Question 1

Reading Training data

In [1]:
```
training_data=open("training_data.txt","r").read().split()
```

In [2]:
```
N=[640000,160000,40000,10000,5000]
```

In [3]:
```
file=[training_data,training_data[:N[1]],training_data[:N[2]],training_data[:N[3]],
```

Calculating Frequency

In [4]:
```
def frequency(data):
    freq={}
    for i in data:
        if i in freq.keys():
            freq[i]+=1
        else:
            freq[i]=1
    return freq
```

In [5]:
```
freq=[]
for i in file:
    freq.append(frequency(i))
```

Calculating MLE models

In [6]:
```
def max_L(freq,N):
    mle={}
    for w in freq.keys():
        mle[w]=freq[w]/N
    return mle
```

In [7]:
```
mle=[]
for i in range(len(N)):
    temp=max_L(freq[i],N[i])
    mle.append(temp)
```

Calculating MAP models

In [8]:
```
def max_a_p(freq,N):
    ma={}
    for w in freq.keys():
        ma[w]=(freq[w]+2-1)/(N+20000-10000)
    return ma
```

In [9]:
```
ma=[]
for i in range(len(N)):
```

```
    temp=max_a_p(freq[i],N[i])
    ma.append(temp)
```

Calculating Predictive Distributions Models

In [10]:
```
def pred_dist(freq,N):
    pd={}
    for w in freq.keys():
        pd[w]=(freq[w]+2)/(N+20000)
    return pd
```

In [11]:
```
pd=[]
for i in range(len(N)):
    temp=pred_dist(freq[i],N[i])
    pd.append(temp)
```

Calculating Perplexity

In [12]:
```
import math
import numpy as np
```

In [13]:
```
def perp(model,data):
    p=0
    for i in data:
        p+=np.log(model[i])
    perp=math.exp(-p/len(data))
    return perp
```

In [14]:
```
print("The perplexity on train set of MLE model is")
for i in range(len(N)):
    print("size: ",N[i]," Perplexity is ",perp(mle[i],file[i]))
```

```
The perplexity on train set of MLE model is
size:  640000  Perplexity is  8506.43367662384
size:  160000  Perplexity is  8292.385691215124
size:  40000  Perplexity is  7478.035656314462
size:  10000  Perplexity is  5005.389219343304
size:  5000  Perplexity is  3388.2567752667333
```

In [15]:
```
print("The perplexity on train set of MAP model is")
for i in range(len(N)):
    print("size: ",N[i]," Perplexity is ",perp(ma[i],file[i]))
```

```
The perplexity on train set of MAP model is
size:  640000  Perplexity is  8506.96513236839
size:  160000  Perplexity is  8303.124332848962
size:  40000  Perplexity is  7669.433287645091
size:  10000  Perplexity is  6453.994771744834
size:  5000  Perplexity is  5915.104263875246
```

In [16]:
```
print("The perplexity on train set of Predicitive Distribution model is")
for i in range(len(N)):
    print("size: ",N[i]," Perplexity is ",perp(pd[i],file[i]))
```

```
The perplexity on train set of Predicitive Distribution model is
size:  640000  Perplexity is  8508.427803625034
size:  160000  Perplexity is  8324.246394665119
size:  40000  Perplexity is  7866.496544080013
size:  10000  Perplexity is  7230.294305050776
size:  5000  Perplexity is  7014.415012644821
```

Reading Test data

In [17]:
```
test_data = open("test_data.txt", "r").read().split()
```

Calculating Test Data Frequency

In [18]:
```
freq_test={}
for i in test_data:
    if i in freq_test:
        freq_test[i]=freq_test[i]+1
    else:
        freq_test[i]=1
```

Testing the models

MLE predictions

In [19]:
```
def test_max_L(test_data,mle,N):
    mle_prediction={}
    for w in test_data.keys():
        if w in mle.keys():
            mle_prediction[w]=mle[w]
        else:
            mle_prediction[w]=0/N
    return mle_prediction
```

In [20]:
```
test_mle=[]
for i in range(len(N)):
    temp=test_max_L(freq_test,mle[i],N[i])
    test_mle.append(temp)
```

MAP Predictions

In [21]:
```
def test_max_a_p(test_data,ma,N):
    ma_prediction={}
    for w in test_data.keys():
        if w in ma.keys():
            ma_prediction[w]=ma[w]
        else:
            ma_prediction[w]=(0+2-1)/(N+20000-10000)
    return ma_prediction
```

In [22]:
```
test_ma=[]
for i in range(len(N)):
```

```
    temp=test_max_a_p(freq_test,ma[i],N[i])
    test_ma.append(temp)
```

Predictive Distribution Predictions

In [23]:
```
def test_pred_dist(test_data,pd,N):
    pd_prediction={}
    for w in test_data.keys():
        if w in pd.keys():
            pd_prediction[w]=pd[w]
        else:
            pd_prediction[w]=(0+2)/(N+20000)
    return pd_prediction
```

In [24]:
```
test_pd=[]
for i in range(len(N)):
    temp=test_pred_dist(freq_test,pd[i],N[i])
    test_pd.append(temp)
```

Perplexities of all predictions

In [25]:
```
print("The perplexity on test set of MLE model is")
for i in range(len(N)):
    print("size: ",N[i]," Perplexity is ",perp(test_mle[i],test_data))
```

```
The perplexity on test set of MLE model is
size:  640000  Perplexity is  8657.623041731129
C:\Users\aarya\AppData\Local\Temp\ipykernel_6808\3930523767.py:4: RuntimeWarning:
divide by zero encountered in log
  p+=np.log(model[i])
size:  160000  Perplexity is  inf
size:  40000  Perplexity is  inf
size:  10000  Perplexity is  inf
size:  5000  Perplexity is  inf
```

In [26]:
```
print("The perplexity on test set of MAP model is")
for i in range(len(N)):
    print("size: ",N[i]," Perplexity is ",perp(test_ma[i],test_data))
```

```
The perplexity on test set of MAP model is
size:  640000  Perplexity is  8654.590090965366
size:  160000  Perplexity is  8839.546029448937
size:  40000  Perplexity is  9380.752312326787
size:  10000  Perplexity is  9992.362371992125
size:  5000  Perplexity is  10098.36492411617
```

In [27]:
```
print("The perplexity on test set of Predictive Distribution model is")
for i in range(len(N)):
    print("size: ",N[i]," Perplexity is ",perp(test_pd[i],test_data))
```

```
The perplexity on test set of Predictive Distribution model is
size:  640000  Perplexity is  8652.803792634657
size:  160000  Perplexity is  8817.904839672385
size:  40000  Perplexity is  9224.511912933269
size:  10000  Perplexity is  9668.062580182157
size:  5000  Perplexity is  9814.024919445475
```

Plotting the Graphs

In [28]:

```
import matplotlib.pyplot as plt
from matplotlib.pyplot import figure
```

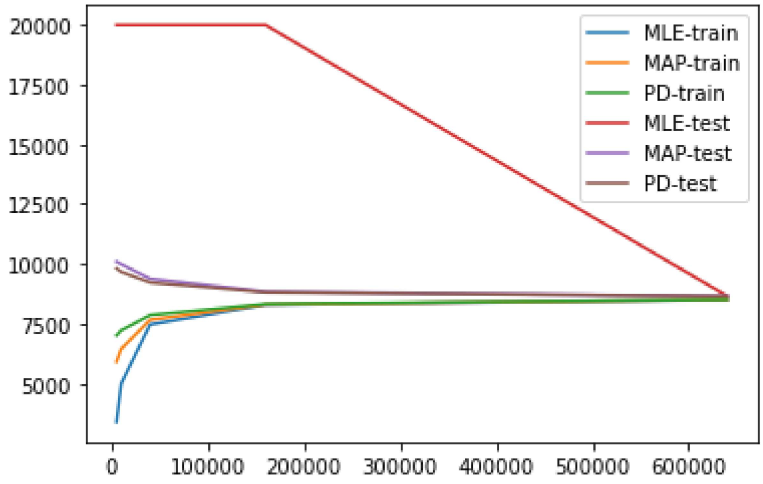
In [29]:

```
x=N
y1=[]
for i in range(len(N)):
    y1.append(perp(mle[i],file[i]))
y2=[]
for i in range(len(N)):
    y2.append(perp(ma[i],file[i]))
y3=[]
for i in range(len(N)):
    y3.append(perp(pd[i],file[i]))
y4=[]
y4.append(perp(test_mle[0],test_data))
for i in range(4):
    y4.append(20000)
y5=[]
for i in range(len(N)):
    y5.append(perp(test_ma[i],test_data))
y6=[]
for i in range(len(N)):
    y6.append(perp(test_pd[i],test_data))
```

In [30]:

```
plt.plot(x, y1)
plt.plot(x, y2)
plt.plot(x, y3)
plt.plot(x, y4)
plt.plot(x, y5)
plt.plot(x, y6)
plt.legend(["MLE-train", "MAP-train", "PD-train", "MLE-test", "MAP-test", "PD-test'

plt.show()
```



Question 2

In [31]:

```
training_data_size=int(len(training_data)/128)
```

In [32]:

```
print(training_data_size)
```

```
5000
```

In [33]:
```
new_training_data=training_data[:training_data_size]
trained_data=pd[4]
K=10000
```

Calculating Log evidence and Perplexity of training data

In [34]:
```
alpha_plot=[1,2,3,4,5,6,7,8,9,10]
natural_log_plot=[]
perp_plot=[]
for a in range(1,11):
    log_second=0
    a0=a*K
    for w in freq[0]:
        try:
            log_second=log_second+math.lgamma((freq[4][w]if w in freq[4].keys()els
        except:
            continue
    log_evid=math.lgamma(K*a)+log_second-math.lgamma(a0+training_data_size)-K*math
    natural_log_plot.append(log_evid)

    task={}
    for w in freq[4].keys():
        if w in freq[4].keys():
            task[w]=(freq[4][w]+a)/(N[4]+(a*10000))
    test_task={}
    for w in freq_test.keys():
        if w in pd[4].keys():
            test_task[w]=pd[4][w]
        else:
            test_task[w]=(0+a)/(N[4]+(a*10000))
    perp_plot.append(perp(test_task,test_data))
```

In [35]:
```
print("Log evidence:")
for a in range(1,11):
    print(a,natural_log_plot[a-1])
```

```
Log evidence:
1 -46113.90994393523
2 -46016.4221833731
3 -46004.650537487054
4 -46005.47130750775
5 -46008.75036478405
6 -46012.29823476736
7 -46015.57636918465
8 -46018.47568450381
9 -46021.00839883395
10 -46023.21824466319
```

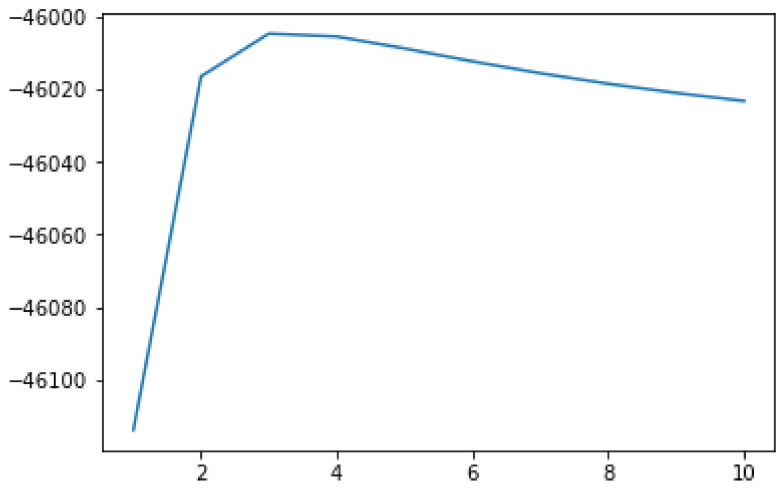
In [36]:
```
print("Perplexity")
for a in range(1,11):
    print(a,perp_plot[a-1])
```

```
Perplexity
1 10826.772237368896
2 9814.024919445475
3 9455.9929217656
4 9272.554265719382
5 9160.984335912612
6 9085.95343431994
7 9032.033421256225
8 8991.411806092978
9 8959.708226012419
10 8934.276020578134
```

Plotting the graphs

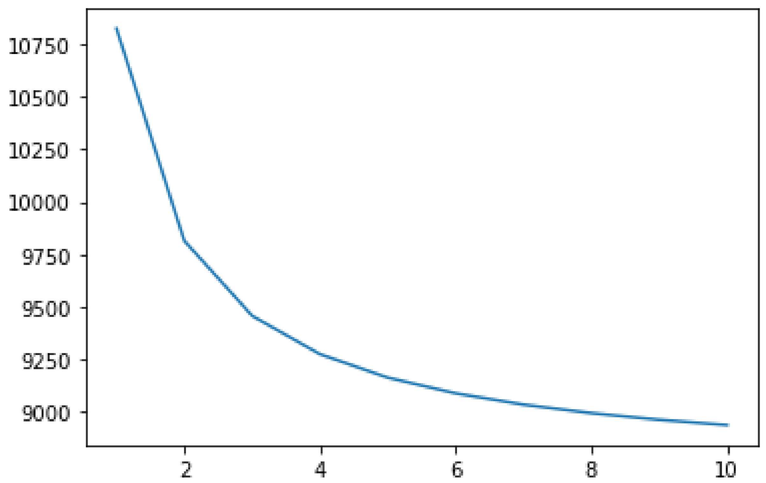
In [37]:
```
plt.plot(alpha_plot,natural_log_plot)
plt.show
```

Out[37]:
```
<function matplotlib.pyplot.show(close=None, block=None)>
```



In [38]:
```
plt.plot(alpha_plot,perp_plot)
plt.show
```

Out[38]:
```
<function matplotlib.pyplot.show(close=None, block=None)>
```



Question 3

In [39]:
```
file1 = open("pg121.txt.clean", "r").read().split()
```

```
file2 = open("pg141.txt.clean", "r").read().split()
file3 = open("pg1400.txt.clean", "r").read().split()
file=file1+file2+file3
```

In [40]:
```
vocab=frequency(file)
vocab1=frequency(file1)
vocab2=frequency(file2)
vocab3=frequency(file3)
```

In [41]:
```
model={}
for w in vocab1.keys():
    model[w]=(vocab1[w]+2)/(len(file1)+2*len(vocab))
```

In [42]:
```
print("Perplexity of file 1 ",perp(model,file1))
```

```
Perplexity of file 1  3345.6956693728525
```

In [43]:
```
test_file2={}
for w in file2:
    if w in model.keys():
        test_file2[w]=model[w]
    else:
        test_file2[w]=(0+2)/(len(file1)+2*len(vocab))
```

In [44]:
```
print("Perplexity of file 2 ",perp(test_file2,file2))
```

```
Perplexity of file 2  4784.495859529101
```

In [45]:
```
test_file3={}
for w in file3:
    if w in model.keys():
        test_file3[w]=model[w]
    else:
        test_file3[w]=(0+2)/(len(file1)+2*len(vocab))
```

In [46]:
```
print("Perplexity of file 3 ",perp(test_file3,file3))
```

```
Perplexity of file 3  6397.17011622876
```

In [ ]:

The assignment is written in ipynb format and can be run using the jupyter notebook

The training data should be named as "training_data.txt"

The test data should be named as "test_data.text"

The three files for the 3rd question are named as "pg121.txt.clean", "pg141.txt.clean", "pg1400.txt.clean"

The files should be present in the same directory as the python notebook

No specific commands to be run along with the notebook

Programming Assignment 1

Machine Learning

-Aaryan Agarwal

Question 1

The first question asked us to evaluate the Maximum Likelihood Estimate, MAP estimate and Predictive Distribution and discuss its effectiveness. This is shown below by calculating the perplexity of each training model and comparing it with test data.

```
The perplexity on train set of MLE model is
size:  640000  Perplexity is  8506.43367662384
size:  160000  Perplexity is  8292.385691215124
size:  40000  Perplexity is  7478.035656314462
size:  10000  Perplexity is  5005.389219343304
size:  5000  Perplexity is  3388.2567752667333
```

```
The perplexity on train set of MAP model is
size:  640000  Perplexity is  8506.96513236839
size:  160000  Perplexity is  8303.124332848962
size:  40000  Perplexity is  7669.433287645091
size:  10000  Perplexity is  6453.994771744834
size:  5000  Perplexity is  5915.104263875246
```

```
The perplexity on train set of Predicitive Distribution model is
size:  640000  Perplexity is  8508.427803625034
size:  160000  Perplexity is  8324.246394665119
size:  40000  Perplexity is  7866.496544080013
size:  10000  Perplexity is  7230.294305050776
size:  5000  Perplexity is  7014.415012644821
```

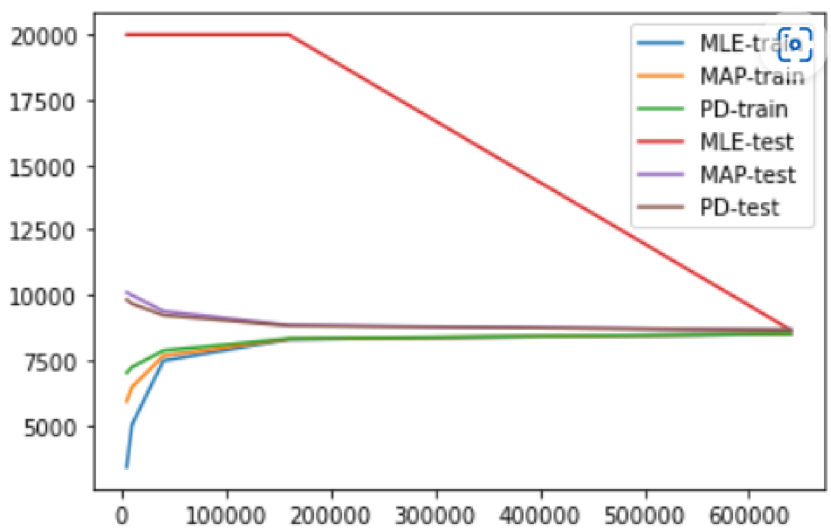
```
The perplexity on test set of MLE model is
size:  640000  Perplexity is  8657.623041731129
```

```
C:\Users\aarya\AppData\Local\Temp\ipykernel_18356\3
  p+=np.log(model[i])
```

```
size:  160000  Perplexity is  inf
size:  40000  Perplexity is  inf
size:  10000  Perplexity is  inf
size:  5000  Perplexity is  inf
```

```
The perplexity on test set of MAP model is
size:  640000  Perplexity is  8654.590090965366
size:  160000  Perplexity is  8839.546029448937
size:  40000  Perplexity is  9380.752312326787
size:  10000  Perplexity is  9992.362371992125
size:  5000  Perplexity is  10098.36492411617
```

```
The perplexity on test set of Predictive Distribution model is
size:  640000  Perplexity is  8652.803792634657
size:  160000  Perplexity is  8817.904839672385
size:  40000  Perplexity is  9224.511912933269
size:  10000  Perplexity is  9668.062580182157
size:  5000  Perplexity is  9814.024919445475
```



The test set perplexities of the different methods decrease with increase in Test data set size. This occurs because of the increase in prior knowledge and words. The increase in word count results in a greater data set which helps the model to generate more accurate predictions thus decreasing the perplexity of the model.

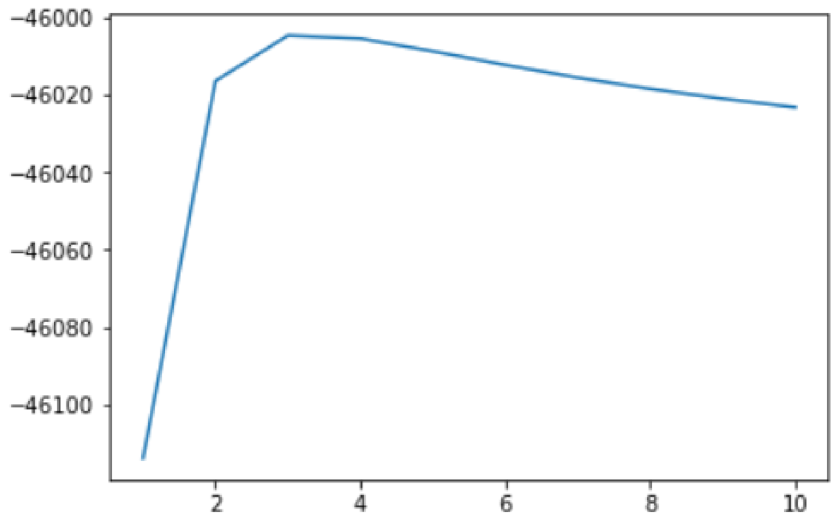
The obvious shortcoming of Maximum Likelihood estimation would be that if a word is not present in the training data, then the probability of the word appearing in the test data would be considered as 0. This can result in false results for words which are not present in the training data.

The test set perplexity is not very sensitive to changes in a’ because the change in numerator will be negligible with respect to the denominator so the perplexity of the model won't have much affect with the changes.

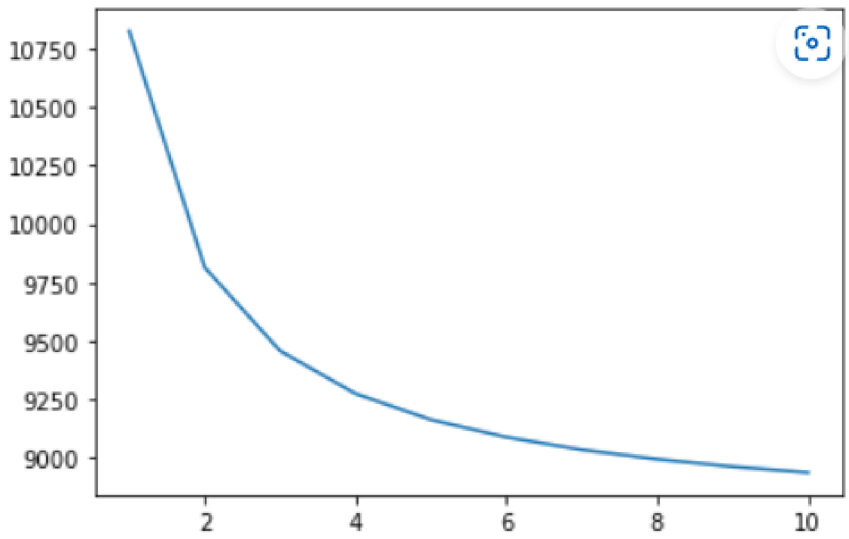
Question 2

In this question we solve for log evidence and perplexity by using the predictive distribution and the dictionary size K=10000 from the Question 1.

```
Log evidence:
1 -46113.90994393523
2 -46016.4221833731
3 -46004.650537487054
4 -46005.47130750775
5 -46008.75036478405
6 -46012.29823476736
7 -46015.57636918465
8 -46018.47568450381
9 -46021.00839883395
10 -46023.21824466319
```



Perplexity
1 10826.772237368896
2 9814.024919445475
3 9455.9929217656
4 9272.554265719382
5 9160.984335912612
6 9085.95343431994
7 9032.033421256225
8 8991.411806092978
9 8959.708226012419
10 8934.276020578134



Yes, maximizing the evidence function is a good method for model selection as it decreases the perplexity of the model.

Question 3

```
Perplexity of file 1  3345.6956693728525
```

```
Perplexity of file 2  4784.495859529101
```

```
Perplexity of file 3  6397.17011622876
```

File 1 is 121 written by J. Austen

File 2 is 141 written by J. Austen

File 3 is 1400 written by C. Dickens

The perplexity of files 1 and 2 are close to each other so we can cluster them together and conclude that both the files are written by a single author.