In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.neural_network import MLPRegressor
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import mean_squared_error
```

In [2]:
```
data = pd.read_csv('3.csv')
data.head()
```

Out[2]:

	X1	X2	X3	X4	X5	Y
0	13.233	38.320	55.618	91.466	106.030	1770.2
1	28.070	32.545	59.518	91.489	110.270	1928.1
2	28.240	34.104	57.003	85.282	109.090	1870.0
3	16.742	34.120	59.946	82.766	93.893	1625.6
4	17.225	21.305	53.570	94.055	103.480	1718.2

In [3]:
```
X = data[['X1','X2','X3','X4','X5']]
X.head()
```

Out[3]:

	X1	X2	X3	X4	X5
0	13.233	38.320	55.618	91.466	106.030
1	28.070	32.545	59.518	91.489	110.270
2	28.240	34.104	57.003	85.282	109.090
3	16.742	34.120	59.946	82.766	93.893
4	17.225	21.305	53.570	94.055	103.480

In [4]:
```
Y = data['Y']
Y.head()
```

Out[4]:
```
0    1770.2
1    1928.1
2    1870.0
3    1625.6
4    1718.2
Name: Y, dtype: float64
```

In [5]:
```
X_train, X_test = X[:2000].to_numpy(), X[2000:].to_numpy()
y_train, y_test = Y[:2000].to_numpy(), Y[2000:].to_numpy()
y_train = y_train.astype('int')
X_train.shape, X_test.shape
```

Out[5]:
```
((2000, 5), (300, 5))
```

In [11]:
```
one_layer = [i for i in range(1,10)]
parameter_space = { "hidden_layer_sizes": one_layer,
                   "activation": ["relu"],
                   "solver": ["adam"],
                   "alpha": [0.00005, 0.0005, 0.005, 0.05, 0.5],
                   "learning_rate": ["constant"],
                   "max_iter": [500],
                   "learning_rate_init": [0.00001, 0.0001, 0.001, 0.01
                   "early_stopping":[True]
                  }
grid = GridSearchCV(MLPRegressor(random_state=3), parameter_space, ver
grid.fit(X_train, y_train)

print("Best score for single layer ANN", grid.best_score_)
print("Best parameters for single layer ANN", grid.best_params_)

single_layer_mlp = MLPRegressor(**grid.best_params_)
single_layer_mlp.fit(X_train, y_train)
print("Single layer Neural Network MAE for=", single_layer_mlp.loss_)
single_layer_train_loss = single_layer_mlp.loss_
y_pred = single_layer_mlp.predict(X_test)
```

```
Fitting 3 folds for each of 225 candidates, totalling 675 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent w
orkers.
[Parallel(n_jobs=-1)]: Done  48 tasks      | elapsed:    8.0s
[Parallel(n_jobs=-1)]: Done 138 tasks      | elapsed:   19.3s
[Parallel(n_jobs=-1)]: Done 264 tasks      | elapsed:   35.4s
[Parallel(n_jobs=-1)]: Done 426 tasks      | elapsed:   60.0s
[Parallel(n_jobs=-1)]: Done 624 tasks      | elapsed:  1.5min
[Parallel(n_jobs=-1)]: Done 675 out of 675 | elapsed:  1.6min finishe
d

Best score for single layer ANN 0.9731056362629437
Best parameters for single layer ANN {'activation': 'relu', 'alpha':
5e-05, 'early_stopping': True, 'hidden_layer_sizes': 9, 'learning_rat
e': 'constant', 'learning_rate_init': 0.01, 'max_iter': 500, 'solver'
: 'adam'}
Single layer Neural Network MAE for= 120.40363198531907
```

In [7]:

```
single_layer_best_score = grid.best_score_
single_layer_error = np.sum((y_pred - y_test)**2)
print("SSE for single layer ANN", single_layer_error)
```

```
SSE for single layer ANN 62215.05488220717
```

In [10]:

```
two_layer = []
for i in range(1,10):
    for j in range(1,10):
        two_layer.append((i,j))

parameter_space = { "hidden_layer_sizes": two_layer,
                   "activation": ["relu"],
                   "solver": ["adam"],
                   "alpha": [0.00005, 0.0005, 0.005, 0.05, 0.5],
                   "learning_rate": ["constant"],
                   "max_iter": [500],
                   "learning_rate_init": [0.00001, 0.0001, 0.001, 0.01
                   "early_stopping":[True]
                  }
grid = GridSearchCV(MLPRegressor(random_state=3), parameter_space, ver
grid.fit(X_train, y_train)

print("Best score for two layer ANN", grid.best_score_)
print("Best parameters for two layer ANN", grid.best_params_)

two_layer_mlp = MLPRegressor(**grid.best_params_)
two_layer_mlp.fit(X_train, y_train)
print("Two layer Neural Network MAE =", two_layer_mlp.loss_)
two_layer_train_loss = two_layer_mlp.loss_
y_pred = two_layer_mlp.predict(X_test)
```

```
Fitting 3 folds for each of 2025 candidates, totalling 6075 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent w
orkers.
[Parallel(n_jobs=-1)]: Done  48 tasks      | elapsed:    9.3s
[Parallel(n_jobs=-1)]: Done 138 tasks      | elapsed:   24.4s
[Parallel(n_jobs=-1)]: Done 264 tasks      | elapsed:   47.9s
[Parallel(n_jobs=-1)]: Done 426 tasks      | elapsed:  1.4min
[Parallel(n_jobs=-1)]: Done 624 tasks      | elapsed:  2.0min
[Parallel(n_jobs=-1)]: Done 858 tasks      | elapsed:  2.9min
[Parallel(n_jobs=-1)]: Done 1128 tasks      | elapsed:  3.9min
[Parallel(n_jobs=-1)]: Done 1434 tasks      | elapsed:  4.9min
[Parallel(n_jobs=-1)]: Done 1776 tasks      | elapsed:  6.4min
[Parallel(n_jobs=-1)]: Done 2154 tasks      | elapsed:  7.9min
[Parallel(n_jobs=-1)]: Done 2568 tasks      | elapsed:  9.7min
[Parallel(n_jobs=-1)]: Done 3018 tasks      | elapsed: 11.6min
[Parallel(n_jobs=-1)]: Done 3504 tasks      | elapsed: 13.6min
```

```
[Parallel(n_jobs=-1)]: Done 4026 tasks      | elapsed: 15.8min
[Parallel(n_jobs=-1)]: Done 4584 tasks      | elapsed: 18.2min
[Parallel(n_jobs=-1)]: Done 5178 tasks      | elapsed: 21.0min
[Parallel(n_jobs=-1)]: Done 5808 tasks      | elapsed: 23.6min
[Parallel(n_jobs=-1)]: Done 6075 out of 6075 | elapsed: 24.7min finis
hed
```

```
Best score for two layer ANN 0.9755546580098092
Best parameters for two layer ANN {'activation': 'relu', 'alpha': 5e-
05, 'early_stopping': True, 'hidden_layer_sizes': (6, 8), 'learning_r
ate': 'constant', 'learning_rate_init': 0.01, 'max_iter': 500, 'solve
r': 'adam'}
Two layer Neural Network MAE = 119.34492701745616
```

In [12]:

```
two_layer_best_score = grid.best_score_
two_layer_error = np.sum((y_pred - y_test)**2)
print("SSE for two layer ANN", two_layer_error)
```

```
SSE for two layer ANN 77532.39566342026
```

In [13]:

```
three_layer = []
for i in range(1,10):
    for j in range(1,10):
        for k in range(1,10):
            three_layer.append((i,j,k))

parameter_space = { "hidden_layer_sizes": three_layer,
                   "activation": ["relu"],
                   "solver": ["adam"],
                   "alpha": [0.00005, 0.0005, 0.005, 0.05, 0.5],
                   "learning_rate": ["constant"],
                   "max_iter": [500],
                   "learning_rate_init": [0.00001, 0.0001, 0.001, 0.01
                   "early_stopping":[True]
                  }
grid = GridSearchCV(MLPRegressor(random_state=3), parameter_space, ver
grid.fit(X_train, y_train)

print("Best score for three layer ANN", grid.best_score_)
print("Best parameters for three layer ANN", grid.best_params_)

three_layer_mlp = MLPRegressor(**grid.best_params_)
three_layer_mlp.fit(X_train, y_train)
print("Three layer Neural Network MAE =", three_layer_mlp.loss_)
three_layer_train_loss = three_layer_mlp.loss_
y_pred = three_layer_mlp.predict(X_test)
```

```
Fitting 3 folds for each of 18225 candidates, totalling 54675 fits
```

```
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent w
```

```
orkers.
[Parallel(n_jobs=-1)]: Done  48 tasks      | elapsed:   10.4s
[Parallel(n_jobs=-1)]: Done 138 tasks      | elapsed:   30.0s
[Parallel(n_jobs=-1)]: Done 264 tasks      | elapsed:   59.5s
[Parallel(n_jobs=-1)]: Done 426 tasks      | elapsed:  1.6min
[Parallel(n_jobs=-1)]: Done 624 tasks      | elapsed:  2.3min
[Parallel(n_jobs=-1)]: Done 858 tasks      | elapsed:  3.1min
[Parallel(n_jobs=-1)]: Done 1128 tasks      | elapsed:  4.2min
[Parallel(n_jobs=-1)]: Done 1434 tasks      | elapsed:  5.4min
[Parallel(n_jobs=-1)]: Done 1776 tasks      | elapsed:  6.6min
[Parallel(n_jobs=-1)]: Done 2154 tasks      | elapsed:  8.1min
[Parallel(n_jobs=-1)]: Done 2568 tasks      | elapsed:  9.7min
[Parallel(n_jobs=-1)]: Done 3018 tasks      | elapsed: 11.6min
[Parallel(n_jobs=-1)]: Done 3504 tasks      | elapsed: 13.5min
[Parallel(n_jobs=-1)]: Done 4026 tasks      | elapsed: 15.6min
[Parallel(n_jobs=-1)]: Done 4584 tasks      | elapsed: 17.9min
[Parallel(n_jobs=-1)]: Done 5178 tasks      | elapsed: 20.3min
[Parallel(n_jobs=-1)]: Done 5808 tasks      | elapsed: 22.7min
[Parallel(n_jobs=-1)]: Done 6474 tasks      | elapsed: 25.2min
[Parallel(n_jobs=-1)]: Done 7176 tasks      | elapsed: 27.8min
[Parallel(n_jobs=-1)]: Done 7914 tasks      | elapsed: 30.7min
[Parallel(n_jobs=-1)]: Done 8688 tasks      | elapsed: 33.9min
[Parallel(n_jobs=-1)]: Done 9498 tasks      | elapsed: 37.2min
[Parallel(n_jobs=-1)]: Done 10344 tasks      | elapsed: 40.6min
[Parallel(n_jobs=-1)]: Done 11226 tasks      | elapsed: 44.2min
[Parallel(n_jobs=-1)]: Done 12144 tasks      | elapsed: 47.3min
[Parallel(n_jobs=-1)]: Done 13098 tasks      | elapsed: 50.5min
[Parallel(n_jobs=-1)]: Done 14088 tasks      | elapsed: 54.5min
[Parallel(n_jobs=-1)]: Done 15114 tasks      | elapsed: 58.6min
[Parallel(n_jobs=-1)]: Done 16176 tasks      | elapsed: 63.8min
[Parallel(n_jobs=-1)]: Done 17274 tasks      | elapsed: 68.9min
[Parallel(n_jobs=-1)]: Done 18408 tasks      | elapsed: 74.2min
[Parallel(n_jobs=-1)]: Done 19578 tasks      | elapsed: 79.0min
[Parallel(n_jobs=-1)]: Done 20784 tasks      | elapsed: 84.1min
[Parallel(n_jobs=-1)]: Done 22026 tasks      | elapsed: 90.1min
[Parallel(n_jobs=-1)]: Done 23304 tasks      | elapsed: 95.3min
[Parallel(n_jobs=-1)]: Done 24618 tasks      | elapsed: 100.8min
[Parallel(n_jobs=-1)]: Done 25968 tasks      | elapsed: 106.0min
[Parallel(n_jobs=-1)]: Done 27354 tasks      | elapsed: 111.1min
[Parallel(n_jobs=-1)]: Done 28776 tasks      | elapsed: 116.2min
[Parallel(n_jobs=-1)]: Done 30234 tasks      | elapsed: 121.2min
[Parallel(n_jobs=-1)]: Done 31728 tasks      | elapsed: 126.5min
[Parallel(n_jobs=-1)]: Done 33258 tasks      | elapsed: 132.3min
[Parallel(n_jobs=-1)]: Done 34824 tasks      | elapsed: 137.7min
[Parallel(n_jobs=-1)]: Done 36426 tasks      | elapsed: 143.7min
[Parallel(n_jobs=-1)]: Done 38064 tasks      | elapsed: 149.7min
[Parallel(n_jobs=-1)]: Done 39738 tasks      | elapsed: 155.7min
[Parallel(n_jobs=-1)]: Done 41448 tasks      | elapsed: 161.6min
[Parallel(n_jobs=-1)]: Done 43194 tasks      | elapsed: 168.1min
[Parallel(n_jobs=-1)]: Done 44976 tasks      | elapsed: 174.7min
```

```
[Parallel(n_jobs=-1)]: Done 46794 tasks      | elapsed: 181.1min
[Parallel(n_jobs=-1)]: Done 48648 tasks      | elapsed: 188.1min
[Parallel(n_jobs=-1)]: Done 50538 tasks      | elapsed: 194.7min
[Parallel(n_jobs=-1)]: Done 52464 tasks      | elapsed: 201.3min
[Parallel(n_jobs=-1)]: Done 54426 tasks      | elapsed: 208.6min
[Parallel(n_jobs=-1)]: Done 54675 out of 54675 | elapsed: 209.5min fi
nished

Best score for three layer ANN 0.977937255000097
Best parameters for three layer ANN {'activation': 'relu', 'alpha': 0
.0005, 'early_stopping': True, 'hidden_layer_sizes': (8, 5, 5), 'lear
ning_rate': 'constant', 'learning_rate_init': 0.01, 'max_iter': 500,
'solver': 'adam'}
Three layer Neural Network MAE = 111.59565488123778
```

In [14]:

```python
three_layer_best_score = grid.best_score_
three_layer_error = np.sum((y_pred - y_test)**2)
print("SSE for two layer ANN", three_layer_error)
```

```
SSE for two layer ANN 70172.6058433293
```

In [15]:

```python
four_layer = []
for i in range(1,10):
    for j in range(1,10):
        for k in range(1,10):
            for l in range(1,10):
                four_layer.append((i,j,k,l))

parameter_space = { "hidden_layer_sizes": four_layer,
                   "activation": ["relu"],
                   "solver": ["adam"],
                   "alpha": [0.00005, 0.0005],
                   "learning_rate": ["constant"],
                   "max_iter": [500],
                   "learning_rate_init": [0.01],
                   "early_stopping":[True]
                  }
grid = GridSearchCV(MLPRegressor(random_state=3), parameter_space, ver
grid.fit(X_train, y_train)

print("Best score for four layer ANN", grid.best_score_)
print("Best parameters for four layer ANN", grid.best_params_)

four_layer_mlp = MLPRegressor(**grid.best_params_)
four_layer_mlp.fit(X_train, y_train)
print("Four layer Neural Network MAE =", four_layer_mlp.loss_)
four_layer_train_loss = four_layer_mlp.loss_
y_pred = four_layer_mlp.predict(X_test)
```

```
Fitting 3 folds for each of 13122 candidates, totalling 39366 fits
```

```
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent w
orkers.
[Parallel(n_jobs=-1)]: Done  48 tasks      | elapsed:   17.6s
[Parallel(n_jobs=-1)]: Done 138 tasks      | elapsed:   36.2s
[Parallel(n_jobs=-1)]: Done 264 tasks      | elapsed:  1.0min
[Parallel(n_jobs=-1)]: Done 426 tasks      | elapsed:  1.6min
[Parallel(n_jobs=-1)]: Done 624 tasks      | elapsed:  2.3min
[Parallel(n_jobs=-1)]: Done 858 tasks      | elapsed:  3.3min
[Parallel(n_jobs=-1)]: Done 1128 tasks      | elapsed:  4.6min
[Parallel(n_jobs=-1)]: Done 1434 tasks      | elapsed:  6.1min
[Parallel(n_jobs=-1)]: Done 1776 tasks      | elapsed:  8.1min
[Parallel(n_jobs=-1)]: Done 2154 tasks      | elapsed: 10.3min
[Parallel(n_jobs=-1)]: Done 2568 tasks      | elapsed: 12.1min
[Parallel(n_jobs=-1)]: Done 3018 tasks      | elapsed: 14.4min
[Parallel(n_jobs=-1)]: Done 3504 tasks      | elapsed: 16.5min
[Parallel(n_jobs=-1)]: Done 4026 tasks      | elapsed: 19.2min
[Parallel(n_jobs=-1)]: Done 4584 tasks      | elapsed: 21.6min
[Parallel(n_jobs=-1)]: Done 5178 tasks      | elapsed: 24.5min
[Parallel(n_jobs=-1)]: Done 5808 tasks      | elapsed: 27.7min
[Parallel(n_jobs=-1)]: Done 6474 tasks      | elapsed: 31.0min
[Parallel(n_jobs=-1)]: Done 7176 tasks      | elapsed: 34.1min
[Parallel(n_jobs=-1)]: Done 7914 tasks      | elapsed: 37.3min
[Parallel(n_jobs=-1)]: Done 8688 tasks      | elapsed: 40.5min
[Parallel(n_jobs=-1)]: Done 9498 tasks      | elapsed: 43.9min
[Parallel(n_jobs=-1)]: Done 10344 tasks      | elapsed: 47.7min
[Parallel(n_jobs=-1)]: Done 11226 tasks      | elapsed: 51.5min
[Parallel(n_jobs=-1)]: Done 12144 tasks      | elapsed: 55.3min
[Parallel(n_jobs=-1)]: Done 13098 tasks      | elapsed: 59.5min
[Parallel(n_jobs=-1)]: Done 14088 tasks      | elapsed: 63.8min
[Parallel(n_jobs=-1)]: Done 15114 tasks      | elapsed: 68.6min
[Parallel(n_jobs=-1)]: Done 16176 tasks      | elapsed: 73.1min
[Parallel(n_jobs=-1)]: Done 17274 tasks      | elapsed: 78.3min
[Parallel(n_jobs=-1)]: Done 18408 tasks      | elapsed: 82.6min
[Parallel(n_jobs=-1)]: Done 19578 tasks      | elapsed: 87.4min
[Parallel(n_jobs=-1)]: Done 20784 tasks      | elapsed: 92.4min
[Parallel(n_jobs=-1)]: Done 22026 tasks      | elapsed: 98.9min
[Parallel(n_jobs=-1)]: Done 23304 tasks      | elapsed: 104.9min
[Parallel(n_jobs=-1)]: Done 24618 tasks      | elapsed: 111.0min
[Parallel(n_jobs=-1)]: Done 25968 tasks      | elapsed: 117.6min
[Parallel(n_jobs=-1)]: Done 27354 tasks      | elapsed: 124.0min
[Parallel(n_jobs=-1)]: Done 28776 tasks      | elapsed: 130.3min
[Parallel(n_jobs=-1)]: Done 30234 tasks      | elapsed: 136.4min
[Parallel(n_jobs=-1)]: Done 31728 tasks      | elapsed: 142.8min
[Parallel(n_jobs=-1)]: Done 33258 tasks      | elapsed: 149.4min
[Parallel(n_jobs=-1)]: Done 34824 tasks      | elapsed: 156.4min
[Parallel(n_jobs=-1)]: Done 36426 tasks      | elapsed: 163.1min
[Parallel(n_jobs=-1)]: Done 38064 tasks      | elapsed: 170.4min
[Parallel(n_jobs=-1)]: Done 39366 out of 39366 | elapsed: 177.2min fi
nished
```

```
Best score for four layer ANN 0.9776153129459398
Best parameters for four layer ANN {'activation': 'relu', 'alpha': 0.
0005, 'early_stopping': True, 'hidden_layer_sizes': (8, 9, 5, 7), 'le
arning_rate': 'constant', 'learning_rate_init': 0.01, 'max_iter': 500
, 'solver': 'adam'}
Four layer Neural Network MAE = 117.4353353074388
```

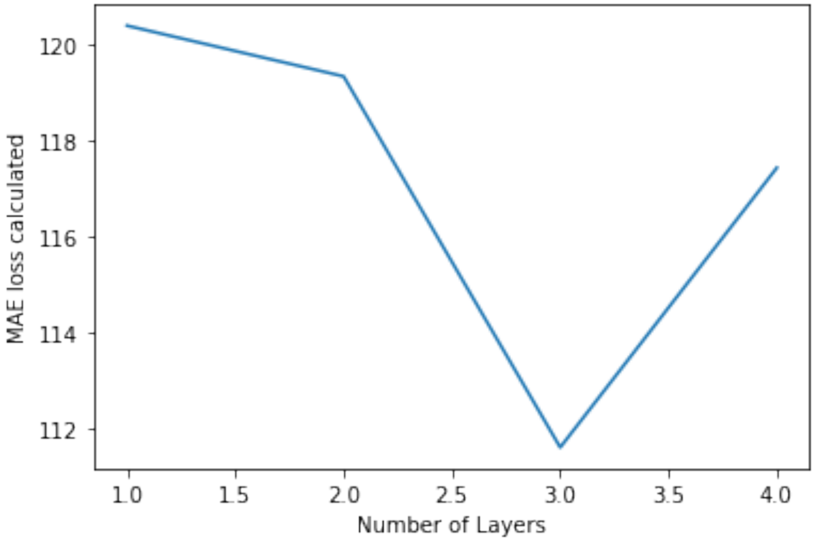
In [53]:

```
four_layer_best_score = grid.best_score_
four_layer_error = np.sum((y_pred - y_test)**2)
print("SSE for two layer ANN", four_layer_error)
```

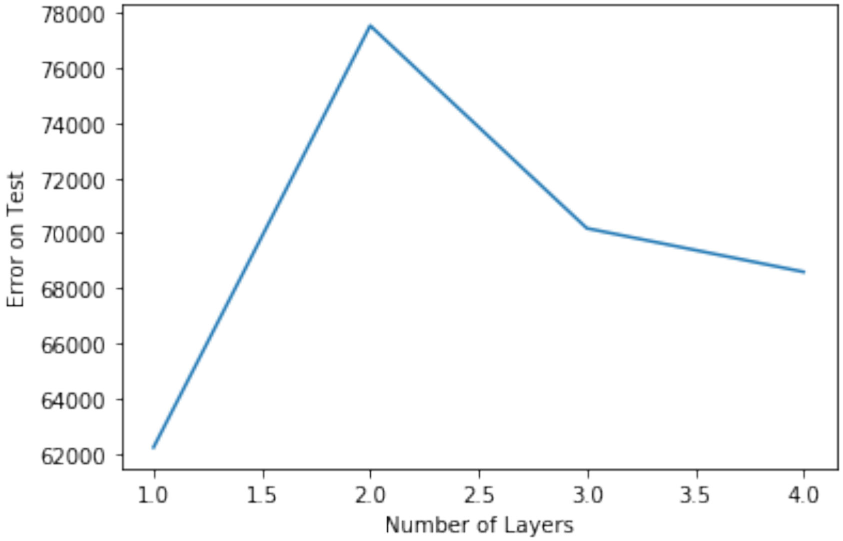
```
SSE for two layer ANN 68589.91037625851
```

In [17]:

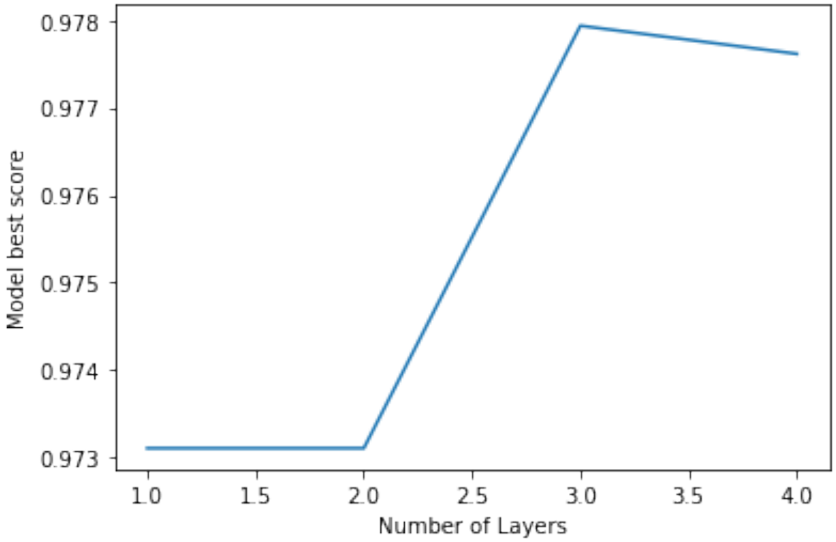
```
plt.plot([1 ,2 ,3,4], [single_layer_train_loss, two_layer_train_loss,
plt.xlabel('Number of Layers')
plt.ylabel("MAE loss calculated")
plt.show()
```



In [18]:
```
plt.plot([1 ,2 ,3,4], [single_layer_error, two_layer_error, three_laye
plt.xlabel('Number of Layers')
plt.ylabel("Error on Test")
plt.show()
```



In [19]:
```
plt.plot([1 ,2 ,3,4], [single_layer_best_score, two_layer_best_score,
plt.xlabel('Number of Layers')
plt.ylabel("Model best score")
plt.show()
```



I have set a range of learning rate in (0.00001, 0.0001, 0.001, 0.01, 0.1) where are for regularization parameter (0.00005, 0.0005, 0.005, 0.05, 0.5) keeping maximum iterations to 500 and default batch number sizes for one, two and three layer neural network. For four layer neural network I have narrowed the learning rate to 0.01 and regularization parameter to (0.00005, 0.0005) by observing the results obtained in single, two and three layer networks. I have calculated the best score(not the accuracy), mean absolute error calculated on train data and SSE on the test data for each layered neural network. I have plotted all the obtained results with respect to the number of layers in the neural network as shown above. From the above graphs we can see that the model starts overfitting once we move from three layer neural network to a four layer neural network also three layer model has highest best score among the others. Thus we will be choosing a three layer neural network with parameters calculated using the GrisearchCV.

In [56]:

```
import statsmodels.api as sm
x_reg, y_reg = X_train, y_train
x_reg_test, y_reg_test = X_test, y_test
x_reg = sm.add_constant(x_reg)
model = sm.OLS(y_reg, x_reg).fit()
y_pred_reg = model.predict(x_reg)
```

In [57]:

```
regression_error_train = np.sum((np.array(y_pred_reg) - y_reg)**2)
print("SSE for linear regression model", regression_error_train)
```

```
SSE for linear regression model 160777.321576731
```

From the above model we can see that for the best ann model the SSE error on the data is 68589.91037625851 where as for the for the regression model the SSE error is 160777.321576731 thus from the results we can see that that the Neural network model is much more accurate than the linear regression model. Thus we can conclude from the result that the a well designed ANN model works better than the linear regression model.