

Question 1.

- a) There are a total of 1 hidden layers used.
- b) There are a total of two weights, which are both equal to 1. The bias is -1.

Question 2.

- a) There are a total of 2 hidden layers. The reason this amount is used is because after doing some experimenting with a different number of hidden layers, we found it to be the best outcome overall.
- b) There are total of 32 nodes in both of the hidden layers. Each layer uses 16 nodes. I found after experimenting that this was yielding the best results.
- c) The hidden layers use the RELU activation function. I used RELU because of its simplicity, efficiency and ability to mitigate the vanishing gradient problem. The sigmoid activation was used for the output layer, and this is because the output data involves using binary classification (the output is 0 or 1).
- d) Yes, 1 hidden layer can be used to solve this problem. This is because there the dataset is relatively small and the input features are not very complex. There would be a total of 5 input nodes, and 1 output node. Through experimenting, I found that there were a total of 7 nodes in the hidden layer which gave the best outcome.
- e) Yes, 5 hidden layers can be used, however, more hidden layers also come with an increase in computational complexity which can lead to overfitting. The neural network might start memorizing the small dataset instead of generalizing for unseen data.
- g) I have attached the model summaries on the next page. The first model summary uses one hidden layer and 2 nodes. The second model summary uses 2 hidden layers and 7 nodes each. The third model uses two hidden layers and 16 nodes each. This yielded the best results thus far. With a total of 385 trainable parameters, the accuracy of the model went up, and the f1 score also went up. The last model summary shows that the accuracy on the training set is 75% while on the test data it is 88%. Examining the precision, recall and f1 score for all summaries, the last one achieved the highest score in both training and testing.

----- Model Summary -----

Model: "Neural-Network"

Layer (type)	Output Shape	Param #
Hidden-Layer (Dense)	(None, 2)	12
Output-Layer (Dense)	(None, 1)	3
Total params: 15		
Trainable params: 15		
Non-trainable params: 0		

----- Weights and Biases -----

Layer: Hidden-Layer

--Kernels (Weights): [[0.02913674 0.24786288]
[0.11304501 0.22204442]
[0.7295234 -0.69202024]
[0.66675997 -0.17056932]
[0.06213845 -0.6944134]]

--Biases: [0.0054591 -0.00364859]

Layer: Output-Layer

--Kernels (Weights): [[0.99775773]
[-1.3148556]]

--Biases: [0.00545785]

----- Evaluation on Training Data -----

	precision	recall	f1-score	support
0	0.50	0.17	0.25	6
1	0.77	0.94	0.85	18
accuracy			0.75	24
macro avg	0.64	0.56	0.55	24
weighted avg	0.70	0.75	0.70	24

----- Evaluation on Test Data -----

	precision	recall	f1-score	support
0	0.00	0.00	0.00	2
1	0.71	0.83	0.77	6

accuracy			0.62	8
macro avg	0.36	0.42	0.38	8
weighted avg	0.54	0.62	0.58	8

----- Model Summary -----

Model: "Neural-Network"

Layer (type)	Output Shape	Param #
Hidden-Layer (Dense)	(None, 7)	42
Hidden-Layer2 (Dense)	(None, 7)	56
Output-Layer (Dense)	(None, 1)	8

=====
Total params: 106

Trainable params: 106

Non-trainable params: 0
=====

----- Weights and Biases -----

Layer: Hidden-Layer

--Kernels (Weights): [[0.68632126 0.6351431 0.3463441
0.1371306 -0.01357999 0.1134448
-0.46217304]
[0.21867448 -0.67890793 -0.10190027 -0.5207516 0.22463644
0.45586398
0.17865059]
[0.44897255 -0.29388386 0.3830622 0.39121816 0.07890634
-0.5860552
-0.52957803]
[-0.309889 0.28624952 0.18905021 -0.3830369 0.15957765
0.30207476
-0.5167856]
[-0.26820412 0.55869144 0.27298287 -0.24127592 0.46650934
-0.41360617
-0.18217248]]
--Biases: [0.00588615 0.00501306 0.00557734 -0.00581597
-0.00594134 -0.00461472
-0.00460158]

Layer: Hidden-Layer2

--Kernels (Weights): [[-0.3528823 0.06972183 -0.25985447
-0.49930155 -0.07877678 0.54205984
0.17887323]
[0.06944279 0.39536297 0.5182618 -0.38579965 0.40857136
0.49253878
-0.08842681]

```

[-0.36583275  0.11213288  0.21386904  0.43787536 -0.13007072
-0.25413454
  0.5873877 ]
[ 0.06925356 -0.2051669  -0.19849932  0.46809897 -0.0573623
-0.2827053
  0.2319309 ]
[ 0.43013492 -0.4562502  -0.5444156   0.5229341  -0.109061
0.13350573
 -0.4504391 ]
[ 0.21516629  0.28422663  0.3263802  -0.02977932  0.16714346
0.42321366
 -0.22181943]
[-0.30757412  0.4158945   0.3509315  -0.5800346  -0.39500755
-0.03444809
 -0.07048333]]
--Biases: [ 0.00050303  0.00153958  0.00526003 -0.0057825
-0.00575928  0.00567512
  0.00599181]
Layer: Output-Layer
--Kernels (Weights): [[ 0.61856174]
[ 0.6367289 ]
[ 0.49625543]
[-0.8331856 ]
[-0.7706644 ]
[ 0.19564858]
[ 0.6260952 ]]
--Biases: [0.00594451]

```

```

----- Evaluation on Training Data -----
              precision    recall  f1-score   support

         0           0.25         0.33         0.29           6
         1           0.75         0.67         0.71          18

 accuracy                   0.58           24
 macro avg           0.50         0.50         0.50           24
 weighted avg           0.62         0.58         0.60           24

```

```

----- Evaluation on Test Data -----
              precision    recall  f1-score   support

         0           0.00         0.00         0.00           2
         1           0.75         1.00         0.86           6

```

accuracy			0.75	8
macro avg	0.38	0.50	0.43	8
weighted avg	0.56	0.75	0.64	8

----- Model Summary -----

Model: "Neural-Network"

Layer (type)	Output Shape	Param #
Hidden-Layer (Dense)	(None, 16)	96
Hidden-Layer2 (Dense)	(None, 16)	272
Output-Layer (Dense)	(None, 1)	17

=====
Total params: 385

Trainable params: 385

Non-trainable params: 0

----- Weights and Biases -----

Layer: Hidden-Layer

--Kernels (Weights): [[-0.31785405 0.23158906 -0.40417343
0.3343889 0.2908284 -0.36904767
-0.41499647 -0.37664104 0.24311498 0.32455233 0.5225409
-0.1368338
0.11742838 -0.22770257 -0.49362913 0.00662944]
[-0.22150221 -0.18165722 -0.51036453 -0.01876776 0.34220943
0.41326407
0.43246427 -0.5283173 0.29743645 -0.09648638 0.25251716
-0.06221917
0.26720095 -0.26177725 -0.09578306 0.24902938]
[0.17323099 0.38713825 0.11519311 0.43947822 -0.37431282
0.06232958
0.26490775 0.10984238 0.3059049 -0.05556222 0.15185623
-0.06454837
0.40061855 -0.00506384 -0.2032196 0.07791123]
[-0.3780523 -0.47932512 -0.33267266 0.43063813 -0.26939946
0.40908056
-0.21228021 0.14055645 0.12494713 0.5020619 0.03487271
-0.2892746
-0.4729504 -0.02283744 -0.19962966 -0.4138674]
[-0.24274725 -0.485142 0.3028684 0.07721405 0.40947086
0.33258167
-0.44465834 -0.29541454 -0.07188188 -0.2820351 0.20561936
0.22512324
0.33311185 0.3946436 0.4926084 -0.30471697]]

```
--Biases: [ 0.00416005  0.00578199 -0.00373807  0.00542325
0.0047474  0.00098521
0.00582156 0.00530577 0.00472642 -0.00585751 0.00525674
-0.00580302
0.00585501 -0.00547817 -0.00155413 0.00359144]
Layer: Hidden-Layer2
--Kernels (Weights): [[-3.09115052e-02  3.69351476e-01
1.33649975e-01 -3.48934203e-01
2.65687883e-01 -1.75172836e-01 -3.01689684e-01  3.59205395e-01
-1.06426412e-02  4.29689497e-01 -1.03357166e-01 -3.28126192e-01
-2.93754399e-01 1.66807622e-01  3.20753247e-01 -1.67394578e-02]
[ 1.63794965e-01 2.70138308e-02 -1.65408298e-01  2.93778867e-01
5.70789687e-02 2.74709493e-01  7.01536462e-02  3.46878469e-02
3.41236591e-01 1.32214606e-01  4.27202314e-01  4.51679938e-02
1.89417407e-01 -3.86100411e-01 -4.18291211e-01 -3.10944617e-01]
[-3.29509616e-01 -1.74194127e-01 -3.42493057e-01 -8.94634426e-02
5.86012527e-02 -3.01963389e-01 -1.58213422e-01 -1.61431104e-01
2.83898592e-01 -4.15582538e-01 -3.97501379e-01 -2.14063853e-01
2.29118854e-01 -4.28451747e-01 -1.34312063e-01  2.49237657e-01]
[-3.61195505e-01 3.28184217e-01 -3.88004869e-01 -2.11952582e-01
2.81507045e-01 5.08576110e-02  1.60452694e-01  2.64751554e-01
-3.47349904e-02 2.22500026e-01  3.35808456e-01  2.99144059e-01
2.76346095e-02 3.77689660e-01 -3.10055196e-01 -3.78618866e-01]
[ 3.09783280e-01 -3.92147265e-02  3.06355447e-01 -2.50993788e-01
-3.29072267e-01 3.81678373e-01 -9.04378667e-02 -2.39847377e-01
-7.21740425e-02 3.23781878e-01 -2.88028926e-01 -1.56177059e-01
-1.51311876e-02 -3.10091853e-01 -1.69805989e-01 -1.22764327e-01]
[-1.87561326e-02 -4.04717177e-01  2.92139798e-01  1.62772745e-01
4.22323883e-01 2.71916956e-01 -2.35979363e-01 -3.57030481e-01
1.90666392e-01 3.59523833e-01  5.58765884e-03 -4.26409543e-01
-3.94078404e-01 4.14416566e-02 -3.61608028e-01  1.17482111e-01]
[-3.37413698e-01 1.34098426e-01 -1.18030742e-01  8.54624882e-02
4.36507821e-01 -1.34299323e-02  2.95675606e-01 -2.59338140e-01
-4.09249738e-02 4.03526038e-01  1.61301628e-01 -3.39712590e-01
-1.06666505e-01 -4.19090569e-01 -2.23868266e-01  1.27521992e-01]
[-3.85655850e-01 -6.35115802e-02  9.68620479e-02  4.18477088e-01
2.34688714e-01 -1.85830906e-01 -8.28911960e-02 -1.55207992e-01
-1.72241982e-02 3.76293927e-01  2.07016636e-02  1.32498622e-01
1.36503577e-02 -2.06282780e-01 -2.82459617e-01 -1.11385435e-01]
[-1.92048877e-01 2.78969239e-02  1.41177773e-01  2.71220654e-01
-3.11389983e-01 1.67364195e-01 -2.86369085e-01 -4.24559057e-01
2.51287729e-01 2.91356832e-01  4.36863959e-01 -2.71047235e-01
-2.52375379e-02 8.15722421e-02 -3.22834849e-01 -1.53238043e-01]
[-2.27769151e-01 2.23716587e-01 -3.70426267e-01  2.69822162e-02
-4.01048362e-01 6.74487054e-02  1.02730706e-01 -9.31237591e-05
```



```

-4.10659969e-01 -1.84272215e-01 -2.85380304e-01  2.90818393e-01
 1.49736688e-01  1.23709783e-01 -3.41249675e-01 -9.42881703e-02]
[ 9.74623561e-02 -1.63777754e-01  3.19391131e-01  4.00221460e-02
 2.72938222e-01 -1.16637543e-01  1.11668788e-01  3.36537153e-01
 3.30651343e-01  2.14249149e-01  3.35345864e-02  1.93522483e-01
 6.77356729e-03  2.76553839e-01  4.15122896e-01  3.23801816e-01]
[ 2.10651398e-01 -1.32067055e-01 -3.59604537e-01 -3.71494979e-01
-1.63764820e-01 -3.35410774e-01 -3.99698734e-01  3.70201498e-01
-3.19091707e-01  1.87509973e-02 -1.76768348e-01  1.44636527e-01
 2.47536689e-01  1.42147645e-01  7.19220787e-02  3.02334130e-01]
[ 1.94700673e-01 -2.30621487e-01  2.72023290e-01 -2.64796525e-01
 2.95011997e-01  1.15911506e-01  2.15882391e-01 -4.13671315e-01
 3.76881063e-01 -1.65141255e-01  9.51239541e-02  1.67994633e-01
-4.26894724e-01 -2.42644191e-01  1.99634451e-02  2.04161704e-01]
[-1.42732605e-01 -2.75190324e-01  1.50412157e-01  3.56038362e-01
 1.15516350e-01 -6.27935529e-02 -1.91145465e-01 -3.36728871e-01
-3.11588347e-01  6.61498355e-03  2.65974104e-01  4.49739620e-02
 4.03044254e-01 -3.59782316e-02  3.03287327e-01  2.70153135e-01]
[ 1.12853855e-01  3.85441512e-01 -4.12597954e-01  2.34098420e-01
 3.68155062e-01 -3.43848586e-01  1.59159154e-01 -2.85618782e-01
-3.99145722e-01 -4.22565758e-01 -4.25317168e-01  2.75951922e-01
-1.91623345e-01  2.76789546e-01 -1.86171532e-02  1.87362656e-01]
[ 2.13346243e-01 -4.12388772e-01 -3.28004777e-01 -7.32035562e-02
 2.07782522e-01  2.59636909e-01 -5.65606132e-02  1.35580525e-01
 2.54916191e-01 -2.04393566e-02 -1.62970066e-01  3.22589666e-01
-1.91806257e-01  7.54489284e-03  3.12358350e-01 -8.19168240e-02]]
--Biases: [ 0.00147305  0.00593958  0.00511236  0.0031134
0.00542455  0.00525738
0.0059691 -0.005968  0.00585222  0.00525639  0.00584606
0.00589673
0.00599007 -0.00589034  0.00377282 -0.0053449 ]
Layer: Output-Layer
--Kernels (Weights): [[ 0.2069839 ]
[ 0.5689052 ]
[ 0.4913295 ]
[ 0.36974162]
[ 0.03882737]
[ 0.5710661 ]
[ 0.2636009 ]
[-0.05450245]
[ 0.5876864 ]
[ 0.570378 ]
[ 0.08911282]
[ 0.4727086 ]
[ 0.16002618]

```

```
[-0.5660862 ]
[ 0.11845055]
[-0.35683468]]
--Biases: [0.00569096]
```

```
----- Evaluation on Training Data -----
      precision    recall  f1-score   support

     0         0.00      0.00      0.00         6
     1         0.75      1.00      0.86        18

 accuracy          0.75         24
  macro avg         0.38      0.50      0.43         24
 weighted avg         0.56      0.75      0.64         24
```

```
----- Evaluation on Test Data -----
      precision    recall  f1-score   support

     0         1.00      0.50      0.67         2
     1         0.86      1.00      0.92         6

 accuracy          0.88         8
  macro avg         0.93      0.75      0.79         8
 weighted avg         0.89      0.88      0.86         8
```