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Date : 10/31/2019

CSE 4309
Assignment 05

Task 1

```
decision_tree('pendigits_training', 'pendigits_test', 'optimized', 50)
```

Print tree 1

```
tree= 1, node= 1, feature=15, thr= 21.57, gain=0.621424
tree= 1, node= 2, feature= 4, thr= 41.18, gain=0.587628
tree= 1, node= 3, feature=13, thr= 58.82, gain=0.697235
tree= 1, node= 4, feature= 9, thr= 15.69, gain=0.670083
tree= 1, node= 5, feature=10, thr= 39.22, gain=0.629044
tree= 1, node= 6, feature= 0, thr= 35.29, gain=0.712500
tree= 1, node= 7, feature= 8, thr= 56.86, gain=0.814218
tree= 1, node= 8, feature=14, thr= 60.78, gain=0.475710
tree= 1, node= 9, feature= 5, thr= 64.71, gain=0.620325
tree= 1, node=10, feature=14, thr= 37.25, gain=0.224713
tree= 1, node=11, feature= 3, thr= 90.20, gain=0.686759
tree= 1, node=12, feature=14, thr= 37.25, gain=0.281171
tree= 1, node=13, feature=10, thr= 29.41, gain=0.584898
tree= 1, node=14, feature=14, thr= 96.08, gain=0.737506
tree= 1, node=15, feature= 7, thr= 24.33, gain=0.205385
tree= 1, node=16, feature= 1, thr= 73.53, gain=0.027989
tree= 1, node=17, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=18, feature=15, thr=  0.41, gain=0.188928
tree= 1, node=19, feature= 9, thr= 60.47, gain=0.530651
tree= 1, node=20, feature=12, thr= 30.06, gain=0.640257
tree= 1, node=21, feature= 8, thr= 34.59, gain=0.140904
tree= 1, node=22, feature= 6, thr= 72.55, gain=0.509615
tree= 1, node=23, feature= 7, thr= 77.10, gain=0.409412
tree= 1, node=24, feature= 1, thr= 84.51, gain=0.550957
tree= 1, node=25, feature=13, thr= 14.78, gain=0.131381
tree= 1, node=26, feature=15, thr= 31.18, gain=0.222560
tree= 1, node=27, feature= 9, thr= 19.61, gain=0.464511
tree= 1, node=28, feature=11, thr= 31.67, gain=0.157508
tree= 1, node=29, feature=13, thr= 71.06, gain=0.344859
tree= 1, node=30, feature= 2, thr= 54.90, gain=0.092930
tree= 1, node=31, feature= 9, thr= 58.82, gain=0.918296
tree= 1, node=32, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=33, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=34, feature= 7, thr= 66.47, gain=0.110097
tree= 1, node=35, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=36, feature=14, thr= 25.49, gain=0.773333
tree= 1, node=37, feature= 0, thr= 39.22, gain=0.203813
tree= 1, node=38, feature= 3, thr= 96.71, gain=0.374672
tree= 1, node=39, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=40, feature= 9, thr=  1.43, gain=0.077936
tree= 1, node=41, feature= 6, thr= 68.14, gain=0.274080
tree= 1, node=42, feature=14, thr= 96.08, gain=0.341335
tree= 1, node=43, feature= 1, thr= 82.35, gain=0.324193
tree= 1, node=44, feature= 2, thr= 88.59, gain=0.253482
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tree= 1, node= 45, feature= 5, thr= 89.29, gain=0.811518
tree= 1, node= 46, feature= 8, thr= 76.47, gain=0.650022
tree= 1, node= 47, feature= 6, thr= 50.47, gain=0.757526
tree= 1, node= 48, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 49, feature= 3, thr= 87.45, gain=0.051386
tree= 1, node= 50, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 51, feature= 0, thr= 53.57, gain=0.129949
tree= 1, node= 52, feature=15, thr= 67.29, gain=0.265884
tree= 1, node= 53, feature=10, thr= 67.06, gain=0.773029
tree= 1, node= 54, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 55, feature=12, thr= 21.57, gain=0.159034
tree= 1, node= 56, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 57, feature= 5, thr= 54.41, gain=0.006884
tree= 1, node= 58, feature= 6, thr= 96.08, gain=0.024998
tree= 1, node= 59, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 60, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 61, feature= 1, thr= 3.92, gain=0.998846
tree= 1, node= 62, feature= 5, thr= 13.35, gain=0.035341
tree= 1, node= 63, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 64, feature= 7, thr= 71.86, gain=0.496889
tree= 1, node= 65, feature=10, thr= 60.78, gain=0.864204
tree= 1, node= 66, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 67, feature= 1, thr= 92.47, gain=0.078528
tree= 1, node= 68, feature= 5, thr= 68.63, gain=0.135036
tree= 1, node= 69, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 70, feature= 8, thr= 18.67, gain=0.368566
tree= 1, node= 71, feature= 7, thr= 73.02, gain=0.050120
tree= 1, node= 72, feature=12, thr= 55.47, gain=0.287642
tree= 1, node= 73, feature= 8, thr= 49.82, gain=0.208356
tree= 1, node= 74, feature= 1, thr= 39.18, gain=0.308576
tree= 1, node= 75, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 76, feature= 5, thr= 15.69, gain=0.106446
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tree= 1, node= 79, feature= 5, thr= 84.31, gain=0.901825
tree= 1, node= 80, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 81, feature= 6, thr= 70.59, gain=0.988057
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tree= 1, node= 89, feature=14, thr= 1.96, gain=0.057144
tree= 1, node= 90, feature= 4, thr= 62.75, gain=0.149994
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tree= 1, node=103, feature=13, thr= 6.08, gain=0.024501
tree= 1, node=104, feature=13, thr= 5.10, gain=0.465185
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tree= 1, node=107, feature= 7, thr= 54.53, gain=0.349184
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tree= 1, node=114, feature= 9, thr= 5.61, gain=0.007149
tree= 1, node=115, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=116, feature= 6, thr= 58.29, gain=0.175730
tree= 1, node=117, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=118, feature= 0, thr= 73.33, gain=0.054012
tree= 1, node=119, feature=11, thr= 9.06, gain=0.541116
tree= 1, node=120, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=121, feature= 7, thr= 67.06, gain=0.321696
tree= 1, node=122, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=123, feature= 0, thr= 60.78, gain=0.098830
tree= 1, node=124, feature= 9, thr= 18.55, gain=0.134335
tree= 1, node=125, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=126, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=127, feature= 1, thr= 79.29, gain=0.678954
tree= 1, node=128, feature= 4, thr= 48.04, gain=0.291818
tree= 1, node=129, feature=11, thr= 39.69, gain=0.517478
tree= 1, node=130, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=131, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=132, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=141, feature= 9, thr= 88.47, gain=0.008575
tree= 1, node=142, feature= 6, thr= 67.45, gain=0.250919
tree= 1, node=143, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=153, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=156, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=157, feature= 3, thr= 89.02, gain=0.028237
tree= 1, node=158, feature= 8, thr= 24.51, gain=0.021367
tree= 1, node=159, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=160, feature=-1, thr= -1.00, gain=0.000000

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tree= 1, node=161, feature=14, thr= 52.94, gain=0.111623
tree= 1, node=162, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=163, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=164, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=165, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=166, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=167, feature= 2, thr= 45.71, gain=0.103275
tree= 1, node=168, feature= 7, thr= 17.69, gain=0.008314
tree= 1, node=169, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=170, feature= 1, thr= 81.37, gain=0.056120
tree= 1, node=171, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=172, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=173, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=175, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=176, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=177, feature=15, thr=  9.12, gain=0.021405
tree= 1, node=178, feature= 6, thr= 21.57, gain=0.053910
tree= 1, node=179, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=180, feature= 1, thr= 66.67, gain=0.077022
tree= 1, node=181, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=182, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=183, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=184, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=185, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=188, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=189, feature= 3, thr= 99.12, gain=0.041635
tree= 1, node=190, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=191, feature= 2, thr= 41.47, gain=0.067329
tree= 1, node=192, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=193, feature= 2, thr= 86.33, gain=0.018695
tree= 1, node=194, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=195, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=196, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=197, feature=-1, thr= -1.00, gain=0.000000

```

classification accuracy=0.8382

```
decision_tree('pendigits_training', 'pendigits_test', 'randomized', 50)
```

Print tree 1

```

tree= 1, node= 1, feature= 1, thr= 98.04, gain=0.384675
tree= 1, node= 2, feature= 1, thr= 76.86, gain=0.270794
tree= 1, node= 3, feature=15, thr=  1.96, gain=0.729004
tree= 1, node= 4, feature=10, thr= 37.25, gain=0.456010
tree= 1, node= 5, feature=16, thr=  4.06, gain=0.989803
tree= 1, node= 6, feature= 2, thr= 52.94, gain=0.159300
tree= 1, node= 7, feature= 4, thr= 43.14, gain=0.533046
tree= 1, node= 8, feature= 3, thr= 88.24, gain=0.306620
tree= 1, node= 9, feature=16, thr=  1.06, gain=0.979198

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tree= 1, node= 10, feature= 8, thr= 49.02, gain=0.557279
tree= 1, node= 11, feature=10, thr= 62.75, gain=0.295632
tree= 1, node= 12, feature= 4, thr= 37.25, gain=0.272861
tree= 1, node= 13, feature= 1, thr= 99.02, gain=0.087186
tree= 1, node= 14, feature= 5, thr= 41.18, gain=0.481514
tree= 1, node= 15, feature= 7, thr= 13.73, gain=0.486735
tree= 1, node= 16, feature= 8, thr= 27.06, gain=0.650764
tree= 1, node= 17, feature=11, thr= 9.88, gain=0.075624
tree= 1, node= 18, feature=14, thr= 31.37, gain=0.282719
tree= 1, node= 19, feature=15, thr= 21.57, gain=0.546072
tree= 1, node= 20, feature= 3, thr= 99.04, gain=0.102343
tree= 1, node= 21, feature= 5, thr= 66.67, gain=0.892553
tree= 1, node= 22, feature= 5, thr= 60.78, gain=0.534672
tree= 1, node= 23, feature= 1, thr= 84.41, gain=0.090320
tree= 1, node= 24, feature= 5, thr= 64.41, gain=0.081357
tree= 1, node= 25, feature= 2, thr= 34.67, gain=0.262697
tree= 1, node= 26, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 27, feature= 8, thr= 25.49, gain=0.389991
tree= 1, node= 28, feature= 3, thr= 68.82, gain=0.100232
tree= 1, node= 29, feature=15, thr= 67.33, gain=0.393956
tree= 1, node= 30, feature=16, thr= 5.02, gain=0.988284
tree= 1, node= 31, feature= 9, thr= 34.51, gain=0.547184
tree= 1, node= 32, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 33, feature= 3, thr= 18.98, gain=0.325029
tree= 1, node= 34, feature= 9, thr= 0.75, gain=0.136540
tree= 1, node= 35, feature=12, thr= 47.65, gain=0.139750
tree= 1, node= 36, feature=12, thr= 54.59, gain=0.016963
tree= 1, node= 37, feature= 8, thr= 48.94, gain=0.035682
tree= 1, node= 38, feature=12, thr= 65.18, gain=0.180643
tree= 1, node= 39, feature= 0, thr= 1.96, gain=0.299923
tree= 1, node= 40, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 41, feature= 4, thr= 29.41, gain=0.167571
tree= 1, node= 42, feature=16, thr= 0.08, gain=0.304819
tree= 1, node= 43, feature= 6, thr= 80.39, gain=0.108950
tree= 1, node= 44, feature= 8, thr= 9.41, gain=0.036992
tree= 1, node= 45, feature=16, thr= 7.04, gain=0.664825
tree= 1, node= 46, feature=14, thr= 23.53, gain=0.130971
tree= 1, node= 47, feature= 4, thr= 49.02, gain=0.155464
tree= 1, node= 48, feature=15, thr= 0.02, gain=0.054820
tree= 1, node= 49, feature= 5, thr= 70.33, gain=0.236547
tree= 1, node= 50, feature= 2, thr= 0.67, gain=0.224190
tree= 1, node= 51, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 52, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 53, feature=14, thr= 7.84, gain=0.819752
tree= 1, node= 54, feature=10, thr= 31.37, gain=0.200349
tree= 1, node= 55, feature=13, thr= 57.65, gain=0.679393
tree= 1, node= 56, feature=11, thr= 14.82, gain=0.065717
tree= 1, node= 57, feature=13, thr= 91.86, gain=0.151003
tree= 1, node= 58, feature=11, thr= 86.49, gain=0.119116
tree= 1, node= 59, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 60, feature=12, thr= 33.33, gain=0.262673
tree= 1, node= 61, feature=15, thr= 32.12, gain=0.743339
tree= 1, node= 62, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 63, feature= 5, thr= 50.59, gain=0.177389
tree= 1, node= 64, feature=12, thr= 45.43, gain=0.684526

tree= 1, node= 65, feature=14, thr= 96.16, gain=0.138713
tree= 1, node= 66, feature= 0, thr= 27.45, gain=0.633637
tree= 1, node= 67, feature= 1, thr= 64.24, gain=0.022660
tree= 1, node= 68, feature=12, thr= 12.71, gain=0.020529
tree= 1, node= 69, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node= 71, feature=15, thr= 9.80, gain=0.089871
tree= 1, node= 72, feature= 8, thr= 41.18, gain=0.144083
tree= 1, node= 73, feature=15, thr= 8.20, gain=0.239500
tree= 1, node= 74, feature=15, thr= 69.41, gain=0.271435
tree= 1, node= 75, feature= 7, thr= 29.18, gain=0.047364
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tree= 1, node= 81, feature=12, thr= 25.25, gain=0.334349
tree= 1, node= 82, feature= 9, thr= 39.51, gain=0.036879
tree= 1, node= 83, feature= 9, thr= 14.02, gain=0.057652
tree= 1, node= 84, feature= 5, thr= 94.65, gain=0.042911
tree= 1, node= 85, feature=12, thr= 35.29, gain=0.207189
tree= 1, node= 86, feature= 1, thr= 79.06, gain=0.050981
tree= 1, node= 87, feature= 9, thr= 54.06, gain=0.554123
tree= 1, node= 88, feature= 8, thr= 73.10, gain=0.590262
tree= 1, node= 89, feature= 8, thr= 66.67, gain=0.285710
tree= 1, node= 90, feature= 3, thr= 86.27, gain=0.035496
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tree= 1, node= 92, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node= 99, feature= 4, thr= 33.73, gain=0.066408
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tree= 1, node=101, feature= 8, thr= 29.41, gain=0.315997
tree= 1, node=102, feature=10, thr= 17.65, gain=0.130710
tree= 1, node=103, feature=16, thr= 5.12, gain=0.412557
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classification accuracy=0.7464

decision_tree('pendigits_training', 'pendigits_test', 'forest3', 50)

Print tree 1

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tree= 1, node= 9, feature= 6, thr= 31.37, gain=0.174058
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tree= 1, node=334, feature= 0, thr= 22.59, gain=0.095444
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tree= 1, node=352, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=353, feature= 7, thr= 87.06, gain=0.063094
tree= 1, node=354, feature=13, thr= 14.12, gain=0.065426
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tree= 1, node=357, feature= 2, thr= 92.55, gain=0.055601
tree= 1, node=358, feature= 5, thr= 79.22, gain=0.056744
tree= 1, node=359, feature= 8, thr= 12.08, gain=0.478040
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tree= 1, node=375, feature= 9, thr= 54.71, gain=0.181166
tree= 1, node=376, feature= 7, thr= 71.47, gain=0.124868
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tree= 1, node=378, feature= 1, thr= 88.27, gain=0.009124
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tree= 1, node=381, feature= 0, thr= 53.76, gain=0.042305
tree= 1, node=382, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=383, feature=-1, thr= -1.00, gain=0.000000

Print tree 2

tree= 2, node= 1, feature=12, thr= 68.63, gain=0.167442
tree= 2, node= 2, feature=16, thr= 4.06, gain=0.999912
tree= 2, node= 3, feature= 8, thr= 50.98, gain=0.539162
tree= 2, node= 4, feature=10, thr= 39.22, gain=0.676477
tree= 2, node= 5, feature=11, thr= 41.18, gain=0.269641
tree= 2, node= 6, feature=16, thr= 7.06, gain=0.987154
tree= 2, node= 7, feature=12, thr= 96.35, gain=0.035861
tree= 2, node= 8, feature= 2, thr= 64.71, gain=0.026389
tree= 2, node= 9, feature=13, thr= 50.98, gain=0.826896
tree= 2, node=10, feature=16, thr= 6.02, gain=0.956113

tree= 2, node= 11, feature=12, thr= 53.33, gain=0.135487
tree= 2, node= 12, feature= 7, thr= 53.45, gain=0.415407
tree= 2, node= 13, feature= 2, thr= 88.24, gain=0.171451
tree= 2, node= 14, feature= 9, thr= 27.45, gain=0.543413
tree= 2, node= 15, feature=10, thr= 85.29, gain=0.401140
tree= 2, node= 16, feature=11, thr= 35.29, gain=0.169102
tree= 2, node= 17, feature=14, thr= 29.41, gain=0.182078
tree= 2, node= 18, feature= 6, thr= 86.27, gain=0.327809
tree= 2, node= 19, feature= 1, thr= 98.49, gain=0.009884
tree= 2, node= 20, feature=15, thr= 7.84, gain=0.171760
tree= 2, node= 21, feature= 8, thr= 78.43, gain=0.364623
tree= 2, node= 22, feature=11, thr= 57.92, gain=0.164747
tree= 2, node= 23, feature= 5, thr= 58.82, gain=0.557267
tree= 2, node= 24, feature= 9, thr= 7.65, gain=0.496048
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tree= 2, node= 32, feature=16, thr= 1.04, gain=0.626297
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tree= 2, node= 34, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node= 35, feature= 6, thr= 84.67, gain=0.049749
tree= 2, node= 36, feature= 3, thr= 97.45, gain=0.652438
tree= 2, node= 37, feature= 5, thr= 68.24, gain=0.542853
tree= 2, node= 38, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node= 39, feature=15, thr= 1.96, gain=0.122134
tree= 2, node= 40, feature=10, thr= 95.41, gain=0.353348
tree= 2, node= 41, feature= 3, thr= 94.90, gain=0.128656
tree= 2, node= 42, feature=14, thr= 43.14, gain=0.195227
tree= 2, node= 43, feature=13, thr= 18.53, gain=0.774319
tree= 2, node= 44, feature=15, thr= 64.71, gain=0.761788
tree= 2, node= 45, feature=13, thr= 85.10, gain=0.483237
tree= 2, node= 46, feature=14, thr= 88.24, gain=0.916856
tree= 2, node= 47, feature= 4, thr= 21.57, gain=0.111045
tree= 2, node= 48, feature= 3, thr= 97.18, gain=0.139475
tree= 2, node= 49, feature=13, thr= 6.59, gain=0.744031
tree= 2, node= 50, feature= 4, thr= 72.55, gain=0.139858
tree= 2, node= 51, feature= 3, thr= 83.76, gain=0.020920
tree= 2, node= 52, feature= 2, thr= 46.43, gain=0.240880
tree= 2, node= 53, feature= 2, thr= 31.10, gain=0.218236
tree= 2, node= 54, feature= 8, thr= 80.78, gain=0.181459
tree= 2, node= 55, feature= 1, thr= 94.12, gain=0.814600
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tree= 2, node= 57, feature=-1, thr= -1.00, gain=0.000000
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tree= 2, node= 60, feature=15, thr= 1.12, gain=0.166116
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tree= 2, node= 63, feature=14, thr= 25.49, gain=0.181291
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tree= 2, node= 68, feature= 5, thr= 68.94, gain=0.409499

tree= 2, node= 69, feature=11, thr= 20.69, gain=0.083172
tree= 2, node= 70, feature= 7, thr= 50.10, gain=0.113785
tree= 2, node= 71, feature= 2, thr= 95.29, gain=0.061220
tree= 2, node= 72, feature= 1, thr= 83.41, gain=0.438687
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tree= 2, node= 76, feature=10, thr= 66.67, gain=0.318167
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tree= 2, node= 97, feature= 9, thr= 66.12, gain=0.600532
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tree= 2, node= 99, feature= 3, thr= 57.84, gain=0.031133
tree= 2, node=100, feature= 7, thr= 53.41, gain=0.007406
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tree= 2, node=122, feature=16, thr= 7.02, gain=0.391244
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tree= 2, node=125, feature=15, thr= 32.67, gain=0.037533
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tree= 2, node=214, feature=14, thr= 49.02, gain=0.050081
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tree= 2, node=230, feature=10, thr= 56.06, gain=0.023093
tree= 2, node=231, feature= 4, thr= 52.24, gain=0.029472
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tree= 2, node=263, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=264, feature=-1, thr= -1.00, gain=0.000000
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tree= 2, node=269, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=270, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=271, feature= 7, thr= 71.71, gain=0.113892
tree= 2, node=272, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=273, feature= 0, thr= 37.25, gain=0.711127
tree= 2, node=274, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=275, feature=14, thr= 1.96, gain=0.238685
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tree= 2, node=277, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=278, feature=14, thr= 42.39, gain=0.129647
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tree= 2, node=287, feature=15, thr= 0.00, gain=0.000000
tree= 2, node=288, feature= 1, thr= 98.59, gain=0.023715
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tree= 2, node=290, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=291, feature= 0, thr= 0.00, gain=0.000000
tree= 2, node=292, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=293, feature=11, thr= 37.67, gain=0.047965
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tree= 2, node=295, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=296, feature=10, thr= 74.67, gain=0.320160
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tree= 2, node=299, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=300, feature=-1, thr= -1.00, gain=0.000000

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tree= 2, node=317, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=318, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=319, feature=15, thr= 52.31, gain=0.219387
tree= 2, node=320, feature=-1, thr= -1.00, gain=0.000000
tree= 2, node=321, feature=-1, thr= -1.00, gain=0.000000
```

Print tree 3

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tree= 3, node= 1, feature=10, thr= 56.86, gain=0.474440
tree= 3, node= 2, feature=12, thr= 47.06, gain=0.201714
tree= 3, node= 3, feature= 9, thr= 19.61, gain=0.486319
tree= 3, node= 4, feature=12, thr= 26.73, gain=0.126750
tree= 3, node= 5, feature=16, thr= 2.12, gain=0.996493
tree= 3, node= 6, feature=12, thr= 65.49, gain=0.200666
tree= 3, node= 7, feature=11, thr= 37.25, gain=0.531127
tree= 3, node= 8, feature=14, thr= 33.33, gain=0.397490
tree= 3, node= 9, feature= 6, thr= 49.02, gain=0.249376
tree= 3, node=10, feature= 4, thr= 39.22, gain=0.072079
tree= 3, node=11, feature= 1, thr= 98.96, gain=0.152755
tree= 3, node=12, feature=13, thr= 62.75, gain=0.237274
tree= 3, node=13, feature= 1, thr= 98.53, gain=0.198872
tree= 3, node=14, feature=14, thr= 52.94, gain=0.296377
tree= 3, node=15, feature= 9, thr= 59.22, gain=0.507451
tree= 3, node=16, feature= 9, thr= 68.29, gain=0.198726
tree= 3, node=17, feature=14, thr= 97.41, gain=0.226534
tree= 3, node=18, feature=10, thr= 21.96, gain=0.244139
tree= 3, node=19, feature= 4, thr= 54.90, gain=0.400172
tree= 3, node=20, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=21, feature= 6, thr= 38.16, gain=0.030716
tree= 3, node=22, feature= 5, thr= 50.98, gain=0.487615
tree= 3, node=23, feature= 5, thr= 55.08, gain=0.489692
tree= 3, node=24, feature= 0, thr= 35.29, gain=0.492148
tree= 3, node=25, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=26, feature= 3, thr= 98.73, gain=0.473862
tree= 3, node=27, feature=13, thr= 57.84, gain=0.843884
tree= 3, node=28, feature= 6, thr= 37.25, gain=0.271946
tree= 3, node=29, feature= 3, thr= 96.47, gain=0.559366
tree= 3, node=30, feature=13, thr= 60.78, gain=0.989247
tree= 3, node=31, feature= 1, thr= 84.31, gain=0.523989
tree= 3, node=32, feature= 5, thr= 52.94, gain=0.283769
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tree= 3, node= 33, feature=15, thr= 1.02, gain=0.660405
tree= 3, node= 34, feature=15, thr= 11.76, gain=0.656212
tree= 3, node= 35, feature= 4, thr= 33.33, gain=0.288270
tree= 3, node= 36, feature= 0, thr= 43.14, gain=0.390099
tree= 3, node= 37, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node= 38, feature= 9, thr= 36.65, gain=0.449841
tree= 3, node= 39, feature=10, thr= 1.10, gain=0.227607
tree= 3, node= 40, feature= 8, thr= 21.18, gain=0.051290
tree= 3, node= 41, feature= 1, thr= 74.06, gain=0.063614
tree= 3, node= 42, feature= 2, thr= 8.35, gain=0.041881
tree= 3, node= 43, feature= 1, thr= 79.00, gain=0.148266
tree= 3, node= 44, feature=14, thr= 78.43, gain=0.625833
tree= 3, node= 45, feature=16, thr= 6.04, gain=0.974677
tree= 3, node= 46, feature=14, thr= 35.29, gain=0.377547
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tree= 3, node=161, feature= 1, thr= 74.06, gain=0.015124
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tree= 3, node=222, feature= 2, thr= 33.43, gain=0.257679
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tree= 3, node=417, feature=-1, thr= -1.00, gain=0.000000

classification accuracy=0.6129

Task 2

a) $H(0.8, 0.2) = -0.8\log_2(0.8) - 0.2\log_2(0.2) = 0.2068$

b)

c)

d) leaf node = Node F; test case = will wait

e) leaf node = Node D; test case = will wait

Task 3

Pick attribute A

entropy at root = 1

1 = {x, x, x}

2 = {x, y, y, y}

3 = {x, y, y}

$$\text{gain} = 1 - [0.3 \cdot 0 + 0.4 \cdot (-0.25\log_2(0.25) - 0.75\log_2(0.75)) + 0.3 \cdot (0.33\log_2(0.33) - 0.67\log_2(0.67))] = 0.72$$

Pick attribute B

entropy at root = 1

1 = {x, y, y, y}

2 = {x, x, x, y}

3 = {x, y}

$$\text{gain} = 1 - [0.4 \cdot (-0.25\log_2(0.25) - 0.75\log_2(0.75)) + 0.4 \cdot (-0.75\log_2(0.75) - 0.25\log_2(0.25)) + 0.2 \cdot (1)] = 0.1510$$

Pick attribute C

entropy at root = 1

1 = {x, y, y, y, y}

2 = {x, x, x, y}

3 = {x}

$$\text{gain} = 1 - [0.5 \cdot (-0.2\log_2(0.2) - 0.8\log_2(0.8)) + 0.4 \cdot (-0.75\log_2(0.75) - 0.25\log_2(0.25)) + 0.1 \cdot (0)] = 0.4768$$

Attribute A achieves highest gain at the root

Task 4

Part a: highest possible entropy = 1 (when all classes are equally distributed)
lowest possible entropy = 0 (every example has the same class)

Part b: highest information gain = 1 (when root has entropy of 1 and all examples in the attribute have the same class)
lowest information gain = 0 (when root has an entropy of 1 and all examples in attribute have equally distributed classes or when root entropy is 0 and all examples in the attribute have the same class)