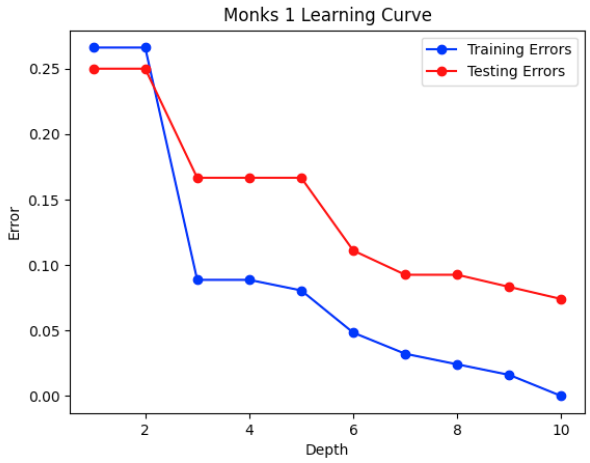
CS 6375.004 Programming Assignment #1
Tahmid Imran and Amogh Yatnatti

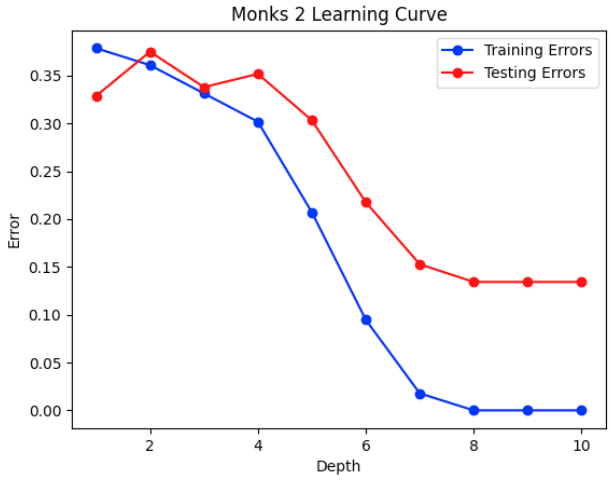
a.

a. Learning Curves

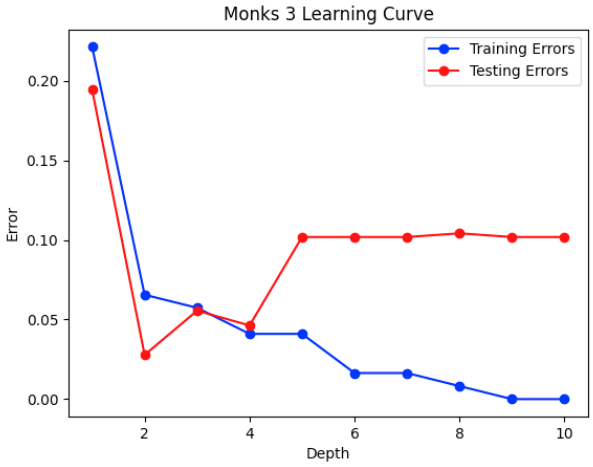
i. Monks 1:



ii. Monks 2:

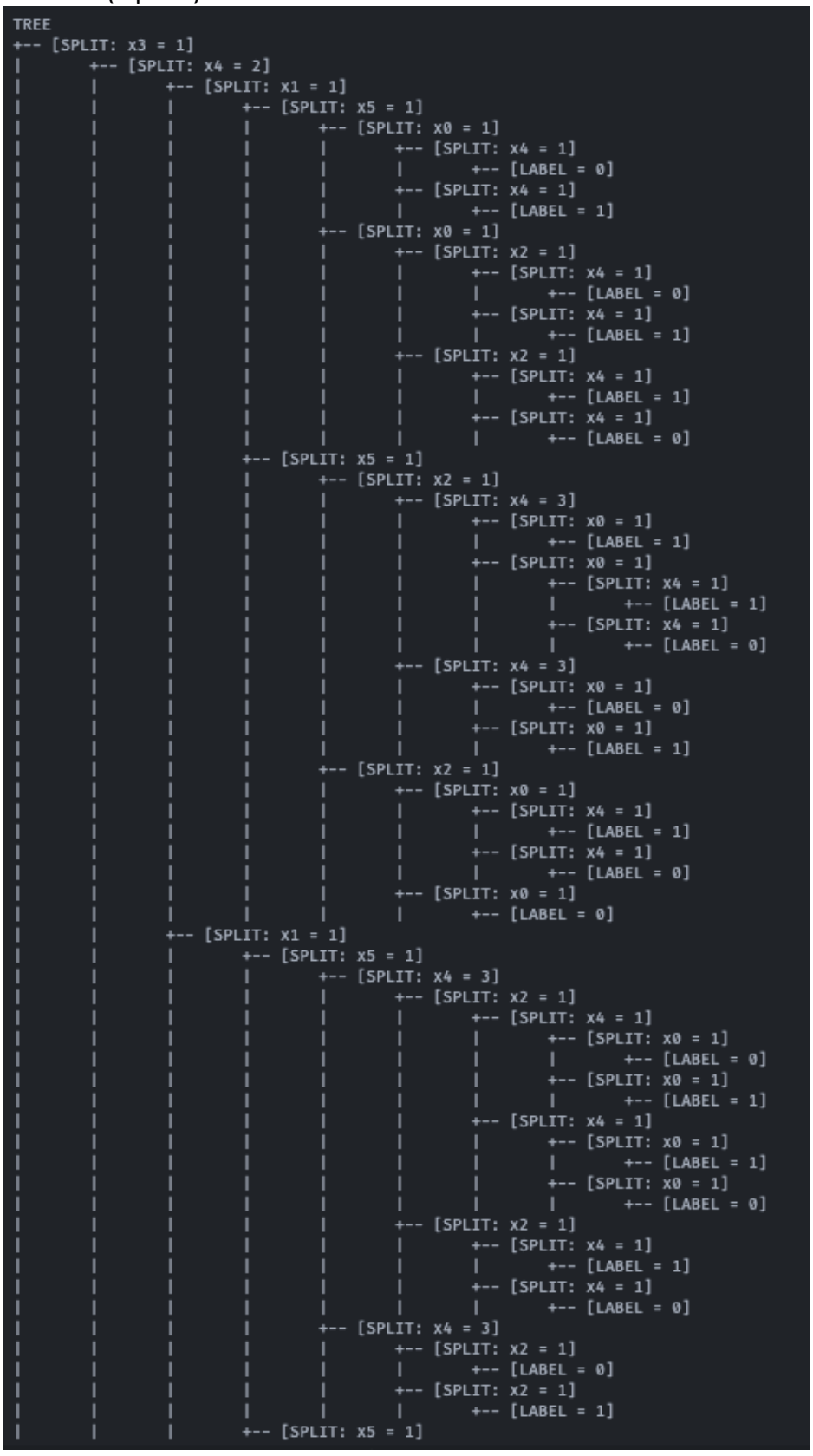


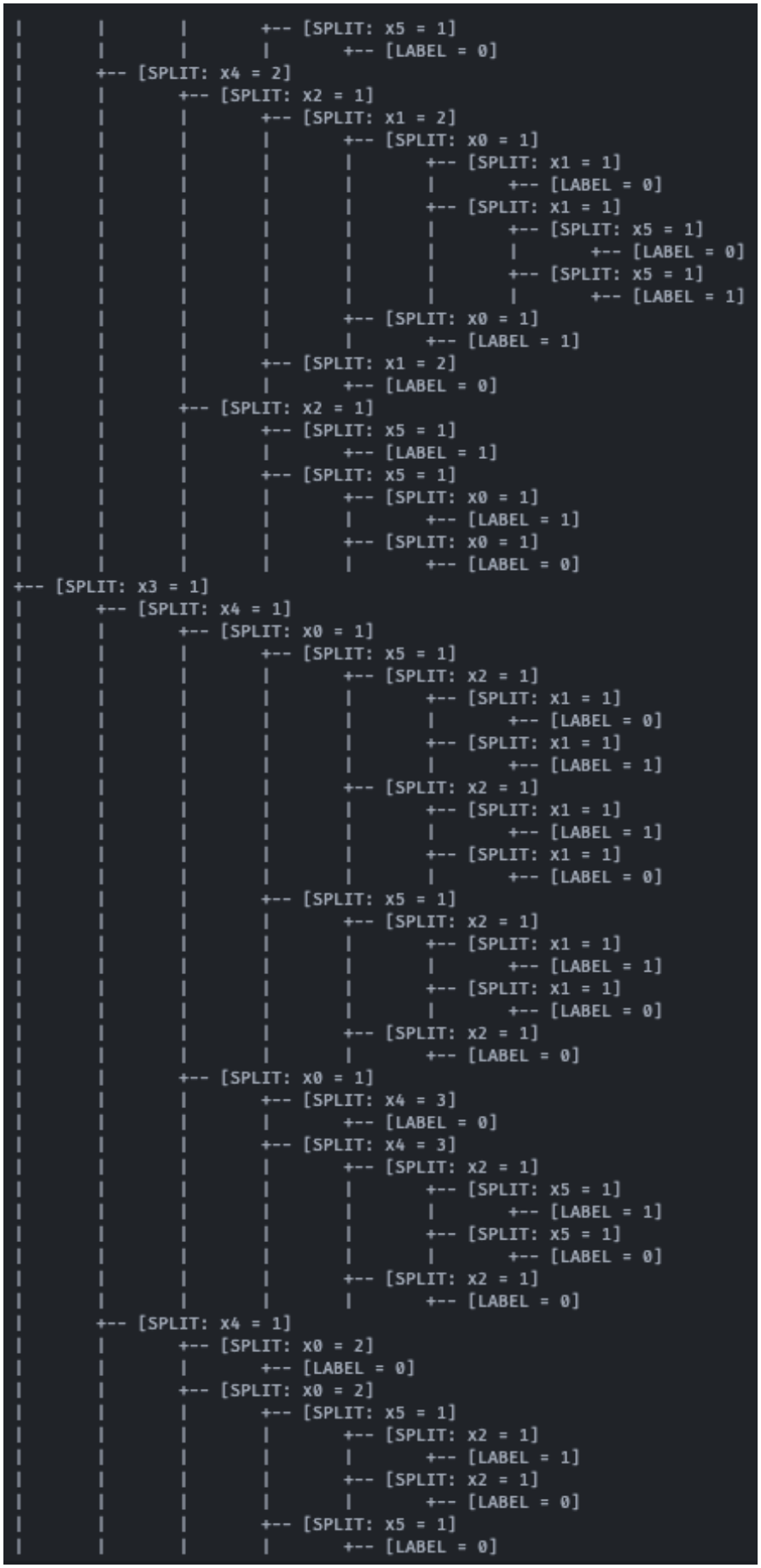
iii. Monks 3:



b. Visualization Trees (of depth 10, doing it for every depth would result in a very long report):
    i. Monks 1:

ii. Monks 2 (2 parts):




| | | +-- [SPLIT: x5 = 1]
| | | | +-- [LABEL = 0]
| | +-- [SPLIT: x4 = 2]
| | | +-- [SPLIT: x2 = 1]
| | | | +-- [SPLIT: x1 = 2]
| | | | | +-- [SPLIT: x0 = 1]
| | | | | | +-- [SPLIT: x1 = 1]
| | | | | | | +-- [LABEL = 0]
| | | | | | +-- [SPLIT: x1 = 1]
| | | | | | | +-- [SPLIT: x5 = 1]
| | | | | | | | +-- [LABEL = 0]
| | | | | | +-- [SPLIT: x5 = 1]
| | | | | | | +-- [LABEL = 1]
| | | | | +-- [SPLIT: x0 = 1]
| | | | | | +-- [LABEL = 1]
| | | | +-- [SPLIT: x1 = 2]
| | | | | +-- [LABEL = 0]
| | | +-- [SPLIT: x2 = 1]
| | | | +-- [SPLIT: x5 = 1]
| | | | | +-- [LABEL = 1]
| | | | +-- [SPLIT: x5 = 1]
| | | | | +-- [SPLIT: x0 = 1]
| | | | | | +-- [LABEL = 1]
| | | | | +-- [SPLIT: x0 = 1]
| | | | | | +-- [LABEL = 0]
+-- [SPLIT: x3 = 1]
| +-- [SPLIT: x4 = 1]
| | +-- [SPLIT: x0 = 1]
| | | +-- [SPLIT: x5 = 1]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [SPLIT: x1 = 1]
| | | | | | +-- [LABEL = 0]
| | | | | +-- [SPLIT: x1 = 1]
| | | | | | +-- [LABEL = 1]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [SPLIT: x1 = 1]
| | | | | | +-- [LABEL = 1]
| | | | | +-- [SPLIT: x1 = 1]
| | | | | | +-- [LABEL = 0]
| | | +-- [SPLIT: x5 = 1]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [SPLIT: x1 = 1]
| | | | | | +-- [LABEL = 1]
| | | | | +-- [SPLIT: x1 = 1]
| | | | | | +-- [LABEL = 0]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [LABEL = 0]
| | +-- [SPLIT: x0 = 1]
| | | +-- [SPLIT: x4 = 3]
| | | | +-- [LABEL = 0]
| | | +-- [SPLIT: x4 = 3]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [SPLIT: x5 = 1]
| | | | | | +-- [LABEL = 1]
| | | | | +-- [SPLIT: x5 = 1]
| | | | | | +-- [LABEL = 0]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [LABEL = 0]
| +-- [SPLIT: x4 = 1]
| | +-- [SPLIT: x0 = 2]
| | | +-- [LABEL = 0]
| | +-- [SPLIT: x0 = 2]
| | | +-- [SPLIT: x5 = 1]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [LABEL = 1]
| | | | +-- [SPLIT: x2 = 1]
| | | | | +-- [LABEL = 0]
| | | +-- [SPLIT: x5 = 1]
| | | | +-- [LABEL = 0]

iii. Monks 3:

```
TREE
+-- [SPLIT: x1 = 3]
|       +-- [SPLIT: x4 = 4]
|       |       +-- [SPLIT: x4 = 3]
|       |       |       +-- [SPLIT: x0 = 2]
|       |       |       |       +-- [LABEL = 1]
|       |       |       +-- [SPLIT: x0 = 2]
|       |       |       |       +-- [SPLIT: x5 = 1]
|       |       |       |       |       +-- [LABEL = 1]
|       |       |       |       +-- [SPLIT: x5 = 1]
|       |       |       |       |       +-- [SPLIT: x4 = 1]
|       |       |       |       |       |       +-- [LABEL = 0]
|       |       |       |       |       +-- [SPLIT: x4 = 1]
|       |       |       |       |       |       +-- [LABEL = 1]
|       |       |       +-- [SPLIT: x4 = 3]
|       |       |       |       +-- [SPLIT: x2 = 1]
|       |       |       |       |       +-- [LABEL = 1]
|       |       |       |       +-- [SPLIT: x2 = 1]
|       |       |       |       |       +-- [SPLIT: x0 = 3]
|       |       |       |       |       |       +-- [SPLIT: x5 = 1]
|       |       |       |       |       |       |       +-- [SPLIT: x0 = 1]
|       |       |       |       |       |       |       |       +-- [SPLIT: x1 = 1]
|       |       |       |       |       |       |       |       |       +-- [SPLIT: x3 = 1]
|       |       |       |       |       |       |       |       |       |       +-- [LABEL = 0]
|       |       |       |       |       |       |       |       |       +-- [SPLIT: x3 = 1]
|       |       |       |       |       |       |       |       |       |       +-- [LABEL = 1]
|       |       |       |       |       |       |       |       +-- [SPLIT: x1 = 1]
|       |       |       |       |       |       |       |       |       +-- [LABEL = 1]
|       |       |       |       |       |       |       +-- [SPLIT: x0 = 1]
|       |       |       |       |       |       |       |       +-- [LABEL = 1]
|       |       |       |       |       |       +-- [SPLIT: x5 = 1]
|       |       |       |       |       |       |       +-- [SPLIT: x3 = 1]
|       |       |       |       |       |       |       |       +-- [LABEL = 0]
|       |       |       |       |       |       |       +-- [SPLIT: x3 = 1]
|       |       |       |       |       |       |       |       +-- [SPLIT: x1 = 1]
|       |       |       |       |       |       |       |       |       +-- [LABEL = 1]
|       |       |       |       |       |       |       +-- [SPLIT: x1 = 1]
|       |       |       |       |       |       |       |       +-- [LABEL = 0]
|       |       |       |       |       +-- [SPLIT: x0 = 3]
|       |       |       |       |       |       +-- [LABEL = 1]
|       |       +-- [SPLIT: x4 = 4]
|       |       |       +-- [LABEL = 0]
+-- [SPLIT: x1 = 3]
|       +-- [SPLIT: x3 = 1]
|       |       +-- [LABEL = 0]
|       +-- [SPLIT: x3 = 1]
|       |       +-- [SPLIT: x2 = 1]
|       |       |       +-- [LABEL = 0]
|       |       +-- [SPLIT: x2 = 1]
|       |       |       +-- [SPLIT: x0 = 1]
|       |       |       |       +-- [LABEL = 1]
|       |       |       +-- [SPLIT: x0 = 1]
|       |       |       |       +-- [LABEL = 0]
```

c. Error Rates from depths 1-10 (might have to zoom in to see the values)

i. Monks 1:

```
Training Error: [0.2661290322580645, 0.2661290322580645, 0.08870967741935484, 0.08870967741935484, 0.08064516129032258, 0.04838709677419355, 0.03225806451612903, 0.024193548387096774, 0.016129032258064516
Testing Error: [0.25, 0.25, 0.16666666666666666, 0.16666666666666666, 0.16666666666666666, 0.1111111111111111, 0.09259259259259259, 0.09259259259259259, 0.08333333333333333]
```

ii. Monks 2:

```
Training Error: [0.378698224852071, 0.3609467455621302, 0.33136094674556216, 0.30177514792899407, 0.27010059171597633, 0.09467455621301775, 0.01775147928994083, 0.0, 0.0]
Testing Error: [0.3287037037037037, 0.375, 0.33796296296296297, 0.35185185185185186, 0.30324074074074076, 0.2175925925925926, 0.1527777777777778, 0.13425925925925927, 0.13425925925
```

iii. Monks 3:

```
Training Error: [0.22131147540983606, 0.06557377049180328, 0.05737704918032787, 0.040983606557377046, 0.040983606557377046, 0.016393442622950082, 0.016393442622950082, 0.008196721311475541, 0.0]
Testing Error: [0.19444444444444445, 0.027777777777777776, 0.05555555555555555, 0.046296296296296294, 0.10185185185185185, 0.10185185185185185, 0.10185185185185185, 0.10416666666666667, 0.10185185185185185]
```

b. Confusion Matrix and Tree of Depths 1 and 2 for Monks 1:

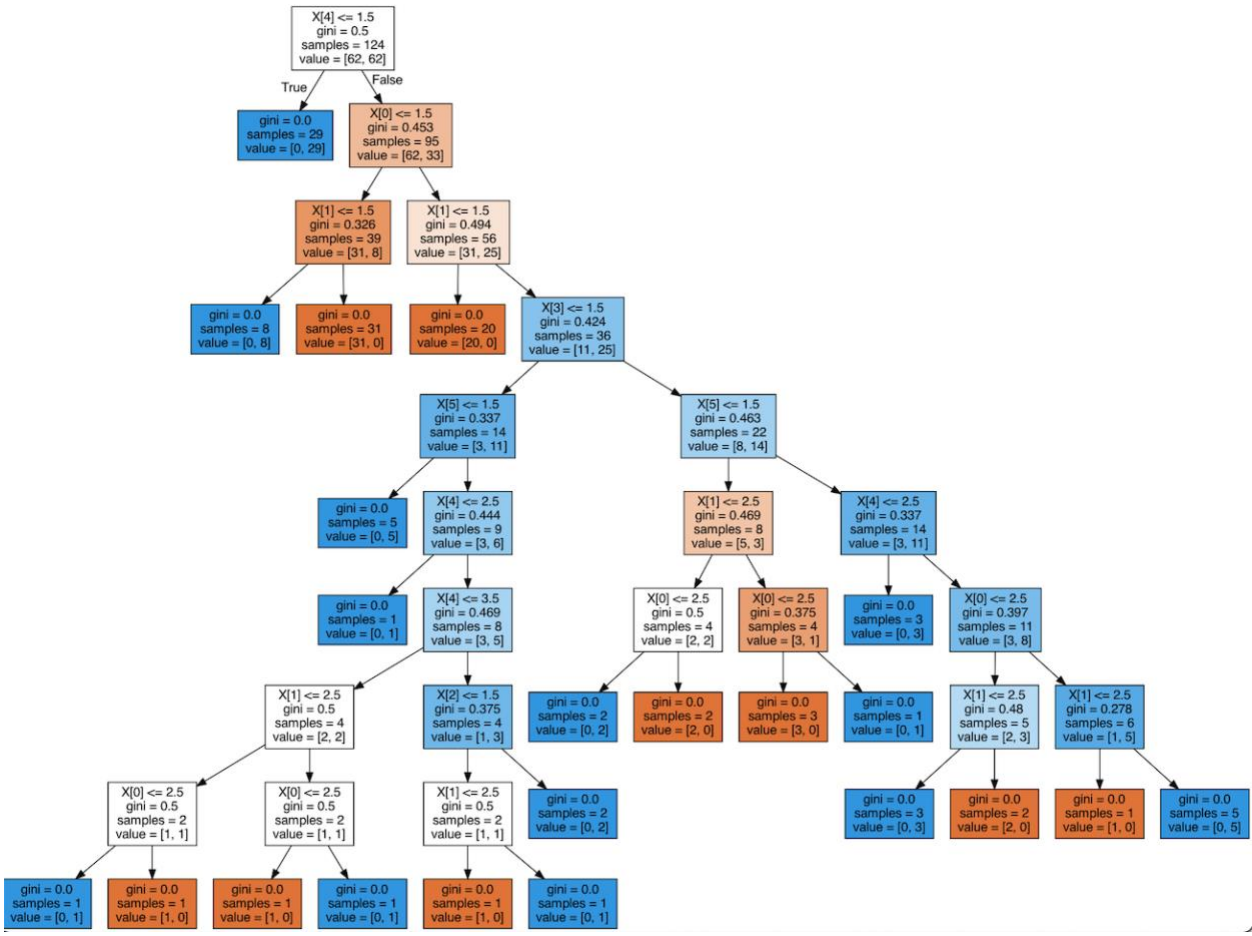
```
TREE
+-- [SPLIT: x4 = 1]
|       +-- [LABEL = 0]
+-- [SPLIT: x4 = 1]
|       +-- [LABEL = 1]
[[108, 108], [0, 216]]
            Confusion Matrix
           Positive   Negative
         |----------|----------|
         |          |          |
Positive |   108    |   108    |
         |          |          |
         |----------|----------|
         |          |          |
Negative |     0    |   216    |
         |          |          |
         |----------|----------|
TREE
+-- [SPLIT: x4 = 1]
|       +-- [SPLIT: x0 = 1]
|       |       +-- [LABEL = 0]
|       +-- [SPLIT: x0 = 1]
|       |       +-- [LABEL = 0]
+-- [SPLIT: x4 = 1]
|       +-- [LABEL = 1]
[[108, 108], [0, 216]]
            Confusion Matrix
           Positive   Negative
         |----------|----------|
         |          |          |
Positive |   108    |   108    |
         |          |          |
         |----------|----------|
         |          |          |
Negative |     0    |   216    |
         |          |          |
         |----------|----------|
```

c. Monks 1 Confusion Matrix and Tree using sklearn's default Decision Tree Algorithm:

a.

```
Sklearn's Confusion Matrix:
[[181  35]
 [ 15 201]]
```

b.


X[4] <= 1.5
gini = 0.5
samples = 124
value = [62, 62]
True
False
gini = 0.0
samples = 29
value = [0, 29]
X[0] <= 1.5
gini = 0.453
samples = 95
value = [62, 33]
X[1] <= 1.5
gini = 0.326
samples = 39
value = [31, 8]
X[1] <= 1.5
gini = 0.494
samples = 56
value = [31, 25]
gini = 0.0
samples = 8
value = [0, 8]
gini = 0.0
samples = 31
value = [31, 0]
gini = 0.0
samples = 20
value = [20, 0]
X[3] <= 1.5
gini = 0.424
samples = 36
value = [11, 25]
X[5] <= 1.5
gini = 0.337
samples = 14
value = [3, 11]
X[5] <= 1.5
gini = 0.463
samples = 22
value = [8, 14]
gini = 0.0
samples = 5
value = [0, 5]
X[4] <= 2.5
gini = 0.444
samples = 9
value = [3, 6]
X[1] <= 2.5
gini = 0.469
samples = 8
value = [5, 3]
X[4] <= 2.5
gini = 0.337
samples = 14
value = [3, 11]
gini = 0.0
samples = 1
value = [0, 1]
X[4] <= 3.5
gini = 0.469
samples = 8
value = [3, 5]
X[0] <= 2.5
gini = 0.5
samples = 4
value = [2, 2]
X[0] <= 2.5
gini = 0.375
samples = 4
value = [3, 1]
gini = 0.0
samples = 3
value = [0, 3]
X[0] <= 2.5
gini = 0.397
samples = 11
value = [3, 8]
X[1] <= 2.5
gini = 0.5
samples = 4
value = [2, 2]
X[2] <= 1.5
gini = 0.375
samples = 4
value = [1, 3]
gini = 0.0
samples = 2
value = [0, 2]
gini = 0.0
samples = 2
value = [2, 0]
gini = 0.0
samples = 3
value = [3, 0]
gini = 0.0
samples = 1
value = [0, 1]
X[1] <= 2.5
gini = 0.48
samples = 5
value = [2, 3]
X[1] <= 2.5
gini = 0.278
samples = 6
value = [1, 5]
X[0] <= 2.5
gini = 0.5
samples = 2
value = [1, 1]
X[0] <= 2.5
gini = 0.5
samples = 2
value = [1, 1]
X[1] <= 2.5
gini = 0.5
samples = 2
value = [1, 1]
gini = 0.0
samples = 2
value = [0, 2]
gini = 0.0
samples = 3
value = [0, 3]
gini = 0.0
samples = 2
value = [2, 0]
gini = 0.0
samples = 1
value = [1, 0]
gini = 0.0
samples = 5
value = [0, 5]
gini = 0.0
samples = 1
value = [0, 1]
gini = 0.0
samples = 1
value = [1, 0]
gini = 0.0
samples = 1
value = [1, 0]
gini = 0.0
samples = 1
value = [0, 1]
gini = 0.0
samples = 1
value = [1, 0]
gini = 0.0
samples = 1
value = [0, 1]

d.

a. Part C (Tree and Confusion Matrix of Depth 1 and 2 of Car's Data):

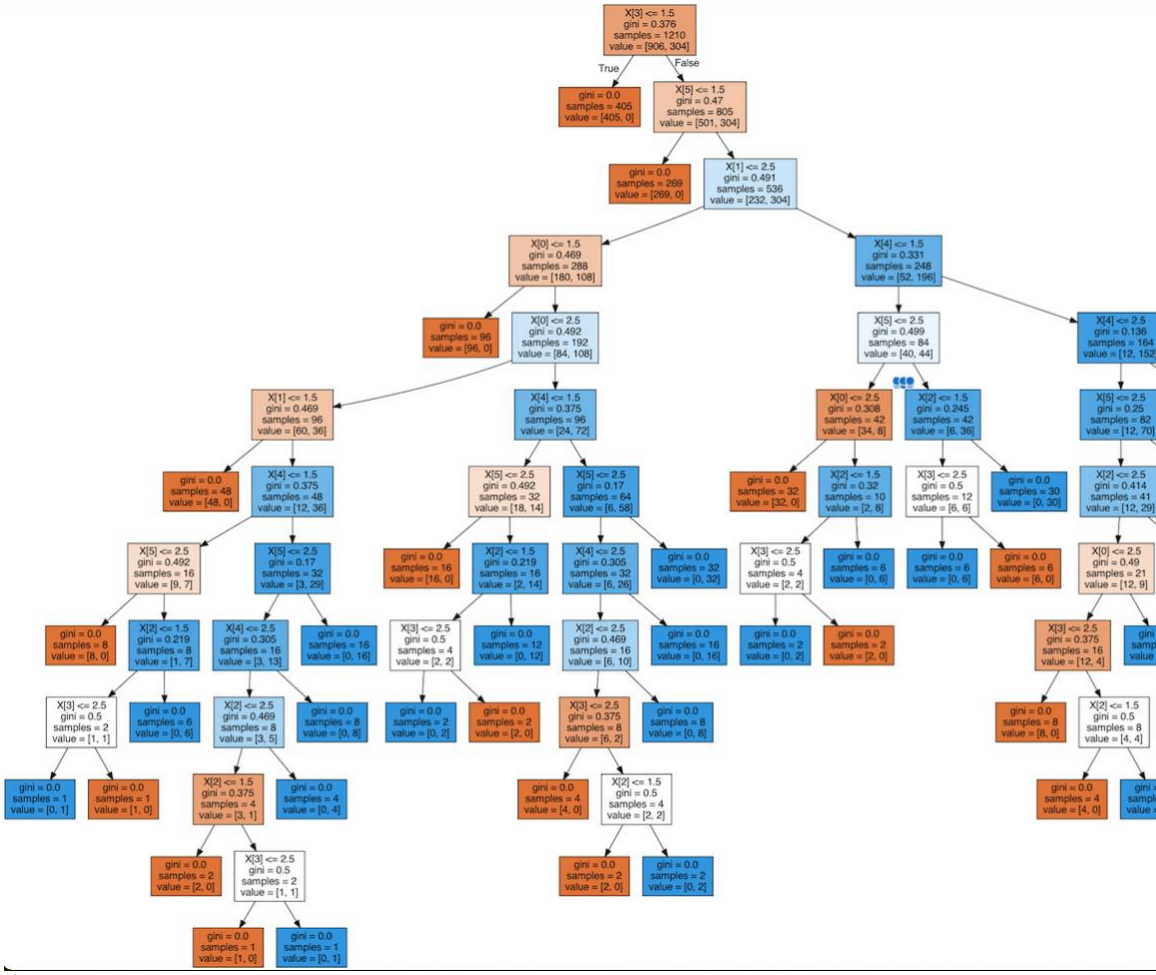
```
TREE
+-- [SPLIT: x3 = 1]
|       +-- [LABEL = 0]
+-- [SPLIT: x3 = 1]
|       +-- [LABEL = 0]
[[0, 214], [0, 304]]
            Confusion Matrix
           Positive   Negative
         |----------|----------|
         |          |          |
Positive |     0    |   214    |
         |          |          |
         |----------|----------|
         |          |          |
Negative |     0    |   304    |
         |          |          |
         |----------|----------|
TREE
+-- [SPLIT: x3 = 1]
|       +-- [SPLIT: x5 = 1]
|       |       +-- [LABEL = 1]
|       +-- [SPLIT: x5 = 1]
|       |       +-- [LABEL = 0]
+-- [SPLIT: x3 = 1]
|       +-- [LABEL = 0]
[[214, 0], [18, 286]]
            Confusion Matrix
           Positive   Negative
         |----------|----------|
         |          |          |
Positive |   214    |     0    |
         |          |          |
         |----------|----------|
         |          |          |
Negative |    18    |   286    |
         |          |          |
         |----------|----------|
```

b. Part D (Car's Data Confusion Matrix and Tree using sklearn's default Decision Tree Algorithm):

i.

```
Sklearn's Confusion Matrix:
[[374   1]
 [ 21 122]]
```

ii.


X[3] <= 1.5
gini = 0.376
samples = 1210
value = [906, 304]
True
False
gini = 0.0
samples = 405
value = [405, 0]
X[5] <= 1.5
gini = 0.47
samples = 805
value = [501, 304]
gini = 0.0
samples = 269
value = [269, 0]
X[1] <= 2.5
gini = 0.491
samples = 536
value = [232, 304]
X[0] <= 1.5
gini = 0.469
samples = 288
value = [180, 108]
X[4] <= 1.5
gini = 0.331
samples = 248
value = [52, 196]
gini = 0.0
samples = 96
value = [96, 0]
X[0] <= 2.5
gini = 0.492
samples = 192
value = [84, 108]
X[5] <= 2.5
gini = 0.499
samples = 84
value = [40, 44]
X[4] <= 2.5
gini = 0.136
samples = 164
value = [12, 152]
X[1] <= 1.5
gini = 0.469
samples = 96
value = [60, 36]
X[4] <= 1.5
gini = 0.375
samples = 96
value = [24, 72]
X[0] <= 2.5
gini = 0.308
samples = 42
value = [34, 8]
X[2] <= 1.5
gini = 0.245
samples = 42
value = [6, 36]
X[5] <= 2.5
gini = 0.25
samples = 82
value = [12, 70]
gini = 0.0
samples = 48
value = [48, 0]
X[4] <= 1.5
gini = 0.375
samples = 48
value = [12, 36]
X[5] <= 2.5
gini = 0.492
samples = 32
value = [18, 14]
X[5] <= 2.5
gini = 0.17
samples = 64
value = [6, 58]
gini = 0.0
samples = 32
value = [32, 0]
X[2] <= 1.5
gini = 0.32
samples = 10
value = [2, 8]
X[3] <= 2.5
gini = 0.5
samples = 12
value = [6, 6]
gini = 0.0
samples = 30
value = [0, 30]
X[2] <= 2.5
gini = 0.414
samples = 41
value = [12, 29]
X[5] <= 2.5
gini = 0.492
samples = 16
value = [9, 7]
X[5] <= 2.5
gini = 0.17
samples = 32
value = [3, 29]
gini = 0.0
samples = 16
value = [16, 0]
X[2] <= 1.5
gini = 0.219
samples = 16
value = [2, 14]
X[4] <= 2.5
gini = 0.305
samples = 32
value = [6, 26]
gini = 0.0
samples = 32
value = [0, 32]
X[3] <= 2.5
gini = 0.5
samples = 4
value = [2, 2]
gini = 0.0
samples = 6
value = [0, 6]
gini = 0.0
samples = 6
value = [0, 6]
gini = 0.0
samples = 6
value = [6, 0]
X[0] <= 2.5
gini = 0.49
samples = 21
value = [12, 9]
gini = 0.0
samples = 8
value = [8, 0]
X[2] <= 1.5
gini = 0.219
samples = 8
value = [1, 7]
X[4] <= 2.5
gini = 0.305
samples = 16
value = [3, 13]
gini = 0.0
samples = 16
value = [0, 16]
gini = 0.0
samples = 12
value = [0, 12]
X[2] <= 2.5
gini = 0.469
samples = 16
value = [6, 10]
gini = 0.0
samples = 16
value = [0, 16]
gini = 0.0
samples = 2
value = [0, 2]
gini = 0.0
samples = 2
value = [2, 0]
X[3] <= 2.5
gini = 0.375
samples = 16
value = [12, 4]
X[3] <= 2.5
gini = 0.5
samples = 2
value = [1, 1]
gini = 0.0
samples = 6
value = [0, 6]
X[2] <= 2.5
gini = 0.469
samples = 8
value = [3, 5]
gini = 0.0
samples = 8
value = [0, 8]
gini = 0.0
samples = 2
value = [0, 2]
gini = 0.0
samples = 2
value = [2, 0]
X[3] <= 2.5
gini = 0.375
samples = 8
value = [6, 2]
gini = 0.0
samples = 8
value = [0, 8]
gini = 0.0
samples = 8
value = [8, 0]
X[2] <= 1.5
gini = 0.5
samples = 8
value = [4, 4]
gini = 0.0
samples = 1
value = [0, 1]
gini = 0.0
samples = 1
value = [1, 0]
X[2] <= 1.5
gini = 0.375
samples = 4
value = [3, 1]
gini = 0.0
samples = 4
value = [0, 4]
gini = 0.0
samples = 4
value = [4, 0]
X[2] <= 1.5
gini = 0.5
samples = 4
value = [2, 2]
gini = 0.0
samples = 2
value = [2, 0]
X[3] <= 2.5
gini = 0.5
samples = 2
value = [1, 1]
gini = 0.0
samples = 2
value = [0, 2]
gini = 0.0
samples = 4
value = [4, 0]
gini = 0.0
samples = 1
value = [1, 0]
gini = 0.0
samples = 1
value = [0, 1]