In [ ]:
```
from machine_learning_functions import *
```

In [ ]:
```
def experiment_linear(a, b, learning_rate, epochs, random_x_function):
    a, b = float(a), float(b)
    model = Model(
        FFN = FFN(
            neurons_per_layer_list=[1, 1],
            activation_functions_list=[None,],
            cost_function=MSE()
        ),
        data_set=create_1_input_1_output_XY_data(
            function=lambda x: a*x+b,
            num_data_items=10000,
            random_x_function=random_x_function
        )
    )
    print(
        model.train_and_evaluate(
            learning_rate=learning_rate,
            epochs=epochs,
            batch_size=50
        )
    )
    model.print_FFN_parameters()
    return model
```

In [ ]:
```
experiment_linear(
    a=2, b=5,
    learning_rate=0.00025,
    epochs=1,
    random_x_function= lambda: random.uniform(-100, 100)
)
```

```
(26.476959844961947, 557.0903921874293)
Parameters of network
{'W1': array([[1.95422062]])}
{'B1': array([0.54006489])}
```

Out[ ]:
```
<machine_learning_functions.Model at 0x257181ac510>
```

In [ ]:
```
experiment_linear(
    a=2, b=5,
    learning_rate=0.00025,
    epochs=1,
    random_x_function= lambda: random.uniform(-100, 100)
)
```

```
(30.39501657132671, 927.1757343554814)
Parameters of network
{'W1': array([[2.0562532]])}
{'B1': array([0.53572177])}
```

Out[ ]:
```
<machine_learning_functions.Model at 0x2572e5740d0>
```

In [ ]:
```
experiment_linear(
    a=1/2, b=-7,
    learning_rate=0.00025,
    epochs=1,
```

```
    random_x_function= lambda: random.uniform(-10, 10)
)
```

```
(55.766794676885354, 38.351180903069235)
Parameters of network
{'W1': array([[0.57050946]])}
{'B1': array([0.44124636])}
```

Out[ ]: <machine_learning_functions.Model at 0x25717fa7950>

In [ ]:
```
experiment_linear(
    a=1/2, b=-7,
    learning_rate=0.00025,
    epochs=5,
    random_x_function= lambda: random.uniform(-10, 10)
)
```

```
(44.86322336570385, 16.632833989096753)
Parameters of network
{'W1': array([[0.55188239]])}
{'B1': array([-0.33177718])}
```

Out[ ]: <machine_learning_functions.Model at 0x25717fa6950>

In [ ]:
```
# greater learning rate caused divergance
experiment_linear(
    a=-3, b=-1/4,
    learning_rate=0.00025,
    epochs=20,
    random_x_function= lambda: random.uniform(-10, 10)
)
```

```
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
Cell In[7], line 2
      1 # greater learning rate caused divergance
----> 2 experiment_linear(
      3     a=-3, b=-1/4,
      4     learning_rate=0.00025,
      5     epochs=20,
      6     random_x_function= lambda: random.uniform(-10, 10)
      7 )

Cell In[2], line 16, in experiment_linear(a, b, learning_rate, epochs, random_x_f
unction)
      2 a, b = float(a), float(b)
      3 model = Model(
      4     FFN = FFN(
      5         neurons_per_layer_list=[1, 1],
   (...)
     13     )
     14 )
     15 print(
---> 16     model.train_and_evaluate(
     17         learning_rate=learning_rate,
     18         epochs=epochs,
     19         batch_size=50
     20     )
     21 )
     22 model.print_FFN_parameters()
     23 return model

File c:\Users\Henry\Documents\compsci presentations\machine_learning_functions.p
y:327, in Model.train_and_evaluate(self, learning_rate, epochs, batch_size)
    324 X, Y = self.X_data[data_item_index], self.Y_data[data_item_index]
    326 # _, cost = self.FFN.foreward_propagate(X, Y)
--> 327 _, cost = self.FFN.foreward_propagate(
    328     input_vector=X,
    329     expected_output_vector=Y
    330 )
    332 total_cost += cost
    334 param_gradients = self.FFN.back_propogate(X, Y, False)

File c:\Users\Henry\Documents\compsci presentations\machine_learning_functions.p
y:238, in FFN.foreward_propagate(self, input_vector, expected_output_vector)
    236     cost = None
    237 else:
--> 238     cost = self.cost_function(layer_activations, expected_output_vector)
    240 return layer_activations, cost

File c:\Users\Henry\Documents\compsci presentations\machine_learning_functions.p
y:197, in MSE.__call__(self, P, Y)
    194 self.diff = (P-Y)
    196 # here I will use dot product rather than transverse vectors which are no
t well supported in numpu :(
--> 197 return (1/self.n) * np.dot(self.diff, self.diff)

KeyboardInterrupt:
```

In [ ]:

```
experiment_linear(
    a=-3, b=-1/4,
    learning_rate=0.00025,
```

```
    epochs=50,
    random_x_function= lambda: random.uniform(-10, 10)
)
```

```
1.153899693613739e-09
Parameters of network
{'W1': array([[-3.00000003]])}
{'B1': array([-0.24996604])}
```

Out[ ]:
```
<machine_learning_functions.Model at 0x1e842aa4c10>
```

In [ ]:
```
def experiment_boolean_logic(input_neurons, output_neurons, function, learning_r
    neurons_per_layer_list = [input_neurons] + [neurons_per_hidden_layer]*hidden
    activation_functions_list = [RELU() for _ in range(hidden_layers)] + [Sigmoi
    model = Model(
        FFN = FFN(
            neurons_per_layer_list=neurons_per_layer_list,
            activation_functions_list=activation_functions_list,
            cost_function=MSE()
        ),
        data_set=create_a_inputs_b_outputs_XY_data(
            a=input_neurons,
            b=output_neurons,
            function=function,
            random_x_function= lambda: random.choice([0.0, 1.0]),
            num_data_items=10000
        )
    )
    print(
        model.train_and_evaluate(
            learning_rate=learning_rate,
            epochs=epochs,
            batch_size=50
        )
    )
    model.print_FFN_parameters()
    return model
```

In [ ]:
```
def logical_and(X):
    a, b = bool(X[0]), int(X[1])
    return float(
        a and b
    )

experiment_boolean_logic(
    input_neurons = 2,
    output_neurons = 1,
    function=logical_and,
    learning_rate=10**-4,
    epochs=10,
    hidden_layers=2,
    neurons_per_hidden_layer=4
)
```

```
0.12960848961263577
Parameters of network
{'W1': array([[-0.65294285,  0.61589101],
       [-0.42820191,  0.95443661],
       [ 0.78559784, -0.6332115 ],
       [-0.49309623,  0.0098737 ]])}
{'B1': array([0.50288722, 0.49578408, 0.50147239, 0.50223506])}
{'W2': array([[-0.28502613,  0.84517966, -0.02225392, -0.51014619],
       [ 0.41362951,  0.76604725,  0.17653435, -0.83507039],
       [-0.73251695,  0.22706445,  0.14197284,  0.32888372],
       [ 0.33971928, -0.36906122,  0.70390109,  0.38498229]])}
{'B2': array([0.499599  , 0.49750374, 0.49630429, 0.50301195])}
{'W3': array([[-0.08625152, -0.55111397, -0.82001057,  0.67107456]])}
{'B3': array([0.50449989])}
```

Out[ ]:
```
<machine_learning_functions.Model at 0x1e82c532ad0>
```

In [ ]:
```python
def logical_and(X):
    a, b = bool(X[0]), int(X[1])
    return np.array([float(a and b)])

and_model = experiment_boolean_logic(
    input_neurons = 2,
    output_neurons = 1,
    function=logical_and,
    learning_rate=10**-2,
    epochs=10,
    hidden_layers=2,
    neurons_per_hidden_layer=4
)
```

```
0.22791140785530437
Parameters of network
{'W1': array([[ 0.71236726,  0.92403822],
       [-0.04563622,  0.82902018],
       [-0.957013  , -0.41655979],
       [ 0.366711  , -0.79908891]])}
{'B1': array([0.58150379, 0.38601112, 0.50171204, 0.48146798])}
{'W2': array([[ 0.61075504, -0.77864653,  0.59993966, -0.49881914],
       [ 0.73361503,  0.61780799, -0.86412893, -0.15360232],
       [ 0.38080145, -0.46465994,  0.07840686,  0.23716035],
       [ 0.95144912, -0.73341645, -0.65706865,  0.1223274 ]])}
{'B2': array([0.55125803, 0.48178318, 0.47786995, 0.58917505])}
{'W3': array([[ 0.5281708 , -0.02111933, -0.17516291,  0.94342531]])}
{'B3': array([0.60308173])}
```

In [ ]:
```python
(
    and_model.FFN.foreward_propagate(np.array([.0, 0.0])),
    and_model.FFN.foreward_propagate(np.array([0.0, 1.0])),
    and_model.FFN.foreward_propagate(np.array([1.0, 0.0])),
    and_model.FFN.foreward_propagate(np.array([1.0, 1.0])),
)
```

Out[ ]:
```
((array([0.02659525]), None),
 (array([0.02199461]), None),
 (array([0.01794683]), None),
 (array([0.01604408]), None))
```

In [ ]:
```python
def half_adder(X):
    a, b = bool(X[0]), bool(X[1])
    sum = a ^ b
```

```
    carry = a and b
    return np.array([float(sum), float(carry)])
experiment_boolean_logic(
    input_neurons = 2,
    output_neurons = 2,
    function=half_adder,
    learning_rate=10**-4,
    epochs=10,
    hidden_layers=2,
    neurons_per_hidden_layer=4
)
```

```
0.3135790065347722
Parameters of network
{'W1': array([[ 0.80417935, -0.26562906],
       [-0.87725767, -0.12092512],
       [-0.78320205, -0.27136584],
       [ 0.35091593,  0.26535257]])}
{'B1': array([0.50024658, 0.50157549, 0.49893939, 0.49868099])}
{'W2': array([[-0.0098028 ,  0.49366171,  0.45025614, -0.34743505],
       [-0.233186  , -0.22733595,  0.75709782,  0.64877799],
       [-0.22303459, -0.92618616,  0.69403422,  0.5781448 ],
       [-0.31351791,  0.18043455,  0.31068989,  0.77025649]])}
{'B2': array([0.50153271, 0.49843039, 0.49935668, 0.50078602])}
{'W3': array([[ 0.70884425, -0.92781434, -0.21895813,  0.07905441],
       [ 0.68910313, -0.41105522, -0.40206512,  0.76649372]])}
{'B3': array([0.50129485, 0.50089337])}
```

Out[ ]: <machine_learning_functions.Model at 0x1e84292bbd0>

In [ ]:
```
def half_adder_bool(A, B):
    return A ^ B, A and B

def full_adder_bool(A, B, Cin):
    S1, C1 = half_adder_bool(A, B)
    S2, C2 = half_adder_bool(S1, Cin)
    sum = S2
    carry = C1 or C2
    return sum, carry
```

In [ ]:
```
def chain_adder_bool(A_sequence, B_sequence):
    carry_out = 0
    sum_sequence = [None for _ in range(16)]
    for i in range(16):
        sum_sequence[i], carry_out = full_adder_bool(A_sequence[i], B_sequence[i
    return sum_sequence
```

In [ ]:
```
def full_adder_float(X):
    a, b, c_in = [bool(e) for e in X]
    s, c_out = full_adder_bool(a, b, c_in)
    return np.array([float(s), float(c_out)])

experiment_boolean_logic(
    input_neurons = 3,
    output_neurons = 2,
    function=full_adder_float,
    learning_rate=10**-4,
    epochs=10,
    hidden_layers=2,
```

```
    neurons_per_hidden_layer=4
)
```

```
0.42989678126870745
Parameters of network
{'W1': array([[-0.13046729,  0.03398441, -0.1298488 ],
       [-0.72423869,  0.78047567, -0.64296893],
       [ 0.6843604 , -0.26595864, -0.22207009],
       [-0.41476843, -0.50194339, -0.78647592]])}
{'B1': array([0.500551  , 0.50042498, 0.49871512, 0.49978004])}
{'W2': array([[-0.65096664, -0.37460568, -0.37066503,  0.75567564],
       [-0.83865972, -0.79582755,  0.49221667, -0.5953249 ],
       [-0.69872521, -0.02073121, -0.10209797,  0.1742665 ],
       [-0.587185  , -0.68434492,  0.86805485,  0.01652106]])}
{'B2': array([0.50025891, 0.49912558, 0.50068528, 0.49920759])}
{'W3': array([[ 0.44302166,  0.35661684,  0.8725924 ,  0.55579853],
       [-0.00385711, -0.42774771, -0.12385615, -0.46034002]])}
{'B3': array([0.50123403, 0.50315067])}
```

Out[ ]: <machine_learning_functions.Model at 0x1e82c50d3d0>

In [ ]:
```
def nibble_chain_adder_float(X):
    X = [bool(e) for e in X]
    As, Bs = X[:16], X[16:]
    S = chain_adder_bool(As, Bs)
    S = np.array([float(e) for e in S])
    return S

experiment_boolean_logic(
    input_neurons = 32,
    output_neurons = 16,
    function=nibble_chain_adder_float,
    learning_rate=10**-4,
    epochs=50,
    hidden_layers=4,
    neurons_per_hidden_layer=16
)
```

```
1.191507532951934
Parameters of network
{'W1': array([[ 6.11125611e-01,  1.14858367e-01, -4.95287944e-01,
        -6.25415027e-01, -2.53345060e-01, -7.54530891e-01,
        -2.92707485e-01,  7.76460302e-01,  5.63399112e-03,
        -7.48106081e-01,  5.69085296e-02,  5.47629344e-01,
        -6.48915951e-01, -3.63134604e-01, -9.06494622e-01,
         1.13467815e-02, -2.61377319e-01,  3.04120455e-01,
         3.08378312e-01,  6.46972992e-02, -4.59864541e-01,
         5.67630634e-01,  9.18967193e-01, -9.82585472e-01,
        -4.20437556e-01, -6.64320203e-02, -6.49667910e-01,
         4.38514490e-01,  9.86187351e-01, -3.54789901e-02,
         6.41888373e-01,  9.04014896e-01],
       [ 8.45828349e-02,  1.01889100e+00,  7.53080810e-01,
         1.55303544e-02,  3.13309410e-02,  7.60985437e-01,
        -4.85823744e-01, -2.66594230e-01,  8.18592904e-01,
         2.22874715e-01, -9.39888359e-01, -7.29218120e-02,
        -4.90382179e-01, -3.78657325e-01, -3.74402574e-01,
         6.30120738e-01,  9.87167866e-01,  5.13258405e-01,
         5.03757902e-02, -3.41695240e-01, -1.00064672e+00,
         6.35986519e-01, -1.00426109e-01,  7.86634844e-01,
        -6.60966125e-01,  5.88368983e-01, -9.68166043e-01,
         2.35563609e-01,  8.44698102e-01,  9.28508884e-01,
         9.45004844e-01,  9.70151623e-01],
       [-1.85784082e-01, -9.06666718e-01, -8.51845260e-01,
        -8.59291429e-01, -5.32047570e-01,  9.73561266e-01,
         9.31511923e-01, -8.27752574e-01, -1.71458553e-01,
         6.54541113e-01,  2.21579305e-01, -4.05657808e-01,
         4.93756126e-01,  6.31896249e-01,  7.51677054e-01,
        -2.12789193e-01, -5.74461575e-02, -7.45721909e-01,
        -9.97473594e-01, -9.15008052e-01,  4.48801437e-01,
         7.66969940e-01, -6.18043729e-01,  6.51739528e-01,
         9.69792975e-01,  2.78251040e-01, -5.08312043e-01,
        -2.44814808e-01,  8.05930067e-01,  8.17313643e-01,
        -8.15825198e-01, -2.97644866e-03],
       [-7.56217119e-01, -4.02215080e-01, -2.86944100e-01,
        -2.71043138e-01, -6.08370072e-01,  4.18348958e-01,
        -7.25725954e-01,  9.77439937e-01, -6.99873384e-01,
         1.04733842e-01,  9.60759238e-01, -4.09616599e-02,
         7.90520750e-01, -3.45184715e-01, -7.69986586e-01,
         5.83566894e-01,  6.44075035e-02,  7.36095718e-02,
        -4.97759313e-01, -1.10053275e-01, -3.04750330e-01,
        -6.59186561e-02, -2.49907906e-01, -8.50615675e-01,
         7.65347009e-01, -5.05322942e-01,  3.58509525e-01,
         8.49757925e-01, -2.82819280e-01, -6.11362068e-01,
         2.62087182e-01, -5.72196162e-01],
       [ 1.84795966e-01, -9.12741378e-01, -6.92449533e-01,
         4.00143719e-01,  6.56798737e-01,  7.38100438e-01,
        -2.66447243e-01,  2.16583200e-01, -3.14465933e-01,
        -8.33346346e-01,  4.14009147e-02,  6.07321668e-01,
         7.65581839e-01, -7.44832344e-01, -2.20606877e-01,
        -4.66204145e-01,  1.75602664e-01, -6.03383403e-01,
        -7.59678399e-02, -5.37270611e-01,  7.72403043e-01,
         9.40103593e-01, -5.89818768e-01,  4.37356990e-01,
         3.60275624e-01, -1.35680476e-02, -3.59014675e-01,
         7.29989970e-01,  2.78955784e-01,  2.66817206e-02,
        -5.47650031e-03, -6.36054812e-01],
       [ 2.54589850e-01, -4.93891516e-01, -8.93293082e-01,
         4.65429979e-01,  7.55074980e-02,  5.67330332e-01,
         2.50829632e-01,  1.25363988e-01,  2.20627255e-01,
```

```
 -5.27182195e-01, -8.62259871e-01,  1.05903098e-01,
 -8.68498579e-01,  3.52009338e-01, -2.06118272e-01,
 -9.73084157e-01,  8.69450738e-01,  6.60251177e-01,
  3.08196248e-01, -4.56999556e-01,  1.42986353e-02,
 -5.61166635e-01, -8.86909866e-01, -3.28299585e-01,
  6.21882106e-01, -9.04677316e-01, -6.83608616e-01,
  5.94442242e-01,  6.25595917e-01,  9.54739989e-01,
 -6.32976426e-01, -7.42669439e-01],
[ 6.19182824e-01,  1.06586529e-01, -4.56525408e-01,
 -3.95272701e-01,  1.92262832e-01,  7.58505749e-01,
 -7.98617993e-01,  6.23837327e-01, -8.39823223e-01,
 -7.45487042e-01, -6.72245230e-01,  9.01233236e-01,
 -3.63990755e-02,  8.77312355e-01, -3.58361581e-01,
  3.41691840e-01, -2.34078845e-01,  5.41636835e-01,
  8.10218224e-01, -5.59245870e-01,  8.54865182e-01,
  6.71152091e-01,  2.51630024e-01, -7.86135972e-01,
 -2.72531919e-01,  9.63829595e-02, -6.76974442e-01,
  5.72282446e-01, -2.71062160e-01,  6.28848392e-01,
  5.57464238e-02, -6.38080660e-01],
[ 4.95431224e-01, -6.68696187e-01,  9.69922165e-01,
  6.55818631e-01, -4.17936009e-01,  9.79376487e-01,
  8.70919587e-01,  5.79144117e-01, -2.97420664e-01,
  3.82299986e-01, -3.60656430e-01,  2.20764302e-01,
  5.87123248e-01, -4.20441062e-01, -9.32442619e-01,
  4.05902798e-01, -6.96261138e-01,  7.95912585e-01,
 -4.10320824e-01, -1.19549996e-01,  7.83910261e-01,
 -3.34766381e-02,  8.83749219e-01, -3.12652621e-01,
  1.09917029e-01,  8.02367216e-01, -7.21541360e-01,
 -1.90824884e-01,  7.20022731e-01, -9.82951676e-01,
  3.04411682e-01,  7.42385471e-01],
[ 1.82520531e-01, -7.67872325e-01,  6.59498797e-01,
  6.34979690e-01, -5.76659425e-01,  2.67982945e-01,
 -3.82649467e-01, -3.04129253e-01, -2.79411893e-01,
  2.44990322e-01,  5.94643356e-01, -8.87641420e-02,
  9.99253465e-01,  9.51483775e-03, -9.39041759e-01,
  8.28988264e-01, -1.66314529e-01,  9.46602576e-01,
  8.09703300e-01, -5.40901215e-01,  9.61724689e-02,
 -4.06366711e-01,  9.66548378e-01, -4.57393679e-01,
 -4.72011294e-01, -4.53568246e-01,  1.03985259e+00,
  9.52566426e-01,  1.01620279e-01,  8.74997847e-01,
 -3.08293198e-01,  8.62196868e-01],
[ 5.95912490e-01,  8.26015974e-01, -4.40332896e-01,
 -1.46409976e-01, -8.81900248e-01,  7.38377862e-01,
 -9.13424238e-02,  7.21551601e-01, -8.47553835e-01,
 -7.45589228e-02,  2.35082149e-01,  8.23937373e-01,
 -5.88036153e-01,  2.91800600e-01,  5.87820572e-01,
 -3.48387166e-01, -4.06183515e-01, -1.10344805e-01,
 -8.57632983e-01, -3.46382158e-01,  2.57759451e-01,
  7.82386077e-01, -2.84309501e-01,  4.68665361e-02,
  7.81614556e-01,  7.74765246e-01, -3.93033106e-01,
  1.02599642e+00, -1.97349566e-01, -4.77376244e-01,
  9.84501098e-02,  6.51589773e-01],
[ 2.88292549e-02, -1.36484860e-01,  9.02953219e-03,
  9.35297437e-01, -1.38514020e-02,  3.40582863e-02,
 -2.20932242e-01,  9.97608269e-02, -7.83722447e-01,
 -3.85872336e-01, -6.87690591e-01, -2.67407696e-01,
 -9.69969076e-01, -6.84326186e-01, -1.55366415e-01,
 -1.88460926e-01, -5.73434523e-01, -2.09156540e-02,
  8.81003317e-01, -8.04440593e-01, -9.08422713e-01,
  9.72347041e-01, -1.36704124e-01, -5.43881873e-01,
```

```
        -7.36680712e-01, -9.19845593e-01, -2.60981740e-01,
         6.44810870e-01,  3.88090687e-01,  2.60865480e-01,
        -3.20995505e-01,  3.90699758e-01],
       [-3.55609000e-01, -2.94970922e-01, -9.52051343e-01,
         2.52880761e-01, -7.10176815e-01,  8.69320675e-01,
         4.39380042e-01,  6.54536542e-01, -1.91907684e-01,
         3.62475919e-01,  2.27236827e-01, -8.10052545e-01,
        -7.33974625e-01,  5.56734424e-01,  4.98404400e-01,
        -6.96181027e-01,  1.17548652e-01,  4.41861006e-01,
         8.59672490e-01, -4.11337789e-01,  9.30547187e-01,
         1.16921399e-01,  6.40018997e-01,  1.14157426e-01,
         4.48593004e-01,  9.51259893e-01,  4.23029150e-02,
        -6.26333662e-02,  7.12177887e-01,  6.21091541e-04,
        -9.63159271e-01,  8.40033530e-01],
       [ 1.85484161e-01,  1.89837437e-01, -5.75337695e-01,
         6.41982258e-01, -1.57098232e-01, -2.20290597e-01,
         1.61073208e-01, -8.44021313e-01, -8.91341322e-01,
        -8.68559766e-01,  3.38251388e-01,  4.51497108e-01,
         8.17831128e-01,  7.94919740e-01,  9.71761909e-01,
         9.84505391e-01, -2.63204298e-01, -1.05362723e+00,
         1.85377925e-01, -3.04749421e-01,  2.72479074e-01,
        -8.68044333e-01, -2.48508076e-01,  8.30137204e-01,
         5.15034765e-01,  1.90894674e-01,  5.40662369e-01,
         6.45512963e-01,  6.93392658e-01, -5.98588019e-01,
        -3.86113714e-01,  7.89279838e-01],
       [-5.25615685e-01, -4.68344345e-01,  2.37584376e-05,
        -8.49223769e-01, -5.62834222e-01, -4.64468494e-01,
        -2.60553941e-01, -4.56836397e-01,  1.54690415e-01,
         1.74395769e-02, -3.74319484e-01, -2.14169929e-01,
         1.66875229e-01,  7.52755690e-01, -3.57465892e-01,
         2.49625356e-01, -5.66322016e-02,  5.82092456e-01,
        -6.29009883e-01, -3.85910481e-01,  4.04302173e-01,
        -1.53794456e-01,  6.23616500e-01,  5.04908863e-01,
         3.27964487e-01, -3.50787808e-01, -3.88843180e-01,
        -9.52319929e-01, -8.65547493e-01,  6.90464535e-01,
         7.61271638e-01, -5.05894003e-01],
       [ 5.82466438e-01,  7.01703858e-01, -2.66588724e-01,
         3.30492136e-03,  2.04459146e-01, -6.22998688e-02,
        -1.03856974e+00,  2.98982493e-01, -9.86201668e-01,
        -8.92233807e-01, -9.14474243e-01, -4.99321517e-01,
         8.34312699e-01, -7.07867716e-01, -5.74386867e-01,
        -5.67730861e-01,  3.57988543e-01,  7.28168863e-01,
        -1.75162771e-01,  7.95825869e-01, -3.52272212e-01,
         6.52397516e-01, -2.84561036e-01, -5.41577450e-01,
         9.66899997e-01,  7.13536870e-01, -5.38683031e-01,
         2.10055455e-01, -4.15494245e-01, -1.06920697e+00,
        -5.64097057e-01,  3.93038752e-02],
       [ 6.93810860e-01,  8.66425553e-02, -9.25243532e-01,
        -4.60677966e-01, -4.84122549e-01,  5.33914557e-03,
         7.85106780e-01,  8.87126781e-01,  5.91000207e-01,
        -3.56880022e-01, -7.83294246e-01, -6.34705915e-01,
        -5.78954140e-01, -1.82010381e-01,  8.81056892e-01,
         4.03915049e-01, -8.65178472e-01, -9.05844255e-01,
         6.45363846e-01,  9.77172304e-02, -4.78320396e-01,
        -8.75685667e-02,  5.50725541e-02, -9.37629321e-01,
         8.08731386e-02,  9.84484811e-01,  1.58998752e-01,
         4.93444486e-02, -7.44101213e-01,  6.85268561e-01,
        -6.53078576e-02,  7.85905841e-01]])}
{'B1': array([0.52744278, 0.64741801, 0.52126945, 0.50745116, 0.49358085,
       0.45590788, 0.53148459, 0.49328729, 0.59640836, 0.60261716,
```

```
            0.49040837, 0.51833081, 0.3988355 , 0.48885021, 0.35112468,
            0.53924811])}
        {'W2': array([[-0.39211907, -0.85721195, -0.05785948, -0.11894905,  0.28552203,
              0.14037353,  0.78285912, -0.19317282, -0.13035841,  0.3639726 ,
              0.90295421,  0.90459497,  0.92640168,  0.95084925,  0.75593934,
              0.37133172],
            [ 0.70640044, -0.93320966, -0.48691724, -0.69047592, -0.45888284,
              0.86786799,  0.20420154,  0.35552053, -1.04213514, -0.39336306,
             -0.35134908, -0.04540253,  0.68761144,  0.77360779, -0.1885527 ,
             -1.02309937],
            [ 0.17447297,  0.66815275,  0.56257784, -0.82854649,  0.96491516,
             -0.52220533, -0.92979356, -0.42134936,  0.50323228, -0.94589797,
             -0.06230193, -0.497384  ,  0.82579439,  0.56109603, -0.68796698,
             -0.40674701],
            [ 0.78412351, -0.89423582,  0.30548243,  0.66018453,  0.701093  ,
              0.08483697, -0.07871317, -0.35073796,  0.40114346, -0.95007349,
              0.23841398,  0.80322852,  0.78187415,  0.59310363,  1.04210248,
              0.853381  ],
            [ 0.76310959,  0.72869497, -0.44146186,  0.9119025 , -0.16915071,
              0.05564149,  0.83612259, -0.26006792, -0.38641989, -0.181703  ,
              0.76147938,  0.23569024, -0.02160998,  0.28236841, -0.3353777 ,
              0.43503306],
            [-0.8515748 , -0.77553216,  0.02893076, -0.60446448, -0.66508294,
              0.0611998 , -0.48776832, -0.70377758,  0.95887351,  0.96199714,
              0.09414913, -0.0195748 ,  0.62345727, -0.17568507, -0.42866115,
              0.80018724],
            [ 0.2300981 , -0.49167989, -0.75952362,  0.41001491,  0.93924947,
              0.10657324, -0.08940458, -0.56054647, -0.75201437, -0.00839819,
              0.19375444, -0.31517569,  0.46739112, -0.75534821, -0.10165073,
              0.96034956],
            [ 0.15047732,  0.61834208,  0.7713447 ,  0.58862075, -0.58781266,
             -0.32578887,  0.42587872,  1.20445116,  0.60977507,  0.97341085,
             -0.66068262,  0.05257429,  0.80182712,  0.76883645, -0.386285  ,
              0.20533193],
            [ 0.28794145, -0.18151763,  0.98663779,  0.36406816,  0.26733212,
             -0.45097831,  0.95818253, -0.48731537,  0.17900809,  0.56246732,
              0.0579746 , -0.78038287,  0.50330403,  0.04527049, -0.72974603,
              0.34024219],
            [ 0.96800298,  0.88842858,  0.99516653,  0.85857122,  0.00360315,
              0.98309447,  0.77862351,  1.03692781, -0.26307942, -0.89970706,
             -0.9319665 ,  0.70827093, -0.63461612, -0.24278307,  0.07518342,
             -0.78297887],
            [-0.26694814, -0.64743783, -0.96689613,  0.7253469 ,  0.87831359,
              0.67351568, -0.15513389,  0.22010093, -0.47083157, -0.32801575,
              0.05565517, -0.95859212,  0.01207235, -0.63020095, -0.57971538,
              0.22138042],
            [ 0.74231854, -0.57106104,  0.62318283,  0.60277175, -0.89732236,
             -0.23524596, -0.02754368, -0.99104612,  0.28136241,  0.83928967,
              0.3037424 ,  0.71673448, -0.69321425, -0.0824096 , -0.99309433,
              0.72781256],
            [-0.79288836, -0.64570458, -0.57762914, -0.92469518,  0.98160528,
             -0.24421691, -0.54566665,  0.24432985, -0.69068534,  0.71370142,
             -0.81581636, -0.80551447,  0.84663682, -0.02676368,  0.76557768,
              0.43140539],
            [ 0.9992168 ,  0.39140756, -0.43781149, -0.68303305,  0.19031544,
             -0.01902004,  0.7809153 , -0.5344656 ,  0.5476201 , -0.65433409,
              0.95760204,  0.09650736,  0.28826399, -0.55281956, -0.96993061,
             -0.70384836],
            [ 0.16503139,  0.60811779, -0.3194037 , -0.73558303,  0.85351362,
             -1.02015572,  0.44568708, -0.67601162, -0.89132324, -0.68556271,
```

```
        -0.65939191, -0.04090106,  0.75708205,  0.19234765,  0.4658718 ,
         0.76133112],
       [ 0.41866869,  0.94560535,  0.69029774, -0.96615935,  0.20877882,
         0.47696605,  1.01689319,  0.79482554, -0.58718642,  0.94733853,
         0.20518229,  0.46645782, -0.81190708, -0.91586776, -0.60067482,
        -0.90109466]])}
{'B2': array([0.45344317, 0.43804704, 0.49409304, 0.52675958, 0.5737221 ,
       0.53227874, 0.50149061, 0.56443421, 0.50691654, 0.5184838 ,
       0.50319882, 0.50338705, 0.4951867 , 0.51348382, 0.46422412,
       0.53803177])}
{'W3': array([[ 0.40514135, -0.06309987,  0.00447166, -0.68015257, -0.46606328,
         0.71704307, -0.79474216, -0.62339401,  0.32393417, -0.1422745 ,
        -0.32165744, -0.2039168 ,  0.01767454,  0.34289544, -0.24007413,
         0.01976158],
       [ 0.56012657, -0.73254112,  0.88621071, -0.02248174,  0.36674581,
         1.01938553, -0.76641891, -0.26809844,  0.55925539, -0.497184  ,
         0.46192507,  0.88116929, -0.32276011,  0.80791552, -0.20135248,
         0.41117561],
       [ 0.76728671, -0.6639007 , -0.58949302, -0.75536576, -0.41393699,
        -0.68885362, -0.65471634,  0.191572  , -0.3212881 , -0.1596386 ,
         0.18927589,  0.57783392, -0.32540294,  0.67038502,  0.85213956,
        -1.00818903],
       [ 1.07084977, -0.11942759,  0.56730975, -0.53320399,  0.80504062,
        -0.75575184, -0.51930179,  1.23424083,  0.34066832,  0.66460817,
        -0.82810236,  0.86542582,  0.66756347,  0.53175931, -0.42522249,
         0.48303681],
       [ 0.74655239,  0.24279199, -0.68803804,  0.56954098, -0.74854754,
        -0.23964836, -0.34400681, -0.80456908, -0.44825672, -0.98624097,
         0.72973024,  0.2984429 , -0.41331002, -0.12934685,  0.85929151,
        -0.32937829],
       [ 0.33913512, -0.96272274,  0.73186987, -0.70154972,  0.80510817,
        -0.0775732 ,  0.67096978, -0.33759906, -0.26502108,  0.01991086,
        -0.799072  ,  0.90324883,  0.01816652,  0.51531655,  0.91167327,
        -0.44086908],
       [-0.47507131,  0.48148275, -0.69169342, -0.34589926,  0.608733  ,
         0.5370588 ,  0.46717855,  0.99641152,  0.5646842 , -0.26743274,
         0.54367985,  0.93684135, -0.62962548, -0.23944855,  0.49835646,
         0.09458445],
       [-0.01548792,  0.29916961,  0.20109432,  1.32399298, -0.35530339,
         0.62028903,  0.15472972,  1.00820596, -0.55597824,  1.11561165,
        -0.59662874,  0.876566  ,  0.70813341,  1.12177361, -0.47260279,
         1.30645925],
       [ 0.60585231, -0.58161492, -0.73943155,  0.16914912,  0.12359442,
         0.69179038, -0.20640241,  0.00394084,  0.64059685, -0.37278045,
         0.71927291,  0.44392081, -0.08628115, -0.88699897, -0.47412348,
         0.17777885],
       [-0.46058535, -0.63996726, -0.17839583,  0.86240219, -0.98821227,
         0.10888624, -0.33539367,  0.61279742,  0.18891291, -0.05679742,
        -0.8610192 , -0.69551827, -0.43128095,  0.65223341,  0.25953371,
         1.0769651 ],
       [ 0.50391404, -0.37962954,  0.808759  , -0.36162111, -0.61095574,
         0.9440685 , -0.9070952 ,  0.73641805,  0.55089759, -1.22264114,
         0.81784827,  0.507832  ,  0.09104002,  0.31276343, -0.33299867,
         0.53774955],
       [-1.10600986, -0.04362382, -0.32811194, -0.11548215, -0.98638883,
         0.5245861 , -0.06699116,  0.1548176 ,  0.66125118,  0.72112408,
        -0.7453031 ,  0.34468362,  0.0564805 ,  0.42837837,  0.79635974,
         0.56629373],
       [ 0.18850909,  0.41039633, -0.16558396,  0.01807652, -0.39958149,
        -0.90804722,  0.03879288, -0.34509798, -0.69558074,  0.72620216,
```

```
          0.28803862,  0.37001449,  0.18751458, -0.65214508,  0.82848513,
          0.68248464],
        [-0.51260467,  0.35974717,  0.54684954, -0.42320897, -0.66951586,
         -0.58816107, -0.83913038, -0.309168  ,  0.02219574,  0.89759824,
         -0.8011127 ,  0.6822883 , -0.63945912, -0.53658532, -0.59162569,
         -0.0532141 ],
        [-1.05772874,  0.18300736, -0.65330729,  0.09241716, -0.14120979,
         -0.63756638,  0.82392264, -0.09399829,  0.16920453,  0.07537282,
          0.49721645, -0.53653501,  0.72382943,  0.31731686, -0.49014331,
          0.70172158],
        [-0.46751439,  0.81632077,  0.05563707,  0.91693243,  0.42970813,
         -0.0638794 ,  0.28198291, -0.21712884,  0.12806715, -0.68394137,
         -0.06678651,  0.23978796,  0.26914216, -0.97949784,  0.68864641,
         -0.61580391]])}
{'B3': array([0.47412365, 0.51164153, 0.48423689, 0.55921915, 0.50001228,
       0.49982586, 0.50514137, 0.56983006, 0.50899383, 0.51734298,
       0.44694731, 0.48620112, 0.5175672 , 0.49493187, 0.45454214,
       0.49692697])}
{'W4': array([[-0.45942746,  0.55674512, -0.13877797, -0.37979569,  0.24473661,
         -0.58511447,  0.88850228,  0.18568081,  0.14409015, -0.72931712,
         -0.63550121, -0.02439618,  0.96324496, -0.34248203, -0.37355921,
         -0.97815383],
        [ 0.97439512,  0.14506516, -0.8888176 , -0.12448852,  0.583695  ,
          0.92738317,  0.39478346,  1.40082425,  0.01095813,  0.50211615,
         -0.58515303,  1.13291879, -0.51186864, -0.11306212,  0.23990407,
         -0.90934495],
        [ 0.32239839, -0.20061169,  0.91060922, -0.50399651,  0.5667696 ,
          0.19651178,  0.60788751, -0.32475139, -0.24487034, -0.08545436,
          0.85074101, -0.36072552,  0.87349341,  0.60337552,  0.38089077,
          0.77182135],
        [ 0.86921764,  0.44368795, -0.8574338 , -0.72589289,  0.28984464,
          0.75414826,  0.29388232,  0.36246088,  0.30000635, -0.11883045,
         -0.79459657, -0.13017828,  0.97160707,  0.18036612, -0.66343565,
         -0.23311679],
        [ 0.82035229,  0.39208505, -0.10820771, -1.00518585,  0.09152193,
         -0.3175418 , -0.35824243, -0.83378738,  0.24378321,  0.53377377,
          0.10159942, -1.05781619, -0.21467706, -0.55137339,  0.44462494,
          0.45203379],
        [ 0.77610342, -0.07925858,  0.09946524, -0.39125533,  0.58366998,
         -0.46178337, -0.78240214, -1.22036567,  0.50139654, -0.98196714,
         -0.13390873,  0.7138413 , -0.64519454, -0.24225318,  0.20737352,
          0.59135173],
        [-0.57515071,  0.27758665, -0.6643944 , -0.60223411, -0.019941  ,
          0.60673006,  0.60715921, -0.38363124, -0.15618482, -0.82418316,
         -0.96767592,  0.47558212, -0.46384037,  0.58657959,  0.67623915,
         -0.55460389],
        [-0.34317979, -0.94092619,  0.88512056,  0.20011103, -0.529923  ,
          0.79420787, -0.587174  ,  0.60877872, -0.43276421,  0.2916031 ,
         -0.50940987,  0.29912302,  0.04437085,  0.95128245,  0.5711632 ,
          0.24160165],
        [ 0.09779586, -0.07105538, -0.33683116, -0.31549847, -0.21456459,
          0.25573084,  0.70901351, -0.38105238,  0.05001975, -0.91123598,
         -0.11217879,  0.07616276,  0.46537421,  0.44196259, -0.26816274,
         -0.69659595],
        [-0.49789565,  1.00373164, -0.96090939, -0.20974857,  0.85254364,
         -0.79898446,  0.905269  ,  1.14182464,  0.66679412, -0.40622686,
         -0.59387778, -0.50559146,  1.08142832,  0.48122549,  0.62136786,
         -0.40751241],
        [ 0.01264231, -0.44954084,  0.84912342,  0.91133707,  0.91847359,
          0.43373552,  0.68856485, -0.4168292 , -0.82997174, -0.40822279,
```

```
        0.39595568, -0.05555057,  0.09732001,  0.10405217,  0.6783524 ,
        0.91953227],
       [-0.51938442,  0.07294621, -0.45315994, -0.85103824, -0.16443874,
        0.53996848, -0.10695716,  0.3043536 , -0.82971285,  0.77615628,
        0.59982803,  0.9055684 , -0.72655429,  0.59290891, -0.85526598,
        0.08522276],
       [-0.2015366 , -0.78361943, -0.97240136,  0.34441644, -0.93749258,
        0.41240637, -0.78842757, -0.66521388, -0.30787907, -0.44190152,
       -0.57920533,  0.53065308, -0.90930268,  0.74532753, -0.53965484,
       -0.03199129],
       [-0.7655565 , -0.86243564,  0.74798971,  0.7679428 ,  0.59654383,
       -0.34197367,  0.24094359,  0.08977391, -0.44314594,  0.15584919,
       -0.28359043, -0.17141289, -0.68644725, -0.69546265, -0.52116961,
       -0.93241082],
       [ 0.02327448, -0.00321274,  0.10603066,  0.94587073, -0.39600523,
        0.44146545,  0.93905005, -0.8099026 , -0.07261247, -0.29241534,
       -0.91809728, -0.01726102, -0.40223318, -0.57989054, -0.40077578,
       -0.37478513],
       [ 0.30822012,  0.99506489,  0.97800812, -0.92947232,  0.08047389,
        0.02140652, -0.38987846, -0.76980172, -0.40998887, -0.87516079,
       -0.80596623,  0.40562471, -0.52990534,  0.7245955 , -0.8913628 ,
       -0.87382439]])}
{'B4': array([0.49991911, 0.53251419, 0.49275724, 0.49984953, 0.46966592,
       0.4729307 , 0.47372738, 0.49789524, 0.5       , 0.52369411,
       0.50964112, 0.48879887, 0.5       , 0.49799808, 0.50197006,
       0.5       ])}
{'W5': array([[ 4.68437519e-01,  1.32004033e-01,  1.82258588e-01,
        -9.54015735e-01, -7.33416169e-01, -2.77290985e-01,
        -7.42451102e-01,  6.05178598e-01, -8.56431502e-01,
         1.82879662e-01, -4.93744708e-02,  9.70254680e-01,
        -8.40572461e-01,  3.74104859e-01,  6.75902352e-01,
        -9.27915705e-01],
       [-4.07983132e-01, -6.61386734e-02, -1.60581834e-01,
        -7.49607550e-01, -7.63595226e-01, -3.69831583e-01,
        -1.03223133e-01, -1.23712551e-01, -3.49045975e-01,
         4.39490941e-01, -3.30888734e-01,  2.30332163e-01,
         3.77924719e-01, -8.25226285e-01,  6.81036307e-01,
        -6.65235404e-01],
       [-1.53574727e-01,  1.00274355e+00, -6.40601372e-02,
        -9.17856433e-01,  3.19356170e-01, -4.06354433e-01,
        -4.87250460e-01,  7.23704290e-01, -7.72746162e-01,
         4.80761263e-01,  2.61123132e-01,  4.39768395e-02,
         4.54739148e-01, -2.90004090e-01, -4.92904440e-01,
        -9.62907797e-02],
       [ 8.86223880e-01, -3.18167077e-01,  8.08087753e-01,
        -2.05974462e-01,  2.22209257e-01, -8.94875301e-01,
         4.58070746e-01,  2.69704936e-01, -9.83938254e-01,
         6.62932174e-01,  8.35548147e-01, -8.20681017e-01,
        -6.32952287e-01,  9.05337998e-01,  2.61159025e-01,
         3.18724162e-01],
       [-8.47605033e-01, -1.20892453e+00, -3.54381277e-01,
         5.50999759e-01,  8.14211877e-01,  8.04128169e-01,
         6.18399948e-01, -5.81227876e-01, -9.02361221e-01,
        -8.32023496e-01, -4.50217879e-01,  6.98020419e-02,
         5.71502191e-01,  9.14183684e-01,  1.11661489e-01,
        -7.86306594e-01],
       [-8.08431195e-01, -6.41989502e-01, -8.85932131e-01,
        -1.67407501e-01, -5.71219925e-01, -5.43030244e-01,
         5.07218899e-01, -5.78888490e-01, -1.57904385e-01,
        -9.99893027e-02,  7.46329745e-01,  1.30199122e-01,
```

```
         4.97322332e-01,  3.54552348e-01,  7.80175344e-01,
         5.19150651e-01],
       [ 5.85604552e-01,  4.43108852e-01,  9.41155550e-01,
        -9.65056646e-01, -3.66363004e-01,  2.69819561e-02,
        -8.24511637e-01, -3.05045624e-01,  3.32980870e-01,
         9.81861693e-02,  7.38671398e-01, -1.72900308e-01,
        -7.81346925e-01, -4.24060241e-01, -7.48167183e-01,
         5.89221037e-03],
       [-3.72562132e-02, -8.66575273e-01, -8.42399971e-01,
         7.35974683e-02, -1.63822390e-01, -9.99875026e-02,
         1.56964045e-01, -2.49789700e-01,  5.31117816e-02,
        -1.29669982e-01, -1.36536262e-01,  5.13153392e-01,
         4.30599506e-02, -6.31340172e-01,  3.95721137e-02,
         3.46418220e-01],
       [ 9.98665287e-01,  6.56206876e-01,  4.96564659e-01,
         7.39952369e-01,  9.98614336e-01,  3.42668967e-01,
         7.19083859e-01,  7.00737327e-01, -1.26897790e-01,
         5.28611981e-01, -3.78147657e-01, -5.25972806e-01,
        -8.94843239e-01, -4.24751813e-01,  9.59607979e-01,
        -3.27392016e-01],
       [-3.05432073e-01, -3.28154700e-01, -9.99754265e-01,
        -9.75877087e-01,  2.91796432e-02,  5.19949349e-01,
         8.69055127e-01, -1.88515902e-01, -7.89399632e-01,
        -7.79134139e-01,  4.48448106e-01, -7.57742397e-01,
        -1.35316538e-01,  3.87895955e-01,  9.42915647e-01,
         3.09043698e-01],
       [ 7.13038499e-03,  4.68464667e-01, -4.12069134e-01,
         4.90952588e-01,  9.15994556e-01,  4.45459385e-01,
        -7.43319558e-01, -5.76472765e-01, -9.42446800e-01,
        -7.09122131e-01, -8.60301480e-01,  1.63781761e-01,
        -3.71239722e-01, -5.39646540e-01, -7.42423036e-01,
        -8.68660290e-01],
       [ 5.85460801e-01,  6.79121799e-01, -7.09404110e-02,
         1.40198181e-02, -8.79289124e-01, -4.73243454e-01,
         3.02477967e-01, -7.06151944e-01,  5.10515331e-02,
         8.41094546e-01, -8.92473327e-01, -1.70937783e-01,
         8.97514326e-01, -9.07364909e-01, -1.28966256e-01,
         8.56069429e-01],
       [ 4.33987839e-01,  9.03542567e-01, -4.75296598e-01,
        -8.59104313e-01, -7.78288052e-01,  2.72610809e-01,
        -2.54309930e-01, -9.36205848e-01,  2.90496606e-01,
        -6.01054820e-02, -8.08030510e-01,  6.12515151e-01,
        -8.70869529e-01, -1.99922149e-02,  3.55530298e-01,
         7.17957561e-01],
       [-2.94737433e-01,  1.78938352e-01,  1.29175823e-01,
         6.42170223e-01, -8.16387384e-01,  6.52504616e-01,
        -1.74095690e-01,  9.98032328e-01,  2.10371518e-01,
         8.66445881e-01,  1.86539194e-01, -9.23217204e-01,
         1.57048165e-01, -5.31677578e-01,  2.13668351e-01,
        -4.10507403e-02],
       [ 8.45923684e-01,  1.21226768e-01,  9.35312838e-01,
        -4.88074895e-01,  4.23079190e-01,  3.13808510e-01,
        -9.65347533e-01,  3.85171954e-01, -2.30065746e-01,
         8.36920248e-01, -2.17724071e-04, -8.54336584e-01,
         2.08650250e-01,  1.74500459e-01,  4.05245732e-01,
        -2.39854652e-01],
       [-9.94013605e-01, -1.50116053e-01,  5.95196768e-01,
         6.96191422e-02, -6.62494801e-01,  5.75460990e-01,
         9.18472985e-01, -2.72495295e-01,  6.92286749e-01,
         2.27255431e-02, -5.71591239e-01, -3.38396444e-01,
```

```
        -8.27708913e-02,  6.85262312e-02, -2.18224353e-02,
         5.58103276e-01]])}
{'B5': array([0.50019306, 0.49986901, 0.50007161, 0.50010097, 0.46669321,
       0.50124327, 0.50026062, 0.49989151, 0.4982677 , 0.49338662,
       0.49991094, 0.50027223, 0.50315545, 0.5001429 , 0.50014689,
       0.49958588])}
```

Out[ ]: <machine_learning_functions.Model at 0x1e842833d50>

In [ ]:
```python
def complex_mathematical_function_experiment(function, epochs, learning_rate, hi
    neurons_per_layer_list = [input_neurons] + [neurons_per_hidden_layer]*hidden
    activation_functions_list = [Sigmoid() for _ in range(hidden_layers)] + [Non
    model = Model(
        FFN = FFN(
            neurons_per_layer_list=neurons_per_layer_list,
            activation_functions_list=activation_functions_list,
            cost_function=MSE()
        ),
        data_set=create_a_inputs_b_outputs_XY_data(
            a=input_neurons,
            b=output_neurons,
            function=function,
            random_x_function=random_x_generator,
            num_data_items=10000
        )
    )
    print(
        model.train_and_evaluate(
            learning_rate=learning_rate,
            epochs=epochs,
            batch_size=50
        )
    )
    model.print_FFN_parameters()
    return model
```

In [ ]:
```python
def pythagerous_function(X):
    a, b = X
    c = (a**2 + b**2)**1/2
    return np.array([c])

complex_mathematical_function_experiment(
    function=pythagerous_function,
    input_neurons=2,
    output_neurons=1,
    random_x_generator=lambda: random.uniform(-10, 10),
    hidden_layers=4,
    neurons_per_hidden_layer=10,
    epochs=20,
    learning_rate=10**-4
)
```

```
826.1524059854028
Parameters of network
{'W1': array([[ 0.56304594, -0.70286613],
       [-4.45720007,  5.76080034],
       [-0.14882578,  0.78182942],
       [-0.42953618,  0.09620127],
       [ 0.06753011, -0.8559187 ],
       [ 0.44008997,  2.02998988],
       [ 0.20274   , -1.11975257],
       [ 1.1316689 , -0.21597949],
       [-0.47337577, -0.38376731],
       [ 0.26034373, -0.74415172]])}
{'B1': array([0.46792926, 1.86286723, 0.49587635, 0.45561988, 0.38114442,
       0.70457421, 0.47414505, 0.39452113, 0.52001625, 0.47902841])}
{'W2': array([[-0.99656534, -0.0291583 ,  0.27362312,  0.85685396, -0.288289  ,
        -0.78383398,  0.41722696, -0.36665639, -0.94868803,  0.5635501 ],
       [ 0.65278481, -0.92997819,  0.47758893,  0.4613792 ,  0.82786383,
         1.00139893,  0.5132631 ,  0.41194329,  0.84236233, -0.42041361],
       [ 0.720952  , -0.16571122, -0.61105809,  0.13080033, -0.42074204,
        -0.23679621,  0.15344648, -0.98942997,  0.11656082,  0.18263149],
       [ 0.94734904, -0.54561613,  0.70456828, -0.0767369 , -0.05077682,
         0.86704126,  0.0860287 ,  0.30713814,  0.16668957, -0.07736793],
       [ 0.88078037, -1.08881536, -0.32139535, -0.22129862, -0.2911662 ,
        -0.9506279 , -0.33667074,  0.81666622, -0.78072451,  0.53646143],
       [-0.25289453, -0.01218813,  0.27771347, -0.21624222, -0.08445848,
        -0.78130593, -0.93759185,  0.4639343 ,  0.58246362, -0.7311715 ],
       [ 0.54698691, -0.36398505, -0.63279683, -0.92463633,  0.98515896,
        -0.16439991, -0.10322686,  0.96923633,  0.6952061 , -0.08393717],
       [ 0.96950517, -0.69220255, -0.1002693 , -0.04357604, -0.2864734 ,
         0.24224327,  0.5867324 ,  0.71561956, -0.04078272,  0.15248874],
       [-0.06861817,  2.36522031,  0.02153851,  0.84809754,  0.45891475,
        -0.1438247 , -0.67395617, -0.44503888,  0.35250002, -0.51411047],
       [ 0.95202452, -0.59402296, -0.78792237, -0.44811339,  0.68962874,
        -1.03509856, -0.47956526, -0.65890561,  0.20792172, -0.83500176]])}
{'B2': array([ 0.68200892,  0.49673724,  0.66838566,  0.41793783,  0.64873287,
        0.53540267,  0.56229157,  1.37361009, -1.53777074,  0.32178897])}
{'W3': array([[-2.31214103e-01, -2.09877841e-01,  7.15622597e-01,
         4.47690220e-01, -1.39923828e-01,  7.52713700e-01,
        -8.38045373e-01, -7.84500704e-01, -4.68184414e-03,
         1.41693473e-01],
       [ 5.41562292e-01,  6.72181952e-01, -3.14773468e-01,
         7.56776533e-01, -2.78797383e-01, -2.42835835e-01,
         4.97739834e-01,  4.85024247e-01,  7.33692920e-01,
        -9.22909956e-01],
       [ 3.54589310e-01, -1.87239130e-01,  1.29219082e-01,
        -3.91211913e-01,  1.00536530e-01,  4.97761596e-01,
        -2.94919385e-01, -4.75037087e-01, -9.79481043e-01,
         9.27021298e-01],
       [-8.58147660e-01, -4.54787923e-01,  3.77907224e-01,
         5.74362895e-01,  6.21561235e-01,  5.46966327e-01,
         3.76762915e-01, -9.15224328e-01,  4.24053755e-01,
        -4.52386871e-01],
       [ 2.07430496e-01, -8.74862929e-01, -6.28715317e-01,
        -2.15505015e-01,  7.85029946e-01, -7.07327206e-02,
        -8.09618934e-01,  4.50426474e-01, -2.22748444e-02,
        -7.85920603e-01],
       [ 6.18837800e-01, -5.85067364e-02, -5.42871392e-01,
         6.69732880e-01, -5.93747737e-01, -1.01329981e-01,
         7.61350984e-02, -5.98589768e-02,  9.17247590e-01,
         7.67449794e-01],
```

```
       [ 2.04698608e-01, -1.72432911e-02,  2.13372101e-02,
         4.21551252e-01, -2.33416582e-01,  4.98089055e-01,
        -2.49445926e-01, -3.21153145e-01, -2.01186827e-01,
        -5.26222006e-02],
       [-9.77724042e-01, -1.14241772e-01, -6.70493134e-01,
         7.12484256e-01,  6.33963721e-01,  3.17091563e-01,
         3.24749275e-01,  5.90053525e-01,  4.10184210e-01,
        -1.52003708e-01],
       [-9.70441309e-01, -1.57155112e-01, -8.25197515e-01,
        -1.77848950e-01, -8.38765226e-01, -5.08501582e-01,
        -4.75789789e-01, -2.47536193e+00, -1.02686077e+01,
         3.35061023e-01],
       [ 3.77707019e-01,  6.29077774e-01, -6.93377506e-01,
        -9.74063050e-01, -8.12422453e-01, -1.02266400e-01,
        -4.25391988e-01, -8.98064604e-01,  1.50167435e-01,
         9.08216701e-01]])}
{'B3': array([ 0.54831008,  0.52879622, -0.01269036,  0.81713357,  0.39942751,
        0.64257347,  0.26821781,  0.67760159, -7.73356512,  0.39889383])}
{'W4': array([[-5.16422782e-01, -1.46960497e-01,  9.35940209e-03,
         3.27473817e-01,  5.84115558e-01,  4.71105032e-01,
        -8.70919318e-01,  9.02853765e-01, -1.31651149e-01,
        -8.83792555e-01],
       [ 7.62562715e-01,  4.99888031e-01,  3.15463444e-01,
         8.73992862e-01,  1.75297476e-01,  4.59673467e-01,
        -5.41229488e-01, -5.62673859e-01,  3.72082534e-01,
         2.56817552e-01],
       [-3.74636641e-01,  1.03111044e-01, -7.75192761e-01,
         8.47565085e-01, -4.89983542e-01, -6.53818670e-01,
        -2.21405503e-02, -1.49832729e-01, -8.02786793e-01,
         1.03012986e+00],
       [ 7.57428623e-02,  8.09695462e-01, -6.84128316e-01,
        -3.87805692e-02, -3.39088429e-01,  3.25764426e-01,
         6.60505074e-01,  8.47598686e-01,  3.86575787e-01,
        -5.81912728e-01],
       [ 5.78005574e-01, -6.80676678e-01,  8.79234651e-01,
        -1.01053745e+00, -1.33264699e-02,  9.21959287e-01,
         1.47725604e-01, -9.67841794e-01, -1.56834694e-01,
         6.24901289e-01],
       [ 2.87310836e-01,  4.98161578e-01,  2.99886614e-01,
         6.04066989e-01, -4.94507870e-01,  4.48564657e-01,
         3.62245273e-01, -1.60662795e-01,  4.77690017e-01,
         3.76005981e-01],
       [-8.73081874e-01,  8.32546238e-01, -2.21870688e-01,
         4.75679475e-02, -2.13019748e-01, -7.26833788e-01,
        -7.20236303e-01, -4.18960322e-01, -5.43470761e-02,
         1.37287770e-01],
       [ 9.47674221e-01, -6.79126374e-01, -8.20440921e-01,
        -6.07226532e-01,  4.06647513e-01,  5.36074389e-01,
        -4.27773570e-01, -1.63736468e-02,  9.29100414e-01,
        -5.07708379e-01],
       [ 7.92879662e-01,  4.80877734e-01,  9.95582169e-02,
         9.58284160e-01, -4.15554171e-01,  8.23359019e-02,
        -8.84314615e-01, -4.29598720e-01,  9.90482540e-01,
        -3.18897121e-01],
       [-4.15443913e-01,  4.41321260e-01, -8.81867808e-03,
        -1.25404826e+00,  1.17109450e-01, -8.84881925e-01,
         5.28596273e-01,  5.52336359e-01, -1.22253184e+01,
         1.35936938e-01]])}
{'B4': array([ 0.85472172,  1.15389946,  1.08288752,  0.95161208,  0.18336971,
        0.59971387,  0.31172581,  0.86071106,  0.64176426, -5.04995126])}
```

```
{'W5': array([[0.88613741, 1.52398442, 1.28366721, 1.27979239, 0.03170021,
        0.48919392, 0.31150676, 0.9005003 , 0.59097771, 0.78051047]])}
{'B5': array([15.97118776])}
```

Out[ ]: <machine_learning_functions.Model at 0x1e842ac7250>

In [ ]:
```
coefficients = [random.uniform(-1, 1) for _ in range(10)]
def polynomial(X):
    x = X[0]
    result = sum(
        coefficients[i]*x**i
        for i in range(10)
    )
    return np.array([result])

complex_mathematical_function_experiment(
    function=polynomial,
    input_neurons=1,
    output_neurons=1,
    random_x_generator= lambda: random.uniform(-10, 10),
    hidden_layers=4,
    neurons_per_hidden_layer=10,
    epochs=20,
    learning_rate=10**-4
)
```

```
3.334399902288701e+16
Parameters of network
{'W1': array([[-103.94643444],
       [-928.46176283],
       [  38.58359977],
       [  14.93198346],
       [ 136.88349599],
       [ -15.12756174],
       [ -38.04405694],
       [  37.27344988],
       [ -85.47113308],
       [  55.25004604]])}
{'B1': array([  8.71810716, -94.77411351,  -5.02707505, -24.18040157,
       -14.67144544,   9.28587638, -36.60329994,  -3.81151203,
       -12.75633944,  -3.72147446])}
{'W2': array([[ -0.98802522,   0.42905777,  -0.66801885,   1.57875617,
          0.74616094,  -1.41459159,  -5.71679553,  -0.03933153,
         -0.60728857,   0.97578554],
       [ -0.04280951,  -0.96165479,   0.11832701,  -0.59664139,
         -0.32016336,   0.3292144 ,   3.02099164,   0.27880595,
          0.26307068,  -1.5617449 ],
       [ 16.52942064,  -3.39167586,  -6.39990724,   1.24514889,
         11.39901969,   4.24793422,   1.74686134,   4.78495963,
         -1.38773846,   1.1572887 ],
       [ -0.05037074,  -1.49871656,   1.82117988,  -1.15952339,
         -1.59921161,   0.85903612,   2.72694364,   0.24390972,
          0.80834524,  -1.25662419],
       [  1.191204  ,  -0.42966708,   0.50798767,  -0.20531313,
         -0.36798615,   0.59235303,   1.09480574,   0.76508775,
         -9.59727683,  -1.26634825],
       [ -0.25554368,   0.84675404,   2.39457224,  -1.47724954,
          0.22543133,  -1.56919299, -15.30803408,  -1.78405598,
         -1.09589949,   1.37529248],
       [  2.26006885,  -0.34422506,   0.83240423,  -1.67270418,
         -2.09439076,   0.9108908 ,   4.52851992,   0.48221192,
          1.77593914,  -0.55997113],
       [  1.34332049,  -1.3883745 ,   2.28989253,  -1.36223411,
         -2.82855135,   2.41030029,   6.1652899 ,   0.15897135,
          0.54320037,  -1.49595565],
       [ -0.16020459,  -0.66754811,   0.20660561, -10.52305821,
          1.12425884,  -0.07236424,  -0.16179095,   0.74747351,
         -0.86627152,  -0.47016942],
       [  1.1070267 ,   9.66714712,   0.52360398,  -1.5689415 ,
         -0.84257192,   7.60896213,   4.09096542,   0.47229777,
         -0.2856676 ,  -0.62924215]])}
{'B2': array([ -59.29893157,  -62.66930842, 3023.36014016,   60.50843407,
         69.4328883 ,  -83.25979194,   65.84455839,   69.57029078,
         71.27698817,  -98.59564246])}
{'W3': array([[-10.19924662, -12.23138468, -19.83211509, -14.78154457,
        -15.75230311, -19.98309521, -14.89142581, -15.82921216,
        -18.00576862, -14.93105562],
       [ -9.40220465, -10.1917058 , -18.09925661, -14.64458142,
        -15.37556525, -17.55608083, -14.90898992, -14.60253552,
        -15.87585112, -13.65035958],
       [  1.58155289,   3.61775053,  11.13642952,   5.34271382,
          6.50544148,   4.39249079,   4.22521702,   4.54861528,
          6.6263636 ,   4.32185522],
       [ -8.77369467, -10.40985887, -21.4929011 , -17.90774408,
        -21.23055106, -21.26396254, -19.64667854, -20.6393511 ,
        -21.3096736 , -17.4384872 ],
```

```
       [ -4.86728952,  -4.19014657,  -6.57915394,  -4.38523989,
        -11.5604303 ,  -9.07090026,  -6.7057343 ,  -6.43783128,
         -7.57849745,  -6.87097605],
       [  0.60672271,   2.74862926,  11.17632932,   3.41071416,
          4.64284261,   1.88965471,   4.21520823,   4.18759635,
          4.46517626,   4.08708999],
       [  0.49301444,   2.92056897,   9.66658771,   2.27646889,
          3.60186517,   0.10363005,   2.79988563,   2.93668302,
          3.67289396,   3.63720059],
       [  1.99986041,   5.5364781 ,  12.40157686,   5.81224008,
          7.32801763,   7.02188433,   7.38575807,   7.35359668,
          8.96089013,   6.32458308],
       [ -3.43293137,  -1.23898285,  -8.78648713, -10.42487978,
         -5.73193073,  -7.64074066,  -5.88023026,  -6.22116232,
         -7.15275867,  -4.38290511],
       [  5.57499085,   6.79485484,  17.43536851,   8.44940893,
         11.69106305,   9.14185636,   9.94424307,   9.42009171,
         10.33764424,   8.33667782]])}
{'B3': array([  -9.00950814,  -91.40745596,  327.54111251, -956.98391997,
        110.19543539,  369.90136649,  351.9065375 ,  387.60120441,
        119.57923448,  507.19611729])}
{'W4': array([[-5.04634256e+00, -4.24621402e+00,  8.69043021e+00,
        -1.12899848e+01, -4.33738170e+00,  9.46546519e+00,
         8.52635611e+00,  7.90301052e+00, -4.17849133e+00,
         1.10592278e+01],
       [-2.37264019e+00, -1.76828904e+00, -9.83770859e+00,
         4.36433965e-01, -5.59499738e-02, -8.93613052e+00,
        -1.08650225e+01, -9.35795724e+00, -2.83145238e+00,
        -1.18097308e+01],
       [-2.11522330e-01, -4.48144579e-01,  8.98454136e+00,
        -6.38413669e+00, -1.15702797e+00,  9.99697313e+00,
         1.14268948e+01,  9.11605405e+00,  4.15582105e-01,
         1.26308648e+01],
       [ 6.93392859e+01,  7.86760363e+01, -2.11845795e+01,
         8.54454841e+01,  4.13155280e+01, -3.49922603e+01,
        -2.75234803e+01, -3.44955774e+01,  4.97862730e+01,
        -6.45212140e+01],
       [-1.79104056e+00, -2.02271832e+00,  8.81151560e+00,
        -8.70617597e+00, -1.44801824e+00,  9.39638794e+00,
         9.77582612e+00,  9.04099232e+00, -1.04388372e+00,
         1.03274786e+01],
       [ 1.00134255e+02,  1.13489185e+02, -2.99374501e+01,
         1.23851579e+02,  5.98034850e+01, -4.95595433e+01,
        -3.90830474e+01, -4.91981032e+01,  7.20404431e+01,
        -9.36849511e+01],
       [ 4.35963369e+01,  4.89876312e+01, -1.40340441e+01,
         5.39387780e+01,  2.60201381e+01, -2.30485750e+01,
        -1.84134930e+01, -2.30687947e+01,  3.08571319e+01,
        -4.15009886e+01],
       [-6.08628197e+00, -4.71520419e+00,  7.96517814e+00,
        -1.18032676e+01, -3.07961214e+00,  8.56564251e+00,
         1.02220795e+01,  9.65478745e+00, -3.79090751e+00,
         1.11935165e+01],
       [ 2.86784736e+01,  3.12505266e+01, -1.13855804e+01,
         3.74044655e+01,  1.89474222e+01, -1.74207446e+01,
        -1.36660773e+01, -1.66331969e+01,  1.99571574e+01,
        -2.89271121e+01],
       [ 1.61435254e+00,  1.33872728e-01, -7.50241474e+00,
         3.92192422e+00,  1.74441198e+00, -8.61356911e+00,
        -9.36719730e+00, -7.15302022e+00, -1.91534724e-01,
```

```
        -1.12063221e+01]])}
{'B4': array([12338.54935797, -8390.20764028, 12456.20719462, -8465.95343807,
       12263.90751826, -9419.26871304, -9215.35888706, 12822.43313807,
       -9576.32577688, -8358.4833314 ])}
{'W5': array([[208.83126933,  55.70998384, 212.18839685,  48.89116254,
        206.77133928,  61.39033189,  72.52987001, 222.75088954,
         83.66332549,  54.96186237]])}
{'B5': array([7875123.67793858])}
```

Out[ ]: `<machine_learning_functions.Model at 0x1e842a80910>`

In [ ]:

```
def area_under_polynomial(X):
    # this find the area under some polynomial given by a set of coefficients wi
    a, b, coefficients = X[0], X[1], X[2:]

    antideriavitve = lambda x: sum(
        coefficients[i]*i*x**(i-1)
        for i in range(1, 10)
    )

    integral = antideriavitve(a) - antideriavitve(b)
    return np.array([integral])

model_integrate = complex_mathematical_function_experiment(
    function=area_under_polynomial,
    input_neurons=12,
    output_neurons=1,
    random_x_generator= lambda: random.uniform(-10, 10),
    hidden_layers=4,
    neurons_per_hidden_layer=10,
    epochs=20,
    learning_rate=10**-4
)
```

```
2.1909708833412882e+18
Parameters of network
{'W1': array([[-3.42435081e+03,  6.20589985e+03,  5.24664565e+03,
        -3.31644773e+03, -1.01306892e+04,  3.30148138e+03,
        -1.36195433e+04, -8.17296306e+03,  9.31025815e+03,
        -9.26415117e+03, -1.59138959e+04, -2.86481845e+02],
       [ 6.90868680e+02,  4.37287117e+02,  4.01278431e+02,
         1.58047271e+02, -4.08040017e+02,  3.95926061e+02,
         5.39872022e+02, -4.86699057e+01,  3.70689019e+02,
         6.17220469e+01, -1.42281162e+02, -9.97819215e+01],
       [ 3.26573267e+02,  4.85583280e+02, -5.57248031e+01,
         4.24779321e+02, -2.54115074e+02,  2.86803779e+02,
        -5.28479806e+01, -5.97558282e+02, -1.70677935e+02,
         2.89607385e+02, -2.23927139e+02, -3.45059606e+02],
       [-1.50334357e+02,  3.13117337e+02, -2.52817286e+02,
         1.76732034e+01, -9.54030555e+01, -1.03988684e+02,
        -1.14339851e+02, -7.29703572e+01,  2.18701227e+02,
        -7.08330829e+01, -5.98659200e+01,  3.45379990e+02],
       [ 9.48136487e+02,  1.81636488e+03, -8.35427054e+02,
         9.90313009e+02, -1.39064261e+01, -1.32771881e+03,
         1.28612433e+02, -1.99549595e+03, -8.09694826e+02,
         4.65300258e+02, -8.76238837e+02, -7.88282660e+02],
       [-8.28067995e+02,  3.55813454e+02, -1.90152796e+02,
        -4.32814560e+02, -7.64764349e+02, -7.38149018e+01,
         6.63255525e+02,  3.71920043e+02,  4.23701234e+01,
        -6.50687849e+02, -1.50426568e+02,  2.62313303e+02],
       [ 1.00291708e+03,  2.44479361e+02, -4.15239240e+02,
        -1.04678401e+03, -3.10871105e+02, -1.00100044e+02,
         1.74362498e+02, -1.01811487e+03,  8.67370967e+01,
        -7.23112504e+02, -8.04000115e+02, -1.11126778e+03],
       [ 1.81893121e+01,  1.60068388e+03,  1.05616458e+03,
        -1.19440387e+03,  2.62958989e+02, -8.73511229e+02,
         3.93043656e+02,  2.86667038e+02,  5.94614843e+02,
         3.10704525e+02, -8.38707112e+02,  4.34875938e+02],
       [ 5.58417578e+02, -1.04013598e+03,  5.50988975e+02,
         7.70522124e+02,  1.01973907e+03,  3.40647359e+01,
         4.88314625e+02, -1.55221476e+01,  1.01952349e+03,
        -4.90717358e+02,  4.94995436e+02, -1.63988843e+01],
       [ 2.80611032e+02,  5.40463745e+01,  2.19815233e+02,
         3.79218309e+02, -1.90671264e+02, -1.18224354e+02,
         2.43642576e+02,  4.91949267e+01, -2.47743458e+02,
         3.04544885e+02, -9.41606916e+01,  1.82852615e+02]])}
{'B1': array([-2316.2847465 ,    -7.51737667,    22.20967385,   -30.10761437,
        -121.86436639,   -38.36966537,    24.55394701,   -30.27825722,
          98.37576158,    13.08771805])}
{'W2': array([[ 6.47744171e+01, -1.53801897e+00, -5.93131756e+00,
        -1.54822073e+00,  1.46833593e+01, -1.03174659e-01,
         6.76062291e+00,  6.42060771e+00,  3.93864138e+00,
        -2.09557830e+00],
       [ 6.05518306e+01, -2.06335277e+00, -3.57556133e+00,
        -2.84923038e+00,  1.09263915e+01,  8.96721601e+00,
         4.84379289e+00,  1.21619704e+01,  6.37123849e+00,
        -2.50816321e+01],
       [ 1.04853789e+02,  1.06711097e+00, -5.84389709e+00,
        -3.67977827e-01,  2.86127557e+01,  8.37164223e+00,
         1.21383442e+01,  1.20717609e+01,  7.28349358e+00,
        -1.55359266e+01],
       [ 7.14375727e+01,  5.57820761e+00, -5.06552182e+00,
        -2.05061901e+00,  1.86898694e+01, -4.14883817e+00,
         8.32685518e+00,  6.44602545e+00,  5.38287680e+00,
```

```
         4.95891653e+00],
        [ 1.53709364e+02,  6.44546209e+00, -9.72565914e+00,
         -3.62234328e+00,  2.83490661e+01, -4.50868614e+00,
          1.14359242e+01,  1.50179099e+01,  6.30200362e+00,
          5.49218955e-01],
        [ 1.11049703e+02, -5.00079214e-02, -6.95191515e+00,
         -7.31813062e-01,  2.27783799e+01,  8.49698513e+00,
          9.27637729e+00,  1.61128189e+01,  7.66503174e+00,
         -1.65913014e+01],
        [-1.80415534e+02, -1.17418027e+01,  9.53776007e+00,
          4.06949775e+00, -5.25349950e+01,  9.55077826e+00,
         -2.17096825e+01, -1.58182427e+01, -8.17137777e+00,
         -4.35291966e+00],
        [-2.06793341e+02, -1.07246709e+01,  1.06988095e+01,
          2.71639187e+00, -3.74756809e+01,  3.28659349e+00,
         -1.35506875e+01, -1.62523770e+01, -7.90637281e+00,
          2.06837682e+01],
        [-1.16241293e+02, -3.23093722e+00,  4.43207890e+00,
          1.50259660e+00, -3.72057506e+01, -6.68090322e+00,
         -1.64815464e+01,  2.53170492e-01, -8.64424073e+00,
          5.44080086e+00],
        [ 5.60597223e+01, -2.22364982e-01, -4.53246821e+00,
          1.49851681e-01,  1.10555979e+01, -2.28913262e-01,
          4.23055654e+00,  7.21121915e+00,  5.51974234e+00,
         -1.05514636e+01]])}
{'B2': array([  6574.21325916,  24472.42735881,  10791.10996205, -10254.80340593,
         -9876.27040476,  13260.44613486,  15694.91245958, -10182.22871173,
         -2557.96158638,   9568.36241844])}
{'W3': array([[ 1.13091315e+03,  1.30532685e+03,  1.26033177e+03,
          9.89971978e+02,  9.93822361e+02,  1.27832775e+03,
          1.58419339e+03,  9.48943688e+02,  1.15817017e+03,
          1.00971404e+03],
        [-5.16788480e+02, -5.94256015e+02, -5.76412046e+02,
         -4.53176659e+02, -4.54352713e+02, -5.84313912e+02,
         -7.25767743e+02, -4.33230713e+02, -5.31846336e+02,
         -4.61656597e+02],
        [ 4.24293554e+02,  4.87648711e+02,  4.72751973e+02,
          3.71790679e+02,  3.71003813e+02,  4.78394672e+02,
          5.97068976e+02,  3.52642289e+02,  4.35035420e+02,
          3.78043400e+02],
        [ 4.16845810e+02,  4.77363753e+02,  4.64479729e+02,
          3.68059369e+02,  3.67996813e+02,  4.70822968e+02,
          5.84058125e+02,  3.53368012e+02,  4.30358627e+02,
          3.71506283e+02],
        [-1.37170746e+02, -1.67804550e+02, -1.64795180e+02,
         -1.21516708e+02, -1.32881636e+02, -1.68340550e+02,
         -2.15440892e+02, -1.32352928e+02, -1.61001646e+02,
         -1.21932712e+02],
        [ 1.45490573e+03,  1.66962970e+03,  1.61508421e+03,
          1.27673276e+03,  1.28258431e+03,  1.63968031e+03,
          2.03381581e+03,  1.22263942e+03,  1.49328904e+03,
          1.29543442e+03],
        [ 4.80740138e+02,  5.49762485e+02,  5.35586292e+02,
          4.26086787e+02,  4.25762824e+02,  5.40889276e+02,
          6.75225612e+02,  4.04637285e+02,  4.96685116e+02,
          4.28593546e+02],
        [ 1.55092744e+02,  1.58107891e+02,  1.53728340e+02,
          1.35617706e+02,  1.38714679e+02,  1.56214803e+02,
          1.95630968e+02,  1.12509981e+02,  1.57556931e+02,
          1.20393720e+02],
```

```
        [-7.38098988e+02, -8.44891886e+02, -8.20939419e+02,
         -6.50881561e+02, -6.51500819e+02, -8.30758319e+02,
         -1.03536964e+03, -6.19826135e+02, -7.62041538e+02,
         -6.56380963e+02],
        [ 8.79491112e-01,  4.58962357e-01,  2.78271034e-02,
          4.19652697e+00,  3.64045127e+00, -2.34423134e-01,
          5.35552338e-01,  2.21806205e+00,  2.72856166e+00,
          4.66767502e-01]])}
{'B3': array([ -41706.53060903,   18737.12924154,   17885.91561922,
        -55106.28402067, -108958.85679005,   40254.5549872 ,
        -16306.32083792, -216307.31116644,   19591.177802  ,
        -33496.09781628])}
{'W4': array([[   556.76279698,    117.05103743,    107.85169104,
           136.33639883,    129.46579535,    540.09239317,
            89.46999647,    139.65457589,    127.88163016,
            94.43569852],
        [  1162.05077562,    244.42428739,    224.48375511,
           284.0046473 ,    268.7706013 ,   1127.96355691,
           186.62799497,    293.17720426,    267.66656844,
           194.41035848],
        [   677.29717362,    142.93975544,    130.49508789,
           165.91307238,    157.06793433,    657.36986408,
           108.07351771,    170.1721496 ,    155.32927701,
           112.57128357],
        [  1038.32496998,    217.55174132,    199.17081613,
           252.71857264,    239.69523661,   1008.96056235,
           165.68652554,    261.59007292,    238.07349838,
           172.87509981],
        [   475.24834835,    101.02248221,     92.00331305,
           116.83302895,    111.18479548,    462.12231305,
            76.44741305,    119.80277269,    109.20572248,
            81.03937581],
        [  1238.21665077,    260.76727863,    237.81123201,
           301.66444622,    285.6535855 ,   1202.47459122,
           198.57042617,    312.51567492,    284.91015931,
           206.653706  ],
        [-71315.02365059, -15016.02089374, -13682.09387276,
         -17326.02771559, -16244.9149399 , -69170.17424601,
         -11352.55411153, -17904.25086821, -16394.31851306,
         -11815.012566  ],
        [  1304.50164038,    273.58597253,    250.76653164,
           318.40458396,    302.14640879,   1266.68612304,
           208.26109178,    329.05282608,    300.2090788 ,
           216.30723232],
        [-14306.62605117,  -3015.24621701,  -2747.21978324,
          -3488.17830379,  -3254.1344697 , -13893.5917661 ,
          -2278.82606809,  -3539.75048476,  -3300.09745825,
          -2365.18572081],
        [  -550.49633907,   -116.98950456,   -106.45015015,
          -139.09432834,   -122.66724028,   -537.38105004,
           -89.37662594,   -139.99495211,   -126.38728579,
           -90.40597461]])}
{'B4': array([59588.11264047, 89398.45415135, 67517.97336965, 70181.42496964,
       54794.07931948, 78083.69179265,  7747.12729841, 81101.33504991,
       -5472.86924777,   417.43565317])}
{'W5': array([[   587.45156607,   1261.64613587,    739.13193502,
           792.58006824,    505.92545423,    969.84421766,
        -29607.09672493,   1042.86463701, -11478.18282863,
          -571.62745477]])}
{'B5': array([61929645.74348348])}
```

In [ ]:
```
model_integrate.FFN.foreward_propagate(
    np.array([0, 5, 3, 2, 5] + 7*[0])
)
```

Out[ ]:
```
(array([61929645.58740462]), None)
```

In [ ]: