Question 1

Data has been modified to use CIFAR-10 rather than MNIST. The biggest differences in the two sets are 1: that CIFAR images are 240 pixels bigger than MNIST (32*32 as opposed to 28*28), and 2: that CIFAR images are in RGB color, and not grayscale. Additionally, the original cnn.py file did not normalize pixel values. This has been changed, and pixel values are now scaled from 0 to 1 rather than from 0 to 255.

Questions 2/3

I conducted experiments with a varying number of convolutional layers and feature maps per layer, for a total of 5 models. As in the original cnn.py, epoch numbering begins at 0.

Model 1 is identical to the original network used to classify MNIST.

```
Accuracies for Model 1
Epoch 0 : 0.3828125
Epoch 1 : 0.4921875
Epoch 2 : 0.52734375
Epoch 3 : 0.5625
Epoch 4 : 0.62109375
Epoch 5 : 0.5859375
Epoch 6 : 0.59375
Epoch 7 : 0.5703125
Epoch 8 : 0.61328125
Epoch 9 : 0.6640625
Epoch 10 : 0.67578125
Epoch 11 : 0.625
Epoch 12 : 0.65625
Epoch 13 : 0.6484375
Epoch 14 : 0.64453125
Epoch 15 : 0.61328125
Epoch 16 : 0.69921875
Epoch 17 : 0.64453125
Epoch 18 : 0.69140625
Epoch 19 : 0.65234375
Epoch 20 : 0.65625
Epoch 21 : 0.70703125
Epoch 22 : 0.703125
Epoch 23 : 0.68359375
Epoch 24 : 0.6796875
Epoch 25 : 0.68359375
Epoch 26 : 0.6875
Epoch 27 : 0.69140625
Epoch 28 : 0.7109375
Epoch 29 : 0.75
```

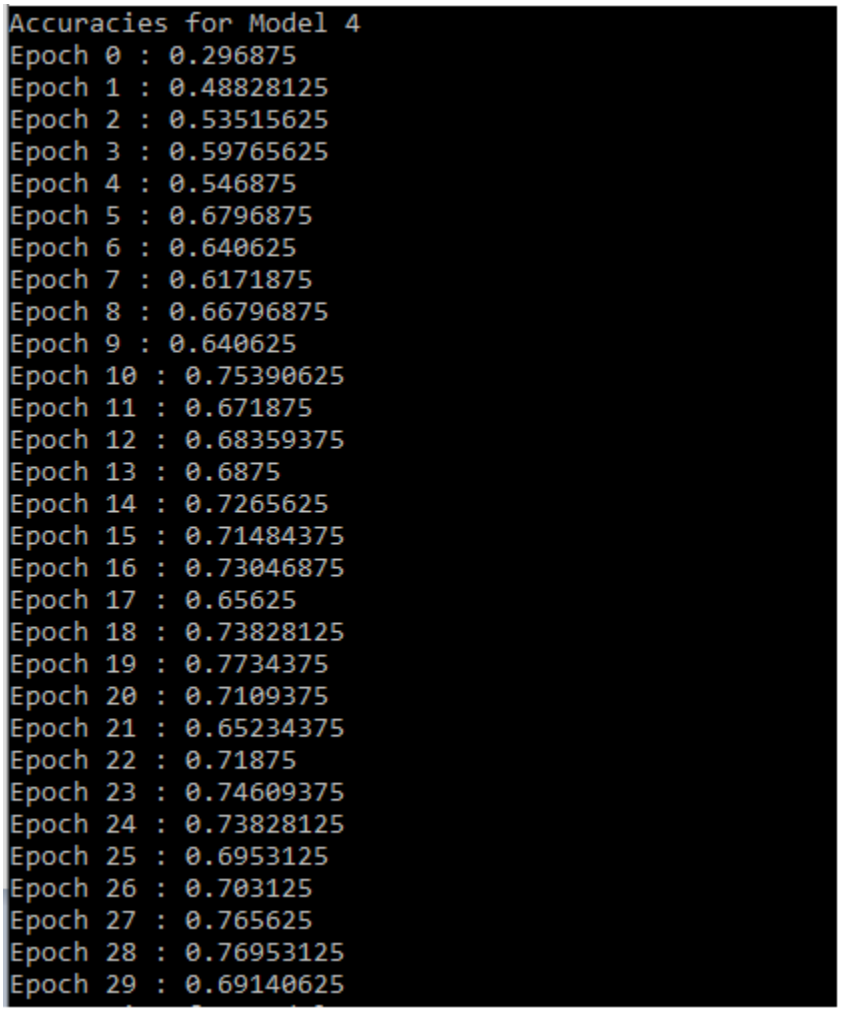
Model 2 adds a second convolutional layer identical to the first.

```
Accuracies for Model 2
Epoch 0 : 0.30078125
Epoch 1 : 0.484375
Epoch 2 : 0.5625
Epoch 3 : 0.54296875
Epoch 4 : 0.5546875
Epoch 5 : 0.546875
Epoch 6 : 0.6484375
Epoch 7 : 0.640625
Epoch 8 : 0.703125
Epoch 9 : 0.671875
Epoch 10 : 0.67578125
Epoch 11 : 0.66015625
Epoch 12 : 0.68359375
Epoch 13 : 0.6953125
Epoch 14 : 0.65234375
Epoch 15 : 0.73828125
Epoch 16 : 0.68359375
Epoch 17 : 0.75
Epoch 18 : 0.6953125
Epoch 19 : 0.7265625
Epoch 20 : 0.72265625
Epoch 21 : 0.69140625
Epoch 22 : 0.7265625
Epoch 23 : 0.70703125
Epoch 24 : 0.6953125
Epoch 25 : 0.72265625
Epoch 26 : 0.66796875
Epoch 27 : 0.67578125
Epoch 28 : 0.6953125
Epoch 29 : 0.71875
```

Model 3 adds a third convolutional layer. The max pooling and dropout components have been moved from the first layer to the third; too many max pooling/dropout layers adversely affect results.

```
Accuracies for Model 3
Epoch 0 : 0.28515625
Epoch 1 : 0.37890625
Epoch 2 : 0.47265625
Epoch 3 : 0.53125
Epoch 4 : 0.578125
Epoch 5 : 0.56640625
Epoch 6 : 0.66015625
Epoch 7 : 0.60546875
Epoch 8 : 0.6484375
Epoch 9 : 0.71875
Epoch 10 : 0.7109375
Epoch 11 : 0.6875
Epoch 12 : 0.69921875
Epoch 13 : 0.671875
Epoch 14 : 0.671875
Epoch 15 : 0.7421875
Epoch 16 : 0.703125
Epoch 17 : 0.703125
Epoch 18 : 0.73046875
Epoch 19 : 0.734375
Epoch 20 : 0.74609375
Epoch 21 : 0.734375
Epoch 22 : 0.734375
Epoch 23 : 0.7734375
Epoch 24 : 0.73828125
Epoch 25 : 0.72265625
Epoch 26 : 0.73828125
Epoch 27 : 0.6875
Epoch 28 : 0.73828125
Epoch 29 : 0.76171875
```

As LeNet5 increases the number of feature maps with each added layer, I decided to try the same thing with models 4 and 5. Model 4 is identical to model 2, but the second convolutional layer has a feature map of size 64.



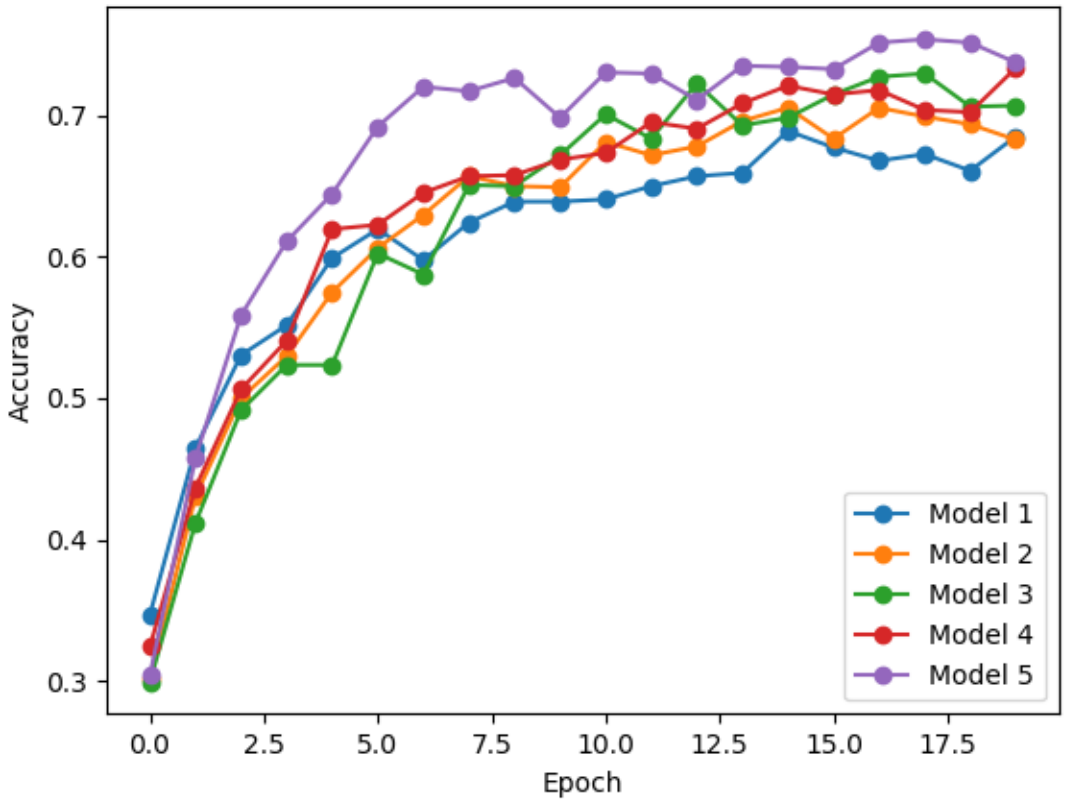
Model 5 is identical to model 3, but with increased feature map sizes (64 on its second convolutional layer, 128 on its third).

```
Accuracies for Model 5
Epoch 0 : 0.3203125
Epoch 1 : 0.51171875
Epoch 2 : 0.5234375
Epoch 3 : 0.6015625
Epoch 4 : 0.64453125
Epoch 5 : 0.60546875
Epoch 6 : 0.60546875
Epoch 7 : 0.69140625
Epoch 8 : 0.703125
Epoch 9 : 0.703125
Epoch 10 : 0.7421875
Epoch 11 : 0.703125
Epoch 12 : 0.6796875
Epoch 13 : 0.69921875
Epoch 14 : 0.67578125
Epoch 15 : 0.703125
Epoch 16 : 0.7421875
Epoch 17 : 0.69921875
Epoch 18 : 0.7265625
Epoch 19 : 0.70703125
Epoch 20 : 0.7109375
Epoch 21 : 0.74609375
Epoch 22 : 0.75390625
Epoch 23 : 0.71484375
Epoch 24 : 0.7421875
Epoch 25 : 0.79296875
Epoch 26 : 0.6953125
Epoch 27 : 0.7421875
Epoch 28 : 0.73828125
Epoch 29 : 0.72265625
```

Question 4

The various models are not drastically different in terms of performance. However, a clear improvement in performance can be seen as more convolutional layers are added, and a further increase in accuracy is noticeable with increased feature map sizes across layers. Model 5 stands as the optimal configuration of those tested, with both the highest accuracy (79.3%) and the most consistency (i.e. the greatest number of epochs with accuracy scores over 70%).

Question 6



A chart showing the accuracy of each model over time. Results were averaged over 5 iterations, 20 epochs per iteration.

Question 7

Epoch	M1 Accuracy	M2 Accuracy	M3 Accuracy	M4 Accuracy	M5 Accuracy
0.0	0.346875	0.3015625	0.29921875	0.32421875	0.30390625
1.0	0.46484375	0.43046875	0.41171875	0.43671875	0.4578125
2.0	0.53046875	0.5	0.49140625	0.50625	0.55859375
3.0	0.5515625	0.5296875	0.5234375	0.540625	0.6109375
4.0	0.59921875	0.575	0.5234375	0.61953125	0.64453125
5.0	0.61953125	0.60625	0.60234375	0.62265625	0.6921875
6.0	0.59765625	0.6296875	0.5875	0.6453125	0.7203125
7.0	0.62421875	0.65703125	0.65078125	0.65703125	0.7171875
8.0	0.6390625	0.65	0.65	0.6578125	0.7265625
9.0	0.6390625	0.64921875	0.671875	0.66875	0.6984375
10.0	0.640625	0.68125	0.70078125	0.6734375	0.73046875
11.0	0.65	0.671875	0.68359375	0.6953125	0.7296875
12.0	0.65703125	0.678125	0.72265625	0.690625	0.7109375
13.0	0.659375	0.69609375	0.69296875	0.70859375	0.73515625
14.0	0.6890625	0.70546875	0.6984375	0.72109375	0.734375
15.0	0.67734375	0.68359375	0.71484375	0.71484375	0.7328125
16.0	0.66796875	0.70546875	0.72734375	0.71796875	0.7515625
17.0	0.67265625	0.69921875	0.7296875	0.70390625	0.75390625
18.0	0.6609375	0.69375	0.70625	0.70234375	0.7515625
19.0	0.68515625	0.6828125	0.70703125	0.73359375	0.7375

Same information as the chart from question 6, now in the form of a table.