

Question 1(a).

neural net 1: test error = 0.0926
neural net 2: test error = 0.1299
neural net 3: test error = 0.0373
neural net 4: test error = 0.034
neural net 5: test error = 0.0343
neural net 6: test error = 0.034
neural net 7: test error = 0.0352
neural net 8: test error = 0.0359
neural net 9: test error = 0.0386

Minimum test error = 0.034

Question 3 (e).

Iteration 1: Training error = 2.64%, Test error = 4.34%
Iteration 2: Training error = 1.55%, Test error = 3.52%
Iteration 3: Training error = 1.04%, Test error = 3.15%
Iteration 4: Training error = 0.84%, Test error = 3.07%
Iteration 5: Training error = 0.69%, Test error = 2.94%
Iteration 6: Training error = 0.62%, Test error = 2.86%
Iteration 7: Training error = 0.57%, Test error = 2.75%
Iteration 8: Training error = 0.50%, Test error = 2.75%
Iteration 9: Training error = 0.52%, Test error = 2.72%
Iteration 10: Training error = 0.50%, Test error = 2.72%
Iteration 11: Training error = 0.48%, Test error = 2.62%
Iteration 12: Training error = 0.45%, Test error = 2.57%
Iteration 13: Training error = 0.49%, Test error = 2.67%
Iteration 14: Training error = 0.42%, Test error = 2.69%
Iteration 15: Training error = 0.42%, Test error = 2.63%
Iteration 16: Training error = 0.41%, Test error = 2.69%
Iteration 17: Training error = 0.41%, Test error = 2.53%
Iteration 18: Training error = 0.44%, Test error = 2.66%
Iteration 19: Training error = 0.41%, Test error = 2.64%
Iteration 20: Training error = 0.42%, Test error = 2.50%
Iteration 21: Training error = 0.40%, Test error = 2.53%
Iteration 22: Training error = 0.38%, Test error = 2.60%
Iteration 23: Training error = 0.41%, Test error = 2.65%
Iteration 24: Training error = 0.41%, Test error = 2.47%
Iteration 25: Training error = 0.37%, Test error = 2.55%
Iteration 26: Training error = 0.37%, Test error = 2.60%
Iteration 27: Training error = 0.38%, Test error = 2.55%
Iteration 28: Training error = 0.37%, Test error = 2.50%

Iteration 29: Training error = 0.38%, Test error = 2.53%
Iteration 30: Training error = 0.38%, Test error = 2.45%
Iteration 31: Training error = 0.37%, Test error = 2.38%
Iteration 32: Training error = 0.39%, Test error = 2.55%
Iteration 33: Training error = 0.34%, Test error = 2.44%
Iteration 34: Training error = 0.37%, Test error = 2.53%
Iteration 35: Training error = 0.35%, Test error = 2.50%
Iteration 36: Training error = 0.34%, Test error = 2.40%
Iteration 37: Training error = 0.34%, Test error = 2.44%
Iteration 38: Training error = 0.32%, Test error = 2.50%
Iteration 39: Training error = 0.34%, Test error = 2.41%
Iteration 40: Training error = 0.36%, Test error = 2.42%
Iteration 41: Training error = 0.35%, Test error = 2.43%
Iteration 42: Training error = 0.35%, Test error = 2.33%
Iteration 43: Training error = 0.38%, Test error = 2.42%
Iteration 44: Training error = 0.35%, Test error = 2.28%
Iteration 45: Training error = 0.36%, Test error = 2.38%
Iteration 46: Training error = 0.32%, Test error = 2.41%
Iteration 47: Training error = 0.36%, Test error = 2.50%
Iteration 48: Training error = 0.33%, Test error = 2.47%
Iteration 49: Training error = 0.34%, Test error = 2.34%
Iteration 50: Training error = 0.36%, Test error = 2.41%
Iteration 800: Training error = 0.52%, Test error = 3.58%
Iteration 801: Training error = 0.52%, Test error = 3.58%
Iteration 802: Training error = 0.52%, Test error = 3.58%
Iteration 803: Training error = 0.51%, Test error = 3.58%
Iteration 804: Training error = 0.51%, Test error = 3.58%
Iteration 805: Training error = 0.51%, Test error = 3.58%
Iteration 806: Training error = 0.51%, Test error = 3.58%
Iteration 807: Training error = 0.51%, Test error = 3.58%
Iteration 808: Training error = 0.51%, Test error = 3.58%
Iteration 809: Training error = 0.51%, Test error = 3.58%
Iteration 810: Training error = 0.51%, Test error = 3.58%
Iteration 811: Training error = 0.50%, Test error = 3.58%
Iteration 812: Training error = 0.50%, Test error = 3.58%
Iteration 813: Training error = 0.50%, Test error = 3.58%
Iteration 814: Training error = 0.50%, Test error = 3.58%
Iteration 815: Training error = 0.50%, Test error = 3.57%
Iteration 816: Training error = 0.50%, Test error = 3.57%
Iteration 817: Training error = 0.50%, Test error = 3.57%
Iteration 818: Training error = 0.49%, Test error = 3.57%
Iteration 819: Training error = 0.49%, Test error = 3.57%
Iteration 820: Training error = 0.49%, Test error = 3.56%
Iteration 821: Training error = 0.49%, Test error = 3.55%

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Iteration 998: Training error = 0.29%, Test error = 3.49%
Iteration 999: Training error = 0.29%, Test error = 3.49%
Iteration 1000: Training error = 0.29%, Test error = 3.49%

Question 4(b).

total squared error = 2.69429611509e-28

Question 4(e).

Epoch 1: Training loss = 3.3, Training error = 94.87%, Test error = 24.94%
Epoch 6: Training loss = 2.0, Training error = 12.52%, Test error = 11.31%
Epoch 11: Training loss = 1.4, Training error = 9.65%, Test error = 9.20%
Epoch 16: Training loss = 1.1, Training error = 7.92%, Test error = 8.06%
Epoch 21: Training loss = 0.89, Training error = 7.02%, Test error = 7.30%
Epoch 26: Training loss = 0.77, Training error = 6.47%, Test error = 6.72%
Epoch 31: Training loss = 0.68, Training error = 6.04%, Test error = 6.46%
Epoch 36: Training loss = 0.62, Training error = 5.74%, Test error = 6.28%
Epoch 41: Training loss = 0.57, Training error = 5.50%, Test error = 6.15%
Epoch 46: Training loss = 0.53, Training error = 5.28%, Test error = 6.00%
Epoch 51: Training loss = 0.5, Training error = 5.09%, Test error = 5.93%
Epoch 56: Training loss = 0.47, Training error = 4.94%, Test error = 5.83%
Epoch 61: Training loss = 0.45, Training error = 4.80%, Test error = 5.67%
Epoch 66: Training loss = 0.43, Training error = 4.68%, Test error = 5.52%
Epoch 71: Training loss = 0.41, Training error = 4.57%, Test error = 5.42%
Epoch 76: Training loss = 0.39, Training error = 4.46%, Test error = 5.38%
Epoch 81: Training loss = 0.38, Training error = 4.36%, Test error = 5.27%
Epoch 86: Training loss = 0.37, Training error = 4.26%, Test error = 5.23%
Epoch 91: Training loss = 0.36, Training error = 4.19%, Test error = 5.20%
Epoch 96: Training loss = 0.34, Training error = 4.11%, Test error = 5.14%
Epoch 101: Training loss = 0.33, Training error = 4.04%, Test error = 5.06%
Epoch 106: Training loss = 0.33, Training error = 3.98%, Test error = 4.99%
Epoch 111: Training loss = 0.32, Training error = 3.93%, Test error = 4.94%
Epoch 116: Training loss = 0.31, Training error = 3.86%, Test error = 4.89%
Epoch 121: Training loss = 0.3, Training error = 3.82%, Test error = 4.85%
Epoch 126: Training loss = 0.3, Training error = 3.77%, Test error = 4.81%
Epoch 131: Training loss = 0.29, Training error = 3.72%, Test error = 4.77%
Epoch 136: Training loss = 0.28, Training error = 3.66%, Test error = 4.74%
Epoch 141: Training loss = 0.28, Training error = 3.62%, Test error = 4.73%
Epoch 146: Training loss = 0.27, Training error = 3.58%, Test error = 4.71%
Epoch 151: Training loss = 0.27, Training error = 3.53%, Test error = 4.66%
Epoch 156: Training loss = 0.26, Training error = 3.48%, Test error = 4.64%

Epoch 161: Training loss = 0.26, Training error = 3.43%, Test error = 4.61%
Epoch 166: Training loss = 0.26, Training error = 3.39%, Test error = 4.60%
Epoch 171: Training loss = 0.25, Training error = 3.35%, Test error = 4.58%
Epoch 176: Training loss = 0.25, Training error = 3.30%, Test error = 4.54%
Epoch 181: Training loss = 0.24, Training error = 3.27%, Test error = 4.50%
Epoch 186: Training loss = 0.24, Training error = 3.24%, Test error = 4.45%
Epoch 191: Training loss = 0.24, Training error = 3.22%, Test error = 4.43%
Epoch 196: Training loss = 0.23, Training error = 3.18%, Test error = 4.42%
Epoch 201: Training loss = 0.23, Training error = 3.14%, Test error = 4.41%
Epoch 206: Training loss = 0.23, Training error = 3.12%, Test error = 4.40%
Epoch 211: Training loss = 0.22, Training error = 3.07%, Test error = 4.39%
Epoch 216: Training loss = 0.22, Training error = 3.05%, Test error = 4.35%
Epoch 221: Training loss = 0.22, Training error = 3.02%, Test error = 4.35%
Epoch 226: Training loss = 0.22, Training error = 2.99%, Test error = 4.34%
Epoch 231: Training loss = 0.21, Training error = 2.96%, Test error = 4.32%
Epoch 236: Training loss = 0.21, Training error = 2.92%, Test error = 4.31%
Epoch 241: Training loss = 0.21, Training error = 2.90%, Test error = 4.30%
Epoch 246: Training loss = 0.21, Training error = 2.88%, Test error = 4.30%
Epoch 251: Training loss = 0.2, Training error = 2.85%, Test error = 4.30%
Epoch 256: Training loss = 0.2, Training error = 2.83%, Test error = 4.29%
Epoch 261: Training loss = 0.2, Training error = 2.80%, Test error = 4.27%
Epoch 266: Training loss = 0.2, Training error = 2.78%, Test error = 4.24%
Epoch 271: Training loss = 0.2, Training error = 2.76%, Test error = 4.23%
Epoch 276: Training loss = 0.19, Training error = 2.75%, Test error = 4.22%
Epoch 281: Training loss = 0.19, Training error = 2.72%, Test error = 4.21%
Epoch 286: Training loss = 0.19, Training error = 2.68%, Test error = 4.20%
Epoch 291: Training loss = 0.19, Training error = 2.65%, Test error = 4.20%
Epoch 296: Training loss = 0.19, Training error = 2.62%, Test error = 4.18%
Epoch 301: Training loss = 0.19, Training error = 2.61%, Test error = 4.16%
Epoch 306: Training loss = 0.18, Training error = 2.60%, Test error = 4.14%
Epoch 311: Training loss = 0.18, Training error = 2.59%, Test error = 4.11%
Epoch 316: Training loss = 0.18, Training error = 2.56%, Test error = 4.09%
Epoch 321: Training loss = 0.18, Training error = 2.54%, Test error = 4.06%
Epoch 326: Training loss = 0.18, Training error = 2.53%, Test error = 4.05%
Epoch 331: Training loss = 0.18, Training error = 2.51%, Test error = 4.04%
Epoch 336: Training loss = 0.17, Training error = 2.49%, Test error = 4.02%
Epoch 341: Training loss = 0.17, Training error = 2.48%, Test error = 3.99%
Epoch 346: Training loss = 0.17, Training error = 2.46%, Test error = 3.99%
Epoch 351: Training loss = 0.17, Training error = 2.46%, Test error = 3.96%
Epoch 356: Training loss = 0.17, Training error = 2.44%, Test error = 3.93%
Epoch 361: Training loss = 0.17, Training error = 2.43%, Test error = 3.91%
Epoch 366: Training loss = 0.17, Training error = 2.40%, Test error = 3.89%
Epoch 371: Training loss = 0.17, Training error = 2.39%, Test error = 3.85%
Epoch 376: Training loss = 0.16, Training error = 2.38%, Test error = 3.85%

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Epoch 821: Training loss = 0.11, Training error = 1.42%, Test error = 3.23%
Epoch 826: Training loss = 0.11, Training error = 1.42%, Test error = 3.22%
Epoch 831: Training loss = 0.11, Training error = 1.41%, Test error = 3.23%
Epoch 836: Training loss = 0.1, Training error = 1.41%, Test error = 3.23%
Epoch 841: Training loss = 0.1, Training error = 1.40%, Test error = 3.23%
Epoch 846: Training loss = 0.1, Training error = 1.40%, Test error = 3.22%
Epoch 851: Training loss = 0.1, Training error = 1.40%, Test error = 3.22%
Epoch 856: Training loss = 0.1, Training error = 1.39%, Test error = 3.21%
Epoch 861: Training loss = 0.1, Training error = 1.39%, Test error = 3.21%
Epoch 866: Training loss = 0.1, Training error = 1.39%, Test error = 3.19%
Epoch 871: Training loss = 0.1, Training error = 1.39%, Test error = 3.18%
Epoch 876: Training loss = 0.1, Training error = 1.38%, Test error = 3.18%
Epoch 881: Training loss = 0.1, Training error = 1.37%, Test error = 3.18%
Epoch 886: Training loss = 0.1, Training error = 1.37%, Test error = 3.18%
Epoch 891: Training loss = 0.1, Training error = 1.37%, Test error = 3.18%
Epoch 896: Training loss = 0.1, Training error = 1.36%, Test error = 3.18%
Epoch 901: Training loss = 0.1, Training error = 1.36%, Test error = 3.18%
Epoch 906: Training loss = 0.1, Training error = 1.35%, Test error = 3.18%
Epoch 911: Training loss = 0.1, Training error = 1.35%, Test error = 3.17%
Epoch 916: Training loss = 0.099, Training error = 1.34%, Test error = 3.17%
Epoch 921: Training loss = 0.099, Training error = 1.34%, Test error = 3.17%
Epoch 926: Training loss = 0.099, Training error = 1.34%, Test error = 3.17%
Epoch 931: Training loss = 0.098, Training error = 1.33%, Test error = 3.18%
Epoch 936: Training loss = 0.098, Training error = 1.32%, Test error = 3.18%
Epoch 941: Training loss = 0.098, Training error = 1.31%, Test error = 3.17%
Epoch 946: Training loss = 0.098, Training error = 1.31%, Test error = 3.17%
Epoch 951: Training loss = 0.097, Training error = 1.31%, Test error = 3.16%
Epoch 956: Training loss = 0.097, Training error = 1.31%, Test error = 3.15%
Epoch 961: Training loss = 0.097, Training error = 1.30%, Test error = 3.15%
Epoch 966: Training loss = 0.096, Training error = 1.30%, Test error = 3.15%
Epoch 971: Training loss = 0.096, Training error = 1.30%, Test error = 3.15%
Epoch 976: Training loss = 0.096, Training error = 1.30%, Test error = 3.15%
Epoch 981: Training loss = 0.095, Training error = 1.29%, Test error = 3.15%
Epoch 986: Training loss = 0.095, Training error = 1.29%, Test error = 3.15%
Epoch 991: Training loss = 0.095, Training error = 1.28%, Test error = 3.13%
Epoch 996: Training loss = 0.095, Training error = 1.28%, Test error = 3.13%

Question 4(h).

batch size = 100, momentum = 0.8

Epoch 1: Training loss = 0.036, Training error = 0.37%, Test error = 2.36%

Epoch 6: Training loss = 0.016, Training error = 0.14%, Test error = 2.26%

Epoch 11: Training loss = 0.014, Training error = 0.12%, Test error = 2.24%
Epoch 16: Training loss = 0.014, Training error = 0.11%, Test error = 2.24%
Epoch 21: Training loss = 0.013, Training error = 0.11%, Test error = 2.24%
Epoch 26: Training loss = 0.013, Training error = 0.11%, Test error = 2.24%
Epoch 31: Training loss = 0.013, Training error = 0.11%, Test error = 2.25%
Epoch 36: Training loss = 0.013, Training error = 0.11%, Test error = 2.26%
Epoch 41: Training loss = 0.013, Training error = 0.11%, Test error = 2.25%
Epoch 46: Training loss = 0.013, Training error = 0.11%, Test error = 2.26%

Minimum Test Error = 2.24%

Figure 1, Question 1 (a): Moons training data

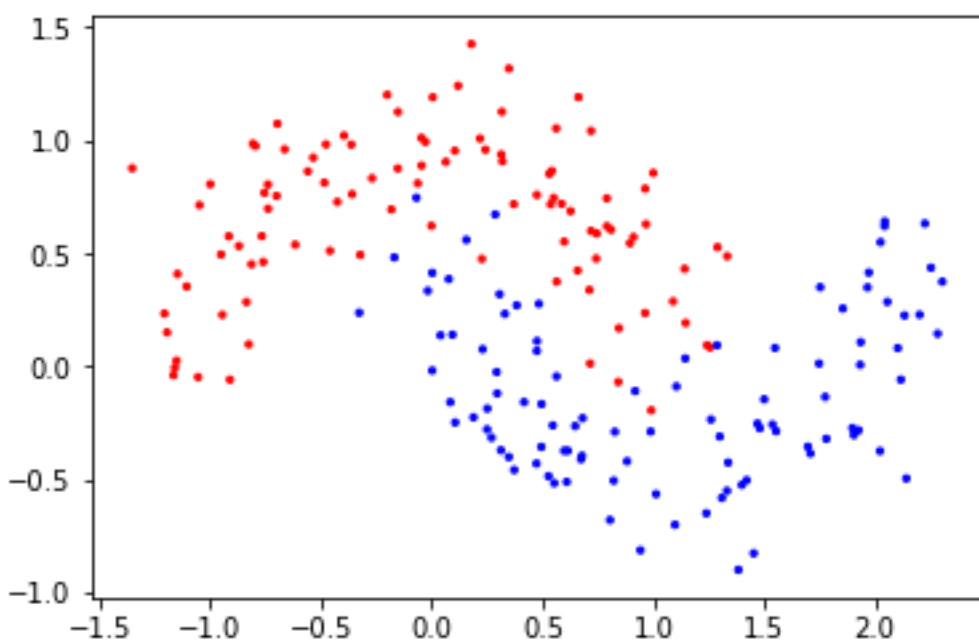


Figure 2, Question 1(a): Moons test data

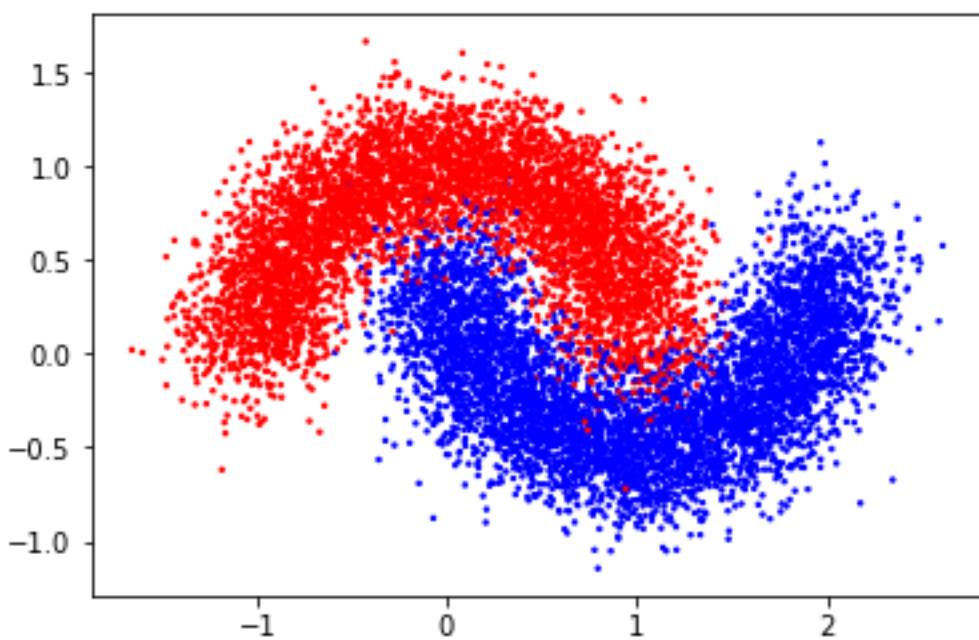


Figure 3, Question 1(b): Contour plots of various training sessions

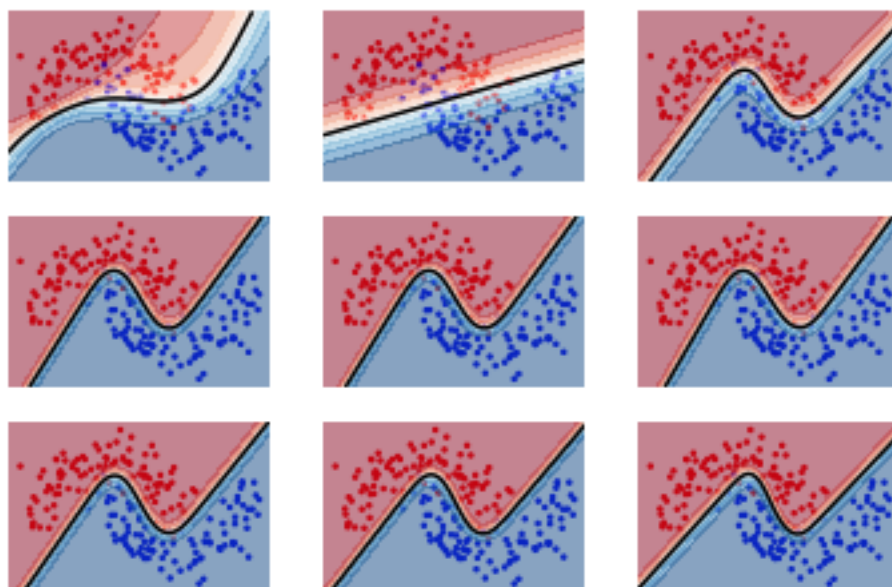
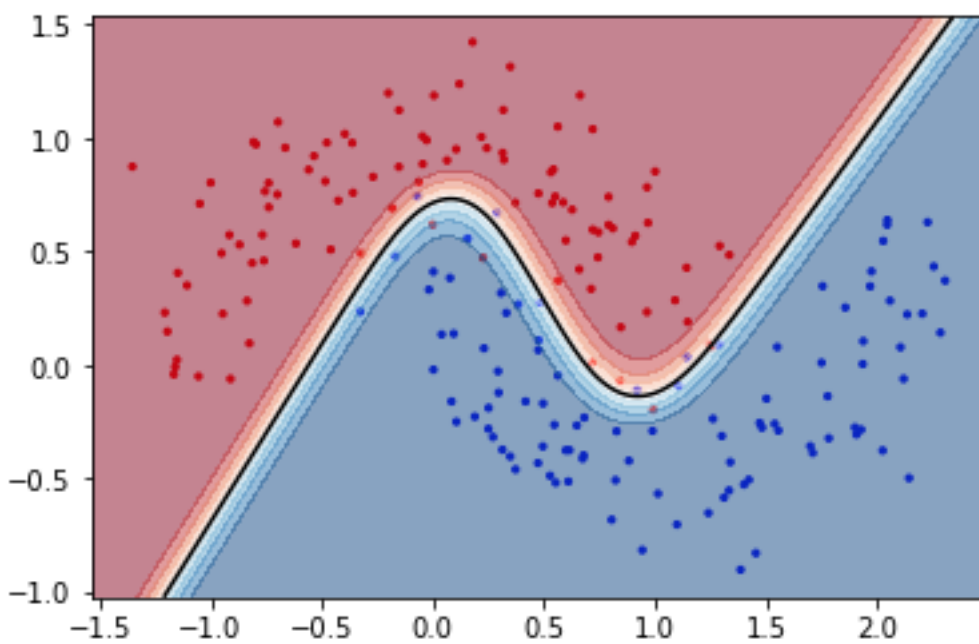


Figure 4, Question 1(b): contour plot for best training session



Question 3(c): some normalized MNIST digits

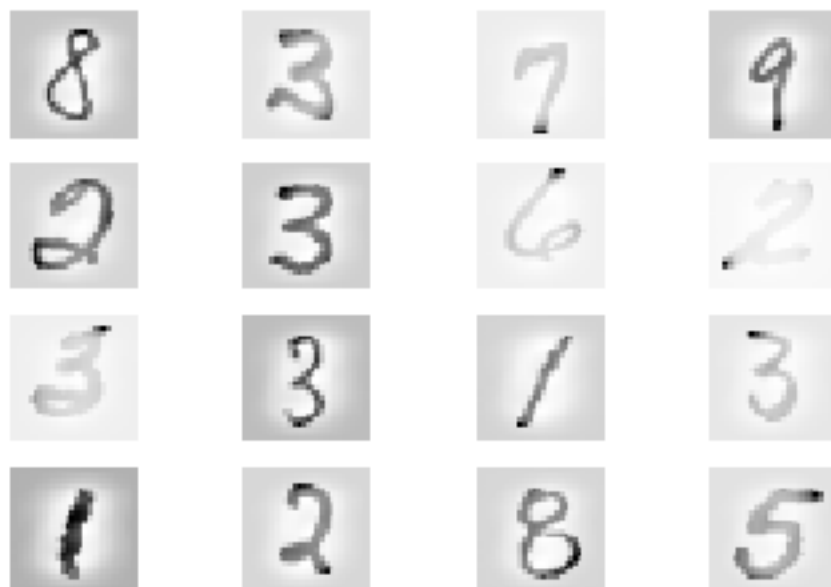


Figure 5, Question 3: training and test error in batch mode

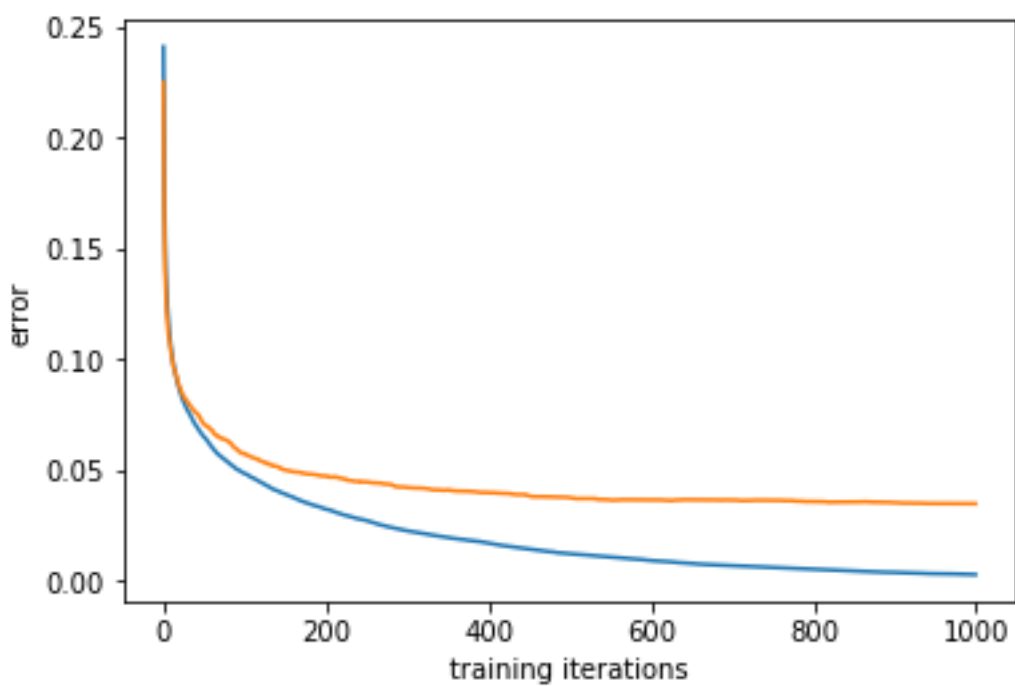


Figure 6, Question 3: test error during last 500 iterations of batch training

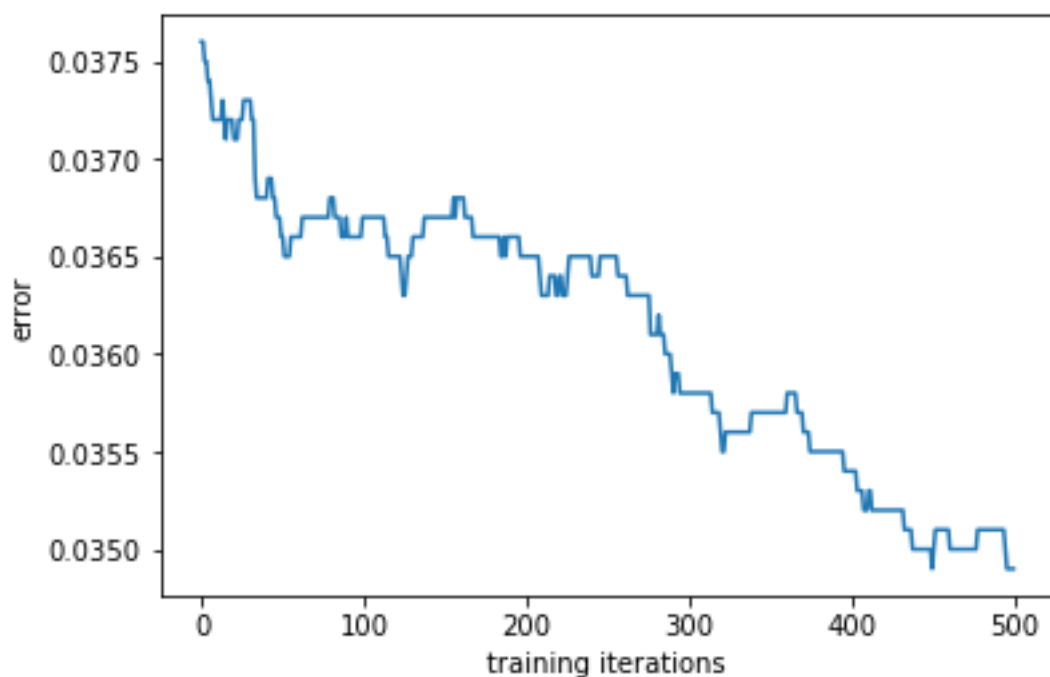


Figure 7, Question 4(d): training and test error for batch gradient descent

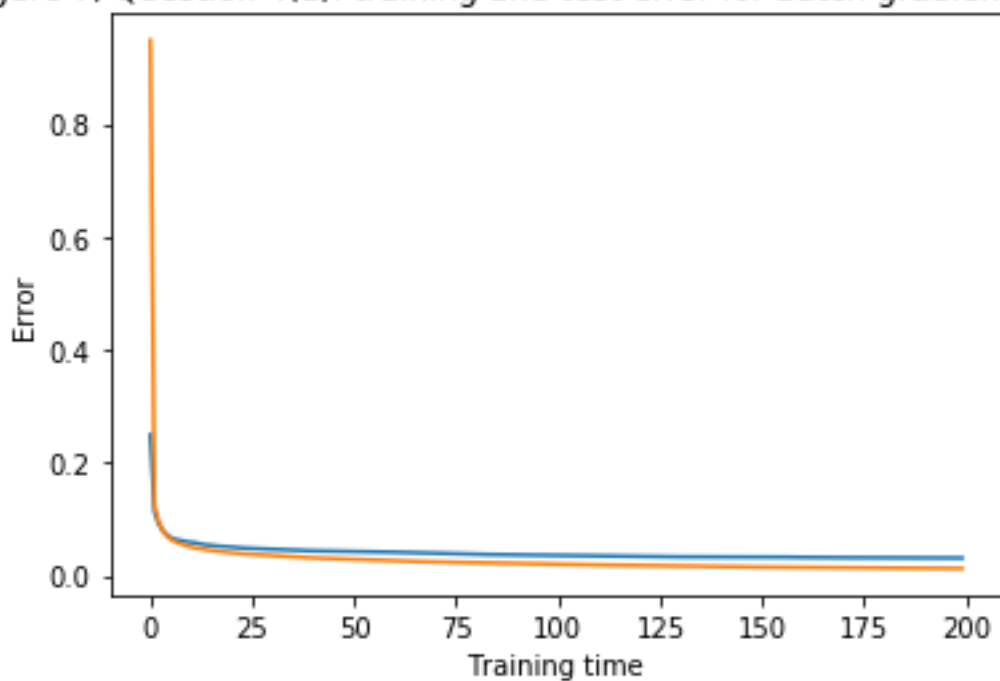


Figure 8, Question 4(d): mean training loss for batch gradient descent

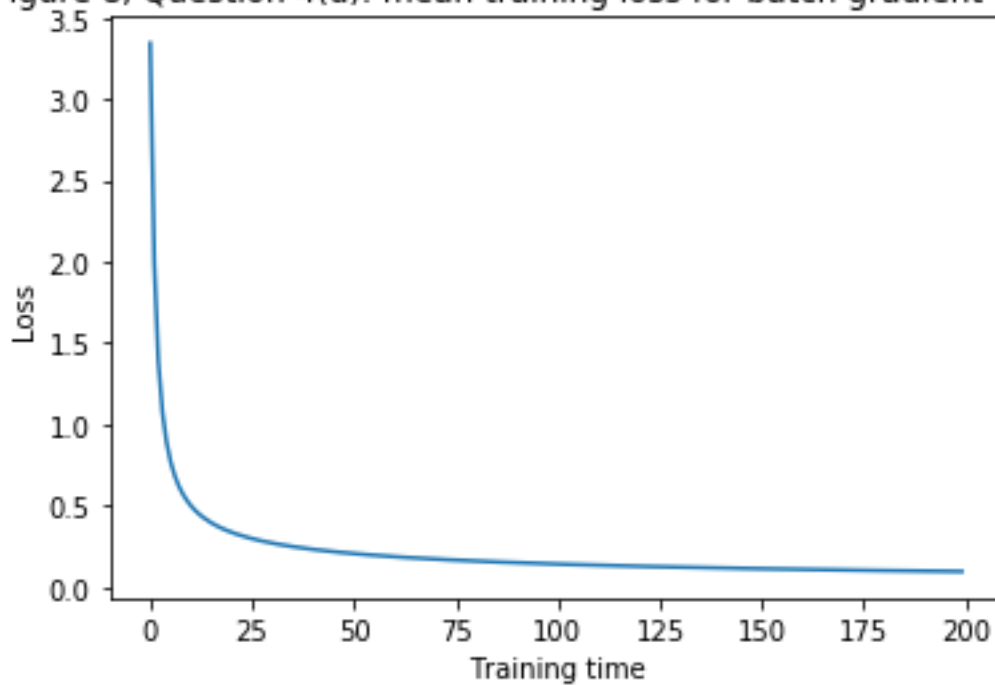


Figure 9, Question 4(d): training and test error for last 500 epochs of bgd

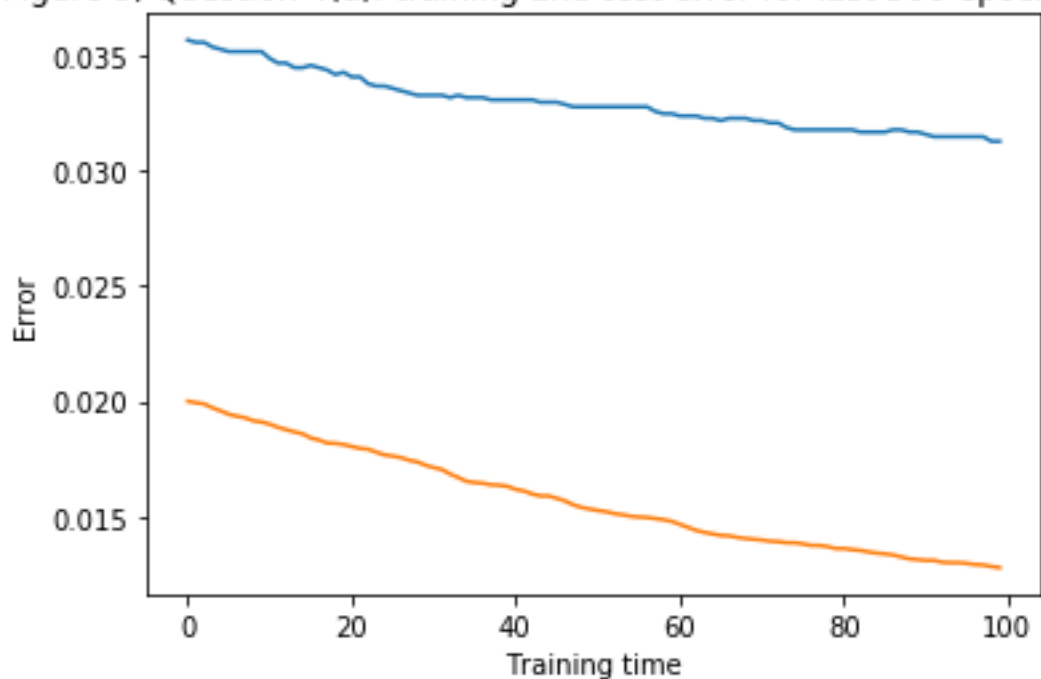


Figure 10, Question 4(d)" mean training loss for last 500 epochs of bgd

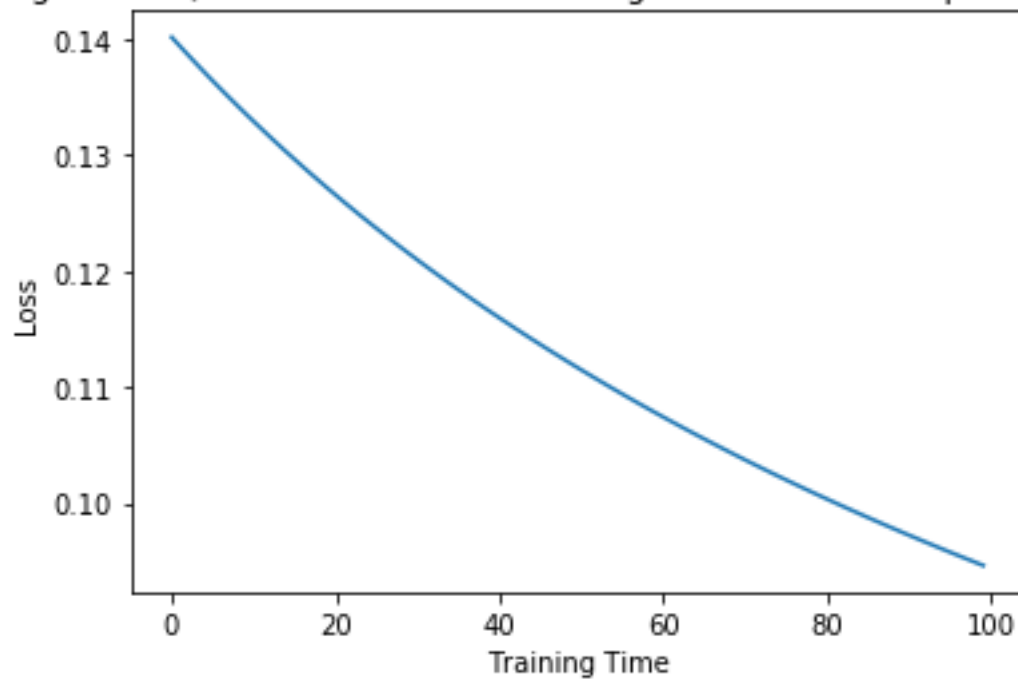


Figure 11, Question 4(g): training and test error for stochastic gradient descent

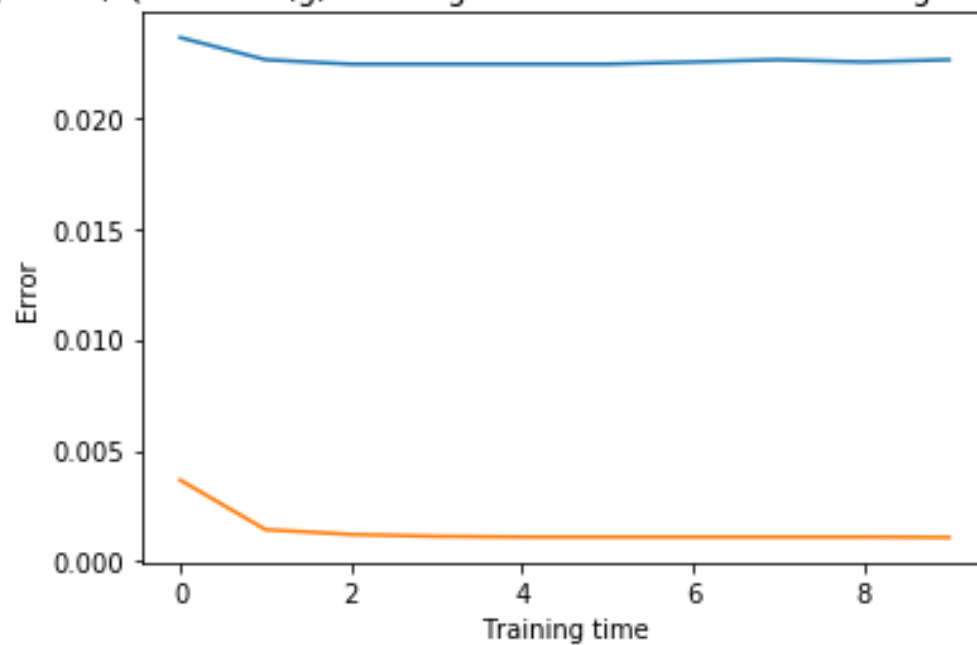


Figure 12, Question 4(g): mean training loss for stochastic gradient descent

