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Section C ¶

In [105]:

```python
#importing libraries
import matplotlib.pyplot as plt
from time import time
from sklearn.model_selection import train_test_split
import pandas as pd
import numpy as np
import seaborn as sns
from sklearn.neural_network import MLPClassifier
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score
df1 = pd.read_csv('fashion-mnist_train.csv')
df2 = pd.read_csv('fashion-mnist_test.csv')
```

In [106]:

```python
df = pd.concat([df1, df2], axis=0)
```

In [108]:

```python
df.shape
```

Out[108]:

```
(70000, 785)
```

In [119]:

```python
df
```

Out[119]:

	label	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	...	pixel775	pixe
51883	6	0	0	0	0	0	0	0	0	0	...	34	
32224	2	0	0	0	0	0	2	0	0	0	...	0	
47989	3	0	0	0	0	0	0	0	0	0	...	0	
48377	3	0	0	0	0	0	0	0	0	0	...	150	
40189	6	0	0	0	0	0	0	0	0	0	...	73	
...	...	...	...	...	...	...	...	...	...	...	...	...	
1676	1	0	0	0	0	0	0	0	0	0	...	145	
41311	2	0	0	0	0	0	1	0	0	0	...	164	
57637	5	0	0	0	0	0	0	0	0	0	...	0	
8059	1	0	0	0	0	0	0	0	0	0	...	52	
44880	6	0	0	0	0	0	0	0	0	0	...	0	

12000 rows × 785 columns

1. MLP, train an MLP classifier on Fashion MNIST dataset (divide training set into 85:15 train to

validation set). The hidden layers should be of sizes (256, 32). Choose appropriate number of epochs and batch size.

In [109]:
```
df = df.sample(n=12000)
df.shape
```

Out[109]:
```
(12000, 785)
```

In [110]:
```
df.describe()
```

Out[110]:

	label	pixel1	pixel2	pixel3	pixel4	pixel5	pixe
count	12000.000000	12000.0	12000.000000	12000.000000	12000.000000	12000.000000	12000.00000
mean	4.551083	0.0	0.008083	0.042333	0.110167	0.281167	0.47283
std	2.857313	0.0	0.429185	2.023993	3.136960	5.207562	6.89824
min	0.000000	0.0	0.000000	0.000000	0.000000	0.000000	0.00000
25%	2.000000	0.0	0.000000	0.000000	0.000000	0.000000	0.00000
50%	5.000000	0.0	0.000000	0.000000	0.000000	0.000000	0.00000
75%	7.000000	0.0	0.000000	0.000000	0.000000	0.000000	0.00000
max	9.000000	0.0	45.000000	218.000000	185.000000	227.000000	226.00000

8 rows × 785 columns

In [111]:
```
dfarr = np.array(df)
```

In [112]:
```
from sklearn.model_selection import train_test_split
X = dfarr[:,1:]/255
Y = dfarr[:,0]
```

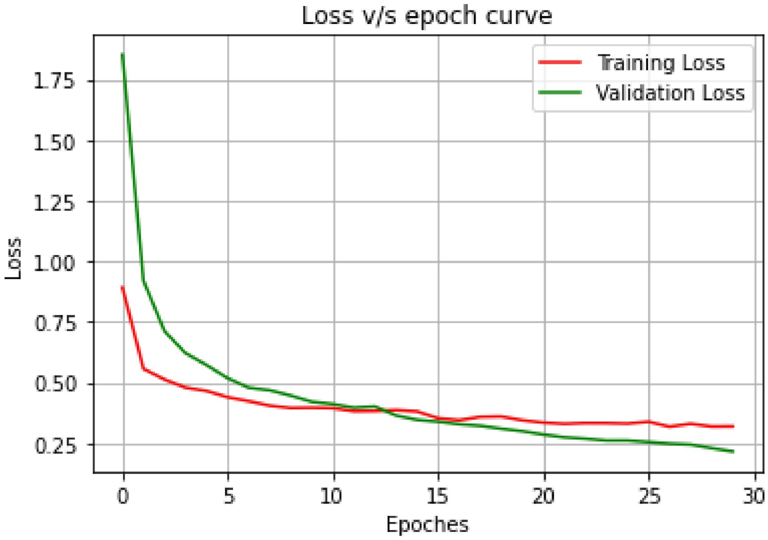
In [113]:
```
X_train, X_test, Y_train, Y_test= train_test_split(X, Y, test_size= 0.15)
```

1.Plot training loss v/s epochs and validation loss v/s epochs for acti vations simgoid, ReLU, tanh and linear (default learning rate). Which is the best activation function? Give analysis and comparison for each.

In [114]:

```
#Linear Activation Function
mlp1 = MLPClassifier(hidden_layer_sizes=(256, 32),activation='identity',max_
fit1=mlp1.fit(X_train, Y_train)
los1 = fit1.loss_curve_
fit2=mlp1.fit(X_test, Y_test)
los2 = fit2.loss_curve_
plt.title("Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los1, color='red', label='Training Loss')
plt.plot(los2, color='green', label='Validation Loss')
plt.grid(True)
plt.legend()
plt.show()
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```



Insights:

In Linear Activation Function The Training loss is maximum in the beginning but decreasing gradually with the increase in number of epoches. Training loss and valiation loss are overlaping in between.

In [115]:

```
#Sigmoid Activation Function
mlp11 = MLPClassifier(hidden_layer_sizes=(256, 32),activation='logistic',max
fit11=mlp11.fit(X_train, Y_train)
los11 = fit11.loss_curve_
fit22=mlp11.fit(X_test, Y_test)
los22 = fit22.loss_curve_
plt.title("Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los11, color='red', label='Training Loss')
plt.plot(los22, color='green', label='Validation Loss')
plt.grid(True)
plt.legend()
plt.show()
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
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rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```
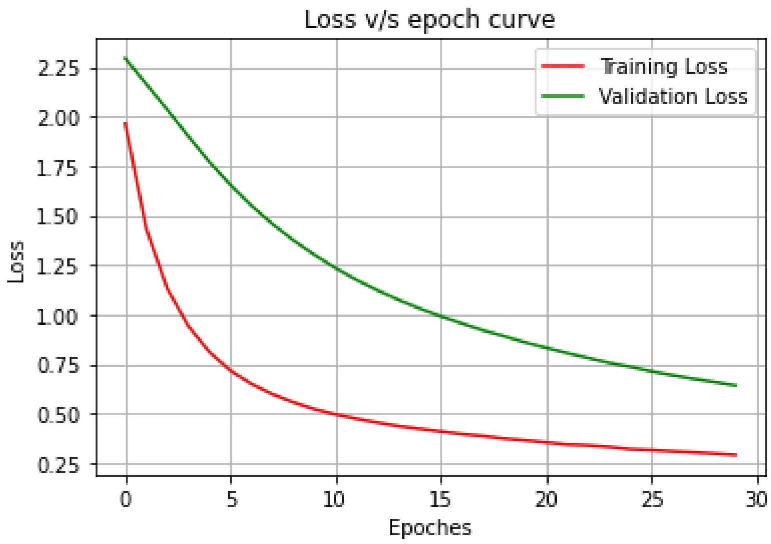



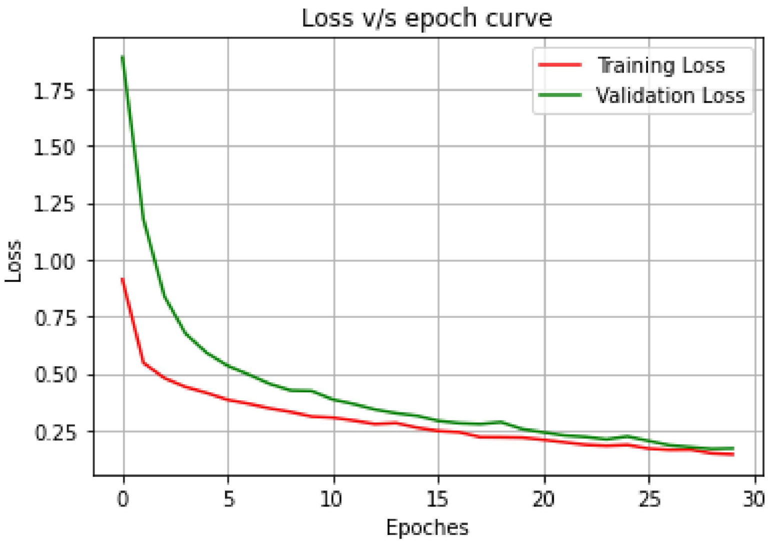
Insights:

In Sigmoid Activation Function The Training loss is maximum in the beginning but decreasing gradually with the increase in number of epoches. Difference between Training loss and valiation loss is more.

In [116]:

```python
#ReLu Activation Function
mlp111 = MLPClassifier(hidden_layer_sizes=(256, 32),activation='relu',max_it
fit111=mlp111.fit(X_train, Y_train)
los111 = fit111.loss_curve_
fit222=mlp111.fit(X_test, Y_test)
los222 = fit222.loss_curve_
plt.title("Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los111, color='red', label='Training Loss')
plt.plot(los222, color='green', label='Validation Loss')
plt.grid(True)
plt.legend()
plt.show()
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```



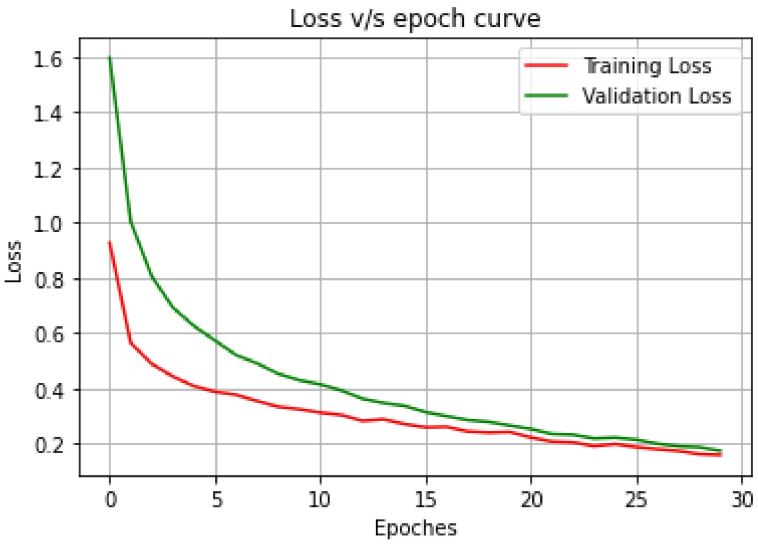
Insights:

In ReLu Activation Function The Training and validation loss is maximum in the beginning but decreasing gradually with the increase in number of epoches. Training loss and valiation loss are overlaping in between and the difference between then is very less.

In [117]:

```python
#Tanh Activation Function
mlp1111 = MLPClassifier(hidden_layer_sizes=(256, 32),activation='tanh',max_i
fit1111=mlp1111.fit(X_train, Y_train)
los1111 = fit1111.loss_curve_
fit2222=mlp1111.fit(X_test, Y_test)
los2222 = fit2222.loss_curve_
plt.title("Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los1111, color='red', label='Training Loss')
plt.plot(los2222, color='green', label='Validation Loss')
plt.grid(True)
plt.legend()
plt.show()
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```

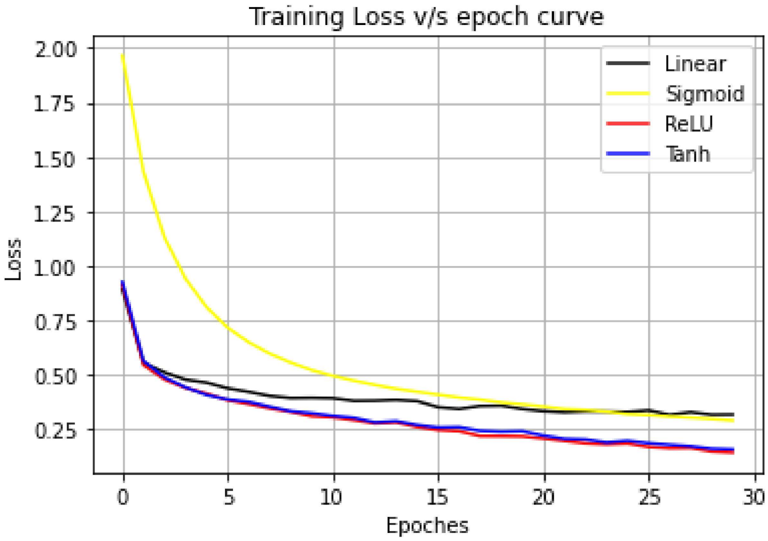


Insights:

In tanh Activation Function The Training and validation loss is maximum in the beginning but decreasing gradually with the increase in number of epoches. Training loss and valiation loss are overlaping in between and the difference between then is less.

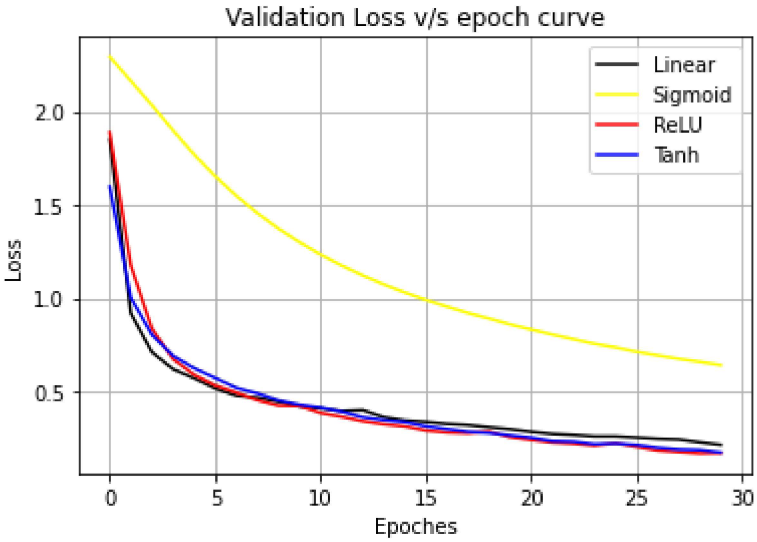
In [118]:

```python
plt.title("Training Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los1, color='black', label='Linear')
plt.plot(los11, color='yellow', label='Sigmoid')
plt.plot(los111, color='red', label='ReLU')
plt.plot(los1111, color='blue', label='Tanh')
plt.grid(True)
plt.legend()
plt.show()
```



In [120]:

```
plt.title("Validation Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los2, color='black', label='Linear')
plt.plot(los22, color='yellow', label='Sigmoid')
plt.plot(los222, color='red', label='ReLU')
plt.plot(los2222, color='blue', label='Tanh')
plt.grid(True)
plt.legend()
plt.show()
```



Conclusion:

From the above plots we can see that the training and validation loss are decreasing gradually with the number of epoches in the case of ReLu activation function. Training and validation Losses are minimum in the case of ReLu as compared to other activation function therefore we can say that Relu is the best activation function for the case of given dataset.

2.Using the best activation function obtained above, train models using learning rates [0.1, 0.01, 0.001]. Plot training loss v/s epochs and validation loss v/s epochs. Which is the best learning rate? Give explanations of the results obtained for each learning rate.

In [127]:

```
c = 0
s = pd.DataFrame(columns = ['rate','epochs','train_accuracy','test_accuracy'
for rate in [0.1, 0.01, 0.001]:
    for epoch in [10,20,30]:
        t = time()
        mlp = MLPClassifier(learning_rate_init=rate, max_iter=epoch)
        mlp.fit(X_train, Y_train)
        e = time() - t
        acc_train = accuracy_score(Y_train, mlp.predict(X_train))
        acc_test = accuracy_score(Y_test, mlp.predict(X_test))
        s.loc[c] = [rate,epoch,acc_train,acc_test,e]
        c=c+1
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(10) reached and the optimization hasn't converged yet.
  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(20) reached and the optimization hasn't converged yet.
  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
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  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
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C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
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C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
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  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
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  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(20) reached and the optimization hasn't converged yet.
  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```

In [128]:

```
s
```

Out[128]:

	rate	epochs	train_accuracy	test_accuracy	time_taken
0	0.100	10.0	0.635490	0.616111	3.223574
1	0.100	20.0	0.585294	0.595000	5.892589
2	0.100	30.0	0.758627	0.723333	9.847516
3	0.010	10.0	0.881961	0.835000	3.308213
4	0.010	20.0	0.930392	0.851111	6.508223
5	0.010	30.0	0.943235	0.862222	10.193228
6	0.001	10.0	0.879118	0.866667	3.718145
7	0.001	20.0	0.902059	0.865000	7.552707
8	0.001	30.0	0.924706	0.863333	11.708856

Conclusion:

So from the above analysis and comparision we can conclude that the best test accuracy and train accuracy is given by the the learning rate = 0.001 and the epoches = 30 Model do not overfit.

Plotting the loss curve by taking these best values with activation fuction function ReLu

In [137]:

```python
mlp1111 = MLPClassifier(hidden_layer_sizes=(256, 32),activation='relu',max_i
fit1111=mlp1111.fit(X_train, Y_train)
los1111 = fit1111.loss_curve_
fit2222=mlp1111.fit(X_test, Y_test)
los2222 = fit2222.loss_curve_
plt.title("Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los1111, color='red', label='Training Loss')
plt.plot(los2222, color='green', label='Validation Loss')
plt.grid(True)
plt.legend()
plt.show()
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
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  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```
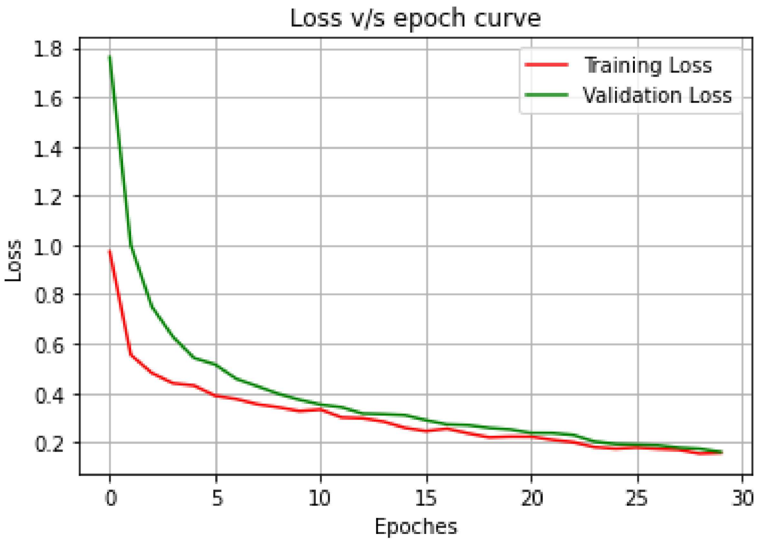



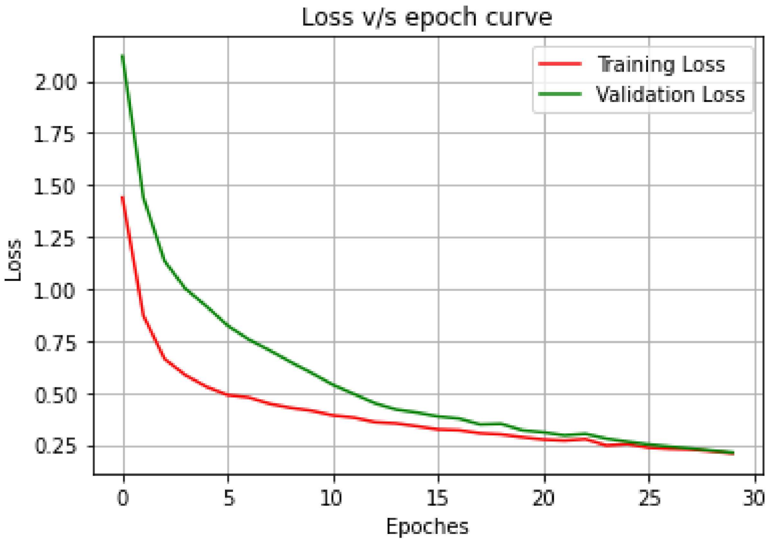
learning rate change the model in response to the estimated error. validation loss and traing losses are decreasing.

3.Decrease the number of neurons in each layer to various values. What do you observe? Plot training loss v/s epochs. Justify your answer.

In [135]:

```python
mlp1111 = MLPClassifier(hidden_layer_sizes=(256, 10),activation='relu',max_i
fit1111=mlp1111.fit(X_train, Y_train)
los1111 = fit1111.loss_curve_
fit2222=mlp1111.fit(X_test, Y_test)
los2222 = fit2222.loss_curve_
plt.title("Loss v/s epoch curve")
plt.xlabel('Epoches')
plt.ylabel('Loss')
plt.plot(los1111, color='red', label='Training Loss')
plt.plot(los2222, color='green', label='Validation Loss')
plt.grid(True)
plt.legend()
plt.show()
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```



Conclusion:

As we decreased the number of neutrons then it would become more dense and the loss will be less. The results will be more accurate.

5. Perform grid search on appropriate parameters of MLPClassifier. Choose the best parameters. Give an analysis of why you might have got those parameters.

In [52]:

```
from sklearn.model_selection import GridSearchCV
mlp = MLPClassifier(max_iter=30)
parameter_space = {'hidden_layer_sizes': [(256,32),(20,)],'activation': ['ta
model = GridSearchCV(mlp_, parameter_space, n_jobs=-1, cv=3)
model.fit(X_train, Y_train)
```

```
C:\Users\user\anaconda3\lib\site-packages\sklearn\neural_network\_multilayer_pe
rceptron.py:582: ConvergenceWarning: Stochastic Optimizer: Maximum iterations
(30) reached and the optimization hasn't converged yet.
  warnings.warn(
```

Out[52]:

```
GridSearchCV(cv=3, estimator=MLPClassifier(max_iter=30), n_jobs=-1,
             param_grid={'activation': ['tanh', 'relu', 'logistic'],
                         'alpha': [0.0001, 0.01, 0.001],
                         'hidden_layer_sizes': [(256, 32), (20,)],
                         'learning_rate': ['constant', 'adaptive',
                                           'invscaling'],
                         'solver': ['sgd', 'adam', 'lbfgs']})
```

In [54]:

```
print('Best parameters are:', model.best_params_)
```

```
Best parameters are: {'activation': 'relu', 'alpha': 0.01, 'hidden_layer_size
s': (256, 32), 'learning_rate': 'invscaling', 'solver': 'adam'}
```

Training and validation Losses are minimum in the case of ReLu therefor we can say that Relu is the best activation function for the case of given dataset.

In [ ]:

```

```