**Question 2**

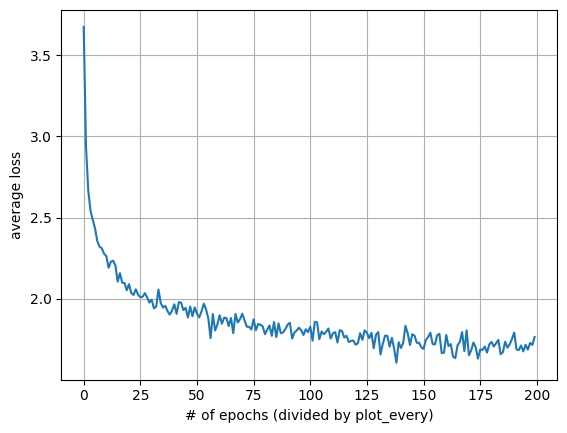
* Advantage of character based language model over word based language model:

Character based language models’ vocabulary is the alphabet or a small set of characters, which means that they are better in handling rare or unseen words. The latter is due to the models ability to “learn” patterns in character sequences rather than just treating unknown words as a “new” word (in comparison to word based language models).

* Advantage of word based language model over character based model:

Since word based language models’ vocabulary is a group of words, they have lower computational overhead. The latter is due to the fact that this group of models treat entire words as a single unit, which leads to them processing fewer tokens when processing text (in comparison to character based language models).

1. Losses plot:

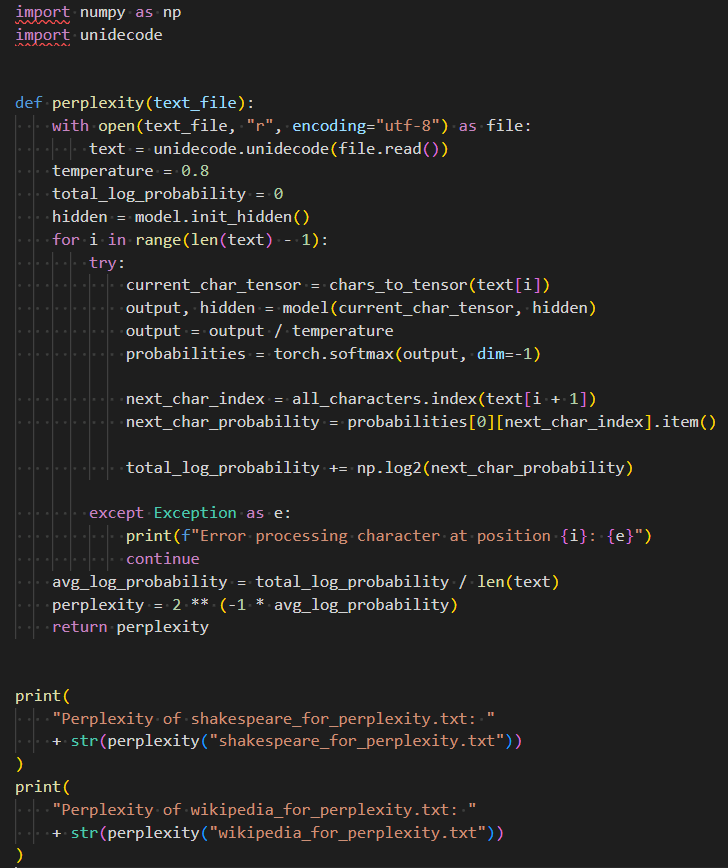


**Question 3**

b. **Model from section 3:**

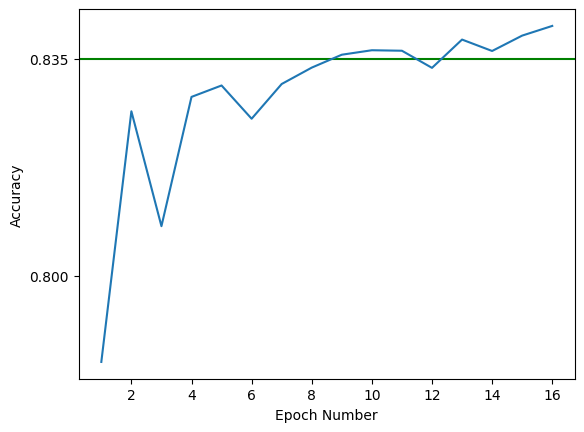
* + Perplexity of shakespeare\_for\_perplexity.txt: 7.13842743290004
  + Perplexity of wikipedia\_for\_perplexity.txt: 18.98281197572183

**Code:**

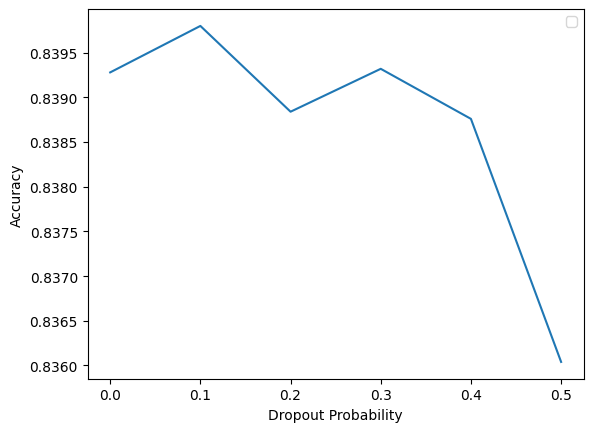


**Question 4**

a. A plot of the evaluation accuracy as a function of the number of epochs:

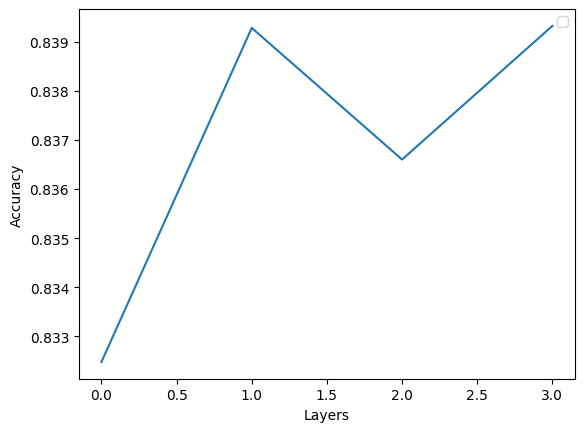


b. A plot of the accuracy of the model across different values of the dropout rate:



c. We thought that we will start seeing the effect of diminishing returns after 1 hidden layer. As we expected, We do not see any significant improvement by adding more than 1 hidden layer.

The linear model has not outperformed the model with 4 hidden layers.  
Plot of the accuracy as a function of the number of layers:



A graph with different colored lines

Description automatically generatedd. A plot of the accuracy across epochs for the different activation functions:

We have learned from this experiment that the activation function does not have a significant effect on the accuracy of the model across the epochs (at least for the configuration we used).

e. The following are 5 examples from the evaluation set that the model classified incorrectly:

1. **Example:** I gave 9 of 10 points. I was sitting in tears nearly the whole movie, because I had to laugh!<br /><br />The story of course wasn\'t excellent, but it also wasn\'t boring. Erkan & Stefan are assigned to become bodyguards for the beautiful Nina. While doing this job they come between the "front-lines" of BND and CIA. Of course the two are neither born bodyguards nor gentlemen, so they run from one disaster into another; and they do this in such a funny way, that when you watch some scenes you won\'t be able to stop the tears! As actors those two "dumbly grinning" characters do quite well, better than some so called professional.<br /><br />You think, the speech of the two heroes is curios or "pseudo-foreign"? Well, if you hear quite a lot Turkish-German people in Munich speaking exactly like them, you will remember Erkan & Stefan. And maybe, in 10 years it might have become the common speech of the youth. (God forbid!)<br /><br />So, if you like to laugh, watch this movie!  
   **Label:** 1  
   **Model Prediction:** 0  
   **Why The Model Classified It Incorrectly:** The model likely predicted 0 because the review contains phrases like "The story of course wasn\'t excellent" and "God forbid!" which may have been interpreted as negative sentiment.
2. **Example:** I love this movie a lot. I must get this on DVD. I have 2 VHS copies, but the quality is so poor that you can\'t read one written joke over the door of the ward. I\'m forever amazed that Blankfield did almost nothing afterward. He made both Dr. Jeckle and Mr. Hyde totally believable.<br /><br />The movie is plagued by it\'s low budget. (One atrocious edit jumps into mid-word and was described on, "Siskel & Ebert".) But, there are a thousand jokes, sight gags to subtle references, that more than compensate. I often find myself quoting lines (or, singing, "I\'ve Got Nothing to Hide") and, from time to time, completely describe a scene which matches some conversation. There are, at least, six scenes which are among my all time favorite comedy bits.<br /><br />Viewers with no history of cocaine use may miss a lot of gags.<br /><br />"Here, take it." \* Visual of driving while waving butt out the window.\* "I said, \'Is this seat taken?\'" "Nice Burn!" Visual of chaps, headdress, jockstrap, & swim fins. \* "Yeah. I\'m right handed." \* "Me! Me!" says the woman trying to sell \'nads. \* "Bernie\'s going to love these." \* "That\'s my feet, Jack." says the black feet. \* "Why should we tell you?"... "SHE\'S AT THE SUPERMARKET!" \* "Ivy!" on supermarket PA. \* Loading whole shopping cart into ambulance. \* etc.  
   **Label:** 1  
   **Model Prediction:** 0  
   **Why The Model Classified It Incorrectly**: The model likely predicted 0 due to phrases highlighting flaws like " The movie is plagued by it\'s low budget" and "one atrocious edit" which may have been interpreted as negative sentiment.
3. **Example:** One of the last surviving horror screen greats - Conrad Radzoff - dies and has his body placed in a mausoleum with televised-before-death snippets of the great Conrad greeting you as you visit. Unfortunately for him and his captors, Conrad\'s body is "borrowed" by a gang of four boys and three girls and taken to a huge manor where they drink with him, toast him, dance with him, laugh with and at him, and then put him to bed in a casket which just happens to by lying in a room upstairs. News of the missing body reaches Radzoff\'s widow and her friend(who happens to be proficient in the black arts) and she holds some kind of ceremony that brings Conrad back to life so he can, in his own words, get "an eye for an eye, a tooth for a tooth." Well, Frightmare is an interesting "bad" film. Sure, it is cheap. The sets look like they were borrowed(which I am sure they were). The special effects and blood and guts are done liberally and with little credibility. The acting is average to below average with a few exceptions. Jeffrey Combs of Re-Animator fame is in tow, but really he does little in this rather thankless role as a horror obsessed teen that needs to steal a dead man\'s body for kicks. None of the "kids" except the pretty girl playing Meg is any good. Nita Talbot plays the "friend" of the Radzoffs with withering interest. Also, look for the big - I mean big - guy that plays the policeman. That is Porky himself of Porkys fame. But thankfully for all of us, one performance does rise above the material. Ferdy Mayne, an oft overlooked actor from Germany who had Christopher Lee features and did star as a vampire in The Fearless Vampire Killers, does a more than commendable job as the aging horror icon in public life and a real demon of a man in private life. Conrad Radzoff in a bad human being in life, living solely for his own pleasures and we see him kill twice before he is even dead(obviously none of the swinging teens at that point). Mayne is able to look very regal, speak very elegantly, and convey menace with ease. If for no other reason, one should see Frightmare for his performance. I do; however, believe that when they showed black and white clips of Radzoff that they used Christopher Lee footage(anyone have any thoughts?). Anyway, one can guess what happens and it does indeed: Radzoff goes out and goes after the kids that disturbed his peace. Again, the formula is trite and overused. The acting for the most part is anemic, and the direction oh so ridiculous. But Mayne gives a good performance in a sea of ineptitude. Definitely worth a little peek. Watching Mayne keep popping up on screens in his mausoleum brought a wry smile to my lips each time.  
   **Label:** 0  
   **Model Prediction:** 1  
   **Why The Model Classified It Incorrectly:** The model likely predicted 1 because of phrases like "definitely worth a little peek", "Mayne gives a good performance", and "brought a wry smile to my lips" which may have been interpreted as positive sentiment.
4. **Example:** This is the funniest sequel I have seen in a long time it is much funnier than the other three and not a bit scary. It has some very gory pieces in the film, but not bad enough to make you sick. In this one he has a female doll companion, hence the name. If you liked the first three then you'll love this, go watch it!  
   **Label:** 1  
   **Model Prediction:** 0  
   **Why The Model Classified It Incorrectly:** The model likely predicted 0 because phrases like "not a bit scary" and "some very gory pieces" which may have been interpreted as positive sentiment.
5. **Example:** I bought this DVD as part of a set of 50 "historic classics." It\'s hardly a classic, and as the plot was updated to the time of its release, is not historic either. The actual title on the DVD is "Indecent," and additionally subtitled "The Private Life of Becky Sharp." Myrna Loy is not very convincing, although in her defense she is saddled with an awful script and trite dialogue. As with many early talkies, and especially ones made by smaller studios, there is little skill demonstrated by the cast and crew. Loy does wear a few gowns that are quite stylish, but her costumes and make-up in the later scenes are overdone. The one saving grace is a tolerable performance by Billy Bevan, who plays one of her many suitors  
   **Label:** 0  
   **Model Prediction:** 1  
   **Why The Model Classified It Incorrectly:** The model likely predicted 1 because of phrases like "Loy does wear a few gowns that are quite stylish" and "a tolerable performance by Billy Bevan" which could have been interpreted as positive.

**Question 5**

1.

1. can be interpreted as a categorical probability distribution due to the following reasons:
   1. since for every , and ’s definition.
   3. Interpretation – Each represents the weight assigned to the corresponding value .
2. From definition, for the categorical distribution to put almost all its weight on a specific , it must be true that: .
3. From the fact that , and the condition from section b we get that and which leads to the fact that:
4. Intuitively, it means that our model gives more attention to the value vector because it finds it more relevant to the query .

2. We define ’ to be the following matrix: .

We define to be . Since the vectors are orthonormal we get that is the projection matrix to the sub space A where lies, thus:

From the fact that and being the projection matrix to the sub space A, we get that:

We finally get:

3. We select where is a large scalar, specifically large enough for the following condition to hold: .

Similarly, we can get that .

For every we get:

Now we calculate :

3.a. Since the covariance matrices are for vanishingly small we get that for all . .

We select where is a large scalar, specifically large enough for the following condition to hold: .

Similarly, we can get that .

For every we get:

Now we calculate :

1. Since we use from section a, for all we get that still . This leads to the attention output being primarily influenced by and , . What’s changed from section is that now the covariance for item has changed, the variability in ’s norm causes fluctuations in .  
   When ’s norm is larger, becomes more dominant, increasing ’s contribution to (in comparison to ). Conversely, when ’s norm is smaller, becomes less dominant, reducing ’s contribution to (in comparison to ).   
   The variability in ​'s norm introduces higher variance in compared to section a, where all keys had consistent norms (since ’s covariances were vanishingly small). So, in comparison to section a, the qualitative behaviour of depends strongly on 's sampled magnitude.

4.a. We select and where is a large scalar, specifically large enough for the following condition to hold: .

We will first focus on :

For every we get:

From here we get that:

Similarly, for we get , which leads to .

Finally, we get:

b. TODO

The query vectors , focus on and , respectively. Since has larger

Since we use and from section a, and . Which leads to being primarily influenced by and being primarily influenced by . What’s changed from section is that now the covariance for item has changed, the variability in ’s norm causes fluctuations in .  
When ’s norm is larger, becomes more dominant, increasing ’s contribution to (in comparison to ). Conversely, when ’s norm is smaller, becomes less dominant, reducing ’s contribution to (in comparison to ).   
The variability in ​'s norm introduces higher variance in compared to section a, where all keys had consistent norms (since ’s covariances were vanishingly small). So, in comparison to section a, the qualitative behaviour of depends strongly on 's sampled magnitude.