Import relevant packages here.

In [ ]:
```
#Import libarys
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
import math
```

Load the data and verify it is loaded correctly.

- Print it (head, tail, or specific rows, choose a sensible number of rows).
- Compare it to the source file.

In [ ]:
```
#Import CSV file
data = pd.read_csv('cf_data.csv')

#Print the first 5 rows of the data set.
print("Head (first 5 rows) of the data set:")
print(data.head())

#Print the last 5 rows of the data set.
print("\nTail (last 5 rows) of the data set:")
print(data.tail())
```

```
Head (first 5 rows) of the data set:
         dv        s         a
0 -0.743240  53.5427  1.242570
1 -0.557230  53.6120  1.777920
2 -0.454769  53.6541  0.544107
3 -0.525396  53.7030 -0.294755
4 -0.601285  53.7592 -0.290961

Tail (last 5 rows) of the data set:
            dv        s         a
73903  5.19874  116.139 -0.795081
73904  5.10428  115.627 -0.314263
73905  5.13764  115.118  0.232283
73906  5.15348  114.599  0.262078
73907  5.25868  113.112 -0.612440
```

In the ensuing, you will use `numpy`.

Let's create a grid for the values to plot. But first create **two arrays named `dv` and `s`** using `numpy.linspace` that hold the grid values at the relevant indices in their respective dimension of the grid.

Create a **grid named `a`** with zeros using `numpy.zeros` in to which calculated acceleration values can be stored.

Let the grid span:

- Speed difference `dv` [m/s]
  - From -10 till 10
  - With 41 evenly spaced values
- Headway `s` [m]
  - From 0 till 200
  - With 21 evenly spaced values

In [ ]:
```
#Introduce the graph dataset
dv = np.linspace( -10 , 10 , 41)
s  = np.linspace( 0 , 200 , 21)
a = np.zeros(( len(s) , len(dv) ))
print(a)
```

```
[[0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
  0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]]
```

Create from the imported data 3 separate `numpy` arrays for each column `dv` , `s` and `a` . (We do this for speed reasons later.)

- Make sure to name them differently from the arrays that belong to the grid as above.
- You can access the data of each column in a `DataFrame` using `data.xxx` where `xxx` is the column name (not as a string).
- Use the method `to_numpy()` to convert a column to a `numpy` array.

In [ ]:
```
#Format the initial data
DV = data.dv.to_numpy()
S = data.s.to_numpy()
A = data.a.to_numpy()
```

Create an algorithm that calculates all the acceleration values and stores them in the grid. The algorithm is described visually in the last part of the lecture. At each grid point, it calculates a weighted mean of all measurements. The weights are given by an exponential function, based on the 'distance' between the grid point, and the measurement values of `dv` and `s`. To get you started, how many `for`-loops do you need?

For this you will need `math`.
Use an *upsilon* of 1.5m/s and a *sigma* of 30m.

Warning: This calculation may take some time. So:

- Print a line for each iteration of the outer-most `for`-loop that shows you the progress.
- Test you code by running it only on the first 50 measurements of the data.

In [ ]:
```
#Constants
upsilon = 1.5  #[m/s]
sigma = 30  #[m]

#Loop trhough the graph in dv and s directions
for dv_index in range(len(dv)):
    for s_index in range(len(s)):

        #Introduce variables to calculate a on point (s,dv)
        nominator = 0
        divider = 0

        #Loop trhough the dataset and calculate nominator and divider for the a value
        for list_index in range(len(DV)):
            omega = math.exp(-abs(dv[dv_index]-DV[list_index])/upsilon - abs(s[s_index
            nominator += omega * A[list_index]
            divider += omega

        #Give an error if the divider is 0
        if divider == 0:
            print("Error: Divider is 0 at s = {s_index} , dv = {dv_index}")
            continue

        #calculate a at (s,dv) and update the graph set
        a_calc = nominator / divider
        print(f"at {dv[dv_index]} and {s[s_index]} a is {a_calc}")
        a[s_index,dv_index] = a_calc
```

```
at -10.0 and 0.0 a is 0.528790290747477
at -10.0 and 10.0 a is 0.5315283748955573
at -10.0 and 20.0 a is 0.5610065116703125
at -10.0 and 30.0 a is 0.6190215259190217
at -10.0 and 40.0 a is 0.6559602878761577
at -10.0 and 50.0 a is 0.6653967014867344
at -10.0 and 60.0 a is 0.6432296051271621
at -10.0 and 70.0 a is 0.6105526310808121
at -10.0 and 80.0 a is 0.5474711544941104
at -10.0 and 90.0 a is 0.4819634971019143
at -10.0 and 100.0 a is 0.4052463376125209
at -10.0 and 110.0 a is 0.32539861884231197
at -10.0 and 120.0 a is 0.25523852484334725
at -10.0 and 130.0 a is 0.18034444745593567
at -10.0 and 140.0 a is 0.12592130030376297
at -10.0 and 150.0 a is 0.041226547621746885
at -10.0 and 160.0 a is -0.061227540939783165
at -10.0 and 170.0 a is -0.17091023936506258
at -10.0 and 180.0 a is -0.25525303797028176
at -10.0 and 190.0 a is -0.3002739973659616
at -10.0 and 200.0 a is -0.23576588460685455
at -9.5 and 0.0 a is 0.5219729611174619
at -9.5 and 10.0 a is 0.5247241370156385
at -9.5 and 20.0 a is 0.5541636401680873
at -9.5 and 30.0 a is 0.6116808143524068
at -9.5 and 40.0 a is 0.6513545691438066
at -9.5 and 50.0 a is 0.6633775836116356
at -9.5 and 60.0 a is 0.6439961701395848
at -9.5 and 70.0 a is 0.6149327713147156
at -9.5 and 80.0 a is 0.5563259973528316
at -9.5 and 90.0 a is 0.49685722679522826
at -9.5 and 100.0 a is 0.427677900169184
at -9.5 and 110.0 a is 0.35706654194812776
at -9.5 and 120.0 a is 0.300236915590369
at -9.5 and 130.0 a is 0.2361515774121843
at -9.5 and 140.0 a is 0.18516048658176182
at -9.5 and 150.0 a is 0.10530466320401552
at -9.5 and 160.0 a is 0.005623528704994863
at -9.5 and 170.0 a is -0.10661905802075262
at -9.5 and 180.0 a is -0.19845864303761035
at -9.5 and 190.0 a is -0.24640053385263117
at -9.5 and 200.0 a is -0.1826040250989219
at -9.0 and 0.0 a is 0.5119608256691196
at -9.0 and 10.0 a is 0.5147360535922961
at -9.0 and 20.0 a is 0.5441653342878867
at -9.0 and 30.0 a is 0.6010275578373626
at -9.0 and 40.0 a is 0.6415782293813539
at -9.0 and 50.0 a is 0.6555951322328487
at -9.0 and 60.0 a is 0.6407486989403874
at -9.0 and 70.0 a is 0.6169498394601576
at -9.0 and 80.0 a is 0.5643078589105427
at -9.0 and 90.0 a is 0.5126035024652151
at -9.0 and 100.0 a is 0.452643085715795
at -9.0 and 110.0 a is 0.39333879362042523
at -9.0 and 120.0 a is 0.3469523981627015
at -9.0 and 130.0 a is 0.29451200765278496
at -9.0 and 140.0 a is 0.2443961891089923
at -9.0 and 150.0 a is 0.16726094181111073
at -9.0 and 160.0 a is 0.07067315256700384
at -9.0 and 170.0 a is -0.0411453260804439
at -9.0 and 180.0 a is -0.13197344030259042
at -9.0 and 190.0 a is -0.17553914006899443
at -9.0 and 200.0 a is -0.13116503115629455
at -8.5 and 0.0 a is 0.49443067231801585
at -8.5 and 10.0 a is 0.4972263813803443
at -8.5 and 20.0 a is 0.5263710898495131
```

```
at -8.5 and 30.0 a is 0.5812992544082259
at -8.5 and 40.0 a is 0.6198523310637163
at -8.5 and 50.0 a is 0.6357362582021479
at -8.5 and 60.0 a is 0.6285564577827977
at -8.5 and 70.0 a is 0.612810614475915
at -8.5 and 80.0 a is 0.5689654311475082
at -8.5 and 90.0 a is 0.5270384489405068
at -8.5 and 100.0 a is 0.4778582095807068
at -8.5 and 110.0 a is 0.4309513003287359
at -8.5 and 120.0 a is 0.3901595891021755
at -8.5 and 130.0 a is 0.34220952576211655
at -8.5 and 140.0 a is 0.2921491481048967
at -8.5 and 150.0 a is 0.2176726924100546
at -8.5 and 160.0 a is 0.12628240208100758
at -8.5 and 170.0 a is 0.01961017658539596
at -8.5 and 180.0 a is -0.06532091972924381
at -8.5 and 190.0 a is -0.10341597485839417
at -8.5 and 200.0 a is -0.07900719551560705
at -8.0 and 0.0 a is 0.47489727152850875
at -8.0 and 10.0 a is 0.4777238344306725
at -8.0 and 20.0 a is 0.5066071172444526
at -8.0 and 30.0 a is 0.5593715260657737
at -8.0 and 40.0 a is 0.596012247662124
at -8.0 and 50.0 a is 0.6116610652324088
at -8.0 and 60.0 a is 0.6123434236915201
at -8.0 and 70.0 a is 0.6056588905242755
at -8.0 and 80.0 a is 0.5717247582016868
at -8.0 and 90.0 a is 0.5369934566857357
at -8.0 and 100.0 a is 0.494701034374901
at -8.0 and 110.0 a is 0.45764208260378547
at -8.0 and 120.0 a is 0.42238739684711946
at -8.0 and 130.0 a is 0.3788881930098651
at -8.0 and 140.0 a is 0.3330718634252915
at -8.0 and 150.0 a is 0.26422406999171866
at -8.0 and 160.0 a is 0.1824003927018732
at -8.0 and 170.0 a is 0.08676715927511423
at -8.0 and 180.0 a is 0.020417080730975864
at -8.0 and 190.0 a is -0.014031623688591382
at -8.0 and 200.0 a is -0.009771328448894636
at -7.5 and 0.0 a is 0.4564992963035492
at -7.5 and 10.0 a is 0.459354095489827
at -7.5 and 20.0 a is 0.4879463474986805
at -7.5 and 30.0 a is 0.5385360321082858
at -7.5 and 40.0 a is 0.5740034241748684
at -7.5 and 50.0 a is 0.5892172199664125
at -7.5 and 60.0 a is 0.5962761650948573
at -7.5 and 70.0 a is 0.5975558509211796
at -7.5 and 80.0 a is 0.5721637280877435
at -7.5 and 90.0 a is 0.5434179874838728
at -7.5 and 100.0 a is 0.5073840168113642
at -7.5 and 110.0 a is 0.47723961460552633
at -7.5 and 120.0 a is 0.4475854613804232
at -7.5 and 130.0 a is 0.4094226420920691
at -7.5 and 140.0 a is 0.36599632433979606
at -7.5 and 150.0 a is 0.30062616940805953
at -7.5 and 160.0 a is 0.22565485276969055
at -7.5 and 170.0 a is 0.13751880473874953
at -7.5 and 180.0 a is 0.09051971056534962
at -7.5 and 190.0 a is 0.059918038613587146
at -7.5 and 200.0 a is 0.05130801952165312
at -7.0 and 0.0 a is 0.4385354461766957
at -7.0 and 10.0 a is 0.4414140438164977
at -7.0 and 20.0 a is 0.469646848015049
at -7.0 and 30.0 a is 0.5176195699850963
at -7.0 and 40.0 a is 0.5508675189841996
at -7.0 and 50.0 a is 0.5649735982805065
```

```
at -7.0 and 60.0 a is 0.5756677414064535
at -7.0 and 70.0 a is 0.5833977148690915
at -7.0 and 80.0 a is 0.5645577837070475
at -7.0 and 90.0 a is 0.5411277436322808
at -7.0 and 100.0 a is 0.5122812451696784
at -7.0 and 110.0 a is 0.4866431989433447
at -7.0 and 120.0 a is 0.46050848581690085
at -7.0 and 130.0 a is 0.4252179986842193
at -7.0 and 140.0 a is 0.3802686853199751
at -7.0 and 150.0 a is 0.31502493307853957
at -7.0 and 160.0 a is 0.23989290053628426
at -7.0 and 170.0 a is 0.14675473044178622
at -7.0 and 180.0 a is 0.10530229729389946
at -7.0 and 190.0 a is 0.07853149007446976
at -7.0 and 200.0 a is 0.06555884334982796
at -6.5 and 0.0 a is 0.42333707692541483
at -6.5 and 10.0 a is 0.42624089134100757
at -6.5 and 20.0 a is 0.4541943239424536
at -6.5 and 30.0 a is 0.4992525908111727
at -6.5 and 40.0 a is 0.5291922014313721
at -6.5 and 50.0 a is 0.5411498110148468
at -6.5 and 60.0 a is 0.5529748357972024
at -6.5 and 70.0 a is 0.5641480858141507
at -6.5 and 80.0 a is 0.5491810233916571
at -6.5 and 90.0 a is 0.5272817353093027
at -6.5 and 100.0 a is 0.5017303129549813
at -6.5 and 110.0 a is 0.47983128832758465
at -6.5 and 120.0 a is 0.45740361175577504
at -6.5 and 130.0 a is 0.42586803595770095
at -6.5 and 140.0 a is 0.38190531152952145
at -6.5 and 150.0 a is 0.3165704717283326
at -6.5 and 160.0 a is 0.2379802936606554
at -6.5 and 170.0 a is 0.1356632375464492
at -6.5 and 180.0 a is 0.09255229251701132
at -6.5 and 190.0 a is 0.0700883593929389
at -6.5 and 200.0 a is 0.0584794772375103
at -6.0 and 0.0 a is 0.4108782223798903
at -6.0 and 10.0 a is 0.41381433650904725
at -6.0 and 20.0 a is 0.44163602638180044
at -6.0 and 30.0 a is 0.48402066751361644
at -6.0 and 40.0 a is 0.5110393022018278
at -6.0 and 50.0 a is 0.5212947415270421
at -6.0 and 60.0 a is 0.5338503132473014
at -6.0 and 70.0 a is 0.5460674090611748
at -6.0 and 80.0 a is 0.5338339594272928
at -6.0 and 90.0 a is 0.5129311495202046
at -6.0 and 100.0 a is 0.4897179332677002
at -6.0 and 110.0 a is 0.4707660442779648
at -6.0 and 120.0 a is 0.45192166305777953
at -6.0 and 130.0 a is 0.4248323731551479
at -6.0 and 140.0 a is 0.3845966812567973
at -6.0 and 150.0 a is 0.32276005898701055
at -6.0 and 160.0 a is 0.2450256188044809
at -6.0 and 170.0 a is 0.1406404782418751
at -6.0 and 180.0 a is 0.09408015809690858
at -6.0 and 190.0 a is 0.06898036705533075
at -6.0 and 200.0 a is 0.05130254585598861
at -5.5 and 0.0 a is 0.39771160563119334
at -5.5 and 10.0 a is 0.40068399453684284
at -5.5 and 20.0 a is 0.42836206857010733
at -5.5 and 30.0 a is 0.4683862591475508
at -5.5 and 40.0 a is 0.4931422833555936
at -5.5 and 50.0 a is 0.5017330847422782
at -5.5 and 60.0 a is 0.5142157913321272
at -5.5 and 70.0 a is 0.5254814880985288
at -5.5 and 80.0 a is 0.5153272474007494
```

```
at -5.5 and 90.0 a is 0.49559581508041334
at -5.5 and 100.0 a is 0.473614918513912
at -5.5 and 110.0 a is 0.4567137888005506
at -5.5 and 120.0 a is 0.44094772342642313
at -5.5 and 130.0 a is 0.41788672180325115
at -5.5 and 140.0 a is 0.38180444683700476
at -5.5 and 150.0 a is 0.32385129580098737
at -5.5 and 160.0 a is 0.24422003846931187
at -5.5 and 170.0 a is 0.14188275738962328
at -5.5 and 180.0 a is 0.09463400133076316
at -5.5 and 190.0 a is 0.06406026711421102
at -5.5 and 200.0 a is 0.03821446184916292
at -5.0 and 0.0 a is 0.3804174048182125
at -5.0 and 10.0 a is 0.38342170713180407
at -5.0 and 20.0 a is 0.4107270110919922
at -5.0 and 30.0 a is 0.4481849340149699
at -5.0 and 40.0 a is 0.47027626664266414
at -5.0 and 50.0 a is 0.47699766108346536
at -5.0 and 60.0 a is 0.4879372769313607
at -5.0 and 70.0 a is 0.49754412768807244
at -5.0 and 80.0 a is 0.488271844319434
at -5.0 and 90.0 a is 0.4709632809243001
at -5.0 and 100.0 a is 0.451614995001328
at -5.0 and 110.0 a is 0.4367037401177634
at -5.0 and 120.0 a is 0.42368257620749117
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at 10.0 and 180.0 a is -0.6499407788335723
at 10.0 and 190.0 a is -0.5875579298158939
at 10.0 and 200.0 a is -0.5685798025147892
```

The following code will plot the data for you. Does it make sense when considering:

- Negative (slower than leader) and positive (faster than leader) speed differences?
- Small and large headways?

In [ ]:
```
#Plot the outcome
X, Y = np.meshgrid(dv, s)
axs = plt.axes()
p = axs.pcolor(X, Y, a, shading='nearest')
axs.set_title('Acceleration [m/s/s]')
axs.set_xlabel('Speed difference [m/s]')
axs.set_ylabel('Headway [m]')
axs.figure.colorbar(p);
axs.figure.set_size_inches(10, 7)
```