

AliquotSequencesMcMenaminBarnesETC (3)

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1 Aliquot sequences

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2.0.1 Introduction

In this project our objective is to investigate a set of intriguing mathematical sequences known as Aliquot sequences. These sequences are applicable to every positive integer, denoted as k , which undergoes a process of summing all of its divisors that are less than the given value k . We call this function $s(k)$, representing the sum of divisors.

The sequence starts by considering the value k , then the sum of divisors function is applied to obtain $s(k)$. These steps form the first two terms of our sequence, denoted as $A_k = \{k, s(k), \dots\}$. Subsequent terms are then computed by iteratively applying our sum of divisors function to the preceding term, resulting in a sequence of the form: $A_k = \{k, s(k), s^2(k), s^3(k), \dots\}$.

We aim to create functions that can not only compute Aliquot sequences for a large number of terms and a large starting value k , but to also classify them into categories. We know one of 4 things can happen for a given n number of terms and a maximum threshold to stop numbers getting arbitrarily large: * The sequence ends in a loop - The sequence ends at 0 - The sequence reaches the given n terms - A term in the sequence exceeds the threshold

We first import some useful libraries.

```
[1]: %pprint
import matplotlib.pyplot as plt
import math
from functools import wraps
from number_theory_lecture_functions import make_mult_func
import random
```

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2.0.2 Sum of divisors function

Before we define the function, we assign values to the threshold at which numbers can't go over and the number of terms we want to look at.

```
[2]: i=10e9
n=30
```

Here we define our function $s(k)$.

To check our function works we manually compute what the function should return for a given number, for example $k = 24$ should return $s(k)=1+2+3+4+6+8+12=36$. We use the fact the sum of divisors function is a multiplicative function and use the function given in lectures, however, we must subtract the initial value as we want the divisors of k not including k .

```
[3]: # This is from the lecture:
def sum_div_pp(p,e):
    """The sum of divisors of p**e."""
    return (p**(e+1)-1)//(p-1)    # Use integer division here to ensure the
    ↪ result has integer type.
sum_div = make_mult_func(sum_div_pp)
# This was the sum of divisors of n, including n.
# So this is the sum of divisors, not including n.
def s(k):
    if n==0:
        return 0
    return sum_div(k)-k
```

For testing the function defined above, We have chosen the sum of divisors of 220 as we know its aliquot sequence is a repeating loop between 220 and 284. The function applied to 24 can also be computed easily.

```
[4]: # Should produce no errors
assert s(6)==6
assert s(1)==0
assert s(220)==284
assert s(24)==36
```

The aliquot sequence is defined as $A_k = \{k, s(k), s^2(k), s^3(k), \dots\}$, this function outputs the sequence A_k with n terms given none of those terms exceed the threshold, otherwise it will stop before the first term exceeds said threshold.

Testing if it loops for $k = 6$ and $k = 284$, also if the next term for $k = 24$ is 36. We also see that the sequence does indeed terminate after $s^j(k) = 0$.

[illegible]

Setting $n = 30$, shows the first 30 terms, large enough to see most patterns or loops, small enough to ensure a reasonable running time.

2.0.4 Detecting Loops

There is a loop in an Aliquot sequence if it cycles through the same values indefinitely, for example, for $k = 562$ we have $s(k) = 284$, $s^2(k) = 220$ and $s^3(k) = 284$ so it will cycle through 284 and 220 until the n^{th} term.

Here we define two ‘detect loops’ functions. We need one that gives a Boolean (True or False) which we label `detect_loop_B`, and one that tells us the loop which we call `detect_loop`. We require the former for the classification function later as we don’t want the output cluttered with ‘Loop detected at ...’.

Boolean detect loop function:

```
[7]: def detect_loop_B(k,n,i):
    seq=aliquot_sequence(k,n,i)
    #We define sequence length to not be simply n as it could terminate at 0
    ↪ before n
    sequence_length=len(seq)
    for i in range(sequence_length):
        for j in range(0,i): # Compare all pairs of elements without repetition
            if seq[i]==seq[j]:
                return True
    return False
```

We test the function:

```
[8]: assert(detect_loop_B(562,n, i))== True
    assert(detect_loop_B(284,n, i))== True

    assert(detect_loop_B(6,n, i))== True
    assert(detect_loop_B(19005,n, i))== False
    assert(detect_loop_B(1264460,n, i))== True
```

Loop finder function:

```
[9]: def detect_loop(k,n,i):
    sequence=[k]
    seen_numbers=set() # A set to hold all the numbers that have already
    ↪ appeared
    for j in range(n-1):
        next_term =s(sequence[-1]) # Applying the sum of divisors function to
        ↪ the last term in the sequence so far
        if next_term==sequence[-1]:
            loop=next_term
            print(f"Loop detected at {k} with the loop: {loop}")
            return
```

```

else:
    if next_term==0 or next_term > i:
        break
    elif next_term in seen_numbers:
        # Loop detected
        loop=sequence[sequence.index(next_term):]
        print(f"Loop detected at {k} with the loop: {loop}")
        return
    seen_numbers.add(next_term)
    sequence.append(next_term)
print(f"No loop detected for {k}.")

```

We test it works.

```

[10]: detect_loop(562,n,i)
      detect_loop(284,n,i)
      detect_loop(25,n,i)
      detect_loop(19005,n,i)
      detect_loop(1264460,n,i)
      detect_loop(6,n,i)

```

```

Loop detected at 562 with the loop: [284, 220]
Loop detected at 284 with the loop: [220, 284]
Loop detected at 25 with the loop: 6
No loop detected for 19005.
Loop detected at 1264460 with the loop: [1547860, 1727636, 1305184, 1264460]
Loop detected at 6 with the loop: 6

```

2.0.5 Classifying the Value

For each $k < 20000$ try to classify it according to the end state of the aliquot sequence starting at k . As stated before every value in the range should fit in one of the four categories.

```

[11]: def classify_aliquot_sequences(max_k, n, threshold):

    # Creating lists to hold classified values
    terminates_at_zero=[]
    enters_a_loop=[]
    exceeds_threshold=[]
    reaches_n_terms=[]

    for k in range(1,max_k):    # Want k only in given range
        sequence_result =aliquot_sequence(k,n,threshold)
        detect_result=detect_loop_B(k,n,threshold)
        if sequence_result[-1] == 0: # If last index of the sequence is 0 we
↪add k to terminates at zero
            terminates_at_zero.append(k)

```

```

else:
    if detect_result:
        enters_a_loop.append(k)
        # We want the detect loop function before the n terms function as a
        ↪ loop can also have n terms
    elif len(sequence_result)==n:
        reaches_n_terms.append(k)
    else:
        exceeds_threshold.append(k)

print("Terminates at 0:",terminates_at_zero)
print()
print()
print()
print("Enters a loop:",enters_a_loop)
print()
print()
print()
print("Reaches n terms:",reaches_n_terms)
print()
print()
print()
print("Exceeds threshold:",exceeds_threshold)

```

```
max_k=20000
```

```
classify_aliquot_sequences(max_k,n,i)
```

```

Terminates at 0: [1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
19, 20, 21, 22, 23, 24, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40,
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19638, 19710, 19740, 19848, 19864, 19888, 19964]

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This code theoretically works, as you can see, for values of $k < 20000$, although it does take a rather long time (around 8 seconds). To make it quicker we must revisit our first two functions.

2.0.6 Making it Quicker

The code above takes a really long time because the function was getting called 20,000 times. To speed this up we Memoize the functions $s(k)$ and `aliquot_sequence`

```

[12]: def memoize(func):
        cache = {} # Set an empty dictionary we add the results to

        @wraps(func) # This tells the wrapper function to remember the important
        ↪ attributes of the original function
        def wrapper(*args, **kwargs): # This wrapper function takes ...
            key = str(args) + str(kwargs)

            if key not in cache:
                cache[key] = func(*args, **kwargs) # We add the key to the cache if
                ↪ it is not already in it

            return cache[key]

```

```

    return wrapper

# We then apply the memoize function to all the previous functions that are
→used in the classify function

@memoize
def s(k):
    if n==0:
        return 0
    return sum_div(k)-k

@memoize
def aliquot_sequence(k,n,i):
    seq=[k]
    for _ in range(n-1):
        next_term=s(seq[-1]) # Applying the sum of divisors function to the
        →last term of the sequence

        if next_term>i:
            break

        elif seq[-1]== 0: # Stop if last element of sequence is zero
            break
        else:
            seq.append(next_term)
    return seq

@memoize
def detect_loop_B2(k, n,threshold):
    seq= aliquot_sequence(k, n,threshold)
    seen =set()
    for num in seq:
        if num in seen:
            return True
        seen.add(num)
    return False

@memoize
def classify_aliquot_sequences_2(max_k, n, threshold):

    terminates_at_zero=[]
    enters_a_loop=[]
    exceeds_threshold=[]
    reaches_n_terms=[]

```

```

for k in range(1,max_k):
    sequence_result =aliquot_sequence(k, n, threshold)
    detect_result=detect_loop_B2(k, n, threshold)
    if sequence_result[-1] == 0: # Last element of the sequence is zero
        terminates_at_zero.append(k)
    else:
        if detect_result:
            enters_a_loop.append(k)

        elif len(sequence_result)==n:
            reaches_n_terms.append(k)
        else:
            exceeds_threshold.append(k)

print("Terminates at 0:",terminates_at_zero)
print()
print()
print()
print("Enters a loop:",enters_a_loop)
print()
print()
print()
print("Reaches n terms:",reaches_n_terms)
print()
print()
print()
print("Exceeds threshold:",exceeds_threshold)

# We set our maximum k value again
max_k = 20000

print(classify_aliquot_sequences_2(max_k,n,i))

```

Terminates at 0: [1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 139, 140, 141, 142, 144, 145, 146, 147, 148, 149, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 211, 212, 213, 214, 215, 216, 217, 218, 219, 221, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 235, 236, 237, 238,

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19992, 19998]

Exceeds threshold: [840, 1464, 1560, 1848, 1992, 2040, 2136, 2250, 2256, 2424,
2430, 2448, 2568, 2712, 2760, 2880, 3048, 3264, 3456, 3480, 3486, 3564, 3630,
3696, 3720, 3796, 3834, 3912, 4016, 4086, 4122, 4128, 4170, 4230, 4392, 4440,
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6978, 6990, 7002, 7008, 7026, 7032, 7038, 7230, 7320, 7364, 7368, 7420, 7482,

7586, 7614, 7698, 7710, 7752, 7800, 7950, 7968, 8024, 8040, 8070, 8080, 8136, 8164, 8176, 8190, 8208, 8232, 8262, 8328, 8346, 8358, 8472, 8496, 8664, 8802, 8838, 8988, 9006, 9024, 9048, 9100, 9120, 9168, 9192, 9240, 9288, 9354, 9366, 9378, 9380, 9424, 9456, 9480, 9588, 9708, 9714, 9716, 9726, 9738, 9772, 9786, 9798, 9810, 9828, 9840, 9858, 9912, 10020, 10176, 10182, 10194, 10206, 10314, 10338, 10344, 10350, 10416, 10464, 10608, 10612, 10668, 10724, 10740, 10780, 10842, 10866, 10872, 10876, 10878, 10892, 10902, 10932, 10938, 10948, 10950, 10962, 10980, 11088, 11112, 11120, 11232, 11298, 11370, 11394, 11400, 11452, 11502, 11508, 11640, 11692, 11732, 11788, 11790, 11800, 11826, 11844, 11900, 12036, 12048, 12120, 12138, 12240, 12252, 12280, 12360, 12408, 12450, 12516, 12540, 12552, 12666, 12678, 12690, 12720, 12726, 12768, 12796, 12852, 12954, 12972, 13014, 13200, 13244, 13332, 13412, 13468, 13524, 13536, 13560, 13580, 13608, 13636, 13692, 13800, 13848, 13860, 13936, 14034, 14046, 14056, 14058, 14082, 14094, 14148, 14160, 14196, 14232, 14280, 14322, 14472, 14492, 14512, 14604, 14622, 14634, 14640, 14641, 14682, 14688, 14694, 14706, 14756, 14796, 14802, 14814, 14834, 14920, 14922, 14924, 15000, 15012, 15036, 15096, 15114, 15148, 15160, 15162, 15174, 15204, 15240, 15260, 15282, 15288, 15360, 15372, 15380, 15440, 15456, 15498, 15576, 15584, 15684, 15708, 15720, 15768, 15774, 15930, 15954, 15960, 15966, 15978, 15990, 16026, 16038, 16056, 16100, 16152, 16182, 16184, 16268, 16322, 16324, 16326, 16364, 16368, 16380, 16440, 16460, 16492, 16554, 16576, 16578, 16592, 16608, 16620, 16626, 16641, 16728, 16812, 16936, 16960, 17088, 17112, 17248, 17256, 17322, 17334, 17448, 17500, 17544, 17556, 17584, 17694, 17712, 17724, 17814, 17826, 17838, 17914, 17948, 17976, 17994, 18004, 18006, 18018, 18030, 18060, 18120, 18144, 18148, 18204, 18228, 18240, 18264, 18336, 18360, 18462, 18490, 18572, 18654, 18666, 18676, 18702, 18720, 18740, 18754, 18768, 18786, 18798, 18810, 18824, 18840, 18864, 18888, 18906, 18960, 19008, 19040, 19086, 19098, 19200, 19284, 19292, 19320, 19338, 19348, 19380, 19396, 19404, 19410, 19500, 19538, 19560, 19572, 19614, 19626, 19638, 19710, 19740, 19848, 19864, 19888, 19964]

None

With the adapted function the computation takes less than 3 seconds for values of $k < 20,000$.

2.0.7 Length of Loops

We now want to investigate how long the loop can be given the aliquot sequence ends in a loop. To do this we redefine our `detect_loop` function so it returns the loop as a list only, then we redefine our classification function so that it only returns the list of values which enter a loop.

We further change the value `n` so it returns longer lists. From here we only require a simple function to find the maximum length of the loops.

```
[13]: i=10e9
def detect_loop2(k, n, threshold): # we want this function to return the loop
    ↪only
    sequence = [k]
    seen_numbers = set()
    for j in range(n - 1):
        next_term = s(sequence[-1])
```

```

        if next_term == 0 or next_term > threshold:
            break
        elif next_term in seen_numbers or next_term == sequence[-1]:
            # Loop detected
            loop = sequence[sequence.index(next_term):]
            return loop
        seen_numbers.add(next_term)
        sequence.append(next_term)
    return None # No loop detected

n=300
max_k=50000

def classify_enters_a_loop(max_k, n, threshold):
    # Same as previous classify function but returns only the enters_a_loop list

    enters_a_loop=[]

    for k in range(1,max_k):
        sequence_result =aliquot_sequence(k, n, threshold)
        detect_result=detect_loop_B2(k, n, threshold)

        if detect_result:
            enters_a_loop.append(k)

    return enters_a_loop

```

```

[14]: print(detect_loop2(1264460,n,i))
      print(detect_loop2(1,n,i))
      print(aliquot_sequence(1, n, i))
      print(len(detect_loop2(1264460,n,i)))
      print(detect_loop2(6,n,i))
      print(detect_loop2(562,n,i))
      print(detect_loop2(284,n,i))
      print(detect_loop2(25,n,i))
      print(detect_loop2(19005,n,i))
      print(detect_loop2(1264460,n,i))
      print(detect_loop2(6,n,i))

```

```

[1547860, 1727636, 1305184, 1264460]
None
[1, 0]
4
[6]
[284, 220]
[220, 284]
[6]
None
[1547860, 1727636, 1305184, 1264460]
[6]

```

```

[16]: n = 300
max_k=20000
enters_a_loop2 = classify_enters_a_loop(max_k, n, 10e11)
def max_loop_length(enters_a_loop2, n, threshold):
    max_length = 0    # Initial max loop length
    for k in enters_a_loop2:
        seq = detect_loop2(k, n,i)
        length = len(seq)
        if length > max_length: # Revalues the max loop length
            max_length = length
    return max_length

print("Max loop length:", max_loop_length(enters_a_loop2, n, i))

```

Max loop length: 28

We then test that a loop is given when the function is applied to a value we know yields a loop.

```

[17]: print(aliquot_sequence(12496,40,i))
print(detect_loop2(12496,40,i))
assert detect_loop2(12496,40,i)[0] ==s(detect_loop2(12496,40,i)[-1])

```

```

[12496, 14288, 15472, 14536, 14264, 12496, 14288, 15472, 14536, 14264, 12496,
14288, 15472, 14536, 14264, 12496, 14288, 15472, 14536, 14264, 12496, 14288,
15472, 14536, 14264, 12496, 14288, 15472, 14536, 14264, 12496, 14288, 15472,
14536, 14264, 12496, 14288, 15472, 14536, 14264]
[14288, 15472, 14536, 14264, 12496]

```

2.0.8 Length of Terminations

We now investigate how long a sequence can be considering it terminates at zero.

```

[18]:

```



```

n=300
# This is our classification code but consolidated so that it only returns the
↳ list of values that terminate at zero
def classify_terminates_at_zero(max_k, n, threshold):

    terminates_at_zero=[]

    for k in range(1,max_k):
        sequence_result =aliquot_sequence(k, n, threshold)

        if sequence_result[-1] == 0:      # If the last element of the sequence
↳ is zero then it terminates at zero
            terminates_at_zero.append(k) # Add to list

    return terminates_at_zero

# We can alter the max value of k here
max_k=50000
terminates_at_zero2=classify_terminates_at_zero(max_k, n, i)

```

```

[19]: def max_term_length(terminates_at_zero2, n, threshold):
        max_length2=0
        for k in terminates_at_zero2:
            seq = aliquot_sequence(k, n, threshold) # Pass n and threshold instead
↳ of i
            length=len(seq)
            if length>max_length2:
                max_length2 = length
        return max_length2

n =1000

print("Max termination length:", max_term_length(terminates_at_zero2, n, i))

```

Max termination length: 215

2.0.9 Plotting Loops

Now that we have found the maximum length of a loop we can define a function which will display the loop on a graph.

To do this we first define a function that can plot the loops graphically. It takes a random value of k (that enters a loop) in the range given by the maximum value of k , then it plots the indices of the Aliquot sequence. We can alter our n value if we wish to see the loop better as for some values we have that the loop length is around 28 making it difficult to see that it loops on the graph.

```

[20]: # We initiate our maximum values for k and n as they have been altered in
↳ previous code

```

```

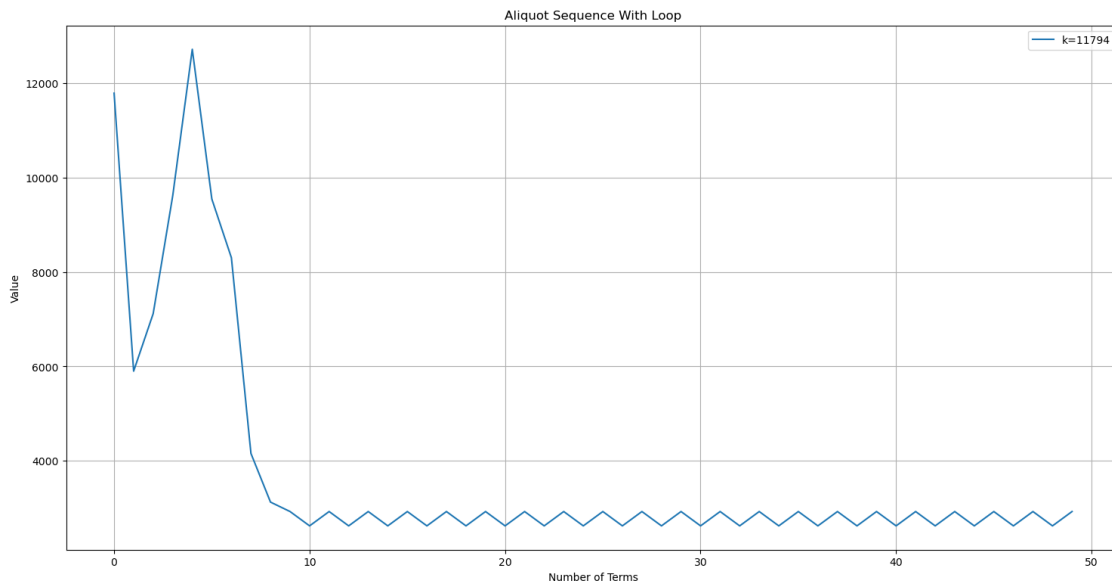
max_k = 20000
n = 50

# Creating the list
enters_a_loop2 = classify_enters_a_loop(max_k, n, i)

# The function
def plot_aliquot_sequences(k,n,threshold):
    # If k doesn't enter a loop we aren't interested in plotting it
    if k in enters_a_loop2:
        seq = aliquot_sequence(k,n,threshold)
        plt.figure(figsize=(18, 9)) # Create figure before plotting
        plt.plot(range(len(seq)), seq, label=f"k={k}") # Plot each term
        ↪ against its index
        plt.xlabel("Number of Terms")
        plt.ylabel("Value")
        plt.title("Aliquot Sequence With Loop")
        plt.grid(True)
        plt.legend()
        plt.show()

# Here we have a code that picks a random value for k that enters a loop
p = random.randint(0, len(enters_a_loop2) - 1)
k = enters_a_loop2[p-1] #The 'pth' index of the list
plot_aliquot_sequences(k, n, i)
detect_loop(k,n,i) # Tells us the loop that was detected if
↪ it is unclear from the graph

```



Loop detected at 11794 with the loop: [2924, 2620]

2.0.10 Abundant or Deficient

As well as the previous classifications we can further sort values into ‘perfect’, ‘deficient’ and ‘abundant’ numbers, defined as follows:

Perfect numbers: $s(k) = k$, e.g $s(6) = 6$

Deficient numbers: $s(k) < k$, e.g $s(25) = 6 < 25$

Abundant numbers: $s(k) > k$, e.g $s(36) = 55 > 36$

Now let we design the function to count ‘abundant’, ‘deficient’ and ‘perfect’ numbers in looping aliquot sequences

Here we count the number of each inside a random loop.

```
[21]: max_k = 20000
      n = 50

      # Creating the list
      enters_a_loop3 = classify_enters_a_loop(max_k, n, i)

      def Ab_De_per_in_loop(k):
          abundant_count2 = 0
          deficient_count2 = 0
          perfect_count2 = 0
          loop=detect_loop2(k,n,i)

          if len(loop)==1: # If the loop is one number then the number must be perfect

              perfect_count2+=1

          else:
              for j in range(len(loop)-1):
                  if loop[j]>loop[j+1]:
                      deficient_count2+=1
                  elif loop[j]<loop[j+1]:
                      abundant_count2+=1

                  if loop[0] >loop[-1]: #If the last term of the loop is
↪greater than the start of the loop it must be abundant
                      abundant_count2+=1

                  elif loop[0]<loop[-1]:
                      deficient_count2+=1
```

```

print("Abundant numbers :", abundant_count2)
print("Deficient numbers :", deficient_count2)
print("Perfect numbers :", perfect_count2)

```

```

[22]: # Pick a random k from the enters a loop list
m=random.randint(0,len(enters_a_loop3)-1)
k=enters_a_loop3[m]
loop=detect_loop2(k,n,i)
print('The value of k is:', k, 'with loop', loop) # So we can validate
print()
Ab_De_per_in_loop(k)

```

The value of k is: 119 with loop [6]

```

Abundant numbers : 0
Deficient numbers : 0
Perfect numbers : 1

```

Now we can look at the whole sequence that ends in a loop.

First we define an aliquot sequence function that stops when it sees a number it already has (just before it enters a loop).

```

[23]: def aliquot_seq_no_loop(k,n,i):
        seq=[k]

        for _ in range(n-1):
            next_term=s(seq[-1]) # Applying the sum of divisors function to the
            ↪last term in the sequence so far

            if next_term>i or next_term in seq: # If it exceeds the threshold or
            ↪enters a loop
                break
            #If the previous term was 0 then the sequence terminates
            elif seq[-1]== 0:
                break
            else:
                seq.append(next_term)
        return seq

```

We test that it does what it should. The normal aliquot sequence of 25 would loop with 6 so it should stop at first 6. Which it does.

```

[24]: print(aliquot_seq_no_loop(25,n,i))

```

[25, 6]

Having an Aliquot sequence funtion that stops before the loop enables us to fint the counts up to the end of the loop (before a number is repeated).

```
[25]: def Ab_De_per_in_loopSeq(k):
    abundant_count3 = 0
    deficient_count3 = 0
    perfect_count3 = 0

    seq2=aliquot_seq_no_loop(k,n,i)

    if s(seq2[-1])==seq2[-1]:    # The sequence loops because of a perfect
↪number
        perfect_count3+=1

    elif s(seq2[-1])>seq2[-1]: # The sequence loops 'up'

        abundant_count3+=1

    else:                        # Sequence loops 'down'
        deficient_count3+=1

    for j in range(len(seq2) - 1):

        if seq2[j] >seq2[j + 1]:

            deficient_count3 += 1
        elif seq2[j] < seq2[j + 1]:

            abundant_count3 += 1

    print("Abundant numbers :", abundant_count3)
    print("Deficient numbers :", deficient_count3)
    print("Perfect numbers :", perfect_count3)
```

```
[26]:     # Pick a random k from the enters a loop list
m=random.randint(0,len(enters_a_loop3)-1)
k=enters_a_loop3[m]
loop=detect_loop2(k,n,i)
seq=aliquot_seq_no_loop(k,n,i)

print('The value of k is:', k, 'with sequence', seq) # So we can validate
print()
Ab_De_per_in_loopSeq(k)
```

The value of k is: 2152 with sequence [2152, 1898, 1210, 1184]

Abundant numbers : 1

Deficient numbers : 3
Perfect numbers : 0

```
[27]: assert s(seq[-1]) in seq
```

It is clear, and intuitive, that if the sequence goes into a loop it must either have $(A, D, P) = (x, y, 1)$ where $x, y \in \mathbb{N}$ or $(A, D, P) = (x, y, 0)$ where $x, y \in \mathbb{N}$ but never $(A, D, P) = (x, y, 0)$ where $x = 0$ or $y = 0$.

2.1 Conclusion

In this project we have successfully produced a function that outputs an Aliquot sequence for any given k , n and threshold; this has aided us in categorizing each value, in a given range, into the four distinct groups.

From these groups we have investigated further, determining the maximum length of sequences that terminate at zero and the maximum length of any loops that may form. Diving deeper into these looped sequences we managed to graphically plot them to help us visualise the cycles.

Additionally, we found that we could further sub-categorize values into the groups 'Deficient', 'Perfect' and 'Abundant', and wrote a function that could count the number of each in a sequence given that the sequence goes into a loop.

```
[ ]:
```