**Poker Probability and Statistics with Python**

Tackle probability and statistics in Python: learn more about combinations and permutations, dependent and independent events, and expected value.

Data scientists create machine learning models to make predictions and optimize decisions. In online poker, the options are whether to bet, call, or fold. You aren't allowed to use software to make those decisions though. That's where most online poker sites draw the line in the rules. Since you can't train a machine learning model, you must train your brain. This requires an endless stream of equity calculations away from the poker table, which use many different probability and statistics concepts.

In this tutorial, you'll learn some of these concepts using a deck of cards and generic poker situations. More specifically, you'll cover the following topics:

* [Probability Theory: An Introduction](https://www.datacamp.com/community/tutorials/statistics-python-tutorial-probability-1#intro)
  + Key Concepts
  + Calculating Probability
* [Probability with Combinations and Permutations](https://www.datacamp.com/community/tutorials/statistics-python-tutorial-probability-1#combinations)
* [Independent versus Dependent Events](https://www.datacamp.com/community/tutorials/statistics-python-tutorial-probability-1#independent)
* [Multiple Events](https://www.datacamp.com/community/tutorials/statistics-python-tutorial-probability-1#events)
  + Mutually Exclusive Events
  + Non-Mutually Exclusive Events
  + Intersection of Independent Events
  + Intersection of Dependent Events

## Probability Theory: An Introduction

Before you get your hands dirty, it's time to consider what probability theory is and why it's important to learn about it when you're getting into data science. Additionally, you'll learn some key concepts that will be handy to consider throughout the tutorial and you'll learn how to calculate the probability of single events.

You'll often wonder in real-life situations what the probabilities are of some event occurring, such as winning the lottery, the victory of your soccer team or a discount on your favorite pair of shoes. "What are the chances..." is an expression you probably use very often. Determining the chances of an event occurring is called "probability".

This type of probability is different from the mathematical way of looking at probability, which you can find in probability theory, a branch of mathematics. And in mathematics, you have two broad categories of interpretations on "probability" is - the "physical" and "evidential" probabilities.

The former are also called objective or frequency probabilities and are associated with random physical systems such as flipping coins, roulette wheels, or rolling dice. In such systems, a given type of event tends to occur at a persistent rate, or "relative frequency", in a long run of trials.

The latter is also called Bayesian probability, which can be assigned to any statement whatsoever, even when no random process is involved, as a way to represent its subjective plausibility, or the degree to which the statement is supported by the available evidence. On most accounts, evidential probabilities are considered to be degrees of belief, defined in terms of dispositions to gamble at certain odds.

**Note** that probability theory is mainly concerned with predicting the likelihood of future events, while statistics analyzes the frequency of past events. This also explains why probability theory is also one of the core topics that you should cover if you want to become a data scientist: as you well know, in data science and machine learning, you'll use data from events that have already occurred to predict future events.

So while probability theory is generally considered to be hard to understand intuitively, the concepts are crucial to data science and predictive analytics.

### Key Concepts and Symbols

Some key concepts that you should probably be aware of for this tutorial are mostly concerned with the frequentist perspective on probability, as this tutorial works with a deck of 52 playing cards.

From that perspective, the fundamental ingredient of probability theory is an experiment that can be repeated, at least hypothetically, under essentially identical conditions. This experiment may lead to different outcomes on different trials or single performances of an experiment. The set of all possible outcomes or results of an experiment is then called a "sample space". An event is a well-defined subset of the sample space.

This is all very theoretical.

Let's consider some examples:

* A somewhat cliché example would be flipping a coin. In this case, the experiment is, in fact, the flipping of a coin. You can toss the coin multiple times, and all these trials might have different outcomes. As there are two possible outcomes -heads or tails- the sample space is 2. However, the event "tossing a coin" can, for example, consist of one outcome "Heads". Similarly, when you toss a coin twice, your event "the first toss results in a Heads" might have an outcome "Heads-Heads" or "Heads-Tails".
* Another example that is maybe less straightforward is an experiment where you spin a globe and you stop it by putting your finger on it. You can spin the globe multiple times and all these times might have different outcomes - You can either land your finger on land or on water. That means that the sample space is 2. An event "my finger is on land" might have an outcome "Land - Water" or "Land - Land".
* A last example is the experiment where you toss a die. You can toss the die multiple times and all of these throws can have different outcomes: 6 to be exact, since your die has 6 numbers (1,2,3,4,5,6). An event "The sum of the results of the two toss is equal to 10" can consist of 10, while the event "the number is even" can consist of 2, 4, or 6.

Now that you have an idea of the key concepts that you'll be using throughout this tutorial, it's time to also consider some probability symbols that you will also encounter:

| **Symbol** | **Meaning** |
| --- | --- |
| ∩∩ | And |
| ∪∪ | Or |
| | | Given |

### Calculating Probability For Single Events

Now that you're completely up to date, you can start to determine the probability of a single event happenings, such as a coin landing on tails. To calculate this probability, you divide the number of possible event outcomes by the sample space.

This means that you have to consider first how many possible ways there are for the coin to land on tails, and the number of possible outcomes. The former is 1, as you have only one possible way to get tails. The latter is 2, as you will either get heads or tails when you flip the coin.

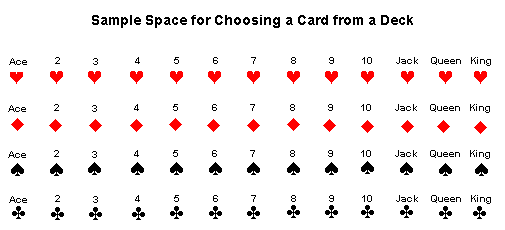
To summarize, the calculation of the probability of an event A will look something like this:

P(A)=Event outcomes favorable to ASample spaceP(A)=Event outcomes favorable to ASample space

In the case of the coin flipping, the probability of the coin landing on tails is 1/2 or 0.5.

**Note** how the probability is always between 0 and 1, where 0 indicates that it's not very probable that the event will happen, where 1 indicates that it's probable that the event will happen.

Now let's consider a second example in which you'll calculate the probability of an event.



There are 52 cards In a standard deck of cards and of those 52 cards, 4 are Aces. If you follow the example of the coin flipping from above to know the probability of drawing an Ace, you'll divide the number of possible event outcomes (4), by the sample space (52):

P(A)=452P(A)=452

**Note** how AA represents the event of "drawing an Ace".

Now, determine the probability of drawing an Ace with the help of Python:

# Sample Space

cards = 52

# Outcomes

aces = 4

# Divide possible outcomes by the sample set

ace\_probability = aces / cards

# Print probability rounded to two decimal places

print(round(ace\_probability, 2))

0.08

The probability of drawing an Ace from a standard deck is 0.08. To determine probability in percentage form, simply multiply by 100.

# Ace Probability Percent Code

ace\_probability\_percent = ace\_probability \* 100

# Print probability percent rounded to one decimal place

print(str(round(ace\_probability\_percent, 0)) + '%')

8.0%

The probability of drawing an Ace as a percent is 8%.

Now that you have seen two examples where you calculated probabilities, it's easy to assume that you might build out your probability calculations to determine, for example, the probability of drawing a card that is a Heart, a face card (such as Jacks, Queens, or Kings), or a combination of both, such as a Queen of Hearts.

In such cases, you might want to create a User-Defined Function (UDF) event\_probability() to which you pass the event\_outcomes and the sample\_space to find the probability of an event in percentage form, since you'll be reusing a lot of the code:

# Create function that returns probability percent rounded to one decimal place

def event\_probability(event\_outcomes, sample\_space):

probability = (event\_outcomes / sample\_space) \* 100

return round(probability, 1)

# Sample Space

cards = 52

# Determine the probability of drawing a heart

hearts = 13

heart\_probability = event\_probability(hearts, cards)

# Determine the probability of drawing a face card

face\_cards = 12

face\_card\_probability = event\_probability(face\_cards, cards)

# Determine the probability of drawing the queen of hearts

queen\_of\_hearts = 1

queen\_of\_hearts\_probability = event\_probability(queen\_of\_hearts, cards)

# Print each probability

print(str(heart\_probability) + '%')

print(str(face\_card\_probability) + '%')

print(str(queen\_of\_hearts\_probability) + '%')

25.0%

23.1%

1.9%

These results probably don't surprise you: as you expected, the chances of drawing a Queen of Hearts are much smaller than the chances of drawing a regular face card or a Heart.

## Probability with Combinations and Permutations

You have seen in the previous section that determining the size of your sample space is key to calculating probabilities. However, this can sometimes prove to be a challenge!

Fortunately, there are ways to make the counting task easier. Two of these ways are permutations and combinations. In this section, you'll see what both of these concepts exactly mean and how you can use them to calculate the size of your sample space!

### Permutations

Permutations are the number of ways a subset of a specified size can be arranged from a given set, generally without replacement. An example of this would be a 4 digit PIN with no repeated digits. The probability of having no repeated digits can be calculated by executing the following calculation:

10×9×8×710×9×8×7

.

You have 10 numbers to choose from, but as you're working without replacement, one option always falls away as you pick a number for the 4-digit pin. This means that in picking the first number for your pin, you'll have 10 numbers to choose from (0 to 9), but for the second number of your pin, you'll only have 9 options to choose from, etc.

On a higher level, you see that the previous paragraph actually considers two things: (1) the numbers to choose from, and (2) the numbers that you actually choose. In the example above, 10 is the number of digits that you can choose from, as you consider all numbers between 0 and 9. However, the actual number of things that you choose is 4, since you have a 4-digit pin.

When calculating the permutations, this means that you consider the full set of the numbers to choose from, which is in reality

10×9×8×7×6×5×4×3×2×110×9×8×7×6×5×4×3×2×1

and you divide the result of this calculation by the difference in the numbers to choose from (10) and the numbers that you actually choose (4). Since you're considering probabilities, this means that this difference will be

6×5×4×3×2×16×5×4×3×2×1

.

**Note** that you can also write the above as

10P4=10!(10−4)!10P4=10!(10−4)!

You'll notice that there is an "10!" and "6!" or "10 factorial" and "6 factorial" in the equation, which is used to indicate that all the consecutive positive integers from 1 up to and including 10 or 6 are to be multiplied together.

The result of this calculation is 5040 permutations. **Note** how this is exactly the same as the calculation that you made above, when you multiplied 10, 9, 8 and 7.

Generalizing the calculations above, this means that the formula to calculate permutations is the following:

nPk=n!(n−k)!nPk=n!(n−k)!

Let's practice this with an example!

To find the number of permutations of pocket Aces, from which you only pick 2, you'll consider the full set of aces to choose from (4) and you also consider the number of aces that you actually choose (2):

4P2=4!(4−2)!4P2=4!(4−2)!

### Combinations

You have seen that when you're working with permutations, the order matters. With combinations, however, this isn't the case: the order doesn't matter. Combinations refers to the number of ways a subset of a specified size can be drawn from a given set.

An example here is the following situation where you have your deck of cards, which consists of 52 cards. Three cards are going to be taken out of the deck. How many different ways can you choose these three cards?

In fact, this should be

52×51×5052×51×50

, which is actually the same as the permutations formula that you have just used! However, with combinations, you don't take the order into account. This means that if you want to figure out how many combinations you actually have, you just create all the permutations and divide by all the redundancies or

3×2×13×2×1

.

This means that your calculation of the combinations will look like this:

52C3=52!(52−3)!3!52C3=52!(52−3)!3!

This calculation can be generalized to the following formula:

nCk=nPkk!nCk=nPkk!

Where you clearly see that the numerator is exactly the same formula as the permutations formula that you have just seen, while the denominator is the factorial of the number of cards that you will actually choose.

Consider another example with Aces. There are four Aces in a deck of cards, and these are all the different combinations of pocket Aces;

1. Ace Hearts / Ace Diamonds
2. Ace Hearts / Ace Clubs
3. Ace Hearts / Ace Spades
4. Ace Diamonds / Ace Clubs
5. Ace Diamonds / Ace Spades
6. Ace Clubs / Ace Spades

There are six combinations of pocket Aces. To find the number of combinations, you first must find the number of permutations:

# Permutations Code

import math

n = 4

k = 2

# Determine permutations and print result

Permutations = math.factorial(n) / math.factorial(k)

print(Permutations)

12.0

To determine the number of combinations, simply divide the number of permutations by the factorial of the size of the subset. Try finding the number of starting hand combinations that can be dealt in Texas Hold’em.

52C2=52P22!52C2=52P22!

# Combinations Code

n = 52

k = 2

# Determine Permutations

Permutations = math.factorial(n) / math.factorial(n - k)

# Determine Combinations and print result

Combinations = Permutations / math.factorial(k)

print(Combinations)

1326.0

## Independent versus Dependent Events

You have read in the introduction that an event is a well-defined subset of the sample space. Events can be classified into two categories: dependent or independent.

Independent events are events that don't impact the probability of the other event(s). Two events A and B are independent if knowing whether event A occurred gives no information about whether event B occurred.

This is true when you, for example, draw an Ace from the deck, replace the card, shuffle the deck, and then drawing another card. The probability of drawing an Ace the first draw is the same as the second.

Dependent events, then, are events that have an impact on the probability of the other event(s).

For example, you draw a card from the deck and then draw a second card from the deck without replacing the first card. In this case, the probability of drawing an Ace the fist draw is not the same as the probability of drawing an Ace on the second draw. After the first card is drawn, the sample space has reduced by 1, from 52 to 51. Depending on what the card was on the first draw, the number of event outcomes may have also changed. If the card was an Ace, there are now only 3 Aces remaining for the second draw.

Let's consider these definitions in formal terms now. Events A and B (which have nonzero probability) are independent if and only if one of the following equivalent statements holds:

P(A∩B)=P(A)P(B)P(A∩B)=P(A)P(B)

P(A|B)=P(A)P(A|B)=P(A)

P(B|A)=P(B)P(B|A)=P(B)

Or, in other words, events A and B are independent if:

* The probability of events A and B to occur equals the product of the probabilities of each event occurring.
* the probability of event A to occur if an event B has already occurred is equal to the probability of an event A to occur.
* The probability of an event B to occur if an event A has already occurred is the same as the probability of an event B to occur.

Let's consider the following example, where you already know the probability of drawing an Ace on the first draw. Now you need to determine the probability of drawing an Ace on the second draw, if the first card drawn was either a King or an Ace:

# Sample Space

cards = 52

cards\_drawn = 1

cards = cards - cards\_drawn

# Determine the probability of drawing an Ace after drawing a King on the first draw

aces = 4

ace\_probability1 = event\_probability(aces, cards)

# Determine the probability of drawing an Ace after drawing an Ace on the first draw

aces\_drawn = 1

aces = aces - aces\_drawn

ace\_probability2 = event\_probability(aces, cards)

# Print each probability

print(ace\_probability1)

print(ace\_probability2)

7.8

5.9

There are a few situations common to poker which are relevant to the concept of dependent events.

But before you get started, a little background info is in order. The game is Texas Hold’em. Played with a standard 52 card deck, Texas Hold’em is the most popular of all the poker variations. Each player is dealt two cards to start the hand and will make the best five-card hand possible by using their two cards combined with the five community cards that are dealt throughout the hand. Cards are dealt in four rounds:

* Pre-Flop: Each player is dealt two cards, known as "hole cards"
* Flop: Three community cards are dealt
* Turn: One community card is dealt
* River: Final community card is dealt

#### Dependent Events: Flush Draw

**Your Hand**

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**Community Cards**

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Your on the Turn and you have four cards to an Ace high Flush. A Flush is a strong poker hand where all five cards are the same suit. What's the probability that the last community card, known as the River Card, is a Diamond?

# Sample Space

cards = 52

hole\_cards = 2

turn\_community\_cards = 4

cards = cards - (hole\_cards + turn\_community\_cards)

# Outcomes

diamonds = 13

diamonds\_drawn = 4

# In poker, cards that complete a draw are known as "outs"

outs = diamonds - diamonds\_drawn

#Determine river flush probability

river\_flush\_probability = event\_probability(outs, cards)

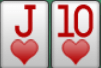
print(river\_flush\_probability)

19.6

There is roughly a 20% chance of hitting your Flush draw on the River. Here’s another one:

#### Dependent Events: Open-Ended Straight Draw

**Your Hand**



**Community Cards**

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Your on the Turn and you have an open-ended Straight draw. A Straight is another strong hand where there are five cards in sequential order. The Straight draw is open-ended because any Eight ( 8, 9, 10, Jack, Queen) or any King (9, 10, Jack, Queen, King) will complete the straight.

What's the probability that the River card completes the Straight?

# Sample Space

cards = 52

hole\_cards = 2

turn\_community\_cards = 4

cards = cards - (hole\_cards + turn\_community\_cards)

# Outcomes

eights = 4

kings = 4

outs = eights + kings

# Determine river straight probability

river\_straight\_probability = event\_probability(outs, cards)

print(river\_straight\_probability)

17.4

There is roughly a 17% chance of hitting your Straight draw on the River.

## Multiple Events

Up until now, you considered only one event when you were calculating the probabilities, but what when you are dealing with multiple events?

An example of multiple events is the question "what is the probability of eating three oatmeal cookies followed by a chocolate chip cookie when you eat four cookies out of a cookie jar filled with these two types of cookies?" Eating four cookies is actually four events.

To calculate the probability for multiple events, you basically determine the number of events (4 in this case), you then determine the probability for each event occurring separately and you multiply all of these probabilities to get your final answer. In the example that was described above, this would be 0.5 x 0.5 x 0.5 x 0.5 or 0.0625.

P(EventA∩EventB)=P(EventA)×P(EventA)P(EventA∩EventB)=P(EventA)×P(EventA)

**Note** that in this case, you calculate the probabilities of eating an oatmeal cookie AND another oatmeal cookie AND a third oatmeal, AND a last chocolate chip cookie. When you're considering events that all have to happen, you multiply the probabilities.

For your deck of playing cards, you could ask yourself the question "What is the probability of getting three Hearts when choosing without replacement?". When you sample or choose without replacement, it means that you choose a card but do not put it back, so that your final selection cannot include that same card. In this case, your probability calculation will be the following: 13/52 x 12/51 x 11/50.

### Mutually Exclusive Events

When you're working with multiple events, you might also have events that are mutually exclusive or disjoint: they cannot both occur. In such cases, you might want to calculate the probability (or the union) of any of multiple mutually exclusive events occurring. In such cases, you don't multiply probabilities, but you simply add together the probability of each event occurring:

P(EventA∪EventB)=P(EventA)+P(EventB)P(EventA∪EventB)=P(EventA)+P(EventB)

It's key here to understand that the "OR" component is very important: drawing a heart OR drawing a club are two mutually exclusive events. A heart is a heart and a club is a club. To determine the probability of drawing a heart or drawing a club, add the probability of drawing a heart to the probability of drawing a club.

P(Heart∪Club)=(1352)+(1352)P(Heart∪Club)=(1352)+(1352)

Now it's time for you to determine the probability of the following mutually exclusive events;

1. Drawing a heart or drawing a club;
2. Drawing an ace, a king or a queen.

# Sample Space

cards = 52

# Calculate the probability of drawing a heart or a club

hearts = 13

clubs = 13

heart\_or\_club = event\_probability(hearts, cards) + event\_probability(clubs, cards)

# Calculate the probability of drawing an ace, king, or a queen

aces = 4

kings = 4

queens = 4

ace\_king\_or\_queen = event\_probability(aces, cards) + event\_probability(kings, cards) + event\_probability(queens, cards)

print(heart\_or\_club)

print(ace\_king\_or\_queen)

50.0

23.1

### Non-Mutually Exclusive Events

You can imagine that not all events are mutually exclusive: Drawing a heart or drawing an ace are two non-mutually exclusive events. The ace of hearts is both an ace and a heart. When events are not mutually exclusive, you must correct for the overlap.

P(EventA∪EventB)=P(EventA)+P(EventB)−P(EventA∪EventB)P(EventA∪EventB)=P(EventA)+P(EventB)−P(EventA∪EventB)

To calculate the probability of drawing a heart or an ace, add the probability of drawing a heart to the probability of drawing an ace and then subtract the probability of drawing the ace of hearts.

P(Heart∪Ace)=(1352)+(452)−(152)P(Heart∪Ace)=(1352)+(452)−(152)

Calculate the probability of the following non mutually exclusive events;

1. Drawing a heart or an ace;
2. Drawing a red card or drawing a face card.

# Sample Space

cards = 52

# Calculate the probability of drawing a heart or an ace

hearts = 13

aces = 4

ace\_of\_hearts = 1

heart\_or\_ace = event\_probability(hearts, cards) + event\_probability(aces, cards) - event\_probability(ace\_of\_hearts, cards)

# Calculate the probability of drawing a red card or a face card

red\_cards = 26

face\_cards = 12

red\_face\_cards = 6

red\_or\_face\_cards = event\_probability(red\_cards, cards) + event\_probability(face\_cards, cards) - event\_probability(red\_face\_cards, cards)

print(round(heart\_or\_ace, 1))

print(round(red\_or\_face\_cards, 1))

30.8

61.6

### Intersection of Independent Events

The probability of the intersection of two independent events is determined by multiplying the probabilities of each event occurring.

P(EventA∩EventB)=P(EventA)×P(EventB)P(EventA∩EventB)=P(EventA)×P(EventB)

If you want to know the probability of drawing an Ace from a deck of cards, replacing it, reshuffling the deck, and drawing another Ace, you multiply the probability of drawing and Ace times the probability of drawing an Ace.

P(Ace∩Ace)=(452)×(452)P(Ace∩Ace)=(452)×(452)

# Sample Space

cards = 52

# Outcomes

aces = 4

# Probability of one ace

ace\_probability = aces / cards

# Probability of two consecutive independant aces

two\_aces\_probability = ace\_probability \* ace\_probability

# Two Ace Probability Percent Code

two\_ace\_probability\_percent = two\_aces\_probability \* 100

print(round(two\_ace\_probability\_percent, 1))

0.6

The probability of drawing two Aces in a row, independently, is 0.592%. What if the second event is dependant?

### Intersection of Dependent Events

The probability of the intersection of two non independent events (Event A & Event B given A) is determined by multiplying the probability of Event A occurring times the probability of Event B given A.

P(EventA∩EventB|A)=P(EventA)×P(EventB|A)P(EventA∩EventB|A)=P(EventA)×P(EventB|A)

The best starting hand you can have in Texas Hold’em is pocket Aces. What is the probability of being dealt two Aces?

P(Ace∩Ace|Ace)=(452)×(351)P(Ace∩Ace|Ace)=(452)×(351)

# Sample Space first draw

cards = 52

# Outcomes first draw

aces = 4

# Probability of ace on first draw

first\_ace\_probability = aces / cards

# Sample Space second draw

cards = cards - 1

# Outcomes second draw

aces = aces - 1

# Probability of ace on second draw after ace on first

second\_ace\_probability = aces / cards

# Probability of two consecutive aces (dependent)

both\_aces\_probability = first\_ace\_probability \* second\_ace\_probability \* 100

print(both\_aces\_probability)

0.4524886877828055

The probability of drawing two dependent Aces in a row is 0.452%. Let's take a look at a couple situations where this comes into play at the poker table.

#### Intersection of Dependent Events: Flop Flush Draw

**Your Hand**

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**Community Cards**

https://s3.amazonaws.com/assets.datacamp.com/blog_assets/Probability+%26+Statistics+Python/image2.png

This is a similar situation as the Flush draw above, except this time you're on the flop and have two more community cards to come instead of just one. How can you determine the probability of getting a Flush by the River? First you need to determine all the different possible scenarios;

* A) Turn Diamond, River Non Diamond (Made Flush)
* B) Turn Non Diamond, River Diamond (Made Flush)
* C) Turn Diamond, River Diamond (Made Flush)
* D) Turn Non Diamond, River Non Diamond (No Flush)

Those are the only four possibilities, and each of those scenarios are mutually exclusive. This means that if you add the probabilities of each of those scenarios occurring, the total will be 1. In other words, one of those four scenarios is definitely going to occur. You want to know the probability of scenario A, B, or C occurring. The simplest approach to figure this out is to determine the probability of scenario D, and subtract that from 1.

# Sample Space on turn

cards = 52

hole\_cards = 2

flop\_community\_cards = 3

cards = cards - (hole\_cards + flop\_community\_cards)

# Outcomes

diamonds = 13

diamonds\_drawn = 4

non\_diamonds\_drawn = 1

outs = diamonds - diamonds\_drawn

turn\_non\_diamonds = cards - outs - non\_diamonds\_drawn

# Probability of not getting a diamond on the turn

no\_diamond\_turn\_probability = turn\_non\_diamonds / cards

# Sample Space on river

turn\_community\_card = 1

cards = cards - turn\_community\_card

# Outcomes on river

river\_non\_diamonds = turn\_non\_diamonds - turn\_community\_card

# Probability of not getting a diamond on the river

no\_diamond\_river\_probability = river\_non\_diamonds / cards

# Probability of not getting a flush

no\_flush\_probability = no\_diamond\_turn\_probability \* no\_diamond\_river\_probability

# Probability of getting a flush

flush\_probability = 1 - no\_flush\_probability

flush\_probability\_percent = flush\_probability \* 100

# Print probability percent rounded to one decimal place

print(round(flush\_probability\_percent, 1))

38.4