Library and Data Import

```
# Import TensorFlow and test if GPU is detected
import tensorflow as tf
tf.config.list_physical_devices()
```

```
[PhysicalDevice(name='/physical_device:CPU:0', device_type='CPU'),
 PhysicalDevice(name='/physical_device:GPU:0', device_type='GPU')]
```

```
# All other needed imports
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix
from sklearn.model_selection import train_test_split
import nltk
from nltk.corpus import stopwords
import re
from tensorflow import keras
from tensorflow.keras import layers
from tensorflow.keras.preprocessing.text import Tokenizer
from keras.preprocessing.sequence import pad_sequences
from nltk.tokenize import word_tokenize
from nltk.stem import WordNetLemmatizer
from keras.models import Sequential
from keras.layers import Dense
from keras.layers import Flatten
from keras.layers import Embedding
from keras.layers import LSTM
from keras.layers import Dropout
from keras.layers import Bidirectional
from tensorflow.keras.callbacks import EarlyStopping

nltk.download('stopwords')
nltk.download('punkt')
nltk.download('wordnet')
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
[nltk_data] Downloading package wordnet to /root/nltk_data...
[nltk_data]   Package wordnet is already up-to-date!
True
```

```
# Read in Yelp, IMDB, Amazon data sets to Pandas DataFrames

yelp = pd.read_csv('yelp_labelled.txt', sep='\t', header=None, names=['comment', 'rating'])

# IMDB file has many lines start with " which causes read_csv to skip the lines by default. Quoting=3 and quotechar=None appears to fix the b
imdb = pd.read_csv('imdb_labelled.txt', sep='\t', header=None, names=['comment', 'rating'], quotechar=None, quoting=3, skip_blank_lines=False

amzn = pd.read_csv('amazon_cells_labelled.txt', sep='\t', header=None, names=['comment', 'rating'])
```

B1. Data Exploration

```
yelp.info()
print(yelp.head())
print()
imdb.info()
print(imdb.head())
print()
amzn.info()
print(amzn.head())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 2 columns):
 #   Column   Non-Null Count  Dtype
```

```
---  ------   --------------  -----
 0   comment  1000 non-null   object
 1   rating   1000 non-null   int64 
dtypes: int64(1), object(1)
memory usage: 15.8+ KB
                                             comment  rating
0                           Wow... Loved this place.       1
1                                 Crust is not good.       0
2          Not tasty and the texture was just nasty.       0
3  Stopped by during the late May bank holiday of...       1
4  The selection on the menu was great and so wer...       1

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 2 columns):
 #   Column   Non-Null Count  Dtype 
---  ------   --------------  -----
 0   comment  1000 non-null   object
 1   rating   1000 non-null   int64 
dtypes: int64(1), object(1)
memory usage: 15.8+ KB
                                             comment  rating
0  A very, very, very slow-moving, aimless movie ...       0
1  Not sure who was more lost - the flat characte...       0
2  Attempting artiness with black & white and cle...       0
3       Very little music or anything to speak of.         0
4  The best scene in the movie was when Gerardo i...       1

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 2 columns):
 #   Column   Non-Null Count  Dtype 
---  ------   --------------  -----
 0   comment  1000 non-null   object
 1   rating   1000 non-null   int64 
dtypes: int64(1), object(1)
memory usage: 15.8+ KB
                                             comment  rating
0  So there is no way for me to plug it in here i...       0
1                        Good case, Excellent value.       1
2                             Great for the jawbone.       1
3  Tied to charger for conversations lasting more...       0
4                                  The mic is great.       1
```

```python
# Check for presence of non-ASCII characters
# Code ref: https://stackoverflow.com/a/18403812
def isascii(s):
    """
    Check if the characters in string s are in the ASCII region, U+0-U+FF.
    Unicode characters will be encoded as >1 byte
    """
    return len(s) == len(s.encode())


for c in (yelp[~yelp['comment'].apply(isascii)]['comment']):
    print(c)

print()

for c in (imdb[~imdb['comment'].apply(isascii)]['comment']):
    print(c)

print()

for c in (amzn[~amzn['comment'].apply(isascii)]['comment']):
    print(c)

print()
```

```
My fiancé and I came in the middle of the day and we were greeted and seated right away.
I really enjoyed Crema Café before they expanded; I even told friends they had the BEST breakfast.
The crêpe was delicate and thin and moist.
The only thing I wasn't too crazy about was their guacamole as I don't like it puréed.

It's practically perfect in all of them � a true masterpiece in a sea of faux "masterpieces.
I'm glad this pretentious piece of s*** didn't do as planned by the Dodge stratus Big Shots... It's gonna help movie makers who aren't
The script is�was there a script?
I'll even say it again � this is torture.
This show is made for Americans - it is too stupid and full with hatred and clichés to be admitted elsewhere.
A cheap and cheerless heist movie with poor characterisation, lots of underbite style stoic emoting (think Chow Yun Fat in A Better Tom
And I forgot: The Casting here i superb, with Trond Fausa Aurvåg being perfect in the role as the Bothersome Man, who doesn't understan
```

```
The script is bad, very bad � it contains both cheesiness and unethical joke that you normally see in rated R or NC-17 movie.
Let's start with all the problems�the acting, especially from the lead professor, was very, very bad.
Technically, the film is well made with impressive camera-work, solid acting and effective music from Riz Ortolani � particularly good
I am so tired of clichés that is just lazy writing, and here they come in thick and fast.
But, Kevin Spacey is an excellent, verbal tsunami as Buddy Ackerman � and totally believable because he is a great actor.
Definitely worth seeing� it's the sort of thought provoking film that forces you to question your own threshold of loneliness.
```

B5. Data Preprocessing

Stopword list modification

```
sw=stopwords.words('english')
print(sw)
```

```
['i', 'me', 'my', 'myself', 'we', 'our', 'ours', 'ourselves', 'you', "you're", "you've", "you'll", "you'd", 'your', 'yours', 'yourself'
```

Per Aleti (2020), removing negating words (not, no, etc.) can impact the accuracy of sentiment analysis. For instance, removing all the above stopwords from a review such as "I didn't like the product" would produce "like product" -- a reversal of the sentiment. I will remove no/nor/not from the stopwords array and replace the contraction "'t" with "not"

```
sw.remove('no')
sw.remove('not')
sw.remove('nor')
```

Lemmatization, stopword removal, non-alphabetic character removal

```
# Code ref: https://dev.to/sunilaleti/don-t-blindly-remove-stopwords-in-sentiment-analysis-3nok
# Code ref: Elleh, D213 Task 2 Data Preprocessing in Python
# Code ref: https://www.geeksforgeeks.org/python-lemmatization-with-nltk/

lemma = WordNetLemmatizer()

def lem(wordlist):
    text = [lemma.lemmatize(word) for word in wordlist]
    return text

def remove_sw(wordlist):
    text = [word for word in wordlist if not word in sw]
    return text

def preprocess(df):
    # change "'t" to " not" and make everything lowercase
    df['comment_processed'] = df['comment'].str.lower().replace({r"\'t":" not"}, regex=True)
    # remove non-alphabetical except for SPACE
    df['comment_processed'].replace({r'[^a-zA-Z\x20]+':' '}, regex=True, inplace=True)
    df['comment_processed'] = df['comment_processed'].apply(nltk.word_tokenize)
    df['comment_processed'] = df['comment_processed'].apply(remove_sw)
    df['comment_processed'] = df['comment_processed'].apply(lem)
    df['comment_processed'] = df['comment_processed'].apply(" ".join)
    return df

yelp = preprocess(yelp)
print(yelp.head())
imdb = preprocess(imdb)
print(imdb.head())
amzn = preprocess(amzn)
print(amzn.head())
```

```
                                             comment  rating  \
0                           Wow... Loved this place.       1
1                                 Crust is not good.       0
2          Not tasty and the texture was just nasty.       0
3  Stopped by during the late May bank holiday of...       1
4  The selection on the menu was great and so wer...       1

                                   comment_processed
```

```
0                                   wow loved place
1                                    crust not good
2                           not tasty texture nasty
3  stopped late may bank holiday rick steve recom...
4                        selection menu great price
                                             comment  rating  \
0  A very, very, very slow-moving, aimless movie ...       0
1  Not sure who was more lost - the flat characte...       0
2  Attempting artiness with black & white and cle...       0
3       Very little music or anything to speak of.         0
4  The best scene in the movie was when Gerardo i...       1

                                   comment_processed
0  slow moving aimless movie distressed drifting ...
1  not sure lost flat character audience nearly h...
2  attempting artiness black white clever camera ...
3                       little music anything speak
4  best scene movie gerardo trying find song keep...
                                             comment  rating  \
0  So there is no way for me to plug it in here i...       0
1                        Good case, Excellent value.       1
2                             Great for the jawbone.       1
3  Tied to charger for conversations lasting more...       0
4                                  The mic is great.       1

                                   comment_processed
0                   no way plug u unless go converter
1                           good case excellent value
2                                       great jawbone
3  tied charger conversation lasting minute major...
4                                           mic great
```

```
# Specifically check one of the lines that had a non-ASCII character (é)
yelp.iloc[[150]]
```

	comment	rating	comment_processed
150	My fiancé and I came in the middle of the day ...	1	fianc came middle day greeted seated right away

Train-test split

```
# Will use yelp+imdb to train/test, amzn to validate

input= pd.concat([yelp,imdb], ignore_index=True)
input.tail()

inX = input.comment_processed
iny = input.rating
valX = amzn.comment_processed
valy = amzn.rating


X_train, X_test, y_train, y_test = train_test_split(inX, iny, test_size=0.25, random_state=4877)

print(X_train, y_train)
print(X_test, y_test)

df_train_out = pd.concat([y_train, X_train], axis=1)
df_test_out = pd.concat([y_test, X_test], axis=1)
df_val_out = pd.concat([valy, valX], axis=1)
df_train_out.to_csv('traindata.csv', index=False)
df_test_out.to_csv('testdata.csv', index=False)
df_val_out.to_csv('valdata.csv', index=False)
```

```
1593    tiny toon kept vibe delivered one popular funn...
533     love authentic mexican food want whole bunch i...
1309    someone strives greatness poetry delivers mudd...
798                                        mediocre food
775                        frozen margarita way sugary taste
                                ...
1                                         crust not good
672                           sushi lover avoid place mean
704                     cashier friendly even brought food
1325                                        never forget
1331                             not seen not waste time
Name: comment_processed, Length: 1500, dtype: object 1593    1
533     1
1309    0
```

```
798     0
775     0
       ..
1       0
672     0
704     1
1325    1
1331    0
Name: rating, Length: 1500, dtype: int64
824                                              awful service
1001    not sure lost flat character audience nearly h...
660     personally love hummus pita baklava falafel ba...
1851                                   dialogue atrocious
1841                                   still trying get bad
                              ...
1849                           like bad two hour tv movie
50      ordered duck rare pink tender inside nice char...
730     food barely lukewarm must sitting waiting serv...
1720           describe painfully dreary time waster film
1547    terribly disappointed film would receive many ...
Name: comment_processed, Length: 500, dtype: object 824     0
1001    0
660     1
1851    0
1841    0
       ..
1849    0
50      1
730     0
1720    0
1547    0
Name: rating, Length: 500, dtype: int64
```

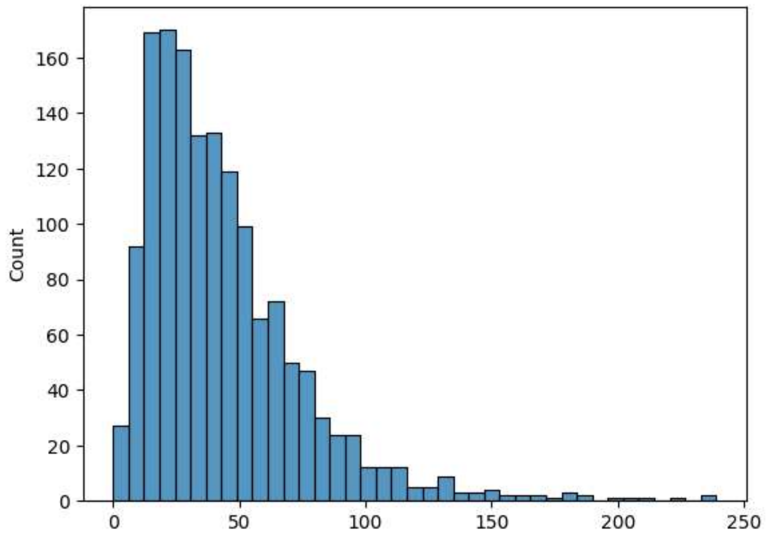
B2. Tokenization

```
# Code ref: https://stackoverflow.com/q/58362316

train_text = X_train.to_numpy()
test_text = X_test.to_numpy()
val_text = valX.to_numpy()

t = Tokenizer(oov_token='<unk>')
t.fit_on_texts(train_text)

X_train_seq = t.texts_to_sequences(train_text)
X_test_seq = t.texts_to_sequences(test_text)
val_seq = t.texts_to_sequences(val_text)


# summarize what was learned
# Code ref: (Brownlee, 2019) https://machinelearningmastery.com/prepare-text-data-deep-learning-keras/
from collections import OrderedDict
print(str(t.word_counts)[:500])
print("Training set length: ",str(t.document_count)[:500],"\n")
print(str(t.word_index)[:500],'...',str(t.word_index)[-500:])
vocab_size = len(t.word_index)
print("Number of words in training index: ",vocab_size)
#print(str(t.word_docs)[:500],'...',str(t.word_docs)[-500:])
print()
print()
# find most common words
wc = t.word_counts
print("List of words in training set ordered by appearance frequency:\n", list(OrderedDict(sorted(wc.items(), key=lambda c: c[1], reverse=T
```

```
OrderedDict([('tiny', 2), ('toon', 1), ('kept', 4), ('vibe', 4), ('delivered', 1), ('one', 80), ('popular', 1), ('funny', 15), ('underr
Training set length:  1500

{'<unk>': 1, 'not': 2, 'movie': 3, 'film': 4, 'good': 5, 'food': 6, 'place': 7, 'one': 8, 'great': 9, 'like': 10, 'bad': 11, 'time': 12
Number of words in training index:  3208


List of words in training set ordered by appearance frequency:
 ['not', 'movie', 'film', 'good', 'food', 'place', 'one', 'great', 'like', 'bad', 'time', 'service', 'really', 'back', 'go', 'also', 'e
```

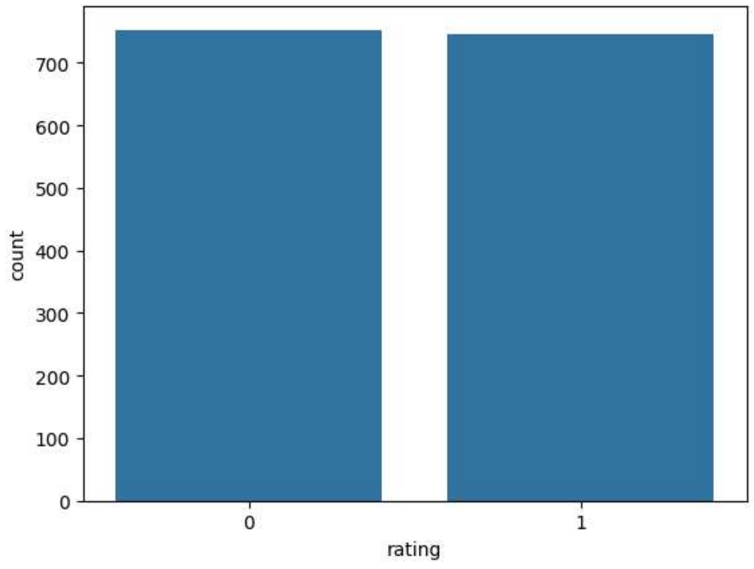
```
length = [len(i) for i in X_train]
print("The Average Review length in the training set is ", np.mean(length))
print("The Max Review length is", np.max(length))
print("The Standard Deviation is", round(np.std(length)))

sns.histplot(length)
plt.show()
```

```
The Average Review length in the training set is  43.844
The Max Review length is 239
The Standard Deviation is 32
```



```
# Show that training set is well-balanced between positive & negative reviews
sns.countplot(x=y_train)
```

```
<Axes: xlabel='rating', ylabel='count'>
```



B3. Padding

```
vocab_size = len(t.word_index)
# Set max length to be 2 SDs above mean length
maxlen = round(np.mean(length) + 2 * (np.std(length)))
print(maxlen)
```

```
107
```

```
# Code ref: https://stackabuse.com/python-for-nlp-movie-sentiment-analysis-using-deep-learning-in-keras/

X_train_pad = pad_sequences(X_train_seq, padding='post', maxlen=maxlen)
X_test_pad = pad_sequences(X_test_seq, padding='post', maxlen=maxlen)
val_pad = pad_sequences(val_seq, padding='post', maxlen=maxlen)

print(X_train_pad.shape)
print(val_pad.shape)

print("\n",val_text[0])
print(val_seq[0],"\n")
val_pad[0]
```

```
(1500, 107)
(1000, 107)

 no way plug u unless go converter
[20, 24, 1305, 49, 1037, 16, 1]

array([  20,   24, 1305,   49, 1037,   16,    1,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0], dtype=int32)
```

```
train_labels = y_train.to_numpy().flatten()
test_labels = y_test.to_numpy().flatten()
val_labels = valy.to_numpy().flatten()
```

Part III - Model creation and fit

```
# Word embedding length - code ref: Ellis, D213 Task 2 Cohort PPT
max_seq_embedding = int(round(np.sqrt(np.sqrt(vocab_size)),0))
print(max_seq_embedding)
```

```
8
```

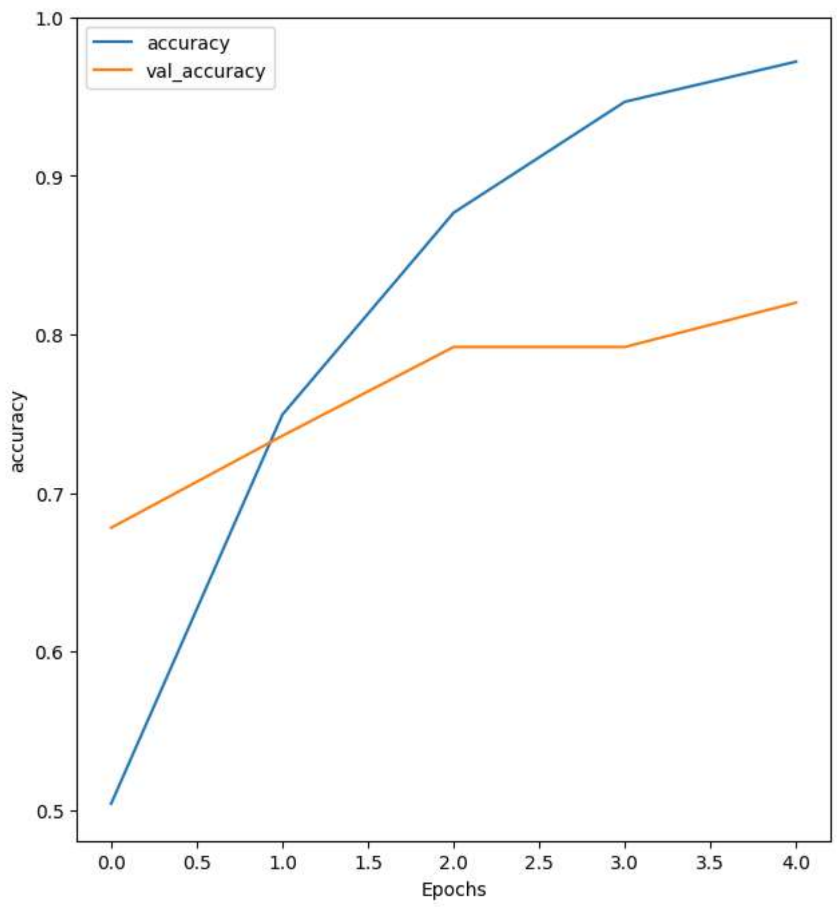
```
# Code ref: https://machinelearningmastery.com/use-word-embedding-layers-deep-learning-keras/
# Code ref: https://www.tensorflow.org/text/tutorials/text_classification_rnn
# Code ref: https://campus.datacamp.com/courses/introduction-to-deep-learning-in-python/fine-tuning-keras-models?ex=6

# Initialize random seed, enable deterministic mode

tf.keras.utils.set_random_seed(4877)
tf.config.experimental.enable_op_determinism()

# Build the model
model = tf.keras.Sequential([
    Embedding(vocab_size, max_seq_embedding, input_length=maxlen),
    #Flatten(),
    #Bidirectional(LSTM(64, return_sequences=True)),
    Bidirectional(LSTM(32)),
    Dense(128, activation='relu'),
    Dropout(0.5),
    #Dense(128, activation='relu'),
    #Dropout(0.5),
    Dense(1, activation='sigmoid')
])

# Compile model
opt = 'adam'
model.compile(optimizer=opt, loss='binary_crossentropy', metrics=['accuracy'])

# Define early_stopping_monitor
early_stopping_monitor = EarlyStopping(patience=2)

history = model.fit(X_train_pad, train_labels, validation_data=(X_test_pad, test_labels), epochs = 100, callbacks=[early_stopping_monitor])

model.summary()
```

```
Epoch 1/100
47/47 [==============================] - 17s 242ms/step - loss: 0.6932 - accuracy: 0.5040 - val_loss: 0.6904 - val_accuracy: 0.6780
Epoch 2/100
47/47 [==============================] - 7s 144ms/step - loss: 0.6529 - accuracy: 0.7493 - val_loss: 0.5857 - val_accuracy: 0.7360
Epoch 3/100
47/47 [==============================] - 4s 90ms/step - loss: 0.3612 - accuracy: 0.8767 - val_loss: 0.4717 - val_accuracy: 0.7920
Epoch 4/100
47/47 [==============================] - 2s 46ms/step - loss: 0.1637 - accuracy: 0.9467 - val_loss: 0.5303 - val_accuracy: 0.7920
Epoch 5/100
47/47 [==============================] - 3s 55ms/step - loss: 0.0897 - accuracy: 0.9720 - val_loss: 0.5247 - val_accuracy: 0.8200
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 embedding (Embedding)       (None, 107, 8)            25664

 bidirectional (Bidirection  (None, 64)                10496
 al)

 dense (Dense)               (None, 128)               8320

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 1)                 129

=================================================================
Total params: 44609 (174.25 KB)
Trainable params: 44609 (174.25 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

D3. Training Process Visualizations

```
# code ref: https://www.tensorflow.org/text/tutorials/text_classification_rnn
def plot_graphs(history, metric):
  plt.plot(history.history[metric])
  plt.plot(history.history['val_'+metric], '')
  plt.xlabel("Epochs")
  plt.ylabel(metric)
  plt.legend([metric, 'val_'+metric])


plt.figure(figsize=(16, 8))
plt.subplot(1, 2, 1)
```

```
plot_graphs(history, 'accuracy')
plt.ylim(None, 1)
plt.subplot(1, 2, 2)
plot_graphs(history, 'loss')
plt.ylim(0, None)
plt.show()
```

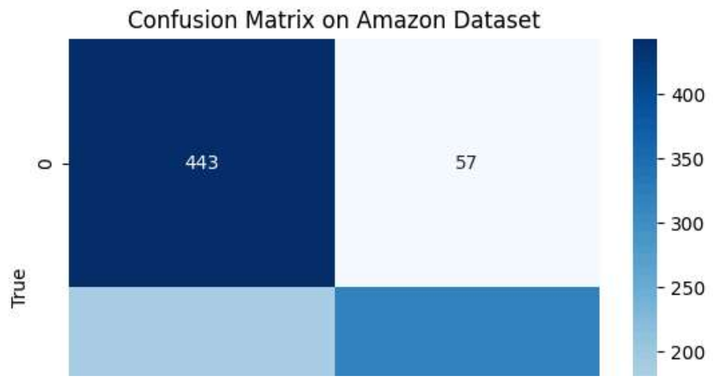


```
16/16 [==============================] - 0s 10ms/step - loss: 0.5247 - accuracy: 0.8200
Accuracy on Test Set: 82.00%
32/32 [==============================] - 0s 9ms/step - loss: 0.6566 - accuracy: 0.7600
Accuracy on Amazon Data: 76.00%
```

D4. Predictive Accuracy

```
scores = model.evaluate(X_test_pad, test_labels)
print("Accuracy on Test Set: %.2f%%" % (scores[1]*100))

scores = model.evaluate(val_pad, val_labels)
print("Accuracy on Amazon Data: %.2f%%" % (scores[1]*100))

# Get predicted labels
# Code ref: https://www.freecodecamp.org/news/binary-classification-made-simple-with-tensorflow/
y_pred = tf.squeeze(model.predict(val_pad))
predicted = np.array([1 if x >= 0.5 else 0 for x in y_pred])

# Create confusion matrix
cm = confusion_matrix(val_labels, predicted)

# Plot confusion matrix
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues")
plt.xlabel("Predicted")
plt.ylabel("True")
plt.title("Confusion Matrix on Amazon Dataset")
plt.show()
```

```
16/16 [==============================] - 0s 8ms/step - loss: 0.5247 - accuracy: 0.8200
Accuracy on Test Set: 82.00%
32/32 [==============================] - 0s 9ms/step - loss: 0.6566 - accuracy: 0.7600
Accuracy on Amazon Data: 76.00%
32/32 [==============================] - 0s 7ms/step
```


Confusion Matrix on Amazon Dataset
True