	2	3	4
1	6	2	4	6	5
2	6	1	2	1	2
3	6	4	2	1	1
4	6	3	2	3	1
5	5	1	4	5	6
...	...	...	...	...	...
9996	6	4	1	6	6
9997	5	1	5	3	6
9998	5	4	5	1	5
9999	5	1	5	6	1
10000	5	5	1	6	4

10000 rows × 5 columns

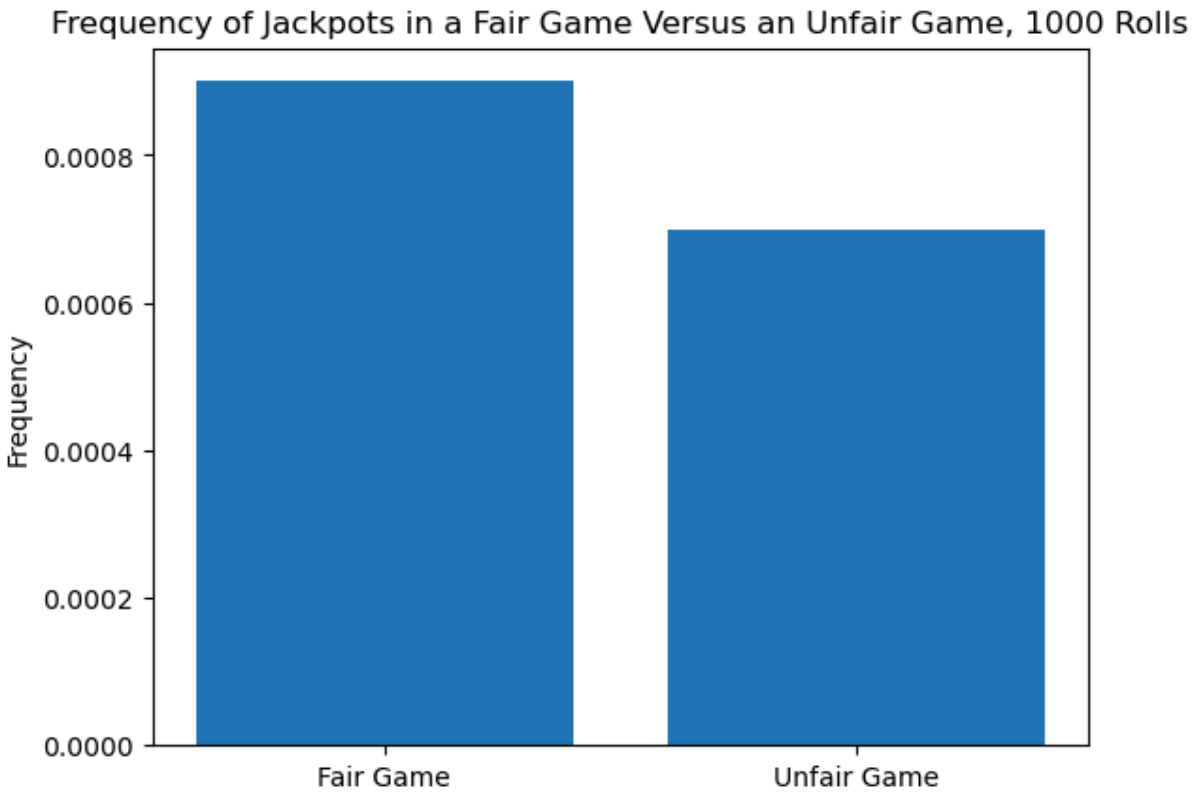
Task 6. For each game, use an Analyzer object to determine the relative frequency of jackpots and show your results, comparing the two relative frequencies, in a simple bar chart.

- Jackpot methods called (1).
- Graph produced (1).

In [26]:
```
fair_a1 = Analyzer(fair_game)
unfair_a1 = Analyzer(unfair_game)

plt.bar(['Fair Game','Unfair Game'], [fair_a1.jackpot()/10000, unfair_a1.jackpot()/
plt.ylabel('Frequency')
plt.title('Frequency of Jackpots in a Fair Game Versus an Unfair Game, 1000 Rolls')

plt.show()
```



Scenario 3: Letters of the Alphabet (7)

Task 1. Create a "die" of letters from A to Z with weights based on their frequency of usage as found in the data file `english_letters.txt`. Use the frequencies (i.e. raw counts) as weights.

- Die correctly instantiated with source file data (1).
- Weights properly applied using weight setting method (1).

In [22]:
```
letters = {}

with open('english_letters.txt', 'r') as file:
    for line in file:
        letter, number = line.split()
        letters[letter] = int(number)

letter_die = Die(np.array(list(letters.keys())))

for letter, freq in letters.items():
    letter_die.change_face_weight(letter,freq)

letter_die.show_face_weights()
```

Out[22]:

faces	weights
E	529117365.0
T	390965105.0
A	374061888.0
O	326627740.0
I	320410057.0
N	313720540.0
S	294300210.0
R	277000841.0
H	216768975.0
L	183996130.0
D	169330528.0
C	138416451.0
U	117295780.0
M	110504544.0
F	95422055.0
G	91258980.0
P	90376747.0
W	79843664.0
Y	75294515.0
B	70195826.0
V	46337161.0
K	35373464.0
J	9613410.0
X	8369915.0
Z	4975847.0
Q	4550166.0

Task 2. Play a game involving 4 of these dice with 1000 rolls.

- Game play method properly called (1).

In [23]:
```
word_game = Game([letter_die,letter_die,letter_die,letter_die])

word_game.play(1000)
word_game.show_result()
```

Out[23]:

	0	1	2	3
1	E	N	E	O
2	A	C	F	M
3	N	T	R	T
4	E	C	R	H
5	L	O	E	M
...	...	...	...	...
996	O	O	N	R
997	D	V	F	S
998	H	E	L	N
999	D	E	D	R
1000	O	G	T	U

1000 rows × 4 columns

Task 3. Determine how many permutations in your results are actual English words, based on the vocabulary found in `scrabble_words.txt`.

- Use permutation method (1).
- Get count as difference between permutations and vocabulary (1).

In [ ]:
```
words = []

with open('scrabble_words.txt','r') as file:
    for line in file:
        words.append(line.split('\n')[0])

words_series = pd.Series(words)

word_a1 = Analyzer(word_game)

#Not sure how to get the count as a difference. Subtracting the permutations from t
#Instead, I got the intersection of the permutation series and the words series, wh

perms = word_a1.permutation_count().index.to_flat_index().to_series().reset_index(d

print(sum(perms.isin(words_series)))
```

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Task 4. Repeat steps #2 and #3, this time with 5 dice. How many actual words does this produce? Which produces more?

- Successfully repreats steps (1).
- Identifies parameter with most found words (1).

In [27]:
```
word_game2 = Game([letter_die,letter_die,letter_die,letter_die,letter_die])

word_game2.play(1000)
word_game2.show_result().head()

word_a2 = Analyzer(word_game2)

perms2 = word_a2.permutation_count().index.to_flat_index().to_series().reset_index(

print(sum(perms2.isin(words_series)))

print(perms2[perms2.isin(words_series)])
```

```
6
106    RAPES
287    TREMS
399    SOLOS
406    SHILL
541    CODEX
878    FANES
dtype: object
```

The game with four dice created more words. The first time I ran this test, the four dice game created 46 words, while the five dice game created 7 words.