2a)

Training the SVM

pcost dcost gap pres dres

0: 1.0279e+06 -2.8782e+07 6e+07 5e-01 6e-13

1: 1.6172e+06 -5.7488e+06 7e+06 8e-13 1e-12

2: 4.0419e+05 -6.5390e+05 1e+06 4e-13 4e-13

3: 6.1997e+04 -8.7523e+04 1e+05 5e-13 2e-13

4: 8.7595e+03 -1.1045e+04 2e+04 4e-14 8e-14

5: 1.1334e+03 -1.6783e+03 3e+03 3e-14 3e-14

6: 9.9097e+01 -2.9262e+02 4e+02 3e-14 1e-14

7: -8.9772e+00 -1.3245e+02 1e+02 3e-15 6e-15

8: -8.6338e+01 -1.7689e+02 9e+01 3e-14 8e-15

9: -1.1330e+02 -1.1786e+02 5e+00 1e-15 8e-15

10: -1.1495e+02 -1.1611e+02 1e+00 1e-14 7e-15

11: -1.1549e+02 -1.1568e+02 2e-01 1e-14 8e-15

12: -1.1557e+02 -1.1557e+02 2e-03 6e-15 1e-14

13: -1.1557e+02 -1.1557e+02 2e-05 9e-15 8e-15

Optimal solution found.

Number of SV: 3

Accuracy on train data with C = 1000: 0.0

Accuracy on test data with C = 1000: 0.8648648648648649

2b)

C = 1000

pcost dcost gap pres dres

0: 2.2711e+05 -3.2336e+08 7e+08 3e-01 1e-09

1: 2.1275e+05 -5.7531e+07 1e+08 4e-02 8e-10

2: 7.7316e+04 -5.1562e+06 1e+07 3e-03 2e-10

3: 3.2827e+04 -4.2589e+05 8e+05 2e-04 2e-11

4: 1.6692e+04 -2.0967e+04 4e+04 2e-06 4e-12

5: 2.5425e+03 -2.7869e+03 5e+03 4e-15 2e-12

6: 3.6222e+02 -4.0613e+02 8e+02 1e-14 7e-13

7: 5.1047e+01 -5.8973e+01 1e+02 4e-15 3e-13

8: 6.9720e+00 -8.7846e+00 2e+01 2e-16 1e-13

9: 8.4914e-01 -1.3982e+00 2e+00 6e-16 4e-14

10: 9.4632e-02 -3.6581e-01 5e-01 4e-16 2e-14

11: -2.2148e-02 -3.3014e-01 3e-01 4e-16 1e-14

12: -8.2896e-02 -2.5822e-01 2e-01 2e-16 1e-14

13: -1.1894e-01 -2.2919e-01 1e-01 2e-16 1e-14

14: -1.4119e-01 -1.9302e-01 5e-02 2e-16 1e-14

15: -1.4885e-01 -1.7884e-01 3e-02 3e-16 2e-14

16: -1.6037e-01 -1.6423e-01 4e-03 2e-16 2e-14

17: -1.6209e-01 -1.6216e-01 7e-05 3e-16 2e-14

18: -1.6212e-01 -1.6212e-01 9e-07 4e-16 2e-14

19: -1.6212e-01 -1.6212e-01 1e-08 2e-16 2e-14

Optimal solution found.

\*\*\* 1-vs-3 \*\*\*

Number of SV: 26

Width of margin: 3.512298902162324

Train Error 1\_vs\_3: 1

Test Error 1\_vs\_3: 0.009302325581395349

C = 2000

pcost dcost gap pres dres

0: 9.3718e+05 -1.2895e+09 3e+09 3e-01 1e-09

1: 8.5629e+05 -2.2956e+08 5e+08 4e-02 2e-09

2: 3.0964e+05 -2.0567e+07 4e+07 3e-03 3e-10

3: 1.3126e+05 -1.6985e+06 3e+06 2e-04 5e-11

4: 6.6693e+04 -8.3647e+04 2e+05 2e-06 9e-12

5: 1.0170e+04 -1.1108e+04 2e+04 5e-14 3e-12

6: 1.4534e+03 -1.6144e+03 3e+03 1e-14 1e-12

7: 2.0658e+02 -2.3271e+02 4e+02 1e-14 5e-13

8: 2.8947e+01 -3.3995e+01 6e+01 1e-15 2e-13

9: 3.8817e+00 -5.1280e+00 9e+00 2e-15 8e-14

10: 4.3427e-01 -8.4593e-01 1e+00 6e-16 3e-14

11: 8.1816e-02 -3.6115e-01 4e-01 4e-16 2e-14

12: -1.2052e-02 -3.6047e-01 3e-01 2e-16 1e-14

13: -8.0600e-02 -2.5815e-01 2e-01 2e-16 1e-14

14: -1.1541e-01 -2.3206e-01 1e-01 2e-16 1e-14

15: -1.4125e-01 -1.9334e-01 5e-02 2e-16 2e-14

16: -1.4847e-01 -1.7944e-01 3e-02 2e-16 2e-14

17: -1.6025e-01 -1.6440e-01 4e-03 2e-16 2e-14

18: -1.6209e-01 -1.6216e-01 7e-05 5e-16 2e-14

19: -1.6212e-01 -1.6212e-01 1e-06 5e-16 2e-14

20: -1.6212e-01 -1.6212e-01 1e-08 7e-16 2e-14

Optimal solution found.

\*\*\* 1-vs-3 \*\*\*

Number of SV: 26

Width of margin: 3.5122989020553774

Train Error 1\_vs\_3: 1

Test Error 1\_vs\_3: 0.009302325581395349

C = 3000

pcost dcost gap pres dres

0: 2.1302e+06 -2.8983e+09 7e+09 3e-01 3e-09

1: 1.9306e+06 -5.1609e+08 1e+09 4e-02 3e-09

2: 6.9697e+05 -4.6231e+07 9e+07 3e-03 4e-10

3: 2.9531e+05 -3.8180e+06 7e+06 2e-04 8e-11

4: 1.5000e+05 -1.8804e+05 4e+05 2e-06 1e-11

5: 2.2882e+04 -2.4964e+04 5e+04 4e-14 6e-12

6: 3.2734e+03 -3.6247e+03 7e+03 1e-14 2e-12

7: 4.6656e+02 -5.2125e+02 1e+03 4e-15 8e-13

8: 6.5890e+01 -7.5656e+01 1e+02 2e-15 3e-13

9: 9.0579e+00 -1.1216e+01 2e+01 2e-15 1e-13

10: 1.1330e+00 -1.7619e+00 3e+00 2e-16 4e-14

11: 9.9757e-02 -3.6914e-01 5e-01 4e-16 2e-14

12: 3.1585e-02 -3.4500e-01 4e-01 3e-16 1e-14

13: -6.7255e-02 -2.7537e-01 2e-01 2e-16 1e-14

14: -1.0148e-01 -2.4995e-01 1e-01 2e-16 1e-14

15: -1.3883e-01 -1.9423e-01 6e-02 2e-16 2e-14

16: -1.4382e-01 -1.8679e-01 4e-02 4e-16 2e-14

17: -1.5673e-01 -1.6897e-01 1e-02 2e-16 2e-14

18: -1.6139e-01 -1.6294e-01 2e-03 2e-16 2e-14

19: -1.6211e-01 -1.6214e-01 2e-05 4e-16 2e-14

20: -1.6212e-01 -1.6212e-01 2e-07 2e-16 2e-14

21: -1.6212e-01 -1.6212e-01 2e-09 2e-16 2e-14

Optimal solution found.

\*\*\* 1-vs-3 \*\*\*

Number of SV: 26

Width of margin: 3.5122989036840635

Train Error 1\_vs\_3: 1

Test Error 1\_vs\_3: 0.009302325581395349

2c)

C = 1000

pcost dcost gap pres dres

0: 6.6953e+05 -5.9202e+08 2e+09 6e-01 2e-09

1: 1.1870e+06 -1.8955e+08 3e+08 1e-01 1e-09

2: 8.5582e+05 -5.1457e+07 9e+07 3e-02 6e-10

3: 4.1806e+05 -7.1135e+06 1e+07 3e-03 2e-10

4: 1.9504e+05 -7.2900e+05 1e+06 2e-04 5e-11

5: 4.6595e+04 -5.4330e+04 1e+05 2e-06 2e-11

6: 6.7523e+03 -7.5488e+03 1e+04 1e-13 7e-12

7: 9.5316e+02 -1.0986e+03 2e+03 3e-14 3e-12

8: 1.3060e+02 -1.6304e+02 3e+02 2e-14 1e-12

9: 1.5991e+01 -2.5849e+01 4e+01 2e-15 4e-13

10: 9.4228e-01 -5.5016e+00 6e+00 3e-16 2e-13

11: -4.4297e-01 -4.0583e+00 4e+00 7e-16 1e-13

12: -1.3181e+00 -3.4389e+00 2e+00 2e-16 1e-13

13: -1.9482e+00 -2.8660e+00 9e-01 2e-15 1e-13

14: -2.2076e+00 -2.5462e+00 3e-01 8e-16 1e-13

15: -2.3236e+00 -2.3647e+00 4e-02 4e-15 1e-13

16: -2.3397e+00 -2.3439e+00 4e-03 2e-16 1e-13

17: -2.3415e+00 -2.3416e+00 8e-05 2e-15 1e-13

18: -2.3415e+00 -2.3415e+00 1e-06 4e-15 1e-13

Optimal solution found.

\*\*\* 3-vs-8 \*\*\*

Number of SV: 87

Width of margin: 0.9241955158877017

Train Error 3-vs-8: 1

Test Error 3-vs-8: 0.03614457831325301

C = 2000

pcost dcost gap pres dres

0: 2.8062e+06 -2.3645e+09 6e+09 6e-01 4e-09

1: 4.8044e+06 -7.5692e+08 1e+09 1e-01 3e-09

2: 3.4372e+06 -2.0537e+08 4e+08 3e-02 1e-09

3: 1.6728e+06 -2.8359e+07 5e+07 3e-03 4e-10

4: 7.7938e+05 -2.9031e+06 5e+06 2e-04 1e-10

5: 1.8611e+05 -2.1620e+05 4e+05 2e-06 3e-11

6: 2.7044e+04 -2.9976e+04 6e+04 4e-13 1e-11

7: 3.8479e+03 -4.3332e+03 8e+03 7e-14 5e-12

8: 5.4015e+02 -6.3136e+02 1e+03 6e-14 2e-12

9: 7.2714e+01 -9.4925e+01 2e+02 5e-14 8e-13

10: 8.1658e+00 -1.5614e+01 2e+01 9e-15 3e-13

11: 1.3206e-01 -4.3376e+00 4e+00 3e-15 1e-13

12: -1.0943e+00 -4.1831e+00 3e+00 3e-15 1e-13

13: -1.7409e+00 -3.4749e+00 2e+00 2e-15 1e-13

14: -2.1266e+00 -2.7100e+00 6e-01 4e-15 1e-13

15: -2.2889e+00 -2.4180e+00 1e-01 7e-15 1e-13

16: -2.3389e+00 -2.3449e+00 6e-03 2e-15 1e-13

17: -2.3415e+00 -2.3416e+00 2e-04 2e-16 1e-13

18: -2.3415e+00 -2.3415e+00 3e-06 1e-15 1e-13

19: -2.3415e+00 -2.3415e+00 5e-08 4e-15 1e-13

Optimal solution found.

\*\*\* 3-vs-8 \*\*\*

Number of SV: 87

Width of margin: 0.9241955386775803

Train Error 3-vs-8: 1

Test Error 3-vs-8: 0.03614457831325301

C = 3000

pcost dcost gap pres dres

0: 6.4099e+06 -5.3175e+09 1e+10 6e-01 5e-09

1: 1.0852e+07 -1.7021e+09 3e+09 1e-01 4e-09

2: 7.7441e+06 -4.6174e+08 8e+08 3e-02 2e-09

3: 3.7640e+06 -6.3736e+07 1e+08 3e-03 6e-10

4: 1.7530e+06 -6.5223e+06 1e+07 2e-04 2e-10

5: 4.1855e+05 -4.8562e+05 9e+05 2e-06 5e-11

6: 6.0874e+04 -6.7283e+04 1e+05 6e-13 2e-11

7: 8.6834e+03 -9.7043e+03 2e+04 3e-13 8e-12

8: 1.2278e+03 -1.4055e+03 3e+03 2e-13 3e-12

9: 1.6927e+02 -2.0783e+02 4e+02 2e-14 1e-12

10: 2.1281e+01 -3.2524e+01 5e+01 7e-15 4e-13

11: 1.3659e+00 -6.0849e+00 7e+00 6e-15 2e-13

12: -2.3646e-01 -4.1909e+00 4e+00 3e-15 1e-13

13: -1.2017e+00 -3.6865e+00 2e+00 3e-15 1e-13

14: -1.9054e+00 -3.0503e+00 1e+00 1e-15 1e-13

15: -2.1765e+00 -2.6017e+00 4e-01 2e-16 1e-13

16: -2.3106e+00 -2.3858e+00 8e-02 9e-15 1e-13

17: -2.3389e+00 -2.3452e+00 6e-03 9e-15 1e-13

18: -2.3415e+00 -2.3416e+00 1e-04 1e-15 1e-13

19: -2.3415e+00 -2.3415e+00 2e-06 2e-16 1e-13

20: -2.3415e+00 -2.3415e+00 3e-08 3e-15 1e-13

Optimal solution found.

\*\*\* 3-vs-8 \*\*\*

Number of SV: 87

Width of margin: 0.9241955390482534

Train Error 3-vs-8: 1

Test Error 3-vs-8: 0.03614457831325301

2d)

pcost dcost gap pres dres

0: 1.8066e+30 -1.2655e+31 1e+31 8e-01 5e-01

1: 5.9461e+29 -9.7468e+29 2e+30 6e-01 4e-01

2: 9.3966e+28 -1.2534e+29 2e+29 3e-01 2e-01

3: 1.3877e+28 -1.6640e+28 3e+28 1e-01 1e-01

4: 2.0027e+27 -2.2476e+27 4e+27 3e-02 5e-02

5: 2.8764e+26 -3.1886e+26 6e+26 2e-02 2e-02

6: 4.1252e+25 -4.5476e+25 9e+25 4e-03 5e-03

7: 5.9131e+24 -6.5061e+24 1e+25 3e-03 3e-03

8: 8.4742e+23 -9.3173e+23 2e+24 3e-03 8e-04

9: 1.2144e+23 -1.3348e+23 3e+23 1e-03 3e-04

10: 1.7402e+22 -1.9126e+22 4e+22 4e-04 1e-04

11: 2.4937e+21 -2.7406e+21 5e+21 7e-05 5e-05

12: 3.5734e+20 -3.9272e+20 8e+20 9e-05 2e-05

13: 5.1206e+19 -5.6275e+19 1e+20 2e-05 6e-06

14: 7.3377e+18 -8.0641e+18 2e+19 5e-06 2e-06

15: 1.0515e+18 -1.1556e+18 2e+18 3e-08 8e-07

16: 1.5067e+17 -1.6559e+17 3e+17 3e-07 3e-07

17: 2.1591e+16 -2.3729e+16 5e+16 3e-07 1e-07

18: 3.0939e+15 -3.4002e+15 6e+15 1e-07 5e-08

19: 4.4335e+14 -4.8725e+14 9e+14 1e-07 2e-08

20: 6.3532e+13 -6.9821e+13 1e+14 4e-08 7e-09

21: 9.1039e+12 -1.0005e+13 2e+13 7e-09 3e-09

22: 1.3046e+12 -1.4337e+12 3e+12 9e-10 9e-10

23: 1.8694e+11 -2.0545e+11 4e+11 3e-10 3e-10

24: 2.6787e+10 -2.9441e+10 6e+10 2e-10 1e-10

25: 3.8384e+09 -4.2190e+09 8e+09 4e-12 5e-11

26: 5.4996e+08 -6.0465e+08 1e+09 1e-11 2e-11

27: 7.8779e+07 -8.6672e+07 2e+08 1e-11 8e-12

28: 1.1278e+07 -1.2430e+07 2e+07 8e-12 3e-12

29: 1.6122e+06 -1.7852e+06 3e+06 7e-13 1e-12

30: 2.2951e+05 -2.5733e+05 5e+05 4e-13 5e-13

31: 3.2302e+04 -3.7453e+04 7e+04 1e-14 1e-13

32: 4.3946e+03 -5.5936e+03 1e+04 2e-13 6e-14

33: 5.2759e+02 -8.9547e+02 1e+03 1e-13 3e-14

34: 1.9624e+01 -1.7431e+02 2e+02 1e-14 1e-14

35: -3.2559e+01 -1.3138e+02 1e+02 8e-15 6e-15

36: -1.0555e+02 -1.4230e+02 4e+01 5e-14 1e-14

37: -1.1459e+02 -1.1811e+02 4e+00 1e-14 9e-15

38: -1.1535e+02 -1.1608e+02 7e-01 3e-14 1e-14

39: -1.1557e+02 -1.1558e+02 2e-02 8e-15 9e-15

40: -1.1557e+02 -1.1557e+02 2e-04 2e-14 9e-15

41: -1.1557e+02 -1.1557e+02 2e-06 6e-15 7e-15

Optimal solution found.

Accuracy of kernel SVM with C=1000 and norm=5: 0.8108108108108109