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 = 0.0354 neural net 7: test error = 0.0359 neural net 8: 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%
```

```
Iteration 822: Training error = 0.49%, Test error = 3.55%
Iteration 823: Training error = 0.49%, Test error = 3.56%
Iteration 824: Training error = 0.48%, Test error = 3.56%
Iteration 825: Training error = 0.48%, Test error = 3.56%
Iteration 826: Training error = 0.48%, Test error = 3.56%
Iteration 827: Training error = 0.48%, Test error = 3.56%
Iteration 828: Training error = 0.48%, Test error = 3.56%
Iteration 829: Training error = 0.48%, Test error = 3.56%
Iteration 830: Training error = 0.48%, Test error = 3.56%
Iteration 831: Training error = 0.48%, Test error = 3.56%
Iteration 832: Training error = 0.48%, Test error = 3.56%
Iteration 833: Training error = 0.47%, Test error = 3.56%
Iteration 834: Training error = 0.47%, Test error = 3.56%
Iteration 835: Training error = 0.47%, Test error = 3.56%
Iteration 836: Training error = 0.47%, Test error = 3.56%
Iteration 837: Training error = 0.47%, Test error = 3.56%
Iteration 838: Training error = 0.47%, Test error = 3.56%
Iteration 839: Training error = 0.47%, Test error = 3.57%
Iteration 840: Training error = 0.47%, Test error = 3.57%
Iteration 841: Training error = 0.47%, Test error = 3.57%
Iteration 842: Training error = 0.46%, Test error = 3.57%
Iteration 843: Training error = 0.46%, Test error = 3.57%
Iteration 844: Training error = 0.46%, Test error = 3.57%
Iteration 845: Training error = 0.46%, Test error = 3.57%
Iteration 846: Training error = 0.46%, Test error = 3.57%
Iteration 847: Training error = 0.46%, Test error = 3.57%
Iteration 848: Training error = 0.46%, Test error = 3.57%
Iteration 849: Training error = 0.46%, Test error = 3.57%
Iteration 850: Training error = 0.45%, Test error = 3.57%
Iteration 851: Training error = 0.45%, Test error = 3.57%
Iteration 852: Training error = 0.45%, Test error = 3.57%
Iteration 853: Training error = 0.45%, Test error = 3.57%
Iteration 854: Training error = 0.45%, Test error = 3.57%
Iteration 855: Training error = 0.44%, Test error = 3.57%
Iteration 856: Training error = 0.44%, Test error = 3.57%
Iteration 857: Training error = 0.44%, Test error = 3.57%
Iteration 858: Training error = 0.44%, Test error = 3.57%
Iteration 859: Training error = 0.44%, Test error = 3.57%
Iteration 860: Training error = 0.43%, Test error = 3.57%
Iteration 861: Training error = 0.43%, Test error = 3.58%
Iteration 862: Training error = 0.43%, Test error = 3.58%
Iteration 863: Training error = 0.43%, Test error = 3.58%
Iteration 864: Training error = 0.43%, Test error = 3.58%
Iteration 865: Training error = 0.43%, Test error = 3.58%
```

```
Iteration 866: Training error = 0.43%, Test error = 3.58%
Iteration 867: Training error = 0.43%, Test error = 3.57%
Iteration 868: Training error = 0.42%, Test error = 3.57%
Iteration 869: Training error = 0.42%, Test error = 3.57%
Iteration 870: Training error = 0.42%, Test error = 3.57%
Iteration 871: Training error = 0.42%, Test error = 3.56%
Iteration 872: Training error = 0.42%, Test error = 3.56%
Iteration 873: Training error = 0.42%, Test error = 3.56%
Iteration 874: Training error = 0.42%, Test error = 3.56%
Iteration 875: Training error = 0.42%, Test error = 3.55%
Iteration 876: Training error = 0.42%, Test error = 3.55%
Iteration 877: Training error = 0.42%, Test error = 3.55%
Iteration 878: Training error = 0.42%, Test error = 3.55%
Iteration 879: Training error = 0.41%, Test error = 3.55%
Iteration 880: Training error = 0.41%, Test error = 3.55%
Iteration 881: Training error = 0.41%, Test error = 3.55%
Iteration 882: Training error = 0.41%, Test error = 3.55%
Iteration 883: Training error = 0.40%, Test error = 3.55%
Iteration 884: Training error = 0.40%, Test error = 3.55%
Iteration 885: Training error = 0.40%, Test error = 3.55%
Iteration 886: Training error = 0.40%, Test error = 3.55%
Iteration 887: Training error = 0.40%, Test error = 3.55%
Iteration 888: Training error = 0.40%, Test error = 3.55%
Iteration 889: Training error = 0.40%, Test error = 3.55%
Iteration 890: Training error = 0.40%, Test error = 3.55%
Iteration 891: Training error = 0.40%, Test error = 3.55%
Iteration 892: Training error = 0.40%, Test error = 3.55%
Iteration 893: Training error = 0.40%, Test error = 3.55%
Iteration 894: Training error = 0.40%, Test error = 3.55%
Iteration 895: Training error = 0.40%, Test error = 3.55%
Iteration 896: Training error = 0.40%, Test error = 3.54%
Iteration 897: Training error = 0.40%, Test error = 3.54%
Iteration 898: Training error = 0.40%, Test error = 3.54%
Iteration 899: Training error = 0.40%, Test error = 3.54%
Iteration 900: Training error = 0.40%, Test error = 3.54%
Iteration 901: Training error = 0.39%, Test error = 3.54%
Iteration 902: Training error = 0.39%, Test error = 3.54%
Iteration 903: Training error = 0.39%, Test error = 3.54%
Iteration 904: Training error = 0.39%, Test error = 3.53%
Iteration 905: Training error = 0.38%, Test error = 3.53%
Iteration 906: Training error = 0.38%, Test error = 3.53%
Iteration 907: Training error = 0.38%, Test error = 3.53%
Iteration 908: Training error = 0.38%, Test error = 3.52%
Iteration 909: Training error = 0.38%, Test error = 3.52%
```

```
Iteration 910: Training error = 0.38%, Test error = 3.52%
Iteration 911: Training error = 0.38%, Test error = 3.53%
Iteration 912: Training error = 0.38%, Test error = 3.53%
Iteration 913: Training error = 0.38%, Test error = 3.52%
Iteration 914: Training error = 0.38%, Test error = 3.52%
Iteration 915: Training error = 0.38%, Test error = 3.52%
Iteration 916: Training error = 0.38%, Test error = 3.52%
Iteration 917: Training error = 0.38%, Test error = 3.52%
Iteration 918: Training error = 0.37%, Test error = 3.52%
Iteration 919: Training error = 0.37%, Test error = 3.52%
Iteration 920: Training error = 0.37%, Test error = 3.52%
Iteration 921: Training error = 0.37%, Test error = 3.52%
Iteration 922: Training error = 0.36%, Test error = 3.52%
Iteration 923: Training error = 0.36%, Test error = 3.52%
Iteration 924: Training error = 0.36%, Test error = 3.52%
Iteration 925: Training error = 0.36%, Test error = 3.52%
Iteration 926: Training error = 0.36%, Test error = 3.52%
Iteration 927: Training error = 0.36%, Test error = 3.52%
Iteration 928: Training error = 0.36%, Test error = 3.52%
Iteration 929: Training error = 0.36%, Test error = 3.52%
Iteration 930: Training error = 0.36%, Test error = 3.52%
Iteration 931: Training error = 0.36%, Test error = 3.52%
Iteration 932: Training error = 0.36%, Test error = 3.52%
Iteration 933: Training error = 0.36%, Test error = 3.51%
Iteration 934: Training error = 0.35%, Test error = 3.51%
Iteration 935: Training error = 0.35%, Test error = 3.51%
Iteration 936: Training error = 0.35%, Test error = 3.51%
Iteration 937: Training error = 0.35%, Test error = 3.51%
Iteration 938: Training error = 0.34%, Test error = 3.50%
Iteration 939: Training error = 0.34%, Test error = 3.50%
Iteration 940: Training error = 0.34%, Test error = 3.50%
Iteration 941: Training error = 0.34%, Test error = 3.50%
Iteration 942: Training error = 0.34%, Test error = 3.50%
Iteration 943: Training error = 0.34%, Test error = 3.50%
Iteration 944: Training error = 0.34%, Test error = 3.50%
Iteration 945: Training error = 0.33%, Test error = 3.50%
Iteration 946: Training error = 0.33%, Test error = 3.50%
Iteration 947: Training error = 0.33%, Test error = 3.50%
Iteration 948: Training error = 0.33%, Test error = 3.50%
Iteration 949: Training error = 0.33%, Test error = 3.50%
Iteration 950: Training error = 0.33%, Test error = 3.49%
Iteration 951: Training error = 0.33%, Test error = 3.50%
Iteration 952: Training error = 0.33%, Test error = 3.51%
Iteration 953: Training error = 0.33%, Test error = 3.51%
```

```
Iteration 954: Training error = 0.33%, Test error = 3.51%
Iteration 955: Training error = 0.33%, Test error = 3.51%
Iteration 956: Training error = 0.33%, Test error = 3.51%
Iteration 957: Training error = 0.33%, Test error = 3.51%
Iteration 958: Training error = 0.33%, Test error = 3.51%
Iteration 959: Training error = 0.33%, Test error = 3.51%
Iteration 960: Training error = 0.33%, Test error = 3.51%
Iteration 961: Training error = 0.33%, Test error = 3.50%
Iteration 962: Training error = 0.33%, Test error = 3.50%
Iteration 963: Training error = 0.33%, Test error = 3.50%
Iteration 964: Training error = 0.33%, Test error = 3.50%
Iteration 965: Training error = 0.33%, Test error = 3.50%
Iteration 966: Training error = 0.33%, Test error = 3.50%
Iteration 967: Training error = 0.32%, Test error = 3.50%
Iteration 968: Training error = 0.32%, Test error = 3.50%
Iteration 969: Training error = 0.32%, Test error = 3.50%
Iteration 970: Training error = 0.32%, Test error = 3.50%
Iteration 971: Training error = 0.32%, Test error = 3.50%
Iteration 972: Training error = 0.32%, Test error = 3.50%
Iteration 973: Training error = 0.32%, Test error = 3.50%
Iteration 974: Training error = 0.32%, Test error = 3.50%
Iteration 975: Training error = 0.32%, Test error = 3.50%
Iteration 976: Training error = 0.32%, Test error = 3.50%
Iteration 977: Training error = 0.32%, Test error = 3.50%
Iteration 978: Training error = 0.32%, Test error = 3.51%
Iteration 979: Training error = 0.31%, Test error = 3.51%
Iteration 980: Training error = 0.31%, Test error = 3.51%
Iteration 981: Training error = 0.31%, Test error = 3.51%
Iteration 982: Training error = 0.31%, Test error = 3.51%
Iteration 983: Training error = 0.31%, Test error = 3.51%
Iteration 984: Training error = 0.31%, Test error = 3.51%
Iteration 985: Training error = 0.31%, Test error = 3.51%
Iteration 986: Training error = 0.31%, Test error = 3.51%
Iteration 987: Training error = 0.31%, Test error = 3.51%
Iteration 988: Training error = 0.30%, Test error = 3.51%
Iteration 989: Training error = 0.30%, Test error = 3.51%
Iteration 990: Training error = 0.30%, Test error = 3.51%
Iteration 991: Training error = 0.30%, Test error = 3.51%
Iteration 992: Training error = 0.30%, Test error = 3.51%
Iteration 993: Training error = 0.30%, Test error = 3.51%
Iteration 994: Training error = 0.30%, Test error = 3.51%
Iteration 995: Training error = 0.30%, Test error = 3.50%
Iteration 996: Training error = 0.30%, Test error = 3.49%
Iteration 997: Training error = 0.30%, Test error = 3.49%
```

```
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%
```

```
Epoch 381: Training loss = 0.16, Training error = 2.35%, Test error = 3.82%
Epoch 386: Training loss = 0.16, Training error = 2.34%, Test error = 3.82%
Epoch 391: Training loss = 0.16, Training error = 2.31%, Test error = 3.81%
Epoch 396: Training loss = 0.16, Training error = 2.30%, Test error = 3.81%
Epoch 401: Training loss = 0.16, Training error = 2.28%, Test error = 3.77%
Epoch 406: Training loss = 0.16, Training error = 2.27%, Test error = 3.77%
Epoch 411: Training loss = 0.16, Training error = 2.24%, Test error = 3.76%
Epoch 416: Training loss = 0.16, Training error = 2.23%, Test error = 3.75%
Epoch 421: Training loss = 0.15, Training error = 2.22%, Test error = 3.74%
Epoch 426: Training loss = 0.15, Training error = 2.20%, Test error = 3.74%
Epoch 431: Training loss = 0.15, Training error = 2.18%, Test error = 3.73%
Epoch 436: Training loss = 0.15, Training error = 2.17%, Test error = 3.72%
Epoch 441: Training loss = 0.15, Training error = 2.16%, Test error = 3.72%
Epoch 446: Training loss = 0.15, Training error = 2.15%, Test error = 3.70%
Epoch 451: Training loss = 0.15, Training error = 2.14%, Test error = 3.70%
Epoch 456: Training loss = 0.15, Training error = 2.13%, Test error = 3.67%
Epoch 461: Training loss = 0.15, Training error = 2.12%, Test error = 3.67%
Epoch 466: Training loss = 0.15, Training error = 2.11%, Test error = 3.67%
Epoch 471: Training loss = 0.15, Training error = 2.09%, Test error = 3.66%
Epoch 476: Training loss = 0.14, Training error = 2.06%, Test error = 3.65%
Epoch 481: Training loss = 0.14, Training error = 2.04%, Test error = 3.61%
Epoch 486: Training loss = 0.14, Training error = 2.03%, Test error = 3.60%
Epoch 491: Training loss = 0.14, Training error = 2.02%, Test error = 3.59%
Epoch 496: Training loss = 0.14, Training error = 2.01%, Test error = 3.58%
Epoch 501: Training loss = 0.14, Training error = 2.00%, Test error = 3.57%
Epoch 506: Training loss = 0.14, Training error = 1.99%, Test error = 3.56%
Epoch 511: Training loss = 0.14, Training error = 1.99%, Test error = 3.56%
Epoch 516: Training loss = 0.14, Training error = 1.97%, Test error = 3.54%
Epoch 521: Training loss = 0.14, Training error = 1.96%, Test error = 3.53%
Epoch 526: Training loss = 0.14, Training error = 1.94%, Test error = 3.52%
Epoch 531: Training loss = 0.14, Training error = 1.93%, Test error = 3.52%
Epoch 536: Training loss = 0.13, Training error = 1.93%, Test error = 3.52%
Epoch 541: Training loss = 0.13, Training error = 1.92%, Test error = 3.52%
Epoch 546: Training loss = 0.13, Training error = 1.91%, Test error = 3.52%
Epoch 551: Training loss = 0.13, Training error = 1.90%, Test error = 3.49%
Epoch 556: Training loss = 0.13, Training error = 1.89%, Test error = 3.47%
Epoch 561: Training loss = 0.13, Training error = 1.88%, Test error = 3.47%
Epoch 566: Training loss = 0.13, Training error = 1.87%, Test error = 3.45%
Epoch 571: Training loss = 0.13, Training error = 1.86%, Test error = 3.45%
Epoch 576: Training loss = 0.13, Training error = 1.84%, Test error = 3.46%
Epoch 581: Training loss = 0.13, Training error = 1.83%, Test error = 3.45%
Epoch 586: Training loss = 0.13, Training error = 1.82%, Test error = 3.44%
Epoch 591: Training loss = 0.13, Training error = 1.82%, Test error = 3.42%
Epoch 596: Training loss = 0.13, Training error = 1.81%, Test error = 3.43%
```

```
Epoch 601: Training loss = 0.13, Training error = 1.80%, Test error = 3.41%
Epoch 606: Training loss = 0.13, Training error = 1.80%, Test error = 3.41%
Epoch 611: Training loss = 0.13, Training error = 1.79%, Test error = 3.38%
Epoch 616: Training loss = 0.12, Training error = 1.78%, Test error = 3.37%
Epoch 621: Training loss = 0.12, Training error = 1.77%, Test error = 3.37%
Epoch 626: Training loss = 0.12, Training error = 1.76%, Test error = 3.36%
Epoch 631: Training loss = 0.12, Training error = 1.75%, Test error = 3.35%
Epoch 636: Training loss = 0.12, Training error = 1.74%, Test error = 3.34%
Epoch 641: Training loss = 0.12, Training error = 1.74%, Test error = 3.33%
Epoch 646: Training loss = 0.12, Training error = 1.72%, Test error = 3.33%
Epoch 651: Training loss = 0.12, Training error = 1.71%, Test error = 3.33%
Epoch 656: Training loss = 0.12, Training error = 1.70%, Test error = 3.33%
Epoch 661: Training loss = 0.12, Training error = 1.68%, Test error = 3.32%
Epoch 666: Training loss = 0.12, Training error = 1.67%, Test error = 3.33%
Epoch 671: Training loss = 0.12, Training error = 1.65%, Test error = 3.32%
Epoch 676: Training loss = 0.12, Training error = 1.65%, Test error = 3.32%
Epoch 681: Training loss = 0.12, Training error = 1.64%, Test error = 3.32%
Epoch 686: Training loss = 0.12, Training error = 1.64%, Test error = 3.31%
Epoch 691: Training loss = 0.12, Training error = 1.63%, Test error = 3.31%
Epoch 696: Training loss = 0.12, Training error = 1.63%, Test error = 3.31%
Epoch 701: Training loss = 0.12, Training error = 1.62%, Test error = 3.31%
Epoch 706: Training loss = 0.12, Training error = 1.61%, Test error = 3.31%
Epoch 711: Training loss = 0.12, Training error = 1.60%, Test error = 3.31%
Epoch 716: Training loss = 0.11, Training error = 1.59%, Test error = 3.30%
Epoch 721: Training loss = 0.11, Training error = 1.59%, Test error = 3.30%
Epoch 726: Training loss = 0.11, Training error = 1.58%, Test error = 3.30%
Epoch 731: Training loss = 0.11, Training error = 1.57%, Test error = 3.29%
Epoch 736: Training loss = 0.11, Training error = 1.55%, Test error = 3.28%
Epoch 741: Training loss = 0.11, Training error = 1.54%, Test error = 3.28%
Epoch 746: Training loss = 0.11, Training error = 1.53%, Test error = 3.28%
Epoch 751: Training loss = 0.11, Training error = 1.52%, Test error = 3.28%
Epoch 756: Training loss = 0.11, Training error = 1.52%, Test error = 3.28%
Epoch 761: Training loss = 0.11, Training error = 1.51%, Test error = 3.28%
Epoch 766: Training loss = 0.11, Training error = 1.51%, Test error = 3.28%
Epoch 771: Training loss = 0.11, Training error = 1.50%, Test error = 3.28%
Epoch 776: Training loss = 0.11, Training error = 1.50%, Test error = 3.28%
Epoch 781: Training loss = 0.11, Training error = 1.50%, Test error = 3.28%
Epoch 786: Training loss = 0.11, Training error = 1.49%, Test error = 3.26%
Epoch 791: Training loss = 0.11, Training error = 1.49%, Test error = 3.25%
Epoch 796: Training loss = 0.11, Training error = 1.48%, Test error = 3.25%
Epoch 801: Training loss = 0.11, Training error = 1.47%, Test error = 3.24%
Epoch 806: Training loss = 0.11, Training error = 1.45%, Test error = 3.24%
Epoch 811: Training loss = 0.11, Training error = 1.44%, Test error = 3.24%
Epoch 816: Training loss = 0.11, Training error = 1.43%, Test error = 3.23%
```

```
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

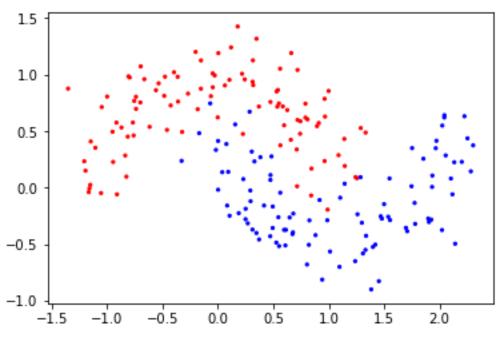


Figure 2, Question 1(a): Moons test data

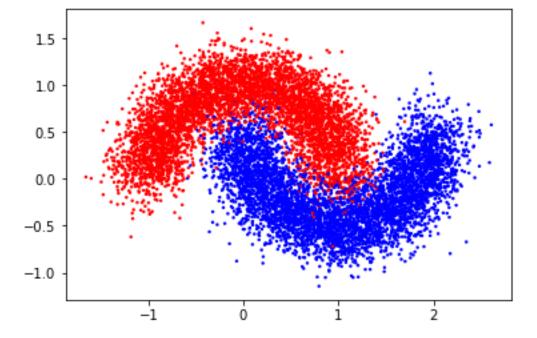


Figure 3, Question 1(b): Contour plots of various training sessions

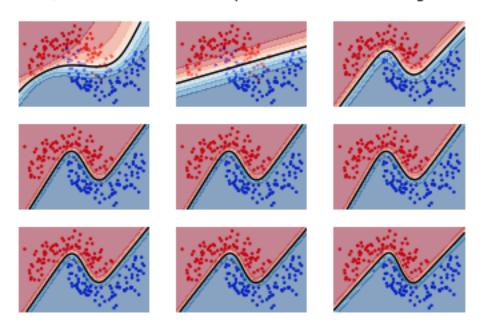
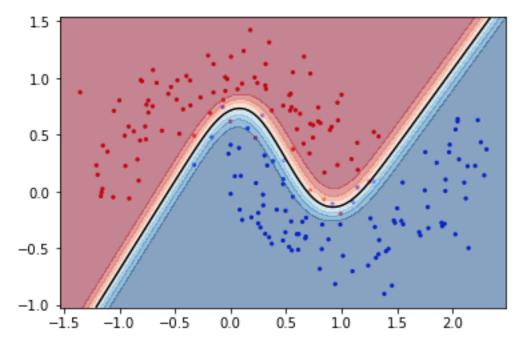


Figure 4, Question 1(b): contour plot for best training session



Question 3(c): some normalized MNIST digits

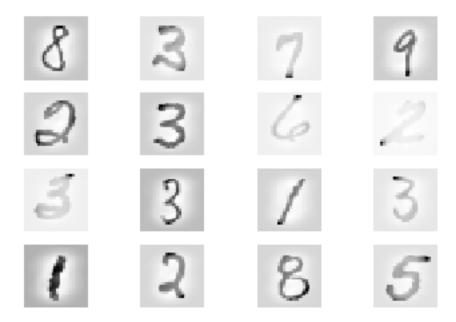


Figure 5, Question 3: training and test error in batch mode

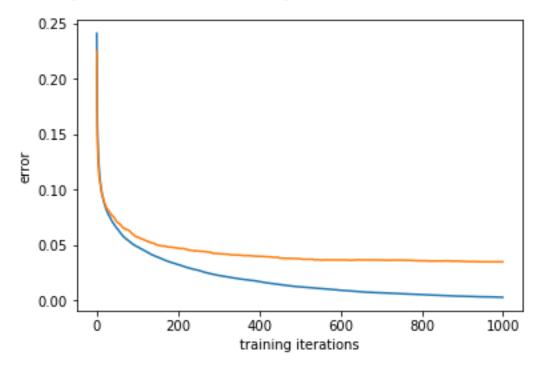


Figure 6, Question 3: test error during last 500 iterations of batch training

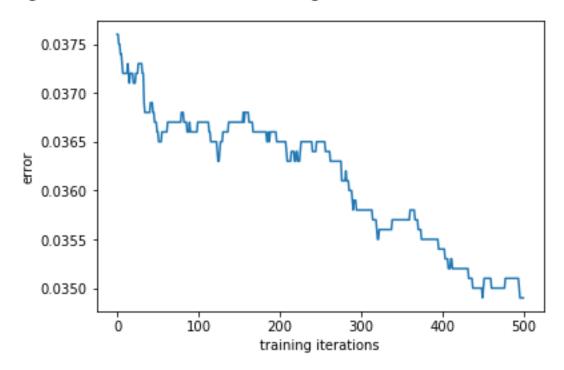


Figure 7, Question 4(d): training and test error for batch gradient descent

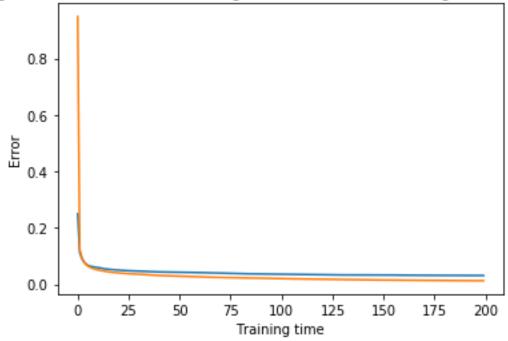


Figure 8, Question 4(d): mean training loss for batch gradient descent

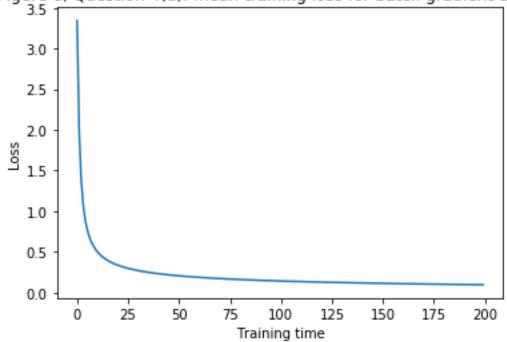


Figure 9, Question 4(d): training and test error for last 500 epochs of bgd

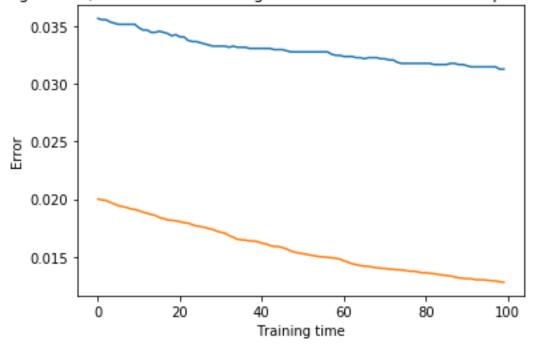


Figure 10, Question 4(d)" mean training loss for last 500 epochs of bgd

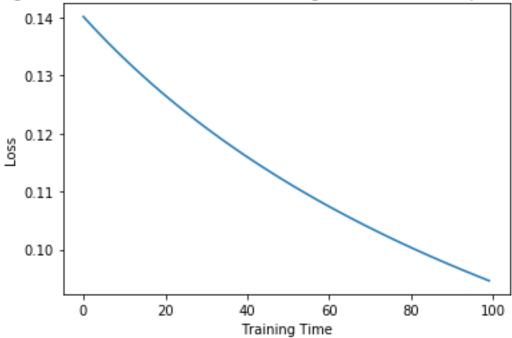


Figure 11, Question 4(g): training and test error for stochastic gradient descent

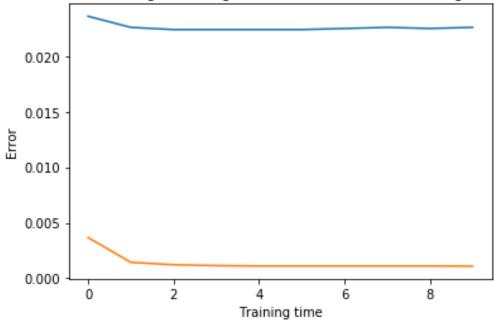


Figure 12, Question 4(g): mean training loss for stochastic gradient descent

