import pandas as pd  
import numpy as np  
from tensorflow.keras import layers, Sequential  
import tensorflow as tf  
  
import matplotlib.pyplot as plt  
import seaborn as sns  
  
from sklearn.model\_selection import train\_test\_split  
from sklearn.feature\_extraction.text import TfidfVectorizer  
from sklearn.metrics import accuracy\_score, confusion\_matrix, precision\_score, recall\_score, f1\_score, classification\_report

data = pd.read\_csv('../data/spam.csv', encoding="ISO-8859-1")  
data.drop(['Unnamed: 2','Unnamed: 3','Unnamed: 4'], axis=1, inplace=True)  
data.drop\_duplicates(inplace=True)  
  
data['v1'].replace(['ham', 'spam'], [0, 1], inplace=True)  
  
data.set\_axis(['Category', 'Message'], axis=1, inplace=True)  
  
data

/var/folders/15/hdxx982s3fj3bxc5v64cbpd00000gn/T/ipykernel\_11381/1066889766.py:7: FutureWarning: DataFrame.set\_axis 'inplace' keyword is deprecated and will be removed in a future version. Use `obj = obj.set\_axis(..., copy=False)` instead  
 data.set\_axis(['Category', 'Message'], axis=1, inplace=True)

Category Message  
0 0 Go until jurong point, crazy.. Available only ...  
1 0 Ok lar... Joking wif u oni...  
2 1 Free entry in 2 a wkly comp to win FA Cup fina...  
3 0 U dun say so early hor... U c already then say...  
4 0 Nah I don't think he goes to usf, he lives aro...  
... ... ...  
5567 1 This is the 2nd time we have tried 2 contact u...  
5568 0 Will Ì\_ b going to esplanade fr home?  
5569 0 Pity, \* was in mood for that. So...any other s...  
5570 0 The guy did some bitching but I acted like i'd...  
5571 0 Rofl. Its true to its name  
  
[5169 rows x 2 columns]

vectorizer = TfidfVectorizer()  
  
X = vectorizer.fit\_transform(data['Message'])  
y = data['Category']

X\_train, X\_test, y\_train, y\_test = train\_test\_split(X.toarray(), y, test\_size=0.3, random\_state=42)

model = tf.keras.Sequential([  
 tf.keras.layers.Dense(10, activation='relu'),  
 tf.keras.layers.Dense(1)  
])

model.compile(optimizer='sgd', loss='mean\_squared\_error', metrics=['accuracy'])  
model.fit(X\_train, y\_train, epochs=200)

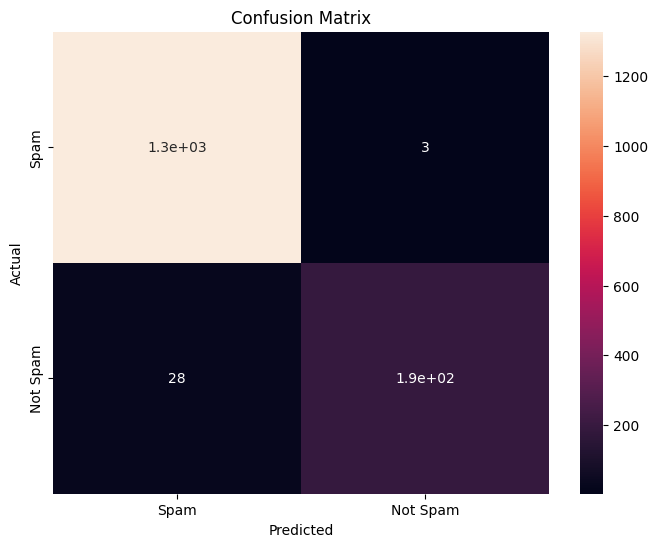
Epoch 1/200  
114/114 [==============================] - 0s 686us/step - loss: 0.1074 - accuracy: 0.8803  
Epoch 2/200  
114/114 [==============================] - 0s 609us/step - loss: 0.1037 - accuracy: 0.8803  
Epoch 3/200  
114/114 [==============================] - 0s 586us/step - loss: 0.1017 - accuracy: 0.8803  
Epoch 4/200  
114/114 [==============================] - 0s 618us/step - loss: 0.0994 - accuracy: 0.8803  
Epoch 5/200  
114/114 [==============================] - 0s 645us/step - loss: 0.0969 - accuracy: 0.8803  
Epoch 6/200  
114/114 [==============================] - 0s 618us/step - loss: 0.0944 - accuracy: 0.8803  
Epoch 7/200  
114/114 [==============================] - 0s 614us/step - loss: 0.0918 - accuracy: 0.8803  
Epoch 8/200  
114/114 [==============================] - 0s 1ms/step - loss: 0.0891 - accuracy: 0.8803  
Epoch 9/200  
114/114 [==============================] - 0s 601us/step - loss: 0.0863 - accuracy: 0.8803  
Epoch 10/200  
114/114 [==============================] - 0s 615us/step - loss: 0.0835 - accuracy: 0.8803  
Epoch 11/200  
114/114 [==============================] - 0s 842us/step - loss: 0.0808 - accuracy: 0.8803  
Epoch 12/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0782 - accuracy: 0.8803  
Epoch 13/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0756 - accuracy: 0.8803  
Epoch 14/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0730 - accuracy: 0.8803  
Epoch 15/200  
114/114 [==============================] - 0s 645us/step - loss: 0.0705 - accuracy: 0.8803  
Epoch 16/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0679 - accuracy: 0.8814  
Epoch 17/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0655 - accuracy: 0.8828  
Epoch 18/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0632 - accuracy: 0.8839  
Epoch 19/200  
114/114 [==============================] - 0s 601us/step - loss: 0.0611 - accuracy: 0.8894  
Epoch 20/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0589 - accuracy: 0.8936  
Epoch 21/200  
114/114 [==============================] - 0s 614us/step - loss: 0.0568 - accuracy: 0.8972  
Epoch 22/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0548 - accuracy: 0.9038  
Epoch 23/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0528 - accuracy: 0.9107  
Epoch 24/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0510 - accuracy: 0.9151  
Epoch 25/200  
114/114 [==============================] - 0s 611us/step - loss: 0.0492 - accuracy: 0.9204  
Epoch 26/200  
114/114 [==============================] - 0s 613us/step - loss: 0.0476 - accuracy: 0.9248  
Epoch 27/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0460 - accuracy: 0.9284  
Epoch 28/200  
114/114 [==============================] - 0s 620us/step - loss: 0.0445 - accuracy: 0.9339  
Epoch 29/200  
114/114 [==============================] - 0s 599us/step - loss: 0.0430 - accuracy: 0.9378  
Epoch 30/200  
114/114 [==============================] - 0s 599us/step - loss: 0.0417 - accuracy: 0.9447  
Epoch 31/200  
114/114 [==============================] - 0s 854us/step - loss: 0.0405 - accuracy: 0.9461  
Epoch 32/200  
114/114 [==============================] - 0s 597us/step - loss: 0.0393 - accuracy: 0.9491  
Epoch 33/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0382 - accuracy: 0.9519  
Epoch 34/200  
114/114 [==============================] - 0s 608us/step - loss: 0.0371 - accuracy: 0.9549  
Epoch 35/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0361 - accuracy: 0.9574  
Epoch 36/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0352 - accuracy: 0.9610  
Epoch 37/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0344 - accuracy: 0.9621  
Epoch 38/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0336 - accuracy: 0.9649  
Epoch 39/200  
114/114 [==============================] - 0s 600us/step - loss: 0.0327 - accuracy: 0.9660  
Epoch 40/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0319 - accuracy: 0.9677  
Epoch 41/200  
114/114 [==============================] - 0s 650us/step - loss: 0.0313 - accuracy: 0.9696  
Epoch 42/200  
114/114 [==============================] - 0s 613us/step - loss: 0.0307 - accuracy: 0.9704  
Epoch 43/200  
114/114 [==============================] - 0s 619us/step - loss: 0.0300 - accuracy: 0.9718  
Epoch 44/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0294 - accuracy: 0.9729  
Epoch 45/200  
114/114 [==============================] - 0s 615us/step - loss: 0.0288 - accuracy: 0.9729  
Epoch 46/200  
114/114 [==============================] - 0s 608us/step - loss: 0.0282 - accuracy: 0.9732  
Epoch 47/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0276 - accuracy: 0.9740  
Epoch 48/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0267 - accuracy: 0.9735  
Epoch 49/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0261 - accuracy: 0.9751  
Epoch 50/200  
114/114 [==============================] - 0s 603us/step - loss: 0.0256 - accuracy: 0.9751  
Epoch 51/200  
114/114 [==============================] - 0s 818us/step - loss: 0.0251 - accuracy: 0.9771  
Epoch 52/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0247 - accuracy: 0.9768  
Epoch 53/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0242 - accuracy: 0.9779  
Epoch 54/200  
114/114 [==============================] - 0s 608us/step - loss: 0.0238 - accuracy: 0.9787  
Epoch 55/200  
114/114 [==============================] - 0s 624us/step - loss: 0.0235 - accuracy: 0.9795  
Epoch 56/200  
114/114 [==============================] - 0s 618us/step - loss: 0.0230 - accuracy: 0.9790  
Epoch 57/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0227 - accuracy: 0.9798  
Epoch 58/200  
114/114 [==============================] - 0s 589us/step - loss: 0.0224 - accuracy: 0.9801  
Epoch 59/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0220 - accuracy: 0.9801  
Epoch 60/200  
114/114 [==============================] - 0s 650us/step - loss: 0.0217 - accuracy: 0.9801  
Epoch 61/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0215 - accuracy: 0.9804  
Epoch 62/200  
114/114 [==============================] - 0s 630us/step - loss: 0.0211 - accuracy: 0.9812  
Epoch 63/200  
114/114 [==============================] - 0s 627us/step - loss: 0.0208 - accuracy: 0.9809  
Epoch 64/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0205 - accuracy: 0.9818  
Epoch 65/200  
114/114 [==============================] - 0s 646us/step - loss: 0.0202 - accuracy: 0.9815  
Epoch 66/200  
114/114 [==============================] - 0s 615us/step - loss: 0.0199 - accuracy: 0.9823  
Epoch 67/200  
114/114 [==============================] - 0s 618us/step - loss: 0.0197 - accuracy: 0.9837  
Epoch 68/200  
114/114 [==============================] - 0s 827us/step - loss: 0.0194 - accuracy: 0.9831  
Epoch 69/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0192 - accuracy: 0.9829  
Epoch 70/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0189 - accuracy: 0.9837  
Epoch 71/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0187 - accuracy: 0.9840  
Epoch 72/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0185 - accuracy: 0.9840  
Epoch 73/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0183 - accuracy: 0.9851  
Epoch 74/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0181 - accuracy: 0.9848  
Epoch 75/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0178 - accuracy: 0.9848  
Epoch 76/200  
114/114 [==============================] - 0s 617us/step - loss: 0.0176 - accuracy: 0.9848  
Epoch 77/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0174 - accuracy: 0.9859  
Epoch 78/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0172 - accuracy: 0.9859  
Epoch 79/200  
114/114 [==============================] - 0s 626us/step - loss: 0.0170 - accuracy: 0.9867  
Epoch 80/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0168 - accuracy: 0.9870  
Epoch 81/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0166 - accuracy: 0.9867  
Epoch 82/200  
114/114 [==============================] - 0s 667us/step - loss: 0.0164 - accuracy: 0.9878  
Epoch 83/200  
114/114 [==============================] - 0s 621us/step - loss: 0.0162 - accuracy: 0.9876  
Epoch 84/200  
114/114 [==============================] - 0s 619us/step - loss: 0.0160 - accuracy: 0.9878  
Epoch 85/200  
114/114 [==============================] - 0s 812us/step - loss: 0.0158 - accuracy: 0.9878  
Epoch 86/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0157 - accuracy: 0.9884  
Epoch 87/200  
114/114 [==============================] - 0s 615us/step - loss: 0.0155 - accuracy: 0.9884  
Epoch 88/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0154 - accuracy: 0.9884  
Epoch 89/200  
114/114 [==============================] - 0s 596us/step - loss: 0.0153 - accuracy: 0.9892  
Epoch 90/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0151 - accuracy: 0.9892  
Epoch 91/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0149 - accuracy: 0.9900  
Epoch 92/200  
114/114 [==============================] - 0s 614us/step - loss: 0.0147 - accuracy: 0.9895  
Epoch 93/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0145 - accuracy: 0.9900  
Epoch 94/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0144 - accuracy: 0.9898  
Epoch 95/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0142 - accuracy: 0.9900  
Epoch 96/200  
114/114 [==============================] - 0s 639us/step - loss: 0.0141 - accuracy: 0.9900  
Epoch 97/200  
114/114 [==============================] - 0s 636us/step - loss: 0.0140 - accuracy: 0.9912  
Epoch 98/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0138 - accuracy: 0.9912  
Epoch 99/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0137 - accuracy: 0.9917  
Epoch 100/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0135 - accuracy: 0.9914  
Epoch 101/200  
114/114 [==============================] - 0s 818us/step - loss: 0.0134 - accuracy: 0.9912  
Epoch 102/200  
114/114 [==============================] - 0s 617us/step - loss: 0.0133 - accuracy: 0.9912  
Epoch 103/200  
114/114 [==============================] - 0s 619us/step - loss: 0.0132 - accuracy: 0.9923  
Epoch 104/200  
114/114 [==============================] - 0s 597us/step - loss: 0.0130 - accuracy: 0.9925  
Epoch 105/200  
114/114 [==============================] - 0s 602us/step - loss: 0.0129 - accuracy: 0.9925  
Epoch 106/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0128 - accuracy: 0.9928  
Epoch 107/200  
114/114 [==============================] - 0s 608us/step - loss: 0.0126 - accuracy: 0.9931  
Epoch 108/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0125 - accuracy: 0.9931  
Epoch 109/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0124 - accuracy: 0.9931  
Epoch 110/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0123 - accuracy: 0.9928  
Epoch 111/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0122 - accuracy: 0.9934  
Epoch 112/200  
114/114 [==============================] - 0s 613us/step - loss: 0.0121 - accuracy: 0.9934  
Epoch 113/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0120 - accuracy: 0.9931  
Epoch 114/200  
114/114 [==============================] - 0s 606us/step - loss: 0.0118 - accuracy: 0.9934  
Epoch 115/200  
114/114 [==============================] - 0s 636us/step - loss: 0.0118 - accuracy: 0.9936  
Epoch 116/200  
114/114 [==============================] - 0s 611us/step - loss: 0.0116 - accuracy: 0.9936  
Epoch 117/200  
114/114 [==============================] - 0s 826us/step - loss: 0.0115 - accuracy: 0.9936  
Epoch 118/200  
114/114 [==============================] - 0s 619us/step - loss: 0.0114 - accuracy: 0.9939  
Epoch 119/200  
114/114 [==============================] - 0s 618us/step - loss: 0.0113 - accuracy: 0.9939  
Epoch 120/200  
114/114 [==============================] - 0s 614us/step - loss: 0.0112 - accuracy: 0.9939  
Epoch 121/200  
114/114 [==============================] - 0s 618us/step - loss: 0.0111 - accuracy: 0.9942  
Epoch 122/200  
114/114 [==============================] - 0s 623us/step - loss: 0.0110 - accuracy: 0.9936  
Epoch 123/200  
114/114 [==============================] - 0s 637us/step - loss: 0.0109 - accuracy: 0.9942  
Epoch 124/200  
114/114 [==============================] - 0s 617us/step - loss: 0.0108 - accuracy: 0.9942  
Epoch 125/200  
114/114 [==============================] - 0s 611us/step - loss: 0.0107 - accuracy: 0.9942  
Epoch 126/200  
114/114 [==============================] - 0s 599us/step - loss: 0.0106 - accuracy: 0.9942  
Epoch 127/200  
114/114 [==============================] - 0s 611us/step - loss: 0.0105 - accuracy: 0.9942  
Epoch 128/200  
114/114 [==============================] - 0s 623us/step - loss: 0.0105 - accuracy: 0.9945  
Epoch 129/200  
114/114 [==============================] - 0s 608us/step - loss: 0.0104 - accuracy: 0.9945  
Epoch 130/200  
114/114 [==============================] - 0s 621us/step - loss: 0.0103 - accuracy: 0.9945  
Epoch 131/200  
114/114 [==============================] - 0s 598us/step - loss: 0.0102 - accuracy: 0.9947  
Epoch 132/200  
114/114 [==============================] - 0s 804us/step - loss: 0.0101 - accuracy: 0.9945  
Epoch 133/200  
114/114 [==============================] - 0s 614us/step - loss: 0.0100 - accuracy: 0.9947  
Epoch 134/200  
114/114 [==============================] - 0s 602us/step - loss: 0.0099 - accuracy: 0.9947  
Epoch 135/200  
114/114 [==============================] - 0s 613us/step - loss: 0.0098 - accuracy: 0.9947  
Epoch 136/200  
114/114 [==============================] - 0s 608us/step - loss: 0.0097 - accuracy: 0.9947  
Epoch 137/200  
114/114 [==============================] - 0s 634us/step - loss: 0.0097 - accuracy: 0.9947  
Epoch 138/200  
114/114 [==============================] - 0s 602us/step - loss: 0.0096 - accuracy: 0.9947  
Epoch 139/200  
114/114 [==============================] - 0s 617us/step - loss: 0.0095 - accuracy: 0.9947  
Epoch 140/200  
114/114 [==============================] - 0s 603us/step - loss: 0.0094 - accuracy: 0.9947  
Epoch 141/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0093 - accuracy: 0.9947  
Epoch 142/200  
114/114 [==============================] - 0s 602us/step - loss: 0.0093 - accuracy: 0.9947  
Epoch 143/200  
114/114 [==============================] - 0s 622us/step - loss: 0.0092 - accuracy: 0.9947  
Epoch 144/200  
114/114 [==============================] - 0s 607us/step - loss: 0.0091 - accuracy: 0.9950  
Epoch 145/200  
114/114 [==============================] - 0s 603us/step - loss: 0.0090 - accuracy: 0.9947  
Epoch 146/200  
114/114 [==============================] - 0s 617us/step - loss: 0.0089 - accuracy: 0.9947  
Epoch 147/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0089 - accuracy: 0.9953  
Epoch 148/200  
114/114 [==============================] - 0s 807us/step - loss: 0.0088 - accuracy: 0.9950  
Epoch 149/200  
114/114 [==============================] - 0s 599us/step - loss: 0.0087 - accuracy: 0.9950  
Epoch 150/200  
114/114 [==============================] - 0s 611us/step - loss: 0.0086 - accuracy: 0.9956  
Epoch 151/200  
114/114 [==============================] - 0s 621us/step - loss: 0.0086 - accuracy: 0.9956  
Epoch 152/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0085 - accuracy: 0.9956  
Epoch 153/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0085 - accuracy: 0.9959  
Epoch 154/200  
114/114 [==============================] - 0s 643us/step - loss: 0.0084 - accuracy: 0.9956  
Epoch 155/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0083 - accuracy: 0.9961  
Epoch 156/200  
114/114 [==============================] - 0s 646us/step - loss: 0.0082 - accuracy: 0.9961  
Epoch 157/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0082 - accuracy: 0.9961  
Epoch 158/200  
114/114 [==============================] - 0s 613us/step - loss: 0.0081 - accuracy: 0.9961  
Epoch 159/200  
114/114 [==============================] - 0s 631us/step - loss: 0.0080 - accuracy: 0.9961  
Epoch 160/200  
114/114 [==============================] - 0s 617us/step - loss: 0.0080 - accuracy: 0.9961  
Epoch 161/200  
114/114 [==============================] - 0s 618us/step - loss: 0.0079 - accuracy: 0.9964  
Epoch 162/200  
114/114 [==============================] - 0s 641us/step - loss: 0.0078 - accuracy: 0.9961  
Epoch 163/200  
114/114 [==============================] - 0s 651us/step - loss: 0.0078 - accuracy: 0.9964  
Epoch 164/200  
114/114 [==============================] - 0s 631us/step - loss: 0.0077 - accuracy: 0.9967  
Epoch 165/200  
114/114 [==============================] - 0s 855us/step - loss: 0.0077 - accuracy: 0.9964  
Epoch 166/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0076 - accuracy: 0.9967  
Epoch 167/200  
114/114 [==============================] - 0s 617us/step - loss: 0.0075 - accuracy: 0.9967  
Epoch 168/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0075 - accuracy: 0.9967  
Epoch 169/200  
114/114 [==============================] - 0s 637us/step - loss: 0.0074 - accuracy: 0.9967  
Epoch 170/200  
114/114 [==============================] - 0s 659us/step - loss: 0.0074 - accuracy: 0.9967  
Epoch 171/200  
114/114 [==============================] - 0s 602us/step - loss: 0.0073 - accuracy: 0.9967  
Epoch 172/200  
114/114 [==============================] - 0s 620us/step - loss: 0.0072 - accuracy: 0.9967  
Epoch 173/200  
114/114 [==============================] - 0s 1ms/step - loss: 0.0072 - accuracy: 0.9967  
Epoch 174/200  
114/114 [==============================] - 0s 604us/step - loss: 0.0071 - accuracy: 0.9967  
Epoch 175/200  
114/114 [==============================] - 0s 599us/step - loss: 0.0071 - accuracy: 0.9967  
Epoch 176/200  
114/114 [==============================] - 0s 603us/step - loss: 0.0070 - accuracy: 0.9967  
Epoch 177/200  
114/114 [==============================] - 0s 626us/step - loss: 0.0070 - accuracy: 0.9970  
Epoch 178/200  
114/114 [==============================] - 0s 737us/step - loss: 0.0069 - accuracy: 0.9970  
Epoch 179/200  
114/114 [==============================] - 0s 685us/step - loss: 0.0068 - accuracy: 0.9970  
Epoch 180/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0068 - accuracy: 0.9975  
Epoch 181/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0067 - accuracy: 0.9970  
Epoch 182/200  
114/114 [==============================] - 0s 605us/step - loss: 0.0067 - accuracy: 0.9972  
Epoch 183/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0066 - accuracy: 0.9972  
Epoch 184/200  
114/114 [==============================] - 0s 596us/step - loss: 0.0066 - accuracy: 0.9975  
Epoch 185/200  
114/114 [==============================] - 0s 594us/step - loss: 0.0065 - accuracy: 0.9975  
Epoch 186/200  
114/114 [==============================] - 0s 612us/step - loss: 0.0064 - accuracy: 0.9978  
Epoch 187/200  
114/114 [==============================] - 0s 621us/step - loss: 0.0064 - accuracy: 0.9975  
Epoch 188/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0064 - accuracy: 0.9978  
Epoch 189/200  
114/114 [==============================] - 0s 602us/step - loss: 0.0063 - accuracy: 0.9975  
Epoch 190/200  
114/114 [==============================] - 0s 609us/step - loss: 0.0062 - accuracy: 0.9978  
Epoch 191/200  
114/114 [==============================] - 0s 636us/step - loss: 0.0062 - accuracy: 0.9978  
Epoch 192/200  
114/114 [==============================] - 0s 625us/step - loss: 0.0062 - accuracy: 0.9981  
Epoch 193/200  
114/114 [==============================] - 0s 613us/step - loss: 0.0061 - accuracy: 0.9986  
Epoch 194/200  
114/114 [==============================] - 0s 809us/step - loss: 0.0061 - accuracy: 0.9986  
Epoch 195/200  
114/114 [==============================] - 0s 610us/step - loss: 0.0060 - accuracy: 0.9983  
Epoch 196/200  
114/114 [==============================] - 0s 614us/step - loss: 0.0060 - accuracy: 0.9986  
Epoch 197/200  
114/114 [==============================] - 0s 638us/step - loss: 0.0059 - accuracy: 0.9986  
Epoch 198/200  
114/114 [==============================] - 0s 613us/step - loss: 0.0059 - accuracy: 0.9986  
Epoch 199/200  
114/114 [==============================] - 0s 614us/step - loss: 0.0058 - accuracy: 0.9986  
Epoch 200/200  
114/114 [==============================] - 0s 616us/step - loss: 0.0058 - accuracy: 0.9986

<keras.src.callbacks.History at 0x304c1a450>

predictions = model.predict(X\_test)  
  
predicted = tf.squeeze(predictions)  
y\_pred = np.array([1 if x >= 0.5 else 0 for x in predicted])  
  
accuracy = accuracy\_score(y\_test, y\_pred) \* 100  
precision = precision\_score(y\_test, y\_pred) \* 100  
recall = recall\_score(y\_test, y\_pred) \* 100  
f1 = f1\_score(y\_test, y\_pred) \* 100  
  
print(f"Accuracy: {accuracy:.2f}%")  
print(f"Precision: {precision:.2f}")  
print(f"Recall: {recall:.2f}")  
print(f"F1-score: {f1:.2f}")  
  
print("\nClassification Report:\n", classification\_report(y\_test, y\_pred))

49/49 [==============================] - 0s 409us/step  
Accuracy: 98.00%  
Precision: 98.46  
Recall: 87.27  
F1-score: 92.53  
  
Classification Report:  
 precision recall f1-score support  
  
 0 0.98 1.00 0.99 1331  
 1 0.98 0.87 0.93 220  
  
 accuracy 0.98 1551  
 macro avg 0.98 0.94 0.96 1551  
weighted avg 0.98 0.98 0.98 1551

plt.figure(figsize=(8, 6))  
  
cm = confusion\_matrix(y\_test, y\_pred)  
sns.heatmap(cm, annot=True, xticklabels=['Spam', 'Not Spam'], yticklabels=['Spam', 'Not Spam'])  
  
plt.xlabel('Predicted')  
plt.ylabel('Actual')  
plt.title('Confusion Matrix')  
plt.show()



new\_email\_content = "SALE SALE SALE, Buy now before the offer ends"  
new\_email\_vector = vectorizer.transform([new\_email\_content])  
  
is\_spam = int(np.round(model.predict(new\_email\_vector.toarray())[0]))  
  
print(f"Email: {new\_email\_content}")  
print(f"Is this email spam? {'No' if is\_spam == 0 else 'Yes'}")

1/1 [==============================] - 0s 32ms/step  
Email: SALE SALE SALE, Buy now before the offer ends  
Is this email spam? No