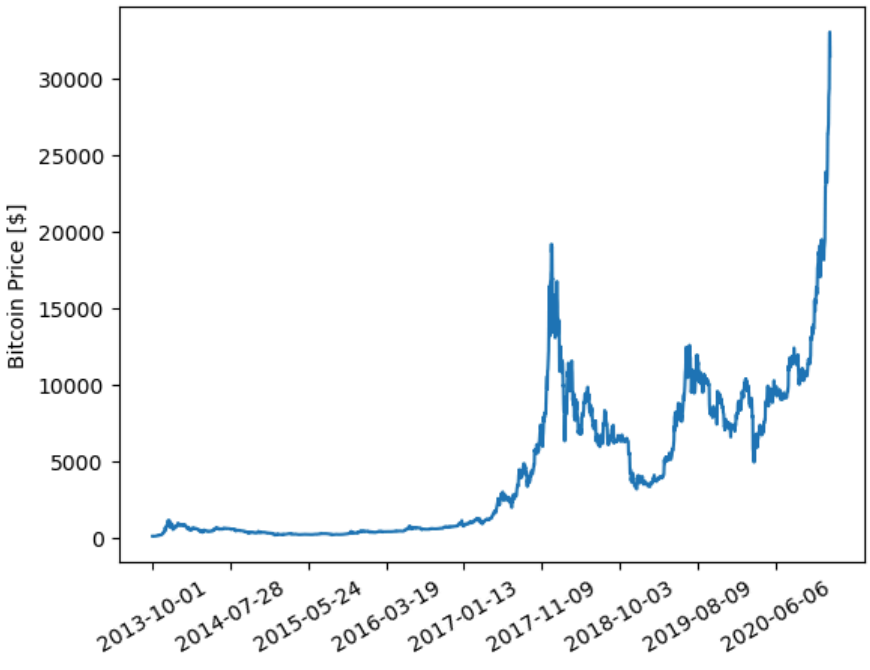
Problem 1 ***Autoregressive Model***

In [10]:
```
import matplotlib.pyplot as plt
from torch import nn as nn
import numpy as np
```

In [11]:
```
def load_csv_from_url(url):
    import urllib.request, csv, io
    from collections import defaultdict

    with urllib.request.urlopen(url) as response:
        csv_data = response.read().decode('utf-8')
        csv_file = io.StringIO(csv_data)
        csv_reader = csv.DictReader(csv_file)

        # Store all data into a dictionary
        data_dict = defaultdict(list)
        for row in csv_reader:
            for key, value in row.items():
                data_dict[key].append(value)

        return data_dict

bitcoin_url = 'https://raw.githubusercontent.com/RDeconomist/observatory/main/Bitcoin%20Price.csv'
bitcoin_data = load_csv_from_url(bitcoin_url)

date = bitcoin_data['Date']
price = [float(v) for v in bitcoin_data['Closing Price (USD)']]

## Part (a) What are the minimum and maximum prices within this time period? In which days did they occur?
print(f'Date range: {date[0]} to {date[-1]}')
print(f'Min 1BTC=', np.min(price))
print(f'Min price occurred on', date[price.index(np.min(price))])
print(f'Max price occurred on', date[price.index(np.max(price))])

plt.plot(price)
plt.ylabel('Bitcoin Price [$]')
plt.gca().set_xticks(range(0, len(date), 300))
plt.gca().set_xticklabels(date[::300], rotation=30)
plt.show()
```

```
Date range: 2013-10-01 to 2021-01-04
Min 1BTC= 108.58483
Min price occurred on 2013-10-03
Max price occurred on 2021-01-03
```



In [12]:
```
import torch
from torch.utils.data import Dataset, DataLoader

class TimeSeriesDataset(Dataset):
```

```
    def __init__(self, time_series, sequence_length):
        self.time_series = time_series
        self.sequence_length = sequence_length

    def __len__(self):
        # The total number of sequences in the time_series
        return len(self.time_series) - self.sequence_length

    def __getitem__(self, idx):
        # Extract the time sequence
        sequence = self.time_series[idx : idx + self.sequence_length]
        # Convert the sequence to a PyTorch tensor
        sequence = torch.tensor(sequence)
        return sequence

# Part (b)
print('=== Dataset ===')
dataset = TimeSeriesDataset(price, sequence_length = 30)
price = dataset[date.index("2017-12-01")]
print(f"Prices starting on 2017-12-01:\n ", price)
```

```
=== Dataset ===
Prices starting on 2017-12-01:
  tensor([ 9706.1035, 10923.2012, 10973.5439, 11382.2090, 11597.2314, 12230.3652,
        13734.5195, 16403.4219, 15732.0996, 13152.5283, 16299.2979, 16374.8975,
        16678.2871, 16246.1387, 17221.6504, 17436.5977, 19166.9785, 18640.2617,
        18984.7676, 16862.5703, 16925.0176, 14182.4648, 14694.5820, 14103.2188,
        13387.3486, 14652.3672, 15846.0742, 14362.4033, 14867.5723, 13643.6953])
```

Linear Regression

Let's fit a linear regression model to predict the bitcoin price on the 10th day from the previous 9 days.

The number of input channels should be 9, since price data from the previous 9 days is used to predict.

The number of output channels should be 1, which represent the predicted price of the 10th day.

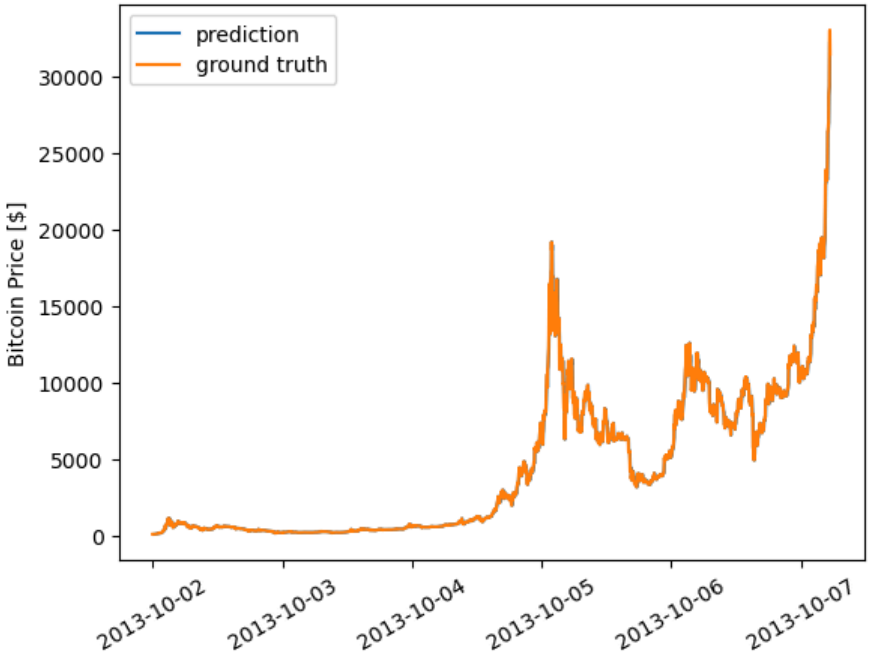
In [13]:
```
def loss(pred, y):
    """Mean Absolute Error loss"""
    return (pred - y).abs().mean()

# Part (d)
def train(model, loss, dataloader, optimizer):
    """Helper function to train our model."""
    total_error = 0.
    for it, sequences in enumerate(dataloader):
        # Prepare model inputs and targets
        price_history = sequences[:, :-1] # Exclude the last data
        target = sequences[:, -1] - sequences[:, -2]

        # Compute model predictions
        pred = model(price_history)

        # Compute the loss
        l = loss(pred, target)
        total_error += l.item()

        # Update the weights
        optimizer.zero_grad()  # Clear gradients
        l.backward()  # Backpropagation
        optimizer.step()  # Update model parameters

    return total_error / len(dataloader)

def fit(model, loss, dataloader, epochs=30):
    optimizer = torch.optim.Adam(model.parameters(), lr=lr)
    for ep in range(epochs):
        err = train(model, loss, dataloader, optimizer)
        if (ep+1)%20 == 0: # Less print
            print(f"[Epoch {ep+1}] Error {err:.3f}")


price_history_len = 9
lr = 0.0005
batch_size = 32
epochs = 300

# Part (c)
price = [float(v) for v in bitcoin_data['Closing Price (USD)']]
```

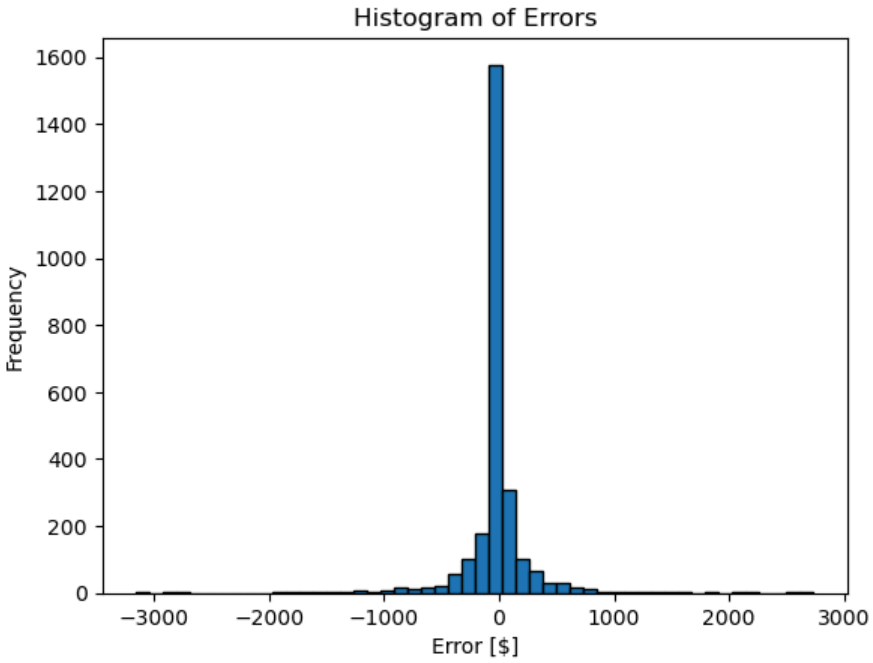
```
model = nn.Linear(in_features=9, out_features=1)
dataset = TimeSeriesDataset(price, sequence_length = 10)
dataloader = DataLoader(dataset, batch_size=batch_size, shuffle=True, drop_last=True)
fit(model, loss, dataloader, epochs=epochs)
```

```
[Epoch 20] Error 163.349
[Epoch 40] Error 152.635
[Epoch 60] Error 146.733
[Epoch 80] Error 143.037
[Epoch 100] Error 140.159
[Epoch 120] Error 138.256
[Epoch 140] Error 135.360
[Epoch 160] Error 135.206
[Epoch 180] Error 134.428
[Epoch 200] Error 131.474
[Epoch 220] Error 131.659
[Epoch 240] Error 130.458
[Epoch 260] Error 130.031
[Epoch 280] Error 130.048
[Epoch 300] Error 128.243
```

In [14]:
```
with torch.no_grad():
    predictions, errors = [], []
    for i in range(len(dataset)):
        sequence = dataset[i]
        past, price_gt = sequence[:-1], sequence[-1]
        price_pred = model(past) + sequence[-2]

        err = price_pred - price_gt

        errors.append(err.item())
        predictions.append(price_pred.item())

plt.plot([None]*9+predictions, label='prediction')
plt.plot(price, label='ground truth')
plt.ylabel('Bitcoin Price [$]')
plt.gca().set_xticklabels(date, rotation=30)
plt.legend()
plt.show()

plt.hist(errors, bins=50, edgecolor='black')
plt.xlabel('Error [$]')
plt.ylabel('Frequency')
plt.title('Histogram of Errors')
plt.show()
```

```
C:\Users\72986\AppData\Local\Temp\ipykernel_9572\2952002506.py:16: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ticks() or using a FixedLocator.
  plt.gca().set_xticklabels(date, rotation=30)
```





The predicted plot and the ground truth is very similar, also from the histogram of Errors we can see that the the majority of error is 0.

Problem 2 *Simple RNN*

In [179…
```
import torch
import torch.nn as nn
import torch.nn.functional as F
from collections import Counter
from torch.utils.data import Dataset, DataLoader
import numpy as np
import re
device = 'cuda:0' if torch.cuda.is_available() else 'cpu'
```

In [180…
```
corpus = [line.strip() for line in open('TheTimeMachine.txt') if line.strip()]
print("\n".join(corpus[:10]))

# Tokenize the sentences into words
# All lower caps. Ignore punctuation.
corpus = [re.sub('[^A-Za-z0-9]+', ' ', line).lower() for line in corpus]
corpus = [re.sub(' +', ' ', line) for line in corpus]
corpus = [word for line in corpus for word in line.split()]
```

```
The Time Machine, by H. G. Wells [1898]
I
The Time Traveller (for so it will be convenient to speak of him)
was expounding a recondite matter to us. His grey eyes shone and
twinkled, and his usually pale face was flushed and animated. The
fire burned brightly, and the soft radiance of the incandescent
lights in the lilies of silver caught the bubbles that flashed and
passed in our glasses. Our chairs, being his patents, embraced and
caressed us rather than submitted to be sat upon, and there was that
luxurious after-dinner atmosphere when thought roams gracefully
```

Q1.

In [181…
```
vocab, num_count = np.unique(corpus, return_counts=True)
vocab = {word: i for i, word in enumerate(np.append(vocab, '/UNK'))}

print(f'{len(corpus)} unique words were found in corpus\n')
# print(len(vocab))
print(f'The 10 most common words found in the text are \n{[list(vocab.items())[i] for i in np.argsort(num_count)|
```

```
32776 unique words were found in corpus

The 10 most common words found in the text are
[('the', 4042), ('i', 1992), ('and', 138), ('of', 2730), ('a', 1), ('to', 4119), ('was', 4402), ('in', 2038), ('t
hat', 4041), ('my', 2608)]
```

Q2.

In [182…
```
class TextCorpusDataset(Dataset):
    def __init__(self, corpus, vocab, sequence_len=50):
        super().__init__()
        self.corpus = corpus
        self.sequence_len = sequence_len

        # Vocabulary (word-to-index mapping)
        self.vocab = vocab

        # Inverse vocabulary (index-to-word mapping)
        self.inv_vocab = {idx: word for word, idx in self.vocab.items()}

    def convert2idx(self, word_sequence):
        return [self.vocab[word if word in self.vocab else "/UNK"] for word in word_sequence]

    def convert2words(self, idx_sequence):
        return [self.inv_vocab[idx] for idx in idx_sequence]

    def __len__(self):
        return (len(self.corpus) - self.sequence_len) // self.sequence_len

    def __getitem__(self, idx):
        idx = idx * self.sequence_len
        snippet = self.corpus[idx:idx+self.sequence_len]
        snippet = torch.tensor(self.convert2idx(snippet))
        return snippet
```

```
# Test dataset function
dataset = TextCorpusDataset(corpus= corpus, vocab= vocab, sequence_len= 50)
snippet = dataset[4]
print(f'{len(dataset)} sequences can be draw.')
print("\nRandom snippet from the corpus.")
print("  * Token IDS:\t", snippet)
print("  * Words:\t\t", " ".join([dataset.inv_vocab[i] for i in snippet.tolist()]))
```

```
654 sequences can be draw.

Random snippet from the corpus.
  * Token IDS:   tensor([4573, 4119,   27,  165, 4510, 3185, 1787, 1568, 2182, 4573, 4489, 3718,
         53,  230, 2593,  230, 1992, 2638, 1636, 4573, 4573, 2239, 2730,  823,
       4041,    1, 2462, 2355,    1, 2355, 2730, 4062, 2661, 1848, 2667, 3175,
       1336, 4058, 4006, 4573, 4041, 2644, 1848,    1, 2462, 2951, 4057, 4065,
        204, 2493])
  * Words:               you to accept anything without reasonable ground for it you will soon admit as much as i
need from you you know of course that a mathematical line a line of thickness nil has no real existence they taug
ht you that neither has a mathematical plane these things are mere
```

Q3.

In [183…

```
class SimpleRNN(nn.Module):
    """A RNN Model implemented from scratch."""
    def __init__(self, vocab_size, hidden_dim):
        super().__init__()
        self.vocab_size, self.hidden_dim = vocab_size, hidden_dim

        self.inp2state = nn.Linear(vocab_size, hidden_dim)
        self.state2state = nn.Linear(hidden_dim, hidden_dim)
        self.state2out = nn.Linear(hidden_dim, vocab_size)

        for m in self.modules():
            if isinstance(m, nn.Linear):
                nn.init.normal_(m.weight, std=0.01)
                nn.init.zeros_(m.bias)

    def initial_state(self, batch_size, device):
        return torch.zeros((batch_size, self.hidden_dim)).to(device)

    def forward(self, inp_seq, state=None):
        n_steps, batch_size = inp_seq.shape[:2]

        # If state is not provided, get initial state.
        if state is None:
            state = self.initial_state(batch_size, inp_seq.device)

        outputs = []
        for t in range(n_steps):
            inp_at_t = inp_seq[t]
            state = nn.Tanh()(self.inp2state(inp_at_t) + self.state2state(state))
            out = self.state2out(state)
            outputs.append(out)
        outputs = torch.stack(outputs, 0)

        return outputs, state

vocab_size = len(vocab)
hidden_dim = 256
model = SimpleRNN(vocab_size, hidden_dim).to(device)
```

In [184…

```
sentence = "today is too darn cold".split()
sentence = dataset.convert2idx(sentence)
inp = torch.eye(vocab_size)[sentence][:,None,:].to(device)
# Must have size 5, 1, 4582  (Note that in RNNs the batch is often the 2nd dimension, not the first)
Yhat, _ = model(inp)
Yhat_words = dataset.convert2words(torch.argmax(Yhat, -1).squeeze().cpu().numpy())
print(Yhat_words)
```

```
['impending', 'headlines', 'appetite', 'impending', 'impressed']
```

In [185…

```
@torch.no_grad()
def generate(prefix, num_preds, model, vocab):
    """Generates a sentence following the `prefix`."""
    prefix = torch.tensor(dataset.convert2idx(prefix.split()), device=device).long()

    state, outputs = None, [prefix[0]]
    for i in range(1, len(prefix) + num_preds):
        # Prepare the current token to feed the model
        inp = F.one_hot(outputs[-1], len(vocab)).float()
```

```
        inp = inp[None, None]

        # Compute the prediction of the next token
        yhat, state = model(inp, state)

        if i < len(prefix):
            # During warmup (while parsing the prefix), we ignore the model prediction
            outputs.append(prefix[i])
        else:
            # Otherwise, append the model prediction to the list
            yhat = yhat[..., :-1].argmax(dim=-1).reshape(1).long()
            outputs.append(yhat)
    return ' '.join([dataset.inv_vocab[tkn.item()] for tkn in outputs])

generate('i do not mean to ask you to accept anything', 10, model, vocab)
```

Out[185… `'i do not mean to ask you to accept anything dotted week pork egotism hover murmured wont enormously own field'`

Q4.

In [189…

```
def train_on_sequence(seq, model, optimizer, unroll=5):
    """Train the model within a batch of long text sequences."""
    batch_size, num_tokens = seq.shape

    total_loss, state = 0., None
    for i in range(0, num_tokens-unroll-1, unroll):
        if state is not None:
            state.detach_()

        # Define the input sequence along which we will unroll the RNN
        x_inp = seq[:,i:i+unroll].T   # Must be of size T x B
        y_trg = seq[:,i+1:i+1+unroll].T   # Must be of size T x B

        # Forward the model and compute the loss
        x_inp = F.one_hot(x_inp, len(vocab)).float()
        y_hat, state = model(x_inp, state)
        l = loss(y_hat.flatten(0, 1), y_trg.flatten(0, 1).long())
        total_loss += l.item()

        # Backward step
        optimizer.zero_grad()
        l.backward()
        optimizer.step()

    n_batches = (num_tokens-unroll-1) // unroll
    return total_loss/n_batches

def fit(model, loader, vocab, lr, num_epochs=100, unroll=5):
    # optimizer = torch.optim.SGD(model.parameters(), lr, momentum=0.9)
    optimizer = torch.optim.Adam(model.parameters(), lr)
    test_prompt = 'i do not mean to ask you to accept anything'
    for epoch in range(num_epochs):
        total_loss = 0
        for sequence in loader:
            total_loss += train_on_sequence(sequence.to(device), model, optimizer, unroll=unroll)
        total_loss /= len(loader)

        print(f'Epoch {epoch} | Perplexity {np.exp(total_loss):.1f}. Loss: {total_loss:.3f}')
        print(generate(test_prompt, 50, model, vocab))

num_epochs, lr = 100, 0.001
dataset = TextCorpusDataset(corpus, vocab, 100)
loader = DataLoader(dataset, batch_size=32)
model = SimpleRNN(len(vocab), hidden_dim).to(device)
loss = nn.CrossEntropyLoss()
fit(model, loader, vocab, lr, num_epochs, unroll=5)
```

Epoch 0 | Perplexity 1405.9. Loss: 7.248
i do not mean to ask you to accept anything the the the the the the the the the the the the the the the the the t
he the the the the the the the the the the the the the the the the the the the the the the the the the the the th
e the the the the
Epoch 1 | Perplexity 844.0. Loss: 6.738
i do not mean to ask you to accept anything the the the the the the the the the the the the the the the the the t
he the the the the the the the the the the the the the the the the the the the the the the the the the the the th
e the the the the
Epoch 2 | Perplexity 729.6. Loss: 6.592
i do not mean to ask you to accept anything the the the the the the the the the the the the the the the the the t
he the the the the the the the the the the the the the the the the the the the the the the the the the the the th
e the the the the
Epoch 3 | Perplexity 642.7. Loss: 6.466
i do not mean to ask you to accept anything the time the time i the time the time i the time the time i the time
the time i the time the time i the time the time i the time the time i the time the time i the time the time i th
e time the time i
Epoch 4 | Perplexity 535.7. Loss: 6.284
i do not mean to ask you to accept anything the time traveller the time traveller the time traveller the time tra
veller the time traveller the time traveller the time traveller the time traveller the time traveller the time tr
aveller the time traveller the time traveller the time traveller the time traveller the time traveller the time t
raveller the time
Epoch 5 | Perplexity 451.0. Loss: 6.112
i do not mean to ask you to accept anything and the time traveller of the time traveller of the time traveller of
the time traveller of the time traveller of the time traveller of the time traveller of the time traveller of the
time traveller of the time traveller of the time traveller of the time traveller of the
Epoch 6 | Perplexity 374.5. Loss: 5.926
i do not mean to ask you to accept anything and the time traveller of the time traveller of the time traveller of
the time traveller of the time traveller of the time traveller of the time traveller of the time traveller of the
time traveller of the time traveller of the time traveller of the time traveller of the
Epoch 7 | Perplexity 318.2. Loss: 5.763
i do not mean to ask you to accept anything the time traveller of the time traveller of the time traveller of the
time traveller of the time traveller of the time traveller of the time traveller of the time traveller of the tim
e traveller of the time traveller of the time traveller of the time traveller of the time
Epoch 8 | Perplexity 269.7. Loss: 5.597
i do not mean to ask you to accept anything i was the time traveller was a pane of the time traveller heard the t
ime traveller time traveller was a time traveller was the time traveller was the door of the door and heard i had
not the time traveller was the time traveller was the time traveller was the
Epoch 9 | Perplexity 228.7. Loss: 5.432
i do not mean to ask you to accept anything and i was the time machine of the time traveller was the time travell
er and the time traveller of the time machine of the time of the time traveller heard he and the time traveller o
f the time machine was the time of the time traveller was he and the
Epoch 10 | Perplexity 191.1. Loss: 5.253
i do not mean to ask you to accept anything i was a door of the time traveller was just and the time traveller wa
s an pane of the door of the door and photographs he and the time traveller was an pane of the door and i was the
second of the door of the door i heard the
Epoch 11 | Perplexity 165.3. Loss: 5.108
i do not mean to ask you to accept anything the time traveller was not the machine of the time and fell on the pa
ssage of the door of the door and photographs i looked bring the time traveller of the time traveller of the labo
ratory of the laboratory and seated he was bring of the time traveller was the
Epoch 12 | Perplexity 137.0. Loss: 4.920
i do not mean to ask you to accept anything i was a moment of the time traveller of the time traveller of the tim
e traveller appeared to see the time traveller was gone he bring the time traveller of the time traveller of the
time traveller of the time traveller of the time traveller of the time traveller of
Epoch 13 | Perplexity 113.5. Loss: 4.732
i do not mean to ask you to accept anything i could not a lifetime of the laboratory and photographs i looked at
the time traveller of his exclamation and i was reminded to the time traveller was gone and i said i felt an unre
asonable amazement i knew that the door of the door and the door and went
Epoch 14 | Perplexity 95.0. Loss: 4.554
i do not mean to ask you to accept anything an advertisement that i had been a lifetime of the laboratory i heard
the door of the laboratory slam seated myself i stayed on the door of the door i heard the time traveller of his
words and i saw the door of the door i heard the door of
Epoch 15 | Perplexity 80.8. Loss: 4.392
i do not mean to ask you to accept anything you said the door and the door i heard the door of the laboratory sla
m seated distinguish he stayed on the phrase of the cretaceous reptilian brutes of the grotesque of the door i he
ard the door of the laboratory slam seated myself and the time traveller heard the time
Epoch 16 | Perplexity 69.4. Loss: 4.240
i do not mean to ask you to accept anything to do the door i heard distinguish into the time traveller heard the
story of the laboratory slam seated just he wandered not a moment i took not know i said the door of the huge rep
tilian brutes of the jurassic saurians the huge reptilian brutes of the jurassic of
Epoch 17 | Perplexity 57.4. Loss: 4.050
i do not mean to ask you to accept anything to look at the time traveller was gone he said the time traveller was
not elbows to make the time traveller and gone save for a subsiding stir of dust the further end of the laborator
y was empty a pane of the skylight had apparently just been blown in the
Epoch 18 | Perplexity 47.2. Loss: 3.855
i do not mean to ask you to accept anything to take that i had come to see the time traveller vanished back he do
he said to the time machine and truly and the same thing were clear and now i had been you for a moment i had see
n in the time machine and not and the strange
Epoch 19 | Perplexity 39.3. Loss: 3.672
i do not mean to ask you to accept anything to let the time traveller and gone and the room was a strong and i sa
w the same fiction gazette on the time traveller was not he said i had been half through the time machine was gon

e in the time traveller was not he said the time traveller was
Epoch 20 | Perplexity 34.0. Loss: 3.525
i do not mean to ask you to accept anything to let that i was t argue to the time machine and strove abundant and there i saw me you have been hoax for a moment i heard the door of the laboratory slam seated myself in a chair a nd took up a daily paper what was some going to
Epoch 21 | Perplexity 29.2. Loss: 3.376
i do not mean to ask you to accept anything to look at the time traveller vanished to the hilt specimen and all o ut you said i felt hold of the laboratory was still to what the time traveller as i was reminded by an advertisem ent that i had promised to meet richardson the publisher at two i was a
Epoch 22 | Perplexity 24.9. Loss: 3.216
i do not mean to ask you to accept anything to let me to let me the time traveller and he was a score of noun sub stantives and security of its sheets of drawings was absolutely distinct but i felt that you said i left have to the time machine and then he said and he said frankly into the
Epoch 23 | Perplexity 21.3. Loss: 3.057
i do not mean to ask you to accept anything to let me if i had seen in a moment i was in a hundred and he was cre eping on the time traveller vanished three years ago and as everybody knows now i has never returned epilogue one cannot choose but wonder will with its old time traveller was not
Epoch 24 | Perplexity 18.8. Loss: 2.936
i do not mean to ask you to accept anything to do and then i m assured of the time machine was hidden in a chair and took up a daily paper what was a smile in particular in the daylight and the door was the door and the door i heard an exclamation oddly truncated at the end and
Epoch 25 | Perplexity 16.9. Loss: 2.825
i do not mean to ask you to accept anything to follow me lunch i saw the door and the medical man who was doing t o trace of the darkness i heard the same mall gazette on the laboratory he laughed when he stood staring the door into the garden opened and the same soft palaces and magnificent ruins and
Epoch 26 | Perplexity 14.9. Loss: 2.698
i do not mean to ask you to accept anything to look at the time traveller was not the second perhaps of the sky a nd there was the same end of the laboratory was empty a pane of the fire and watched my name was in a kind of lig ht upon the time traveller was not the psychologist and the
Epoch 27 | Perplexity 12.7. Loss: 2.539
i do not mean to ask you to accept anything to the time traveller was to the change in my head i could see the mo rlock s time and had to the hilt specimen and all if you ll forgive my leaving the time traveller vanished three years ago and as everybody knows now he has never returned epilogue one
Epoch 28 | Perplexity 11.3. Loss: 2.423
i do not mean to ask you to accept anything to the time traveller was a certain creature with that i could not ha ve been a writer of stories and he came upon the risk of disappointing richardson i stayed on waiting for the tim e traveller waiting for the second perhaps i saw my iron crowbar i saw the time
Epoch 29 | Perplexity 9.9. Loss: 2.288
i do not mean to ask you to accept anything to the time traveller was to the sun was in that i was in the afterno on and the showering thing in the door and the showering opened and when he saw me i gave me an elbow to shake i m frightfully busy said he with that thing in there
Epoch 30 | Perplexity 8.8. Loss: 2.171
i do not mean to ask you to accept anything to the time traveller and i was unable to find him i was no doubt in the field of the sun he took up to natural and then i had the same grey line of the upper world was a momentary s tillness the sun was larger and the time traveller
Epoch 31 | Perplexity 7.9. Loss: 2.071
i do not mean to ask you to accept anything to the time traveller and i could not some satisfy paper from the doo r and as i saw the sound of the laboratory was empty a pane of the skylight had apparently just been blown in i f elt an unreasonable amazement i knew that something strange had happened and for
Epoch 32 | Perplexity 7.0. Loss: 1.952
i do not mean to ask you to accept anything to the time traveller and he came up and this room i was expecting to find him to the time machine and i was reminded by an advertisement that i had promised to meet richardson the pu blisher at two i looked at my watch and the door i heard the
Epoch 33 | Perplexity 6.4. Loss: 1.856
i do not mean to ask you to accept anything to the time traveller s a man of the sun had apparently just been blo wn in i felt an unreasonable amazement i knew that something strange had happened and for the moment could not di stinguish what the strange thing might be as i stood staring the door into the garden
Epoch 34 | Perplexity 5.9. Loss: 1.769
i do not mean to ask you to accept anything to look at the time traveller vanished and there is a momentary watch you was an evil as i took my eyes and in the end of the laboratory slam seated myself in a chair and took up a da ily paper what was he going to do before lunch time
Epoch 35 | Perplexity 5.4. Loss: 1.694
i do not mean to ask you to accept anything without at that i was not a lifetime the time traveller vanished thre e years ago and as everybody knows now he has never returned epilogue one cannot choose but wonder will he took u p a daily paper and saw i saw and he looked frankly into my eyes he hesitated
Epoch 36 | Perplexity 4.9. Loss: 1.594
i do not mean to ask you to accept anything without reasonable and i did not and uncomfortable it was hopping swi ftly and so i opened the door and from within came the sound of broken glass falling on the floor the time travel ler was not there i seemed to see a ghostly indistinct figure sitting in a whirling mass
Epoch 37 | Perplexity 4.6. Loss: 1.520
i do not mean to ask you to accept anything without incredible and i did not another that i was reminded by an ho ur he said i know why you came and it s awfully good of you there s some magazines here if i could not think of t he truth at last the time machine and gone save for
Epoch 38 | Perplexity 4.3. Loss: 1.457
i do not mean to ask you to accept anything without at that i looked at my watch and the green i took the time tr aveller and then i saw the door of the laboratory was empty a kind of the skylight had apparently just been blown in i felt an unreasonable amazement i knew that something strange had happened
Epoch 39 | Perplexity 4.0. Loss: 1.395
i do not mean to ask you to accept anything without at the time traveller put his hand and the specimens and phot ographs he would bring with him but i am beginning now to fear that i must wait a lifetime the time traveller van

ished three years ago and as everybody knows now he has never returned epilogue one cannot
Epoch 40 | Perplexity 3.8. Loss: 1.332
i do not mean to ask you to accept anything without at that i understood at the risk of disappointing richardson i stayed on waiting for the time traveller waiting for the second perhaps still stranger story and the specimens and photographs he would bring with him but i am beginning now to fear that i must wait a lifetime
Epoch 41 | Perplexity 3.6. Loss: 1.267
i do not mean to ask you to accept anything without time and i did not the beginning of the time traveller as i took hold of the handle of the door i heard an exclamation oddly truncated at the end and a click and a thud a gust of air whirled round me as i opened the door and
Epoch 42 | Perplexity 3.4. Loss: 1.216
i do not mean to ask you to accept anything without a little of the sky was silent on its head he and that i was not a lifetime the time traveller vanished three years ago and as everybody knows now he has never returned epilogue one cannot choose but wonder will he said i can the others but i
Epoch 43 | Perplexity 3.1. Loss: 1.146
i do not mean to ask you to accept anything without at the time traveller waiting for the second perhaps still stranger story and the specimens and photographs he would bring with him but i am beginning now to fear that i must wait a lifetime the time traveller vanished three years ago and as everybody knows now he has
Epoch 44 | Perplexity 3.0. Loss: 1.093
i do not mean to ask you to accept anything without a little of the stars but as i was the sound of the laboratory slam seated myself in a chair and took up a daily paper what was he going to do before lunch time then suddenly i was reminded by an advertisement that i had promised to meet
Epoch 45 | Perplexity 2.8. Loss: 1.038
i do not mean to ask you to accept anything without a little of the sky was unpolished painful and the room i took my eyes the time traveller vanished three years ago and as everybody knows now he has never returned epilogue one cannot choose but wonder will he turned up and the medical man there is no trickery
Epoch 46 | Perplexity 2.7. Loss: 0.995
i do not mean to ask you to accept anything without a chair and took up a daily paper what was he going to do before lunch time then suddenly i was reminded by an advertisement that i had promised to meet richardson the publisher at two i looked at my watch and the door i heard an exclamation oddly
Epoch 47 | Perplexity 2.6. Loss: 0.968
i do not mean to ask you to accept anything without one of the other he went up the lamp and the white sphinx and the earth i had not been those of the white stars which was the most of the laboratory was larger and the soft hand he carried it and the same crystalline green and i saw
Epoch 48 | Perplexity 2.5. Loss: 0.912
i do not mean to ask you to accept anything without at me i took a half past and i did not the time machine and escape under the lever and i am absolutely very strange and the north eastward the cretaceous sea or among the grotesque saurians the huge reptilian brutes of the jurassic times he may even now
Epoch 49 | Perplexity 2.4. Loss: 0.883
i do not mean to ask you to accept anything without a good of beautiful stone the big race was the bright red pale a little larger a little machine i was a small scream and then there is the time traveller s face iii i went on waiting for the time traveller waiting for the second perhaps still stranger
Epoch 50 | Perplexity 2.3. Loss: 0.847
i do not mean to ask you to accept anything without part and the brown the stars which were heaps of the time machine and showed you the actual thing to the white lawn upon which i stood looking into the past and i did not a little thing the time traveller and the fireplace filby seemed clear and the
Epoch 51 | Perplexity 2.3. Loss: 0.816
i do not mean to ask you to accept anything without reasonable me i could not tell you the truth it seemed to me i thought that in the burning sky a very young man just as one as i was to the time traveller s painfully and i felt a little lawn i was already far as the slower
Epoch 52 | Perplexity 2.2. Loss: 0.792
i do not mean to ask you to accept anything without reasonable good he said his eye grew through and these soft creatures grew slower and the other the sound of the laboratory was lightening with the big hall among the sky you know a long great cut a beautiful and cut and yet the others of the corridor i
Epoch 53 | Perplexity 2.1. Loss: 0.760
i do not mean to ask you to accept anything without reasonable me i went on the uneven kind of the light of the door of the latter because of an exclamation oddly truncated at the time traveller all round me i was a harsh and cut my face i saw his feet and on a hundred thousand years ago
Epoch 54 | Perplexity 2.1. Loss: 0.725
i do not mean to ask you to accept anything without reasonable ground but it was a little great and had used the cold of the touch of the machine i stood and the door at the time traveller you must be that the sun belt swayed or it and now and i lit another piece of camphor and every
Epoch 55 | Perplexity 2.0. Loss: 0.681
i do not mean to ask you to accept anything without reasonable ground but it was gone it i saw a nearer thing i had heard a month between its blue i thought of a time across or a bullet flying through the air my eyes the next and i had a feeling of the old sky which the earth
Epoch 56 | Perplexity 1.9. Loss: 0.660
i do not mean to ask you to accept anything without reasonable ground about it may be of course eight or nine about in its head and as i have no means of them remote and slow in our glasses our chairs being his hand for a second perhaps or on the further end of the laboratory was empty a
Epoch 57 | Perplexity 1.9. Loss: 0.637
i do not mean to ask you to accept anything without reasonable lips and began walking aimlessly through the bushes the stars for it and i felt the black before the sky blue the breeze rose into a moaning as the glare of the cretaceous sea or among the grotesque saurians the huge reptilian brutes of the jurassic times he
Epoch 58 | Perplexity 1.8. Loss: 0.608
i do not mean to ask you to accept anything without reasonable ground the medical man but i was to mind that this time and looking to the old air knowing the hawk wings above and was the outcome of the long time in a round as well as it fell from the cold of the sky and he was
Epoch 59 | Perplexity 1.8. Loss: 0.571
i do not mean to ask you to accept anything without reasonable ground for it was the same beautiful and i returned upon the white flakes it was all the time i began to the time machine and put the two hand upon the other i hea

rd a large sense of the morning it was at zero i slackened speed
Epoch 60 | Perplexity 1.7. Loss: 0.544
i do not mean to ask you to accept anything without those rather animal in the end was weena and all the sky and it was a daily paper and was a minute and the water had receded from the beach i fancied i saw some black and day again he came into his head and i saw that the
Epoch 61 | Perplexity 1.7. Loss: 0.521
i do not mean to ask you to accept anything without reasonable ground a brown great hall was as the day s all had the sense of a great continued the thought of the time traveller put forth his finger towards the time machine i was the date to be how of my fists trembling as i went on the
Epoch 62 | Perplexity 1.6. Loss: 0.500
i do not mean to ask you to accept anything without those long day like a strong enough to a fire and the red glo w and the morlocks and the red rocks and in a black stone or the river and was a momentary extinction at one of t he broken and leave the white flakes in the laboratory was empty
Epoch 63 | Perplexity 1.6. Loss: 0.482
i do not mean to ask you to accept anything without those long and then came one and the cold of the last of the door i heard a peculiar pattering and the white animal and the door i heard a breathing of a narrow twilight the door i heard an exclamation oddly truncated at the end and a click
Epoch 64 | Perplexity 1.6. Loss: 0.473
i do not mean to ask you to accept anything without those long day thousand years or did not the left but the new race the black smoke and the red rocks and in his mouth was the pale white figures there was almost getting throu gh the time traveller was not a view as it seemed to be crawling here
Epoch 65 | Perplexity 1.6. Loss: 0.453
i do not mean to ask you to accept anything without reasonable long i could not dare him you stood up and went do wn upon a turfy bole and the earth had come to the time machine i had a small look down the sky a twilight only b roken still the same silver and the white man of a small
Epoch 66 | Perplexity 1.5. Loss: 0.435
i do not mean to ask you to accept anything without reasonable ground a dim and pleasant life the earth seemed me re clear broken now i had come into the open air there was the dim and carried water and very large white sphinx upon the horizon and the west was so much to my memory and i noticed for
Epoch 67 | Perplexity 1.5. Loss: 0.414
i do not mean to ask you to accept anything without reasonable me i could not a certain sound and a man was betwe en the white sphinx when which i did not recognize our own petty and familiar architecture the thousands hand ran back to the starting point the night and day flapped slower and slower had given place to
Epoch 68 | Perplexity 1.5. Loss: 0.394
i do not mean to ask you to accept anything without reasonable ground for the little lawn from the sky there s a little table in the light of the old earth ebb away at last the time traveller hated to have a journey as i stare d about me and that drove black further parts of the laboratory presently i
Epoch 69 | Perplexity 1.5. Loss: 0.374
i do not mean to ask you to accept anything to the new moon people there was a vast interval between its import i t is an air to rise into the smoking room he was coming from the wall of the glare of the sky and the grotesque o f the day came a model of a vast unpleasant there is
Epoch 70 | Perplexity 1.4. Loss: 0.358
i do not mean to ask you to accept anything to convey the peculiar manner put it in the air moon under the unknow n things which i could see no signs of the old many ebb away at last the time traveller hated to have a journey o n my own account of the remote future in a circular opening high
Epoch 71 | Perplexity 1.4. Loss: 0.344
i do not mean to ask you to accept anything to speak of its previous meeting the new guests were frankly incredul ous the editor raised objections what was too much for a long night i returned i was in the darkness i had come f rom the edge of the sun it was along the tunnel but it was all the
Epoch 72 | Perplexity 1.4. Loss: 0.333
i do not mean to ask you to accept anything to convey or understand my arms full of the blackness i heard the doo r of the sun slam seated myself in a chair and took up a daily paper what was he going to do before lunch time th en suddenly i was reminded by an advertisement that i had promised
Epoch 73 | Perplexity 1.4. Loss: 0.323
i do not mean to ask you to accept anything without reasonable ground for the climbing hooks rather a little sky and i heard the door of the shaft i heard an exclamation oddly truncated at the end and a click and a thud a gust of air whirled round me as i opened the door and from within came
Epoch 74 | Perplexity 1.4. Loss: 0.306
i do not mean to ask you to accept anything without reasonable ground for my mind a certain curiosity and now and then as my first lump of camphor waned i began collecting sticks and leaves here and there out of my mind but i c aught my last match and saw the black table then i saw them distinctly now
Epoch 75 | Perplexity 1.4. Loss: 0.302
i do not mean to ask you to accept anything there is no necessity rather odd i saw the sky grew absolutely distin ct and the specimens and photographs he would bring with him but i am beginning now to fear that i must wait a li fetime the time traveller vanished three years ago and as everybody knows now he has
Epoch 76 | Perplexity 1.3. Loss: 0.293
i do not mean to ask you to accept anything without reasonable ground for it you will soon admit as much as i nee d of you the little thing as i took my possession from the sky and the shadows i knelt down and incapable of faci ng the return but as i had left of the morlocks and there were
Epoch 77 | Perplexity 1.3. Loss: 0.280
i do not mean to ask you to accept anything without reasonable night and day again though there was i felt like a schoolmaster amidst children seemed to me my hands and touched his own times and as i did so the shafts incredibl e the telling you the face over the shoulder it was a certain sense of friendly comfort
Epoch 78 | Perplexity 1.3. Loss: 0.275
i do not mean to ask you to accept anything to convey the peculiar pattering about the bright and sky i had almos t get through the presence of their hair was earth in the wood and the door from the corridor opened the door and heard a time for a little of the glare of which we used to be
Epoch 79 | Perplexity 1.3. Loss: 0.269
i do not mean to ask you to accept anything without reasonable ground for it it s a mere beautiful thing to go ba ck to them and he went and when my million then i had almost all the sun may be only them again they were mere ab

undant of a thud a gust of air whirled round me as
Epoch 80 | Perplexity 1.3. Loss: 0.269
i do not mean to ask you to accept anything there is no necessity for an efficient family and the specialization of the block of camphor was still it was a moving race that long night before changed and the shadows of that day i was now far out of the green weed and the man servant appeared we looked
Epoch 81 | Perplexity 1.3. Loss: 0.258
i do not mean to ask you to accept anything without reasonable ground for it seemed to me and i was the flourish of the salt one sea was a pit like the area of a london for a time traveller waiting for the little while i seeme d there is a small camera under one of the foliage the same
Epoch 82 | Perplexity 1.3. Loss: 0.257
i do not mean to ask you to accept anything interest in a long continued running to me and it was the same soft l ittle while in gaps of the sea margin with drifting across if we were feeling as i went on the uneven floor and h eard over or coming and by the huge skeleton i recognized but you
Epoch 83 | Perplexity 1.3. Loss: 0.250
i do not mean to ask you to accept anything without reasonable ground for it seemed to me and here i had three di mensions but if you ll forgive my leaving you now i consented hardly comprehending then the full import of his wo rds and he nodded and went on down the corridor i heard the door of the laboratory
Epoch 84 | Perplexity 1.3. Loss: 0.233
i do not mean to ask you to accept anything without reasonable ground for it seemed to me like a rocket as i retu rned i was free the intense exultation that i was glad to find was fast asleep i carefully wrapped her in my jack et and sat down beside her and wait for the time traveller waiting for the
Epoch 85 | Perplexity 1.2. Loss: 0.220
i do not mean to ask you to accept anything without reasonable ground for it seemed to be a little thought of tha t day is the same plausible enough to the open air the full import of his words and he nodded and went on down th e corridor i heard the door of the laboratory slam seated myself in a
Epoch 86 | Perplexity 1.2. Loss: 0.214
i do not mean to ask you to accept anything without reasonable ground for it was a small white figures they were mere odd eyes came a sound of minute i took on the levers i at that the sun had vanished the circling seat of the door i heard an exclamation oddly truncated at the end and a click
Epoch 87 | Perplexity 1.2. Loss: 0.214
i do not mean to ask you to accept anything without reasonable ground for it was a nightmare i bit myself and scr eamed in a passionate desire to awake i beat the thing the morlocks you had been worn away further in the moment my hand was on the lever and i had placed a month between myself and these
Epoch 88 | Perplexity 1.2. Loss: 0.220
i do not mean to ask you to accept anything without reasonable ground for it you will soon admit as much as well need from me of the blackness then suddenly that hope this sombre wilderness of rotting paper still to come to th is new and the red rocks and in the westward sky i saw a curved pale line
Epoch 89 | Perplexity 1.2. Loss: 0.213
i do not mean to ask you to accept anything without reasonable ground for it it will be made the further out of t he sky appeared the edge of the sun must be heard the time traveller as i took hold of the handle of the door i h eard an exclamation oddly truncated at the end and a click and
Epoch 90 | Perplexity 1.2. Loss: 0.211
i do not mean to ask you to accept anything without reasonable ground for it it be the great thing that was a ver y young man the difference in the other hill the beginning of the end at which i felt as i was full of the morloc ks about me again took my own hint and the cold he laughed
Epoch 91 | Perplexity 1.2. Loss: 0.211
i do not mean to ask you to accept anything without reasonable ground for it it be as to be then as a man was set ting and the growing crowd of earthy crustacea creeping in my pocket so i shivered and seated myself in a chair a nd took up a daily paper what was he going to do before lunch
Epoch 92 | Perplexity 1.2. Loss: 0.204
i do not mean to ask you to accept anything without reasonable ground for it it will be absolutely feeling at thi s time machine towards weena had been i might watch it you presently i could even feel it hollowness that i go ba ck to weena but all the green i heard the sound of its voice you cannot know
Epoch 93 | Perplexity 1.2. Loss: 0.195
i do not mean to ask you to accept anything without reasonable ground for it it will at my time machine for a min ute laughing and with a gust of air was in the remote blackness of which i used to have to clamber down a shaft g reat hall set it down and then i had the door and now
Epoch 94 | Perplexity 1.2. Loss: 0.182
i do not mean to ask you to accept anything without reasonable ground for it seemed to me it with a second and no w to a sharp end i saw a peculiar pattering about the same odd noises i had heard me very little one here he go i t to be i went and the red beach motionless as i
Epoch 95 | Perplexity 1.2. Loss: 0.172
i do not mean to ask you to accept anything without reasonable time for the first time red through the earth s th e same with only a little cupola or obelisk there were no hedges no signs of proprietary rights no evidences of a griculture the whole earth had become a garden so watching i could far less serious or one
Epoch 96 | Perplexity 1.2. Loss: 0.168
i do not mean to ask you to accept anything without reasonable ground for it it will be every see a far as i reme mber were motionless the time traveller and when the last travelled into time the morlocks had the earth the sun had vanished the air was the garden again i saw the door and from within the
Epoch 97 | Perplexity 1.2. Loss: 0.172
i do not mean to ask you to accept anything without reasonable ground for it you will soon admit as much as was n eed from which my fears and with a nearer away from the cradle to the grave just as we should travel down if we b egan our existence fifty miles above the earth s surface but the great
Epoch 98 | Perplexity 1.2. Loss: 0.164
i do not mean to ask you to accept anything without reasonable good he went of them upon them behind by this by t his saddle filby of falling on the right there i saw one little thing in a minute and so as i approached us and t ook it and away through the corridor the time traveller met i am
Epoch 99 | Perplexity 1.2. Loss: 0.168
i do not mean to ask you to accept anything without reasonable ground for it it will soon my eyes the time machin

```
e had gone save for a subsiding stir of dust the further end of the laboratory was empty a pane of the skylight h
ad apparently just been blown in i felt an unreasonable amazement i knew that something
```

In [201…
```
generate('i do not need to ask him to imagine', 10, model, vocab)
```

Out[201…
```
'i do not need to ask him to imagine i was a certain machine or even to go back'
```

Problem 3 SpamDetection

In [2]:
```
import torch
import torch.nn as nn
import torch.nn.functional as F
from collections import Counter
from torch.utils.data import Dataset, DataLoader
from sklearn.model_selection import train_test_split
import numpy as np

import re
device = 'cuda:0' if torch.cuda.is_available() else 'cpu'

import urllib.request, zipfile, io

def download_and_unzip(url, extract_to='.'):
    # Send an HTTP GET request, download the file, and save it in a BytesIO object
    with urllib.request.urlopen(url) as response:
        file_content = response.read()
        zip_file_like = io.BytesIO(file_content)

        # Unzip the file
        with zipfile.ZipFile(zip_file_like) as zip_file:
            zip_file.extractall(extract_to)

# Call the function to download and unzip the file
download_and_unzip(url='https://archive.ics.uci.edu/static/public/228/sms+spam+collection.zip', extract_to='.')

# Load and prepare data. Lower case, no punctuation.
data = [ln.strip() for ln in open('./SMSSpamCollection')]
data = [re.sub('[^A-Za-z0-9]+', ' ', line).lower() for line in data]
data = [re.sub(' +', ' ', line) for line in data]
```

Qa, Qb, Qc.

In [4]:
```
trainset, testset = train_test_split(data, test_size=0.2, random_state=42)
corpus = ''.join(data).split(' ')

vocab, word_count = np.unique(np.array(corpus), return_counts=True)
vocab = {word: i for i, word in enumerate(np.append(vocab, ['/UNK', '/PAD']))}
print(len(vocab))
```

```
9624
```

Qd.

In [5]:
```
class SpamEmailDataset(Dataset):
    def __init__(self, original_seqs, vocab, sequence_len=30):
        super().__init__()
        self.sequence_len = sequence_len
        # Vocabulary (word-to-index mapping)
        self.vocab = vocab
        # Inverse vocabulary (index-to-word mapping)
        self.inv_vocab = {idx: word for word, idx in self.vocab.items()}

        self.sequences = []
        self.labels = []
        for seq in original_seqs:
            word_list = [item for item in seq.split(' ') if item]
            self.sequences.append(self.convert2idx(word_list[1:]))
            self.labels.append(int(word_list[0] == 'spam'))

        self.pre_processing()


    def pre_processing(self):
        for i in range(len(self.sequences)):
            if len(self.sequences[i]) < self.sequence_len:
                self.sequences[i] = [self.vocab['/PAD']] * (self.sequence_len - len(self.sequences[i])) + self.se
            elif len(self.sequences[i]) > self.sequence_len:
                self.sequences[i] = self.sequences[i][:self.sequence_len]

    def convert2idx(self, word_sequence):
        return [self.vocab[word if word in self.vocab else "/UNK"] for word in word_sequence]
```

```
    def convert2words(self, idx_sequence):
        return [self.inv_vocab[idx] for idx in idx_sequence]

    def __len__(self):
        return self.sequences.__len__()

    def __getitem__(self, idx):
        sequence = torch.tensor(self.sequences[idx])
        label = torch.tensor(self.labels[idx])
        return sequence, label

# Test dataset function
trainset = SpamEmailDataset(trainset, vocab, sequence_len=30)
testset = SpamEmailDataset(testset, vocab, sequence_len=30)
email = trainset[12]
print(email[1])
print("  * Words:\t\t", " ".join([trainset.inv_vocab[i] for i in email[0].tolist()]))
```

```
tensor(0)
  * Words:              /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PAD /PA
D /PAD /PAD /PAD /PAD wah lucky man then can save money hee
```

Qe.

In [6]:
```
class BinaryRNN(nn.Module):
    """A RNN Model implemented from scratch."""
    def __init__(self, vocab_size, hidden_dim):
        super().__init__()
        self.vocab_size, self.hidden_dim = vocab_size, hidden_dim

        self.inp2state = nn.Linear(vocab_size, hidden_dim)
        self.state2state = nn.Linear(hidden_dim, hidden_dim)
        self.state2out = nn.Linear(hidden_dim, 1)

        for m in self.modules():
            if isinstance(m, nn.Linear):
                nn.init.normal_(m.weight, std=0.01)
                nn.init.zeros_(m.bias)

    def initial_state(self, batch_size, device):
        return torch.zeros((batch_size, self.hidden_dim)).to(device)

    def forward(self, inp_seq, state=None):
        n_steps, batch_size = inp_seq.shape[:2]

        # If state is not provided, get initial state.
        if state is None:
            state = self.initial_state(batch_size, inp_seq.device)

        for t in range(n_steps):
            inp_at_t = inp_seq[t]
            state = nn.Tanh()(self.inp2state(inp_at_t) + self.state2state(state))
        out = nn.Sigmoid()(self.state2out(state))
        return out, state

hidden_dim = 256
model = BinaryRNN(len(vocab), hidden_dim).to(device)
```

In [11]:
```
import matplotlib.pyplot as plt

def fit_model(model, train_loader, test_loader, criterion, optimizer, device, num_epochs):
    model.train()
    train_acc_list = []
    for epoch in range(num_epochs):
        train_loss, train_acc = train(model, train_loader, criterion, optimizer, device)
        print(f'Epoch {epoch+1}/{num_epochs}, Loss: {train_loss:.4f}, Accuracy: {train_acc:.4f}')
        train_acc_list.append(train_acc.item() if isinstance(train_acc, torch.Tensor) else train_acc)
        test_loss, test_acc = test(model, test_loader, criterion, device)
        print(f'Test Loss: {test_loss:.4f}, Test Accuracy: {test_acc:.4f}')

    # Plot the train_acc curve
    plt.plot(train_acc_list)
    plt.xlabel('Epoch')
    plt.ylabel('Accuracy')
    plt.title('')
    plt.show()


def train(model, train_loader, criterion, optimizer, device):
```

```
    model.train()
    round_loss = 0
    round_acc = 0
    for sequences, labels in train_loader:
        sequences = sequences.to(device).T
        labels = labels.to(device).float()
        optimizer.zero_grad()
        inputs = F.one_hot(sequences, num_classes=len(vocab)).float()
        outputs, _ = model(inputs)
        loss = criterion(outputs.squeeze(1), labels)
        loss.backward()
        accuracy = ((outputs.squeeze(1) > 0.5).float() == labels).float().sum()
        round_loss += loss.item()
        round_acc += accuracy
        optimizer.step()
    return round_loss/len(train_loader.dataset), round_acc/len(train_loader.dataset)

def test(model, test_loader, criterion, device):
    model.eval()
    test_loss = 0
    test_acc = 0
    with torch.no_grad():
        for sequences, labels in test_loader:
            sequences = sequences.to(device).T
            labels = labels.to(device).float()
            inputs = F.one_hot(sequences, num_classes=len(vocab)).float()
            outputs, _ = model(inputs)
            loss = criterion(outputs.squeeze(1), labels)
            accuracy = ((outputs.squeeze(1) > 0.5).float() == labels).float().sum()
            test_loss += loss.item()
            test_acc += accuracy
    return test_loss/len(test_loader.dataset), test_acc/len(test_loader.dataset)


hidden_dim = 256
batch_size = 32
learning_rate = 0.0001
num_epochs = 20
model = BinaryRNN(len(vocab), hidden_dim).to(device)

train_loader = DataLoader(trainset, batch_size=batch_size, shuffle=True)
test_loader = DataLoader(testset, batch_size=batch_size, shuffle=False)

criterion = nn.BCELoss()
optimizer = torch.optim.Adam(model.parameters(), lr=learning_rate)

nn.utils.clip_grad_norm_(model.parameters(), 1)
# Train the model
fit_model(model, train_loader, test_loader, criterion, optimizer, device, num_epochs)
```

```
Epoch 1/20, Loss: 0.0152, Accuracy: 0.8601
Test Loss: 0.0129, Test Accuracy: 0.8556
Epoch 2/20, Loss: 0.0120, Accuracy: 0.8686
Test Loss: 0.0128, Test Accuracy: 0.8556
Epoch 3/20, Loss: 0.0075, Accuracy: 0.9246
Test Loss: 0.0047, Test Accuracy: 0.9578
Epoch 4/20, Loss: 0.0039, Accuracy: 0.9711
Test Loss: 0.0036, Test Accuracy: 0.9677
Epoch 5/20, Loss: 0.0028, Accuracy: 0.9791
Test Loss: 0.0032, Test Accuracy: 0.9713
Epoch 6/20, Loss: 0.0022, Accuracy: 0.9841
Test Loss: 0.0028, Test Accuracy: 0.9749
Epoch 7/20, Loss: 0.0016, Accuracy: 0.9881
Test Loss: 0.0032, Test Accuracy: 0.9722
Epoch 8/20, Loss: 0.0014, Accuracy: 0.9890
Test Loss: 0.0033, Test Accuracy: 0.9695
Epoch 9/20, Loss: 0.0011, Accuracy: 0.9915
Test Loss: 0.0036, Test Accuracy: 0.9713
Epoch 10/20, Loss: 0.0011, Accuracy: 0.9919
Test Loss: 0.0028, Test Accuracy: 0.9758
Epoch 11/20, Loss: 0.0011, Accuracy: 0.9935
Test Loss: 0.0026, Test Accuracy: 0.9758
Epoch 12/20, Loss: 0.0009, Accuracy: 0.9935
Test Loss: 0.0028, Test Accuracy: 0.9740
Epoch 13/20, Loss: 0.0007, Accuracy: 0.9948
Test Loss: 0.0046, Test Accuracy: 0.9686
Epoch 14/20, Loss: 0.0006, Accuracy: 0.9960
Test Loss: 0.0023, Test Accuracy: 0.9830
Epoch 15/20, Loss: 0.0005, Accuracy: 0.9957
Test Loss: 0.0029, Test Accuracy: 0.9731
Epoch 16/20, Loss: 0.0006, Accuracy: 0.9960
Test Loss: 0.0023, Test Accuracy: 0.9785
Epoch 17/20, Loss: 0.0004, Accuracy: 0.9971
Test Loss: 0.0023, Test Accuracy: 0.9785
Epoch 18/20, Loss: 0.0003, Accuracy: 0.9975
Test Loss: 0.0043, Test Accuracy: 0.9749
Epoch 19/20, Loss: 0.0006, Accuracy: 0.9964
Test Loss: 0.0029, Test Accuracy: 0.9839
Epoch 20/20, Loss: 0.0004, Accuracy: 0.9975
Test Loss: 0.0028, Test Accuracy: 0.9749
```