

Q1a)

The set of equation that meets the requirement would be the following:

$$\begin{cases} 1 - (1 - (\tau_1)^r)^B \geq p_1 \\ 1 - (1 - (\tau_2)^r)^B \leq p_2 \end{cases}$$

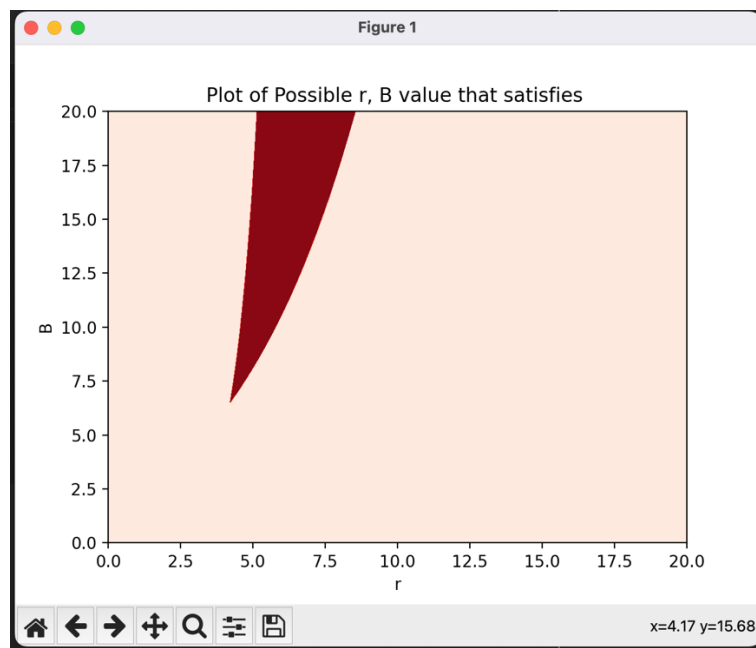
Q1b)

Code:

```
q1a_plt.py > ...
1 import numpy as np
2 import matplotlib.pyplot as plt
3
4 # Define the inequalities
5 def upperbound(x, y):
6     return 1 - (1 - 0.8**x)**y >= 0.96
7
8 def lowerbound(x, y):
9     return 1 - (1 - 0.3**x)**y <= 0.84
10
11 # Generate x and y values
12 x = np.linspace(0, 20, 1000)
13 y = np.linspace(0, 20, 1000)
14 r, B = np.meshgrid(x, y)
15
16 # Calculate the boolean mask for upper and lower bound
17 mask1 = upperbound(r, B)
18 mask2 = lowerbound(r, B)
19
20 # Create a combined mask satisfies both requirement
21 combined_mask = np.logical_and(mask1, mask2)
22
23 # Plot the region
24 plt.contourf(r, B, combined_mask, cmap='Reds')
25 plt.xlabel('r')
26 plt.ylabel('B')
27 plt.title('Plot of Possible r, B value that satisfies ')
28 plt.show()
```

b1) line 6 and line 9 of the code, same as the one in part 1a

b2) Graph:



b3) Overall satisfy. Since it is 96-dim signature, so r=6 and B=16 would be a good choice.

Q2a)

Approach:

First mapper:

Generate 10 random centroids and determine each vector's nearest centroid. Output the centroid id as the key and the vector as the value for each vector.

```
q2a_1_mapper.py > ...
1  #!/usr/bin/env python3
2  """q2a_1_mapper.py"""
3
4  import sys
5  import numpy as np
6
7  K=10
8
9  centroid_ls = []
10 vector_ls = []
11
12 count = 0
13 for line in sys.stdin:
14     count += 1
15     vector_ls.append(np.fromstring(line.strip(), sep=",", dtype=int))
16
17 for k, v in enumerate(np.random.randint(0, count+1, size=K)):
18     centroid_ls.append(vector_ls[v])
19
20 for vector in vector_ls:
21     # compare
22     nearest_ct_key = -1
23     min_distance = None
24     for key, ct in enumerate(centroid_ls):
25         if min_distance == None:
26             min_distance = np.sum(np.square(vector - ct))
27             nearest_ct_key = key
28         else:
29             cur_dis = np.sum(np.square(vector - ct))
30             if cur_dis < min_distance:
31                 min_distance = cur_dis
32                 nearest_ct_key = key
33
34     print(f"{nearest_ct_key}\t{list(vector)}")
```

Reducer:

Recalculate the centroid vector for each key.

```
q2a_reducer.py > ...
1  #!/usr/bin/env python3
2  """q2a_reducer.py"""
3
4  import sys
5  import numpy as np
6  import ast
7
8  current_centroid_key = None
9  ct_vector = None
10 cur_count = 0
11 centroid_key = None
12
13 for line in sys.stdin:
14     centroid_key, vector = line.strip().split('\t')
15     vector = ast.literal_eval(vector)
16
17     if centroid_key != current_centroid_key:
18         if current_centroid_key != None:
19             print(f"{current_centroid_key}\t{cur_count}\t{list(ct_vector/cur_count)}")
20             cur_count = 1
21             current_centroid_key = centroid_key
22             ct_vector = np.array(vector)
23         else:
24             ct_vector += np.array(vector)
25             cur_count += 1
26
27 if current_centroid_key == centroid_key:
28     print(f"{current_centroid_key}\t{cur_count}\t{list(ct_vector/cur_count)}")
29
```

Second mapper:

Read the centroid and sort them by key (in case of multiple reduce and preserve ordering for better observation of convergence). Recalculate the centroid vector

```
q2a_2_mapper.py > ...
1  #!/usr/bin/env python3
2  """q2a_2_mapper.py"""
3
4  import sys
5  import numpy as np
6  import ast
7
8  K=10
9
10 centroid_ls = []
11 vector_ls = []
12
13 count = 0
14 for line in sys.stdin:
15     count += 1
16     vector_ls.append(np.fromstring(line.strip(), sep=",", dtype=int))
17
18 with open("output_file", 'r') as f:
19     temp_ls = []
20     for line in f:
21         centroid_id, count, ct_vector = line.strip().split('\t')
22         temp_ls.append((int(centroid_id), ct_vector))
23
24     temp_ls = sorted(temp_ls, key=lambda x: x[0])
25
26     for i in temp_ls:
27         centroid_ls.append(np.array(ast.literal_eval(i[1])))
28
29 for vector in vector_ls:
30     # compare
31     nearest_ct_key = -1
32     min_distance = None
33     for key, ct in enumerate(centroid_ls):
34         if min_distance == None:
35             min_distance = np.sum(np.square(vector - ct))
36             nearest_ct_key = key
37         else:
38             cur_dis = np.sum(np.square(vector - ct))
39             if cur_dis < min_distance:
40                 min_distance = cur_dis
41                 nearest_ct_key = key
42
43     print(f"{nearest_ct_key}\t{list(vector)}")
```

Reducer:

Recalculate the centroid vector for each key.

```
q2a_reducer.py > ...
1  #!/usr/bin/env python3
2  """q2a_reducer.py"""
3
4  import sys
5  import numpy as np
6  import ast
7
8  current_centroid_key = None
9  ct_vector = None
10 cur_count = 0
11 centroid_key = None
12
13 for line in sys.stdin:
14     centroid_key, vector = line.strip().split('\t')
15     vector = ast.literal_eval(vector)
16
17     if centroid_key != current_centroid_key:
18         if current_centroid_key != None:
19             print(f"{current_centroid_key}\t{cur_count}\t{list(ct_vector/cur_count)}")
20             cur_count = 1
21             current_centroid_key = centroid_key
22             ct_vector = np.array(vector)
23         else:
24             ct_vector += np.array(vector)
25             cur_count += 1
26
27 if current_centroid_key == centroid_key:
28     print(f"{current_centroid_key}\t{cur_count}\t{list(ct_vector/cur_count)}")
29
```

Copy the output file to a destination for chained Hadoop jobs

After that, a beautifier program is used to meet the format required in the homework
Command:

```
q2a_beautify.py > ...
1 import sys
2
3 for line in sys.stdin:
4     id, count, vector = line.strip().split('\t')
5     print(f"Centroid {id}: {count}, {vector}")
```

[illegible]

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[illegible]

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Q2b)

Approach:

Similar to q2a for random seeds

First mapper of provided seeds:

Get the seed centroid by reading it

```
q2b_1_provided_1_mapper.py > ...
1  #!/usr/bin/env python3
2  """q2b_1_provided_1_mapper.py"""
3
4  import sys
5  import numpy as np
6  import ast
7
8  K=10
9
10 centroid_ls = []
11 vector_ls = []
12
13 with open("random_seed_1", 'r') as f:
14     for line in f:
15         centroid_ls.append(np.array(list(ast.literal_eval(line.strip()))))
16
17 count = 0
18 for line in sys.stdin:
19     count += 1
20     vector_ls.append(np.fromstring(line.strip(), sep=",", dtype=int))
21
22
23 for vector in vector_ls:
24     # compare
25     nearest_ct_key = -1
26     min_distance = None
27     for key, ct in enumerate(centroid_ls):
28         if min_distance == None:
29             min_distance = np.sum(np.square(vector - ct))
30             nearest_ct_key = key
31         else:
32             cur_dis = np.sum(np.square(vector - ct))
33             if cur_dis < min_distance:
34                 min_distance = cur_dis
35                 nearest_ct_key = key
36
37 print(f"{nearest_ct_key}\t{list(vector)}")
```

Reducer is the same as q2a

```
q2b_reducer.py > ...
1  #!/usr/bin/env python3
2  """q2b_reducer.py"""
3
4  import sys
5  import numpy as np
6  import ast
7
8  current_centroid_key = None
9  ct_vector = None
10 cur_count = 0
11 centroid_key = None
12
13 for line in sys.stdin:
14     centroid_key, vector = line.strip().split('\t')
15     vector = ast.literal_eval(vector)
16
17     if centroid_key != current_centroid_key:
18         if current_centroid_key != None:
19             print(f"{current_centroid_key}\t{cur_count}\t{list(ct_vector/cur_count)}")
20             cur_count = 1
21             current_centroid_key = centroid_key
22             ct_vector = np.array(vector)
23         else:
24             ct_vector += np.array(vector)
25             cur_count += 1
26
27 if current_centroid_key == centroid_key:
28     print(f"{current_centroid_key}\t{cur_count}\t{list(ct_vector/cur_count)}")
29
```

Second mapper

```
q2b_2_provided_1_mapper.py > ...
1  #!/usr/bin/env python3
2  """q2b_2_provided_1_mapper.py"""
3
4  import sys
5  import numpy as np
6  import ast
7
8  K=10
9
10 centroid_ls = []
11 vector_ls = []
12
13 count = 0
14 for line in sys.stdin:
15     count += 1
16     vector_ls.append(np.fromstring(line.strip(), sep=",", dtype=int))
17
18 with open("provided_1_output_file", 'r') as f:
19     temp_ls = []
20     for line in f:
21         centroid_id, count, ct_vector = line.strip().split('\t')
22         temp_ls.append((int(centroid_id), ct_vector))
23
24     temp_ls = sorted(temp_ls, key=lambda x:x[0])
25
26     for i in temp_ls:
27         centroid_ls.append(np.array(ast.literal_eval(i[1])))
28
29 for vector in vector_ls:
30     # compare
31     nearest_ct_key = -1
32     min_distance = None
33     for key, ct in enumerate(centroid_ls):
34         if min_distance == None:
35             min_distance = np.sum(np.square(vector - ct))
36             nearest_ct_key = key
37         else:
38             cur_dis = np.sum(np.square(vector - ct))
39             if cur_dis < min_distance:
40                 min_distance = cur_dis
41                 nearest_ct_key = key
42
43     print(f"{nearest_ct_key}\t{list(vector)}")
```

And the rest is similar to q2a

Shell script ran

```
$ q2b_provided_1_shell.sh
1  #!/bin/bash
2
3  for i in {1..100}; do
4      echo "Running iteration $i..."
5      hadoop jar /usr/lib/hadoop-mapreduce/hadoop-streaming-2.10.1.jar \
6          -files hdfs://dicvmc2.ie.cuhk.edu.hk/user/s1155157657/hw3/q2_output/provided_1_output_file \
7          -D mapred.map.tasks=5 -D mapred.reduce.tasks=1 \
8          -file q2b_2_provided_1_mapper.py -mapper q2b_2_provided_1_mapper.py \
9          -file q2b_reducer.py -reducer q2b_reducer.py \
10         -input hw3/train_img -output hw3/q2_output/provided_1_output_$i
11
12     hadoop fs -cp -f hw3/q2_output/provided_1_output_$i/part-00000 hw3/q2_output/provided_1_output_file
13     sync
14 done
```

After converging, download the output:

`hadoop fs -get hw2/q2_output/random_1_output_74/part-00000 .`

And

`mv part-00000 output_2b_random_74`

similar for other runs.

Then run the check_details.py and check_details_reducer.py
Just like a MapReduce program but on local machine.

```
python3 check_details.py > out_2b_rand_1  
cat out_2b_rand_1 | sort -k1,1 | python3 check_details_reducer.py
```

Change the input file name for different run for the 4 result

python3 check_details.py

```
check_details.py > ...  
1  #!/usr/bin/env python3  
2  """check_details.py"""  
3  
4  import sys  
5  import numpy as np  
6  import ast  
7  
8  vector_ls = []  
9  label_ls = []  
10 count = 0  
11 centroid_ls = []  
12  
13  
14 with open('MNIST/train_img', 'r') as f:  
15     for line in f:  
16         count += 1  
17         vector_ls.append(np.fromstring(line.strip(), sep=",", dtype=int))  
18  
19 with open('MNIST/train_label', 'r') as f:  
20     for line in f:  
21         label_ls.append(int(line.strip()))  
22  
23 with open('output_2b_provided_126', 'r') as f:  
24     for line in f:  
25         i, each_count, vt = line.strip().split('\t')  
26         centroid_ls.append(np.array(ast.literal_eval(vt)))  
27  
28  
29 for i, vector in enumerate(vector_ls):  
30     # compare  
31     nearest_ct_key = -1  
32     min_distance = None  
33     for key, ct in enumerate(centroid_ls):  
34         if min_distance == None:  
35             min_distance = np.sum(np.square(vector - ct))  
36             nearest_ct_key = key  
37         else:  
38             cur_dis = np.sum(np.square(vector - ct))  
39             if cur_dis < min_distance:  
40                 min_distance = cur_dis  
41                 nearest_ct_key = key  
42  
43     print(f"{str(nearest_ct_key)}, {str(label_ls[i])}\t{1}")
```

python3 check_details_reducer.py

```
check_details_reducer.py > ...  
1  #!/usr/bin/env python3  
2  """check_details_reducer.py"""  
3  
4  import sys  
5  import numpy as np  
6  
7  current_centroid_key = None  
8  cur_count = 0  
9  centroid_key = None  
10  
11 for line in sys.stdin:  
12     centroid_key, count = line.strip().split('\t')  
13     count = int(count)  
14  
15     if centroid_key != current_centroid_key:  
16         if current_centroid_key != None:  
17             print(f"{current_centroid_key}\t{cur_count}")  
18             cur_count = 1  
19             current_centroid_key = centroid_key  
20         else:  
21             cur_count += 1  
22  
23 if current_centroid_key == centroid_key:  
24     print(f"{current_centroid_key}\t{cur_count}")  
25
```

Output follow this format:
(Cluster id),(ground-truth label) (count)

Random Seed 1:

```
hadoop fs -get hw2/q2_output/random_1_output_74/part-00000 .  
mv part-00000 output_2b_random_74
```

change file name in check_details.py

```
python3 check_details.py > out_2b_rand_1  
cat out_2b_rand_1 | sort -k1,1 | python3 check_details_reducer.py
```

Result:

```
0,0 32  
0,1 2964  
0,2 366  
0,3 87  
0,4 245  
0,5 731  
0,6 193  
0,7 238  
0,8 396  
0,9 79  
1,1 3726  
1,2 328  
1,3 372  
1,4 99  
1,5 116  
1,6 232  
1,7 229  
1,8 280  
1,9 140  
2,0 4677  
2,2 56  
2,3 33  
2,4 4  
2,5 65  
2,6 74  
2,7 13  
2,8 28  
2,9 29  
3,0 14  
3,1 9  
3,2 37  
3,3 163  
3,4 1634  
3,5 319  
3,6 1  
3,7 2372  
3,8 211  
3,9 2499  
4,0 27  
4,1 7  
4,2 61
```

4,3 32
4,4 1519
4,5 264
4,6 1
4,7 2848
4,8 229
4,9 1721
5,0 567
5,1 6
5,2 140
5,3 1220
5,4 12
5,5 1811
5,6 113
5,7 3
5,8 3124
5,9 44
6,0 41
6,1 9
6,2 4190
6,3 212
6,4 15
6,5 13
6,6 77
6,7 31
6,8 44
6,9 4
7,0 98
7,1 4
7,2 235
7,3 65
7,4 2183
7,5 184
7,6 621
7,7 526
7,8 133
7,9 1340
8,0 238
8,1 11
8,2 158
8,3 60
8,4 131
8,5 145
8,6 4576
8,7 2
8,8 55
8,9 8
9,0 229
9,1 6
9,2 387
9,3 3887
9,5 1773
9,6 30
9,7 3

9,8 1351
9,9 85

Cluster index	Major Label of the cluster	# Train images belonging to the cluster	# Correctly clustered images	Classification Accuracy(%)
0	1	5331	2964	55.60
1	1	5522	3726	67.48
2	0	4979	4677	93.93
3	9	7259	2499	34.43
4	7	6709	2848	42.45
5	8	7040	3124	44.38
6	2	4636	4190	90.38
7	4	5389	2183	40.51
8	6	5384	4576	84.99
9	3	7751	3887	50.15
Total Set	N/A	60000	34674	57.79

Random Seed 2:

```
hadoop fs -get hw3/q2_output/random_2_output_102/part-000000 .  
mv part-000000 output_2b_random_102  
modify check_details.py  
python3 check_details.py > out_2b_rand_2  
cat out_2b_rand_2 | sort -k1,1 | python3 check_details_reducer.py
```

Result:

```
0,0 50  
0,1 9  
0,2 55  
0,3 37  
0,4 1599  
0,5 554  
0,6 4  
0,7 1900  
0,8 321  
0,9 1666  
1,0 20  
1,1 6606  
1,2 698  
1,3 393  
1,4 147  
1,5 668  
1,6 361  
1,7 384  
1,8 595  
1,9 156  
2,0 547  
2,1 20  
2,2 141  
2,3 1211  
2,4 8  
2,5 1614  
2,6 101  
2,7 6  
2,8 2992  
2,9 36  
3,0 12  
3,1 37  
3,2 48  
3,3 207  
3,4 2145  
3,5 457  
3,6 7  
3,7 425  
3,8 380  
3,9 2763  
4,0 45  
4,1 41  
4,2 4179
```

4,3 223
4,4 16
4,5 14
4,6 44
4,7 38
4,8 54
4,9 3
5,0 254
5,1 14
5,2 140
5,3 70
5,4 103
5,5 154
5,6 4364
5,7 1
5,8 45
5,9 7
6,0 3
6,1 3
6,2 60
6,3 30
6,4 4
6,5 10
6,7 3170
6,8 6
6,9 122
7,0 217
7,1 11
7,2 379
7,3 3892
7,4 1
7,5 1773
7,6 28
7,7 5
7,8 1307
7,9 86
8,0 130
8,1 1
8,2 202
8,3 37
8,4 1817
8,5 113
8,6 940
8,7 327
8,8 124
8,9 1085
9,0 4645
9,2 56
9,3 31
9,4 2
9,5 64
9,6 69
9,7 9
9,8 27

Cluster index	Major Label of the cluster	# Train images belonging to the cluster	# Correctly clustered images	Classification Accuracy(%)
0	7	6195	1900	30.67
1	1	10028	6606	65.88
2	8	6676	2992	44.82
3	9	6481	2763	42.63
4	2	4657	4179	89.74
5	6	5152	4364	84.70
6	7	3408	3170	93.02
7	3	7699	3892	50.55
8	4	4776	1817	38.04
9	0	4928	4645	94.26
Total Set	N/A	60000	36328	60.55

Provided seed 1:

```
hadoop fs -get hw3/q2_output/provided_1_output_39/part-000000  
mv part-000000 output_2b_provided_39
```

modify check_details.py

```
python3 check_details.py > out_2b_prov_1  
cat out_2b_prov_1 | sort -k1,1 | python3 check_details_reducer.py
```

result:

```
0,0 3906  
0,2 35  
0,3 21  
0,4 6  
0,5 48  
0,6 68  
0,7 12  
0,8 31  
0,9 35  
1,0 14  
1,1 6628  
1,2 696  
1,3 403  
1,4 193  
1,5 589  
1,6 433  
1,7 473  
1,8 576  
1,9 235  
2,0 7  
2,1 39  
2,2 4146  
2,3 143  
2,4 26  
2,5 5  
2,6 69  
2,7 50  
2,8 46  
2,9 13  
3,0 218  
3,1 9  
3,2 275  
3,3 3954  
3,5 1830  
3,6 26  
3,7 4  
3,8 1036  
3,9 94  
4,0 41  
4,1 12  
4,2 155  
4,3 164
```

4,4 2614
4,5 319
4,6 86
4,7 1148
4,8 180
4,9 2394
5,0 1508
5,1 6
5,2 178
5,3 524
5,4 45
5,5 1370
5,6 788
5,7 14
5,8 225
5,9 17
6,0 157
6,1 11
6,2 164
6,3 40
6,4 96
6,5 82
6,6 4409
6,7 4
6,8 41
6,9 6
7,0 3
7,1 5
7,2 96
7,3 40
7,4 7
7,5 20
7,7 4255
7,8 20
7,9 192
8,0 62
8,1 23
8,2 188
8,3 820
8,4 11
8,5 835
8,6 30
8,7 47
8,8 3505
8,9 62
9,0 7
9,1 9
9,2 25
9,3 22
9,4 2844
9,5 323
9,6 9
9,7 258
9,8 191

9,9 2901

Cluster index	Major Label of the cluster	# Train images belonging to the cluster	# Correctly clustered images	Classification Accuracy(%)
0	0	4162	3906	93.85
1	1	10240	6628	64.73
2	2	4544	4146	91.24
3	3	7446	3954	53.10
4	4	7113	2614	36.75
5	0	4675	1508	32.26
6	6	5010	4409	88.0
7	7	4638	4255	91.74
8	8	5583	3505	62.78
9	9	6589	2901	44.03
Total Set	N/A	60000	37826	63.04

Provided seed 2:

```
hadoop fs -get hw3/q2_output/provided_2_output_126/part-00000  
mv part-00000 output_2b_provided_126
```

modify check_details.py

```
python3 check_details.py > out_2b_prov_2  
cat out_2b_prov_2 | sort -k1,1 | python3 check_details_reducer.py
```

Result:

```
0,0 2771  
0,2 10  
0,3 18  
0,4 2  
0,5 62  
0,6 106  
0,7 7  
0,8 34  
0,9 21  
1,0 19  
1,1 6605  
1,2 687  
1,3 395  
1,4 239  
1,5 864  
1,6 436  
1,7 371  
1,8 576  
1,9 173  
2,0 22  
2,1 38  
2,2 4201  
2,3 238  
2,4 16  
2,5 17  
2,6 94  
2,7 38  
2,8 55  
2,9 5  
3,0 163  
3,1 10  
3,2 333  
3,3 4017  
3,5 1804  
3,6 30  
3,7 3  
3,8 1192  
3,9 93  
4,0 52  
4,1 8  
4,2 194  
4,3 67
```

4,4 2259
4,5 196
4,6 418
4,7 585
4,8 130
4,9 1461
5,0 2500
5,2 95
5,3 118
5,4 7
5,5 229
5,6 101
5,7 14
5,8 29
5,9 17
6,0 193
6,1 14
6,2 170
6,3 59
6,4 126
6,5 137
6,6 4642
6,7 2
6,8 56
6,9 8
7,0 19
7,1 6
7,2 59
7,3 43
7,4 1609
7,5 352
7,6 1
7,7 2752
7,8 212
7,9 1672
8,0 164
8,1 28
8,2 162
8,3 1007
8,4 13
8,5 1450
8,6 87
8,7 15
8,8 3390
8,9 38
9,0 20
9,1 33
9,2 47
9,3 169
9,4 1571
9,5 310
9,6 3
9,7 2478
9,8 177

9,9 2461

Cluster index	Major Label of the cluster	# Train images belonging to the cluster	# Correctly clustered images	Classification Accuracy(%)
0	0	3031	2771	91.42
1	1	10365	6605	63.72
2	2	4724	4201	88.92
3	3	7645	4017	52.54
4	4	5370	2259	42.06
5	0	3110	2500	80.38
6	6	5407	4642	85.85
7	7	6725	2752	40.92
8	8	6354	3390	53.35
9	7	7269	2478	34.09
Total Set	N/A	60000	35615	59.36

To conclude, provided seed 1 has the best accuracy. So it is the best random seed.

Q2c)

Code:

Same as check_details.py

But this time we already know the label so the format would be:

(cluster_id),(truth_label) (count)

Result:

```
0,0 656
0,2 9
0,3 1
0,5 6
0,6 17
0,7 1
0,8 7
0,9 6
1,0 2
1,1 1110
1,2 139
1,3 54
1,4 27
1,5 87
1,6 44
1,7 84
1,8 74
1,9 28
2,0 1
2,1 13
2,2 702
2,3 27
2,4 3
2,5 2
2,6 15
2,7 15
2,8 8
2,9 2
3,0 49
3,1 3
3,2 52
3,3 707
3,5 312
3,6 3
3,8 185
3,9 8
4,0 3
4,2 21
4,3 17
4,4 454
4,5 51
4,6 20
4,7 174
4,8 24
4,9 442
```

5,0	225
5,2	27
5,3	76
5,4	12
5,5	218
5,6	110
5,7	2
5,8	32
5,9	6
6,0	37
6,1	3
6,2	22
6,3	4
6,4	16
6,5	16
6,6	742
6,8	12
6,9	2
7,0	1
7,2	15
7,3	5
7,5	7
7,7	700
7,8	13
7,9	25
8,0	5
8,1	6
8,2	40
8,3	117
8,4	1
8,5	138
8,6	5
8,7	8
8,8	583
8,9	15
9,0	1
9,2	5
9,3	2
9,4	469
9,5	55
9,6	2
9,7	44
9,8	36
9,9	475

Cluster index	Major Label of the cluster	# Test images belonging to the cluster	# Correctly clustered images	Classification Accuracy(%)
0	0	703	656	93.31
1	1	1649	1110	67.31
2	2	788	702	89.09
3	3	1319	707	53.60
4	4	1206	454	37.65
5	0	708	225	31.78
6	6	854	742	86.89
7	7	766	700	91.38
8	8	918	583	63.51
9	9	1089	475	43.62
Total Set	N/A	10000	6354	63.54

Q3a)

Pink part is the comment

上午 12:33 11月18日 週六 17%

erg4300Hv

```
Procedure CalProb(n, k)
  prob ← 1
  for i = 1 to dim(X[n]):
    prob ← prob * ((q[n][i]**X[n][i])*(1-q[n][i]**(1-X[n][i]))
  return prob //  $\prod_{i=1}^D q_i^{x_i} (1-q_i)^{(1-x_i)}$ 

Procedure CalVariable(n, k):
  local_sum ← 0
  for j = 1 to K:
    local_sum ← local_sum +  $\pi[j] * \text{CalProb}(n, k)$ 
  return  $\pi[j] * \text{CalProb}(n, k) / \text{local\_sum}$  //  $\frac{\pi_k p(x_n | q_k)}{\sum_{j=1}^K \pi_j p(x_n | q_k)}$ 

global X ← data points
global  $\pi \leftarrow [\pi_1, \pi_2, \pi_3, \dots, \pi_k]$ 
global  $q \leftarrow [q_1, q_2, q_3, \dots, q_k]$ 
global k ← number of cluster
global N ← number of vectors

while not converge:
  for k = 0 to k
    count ← 0
    sum_all ← 0
    for n = 0 to N
      output_param = CalVariable(n, k) //  $y(z_{nk})$ 
      sum_all += output_param //  $\sum_{n=1}^N y(z_{nk})$ 
      sum_all_x += output_param * X[n] //  $\sum_{n=1}^N y(z_{nk}) x_n$ 
    q[k] = sum_all_x / sum_all
     $\pi[k] = \text{sum\_all} / N$ 
```