The following is a perceptron trained for implementing AND gate

TASK1: Print the bias and weight vectors for individual epochs of the training phase

TASK2: Determine the minimum threshold required to generate the correct output

TASK3: Observe the effect of changing the learning rate on the outputs

In the following sections, I'll implement each of the above-listed tasks:

The following is the code:

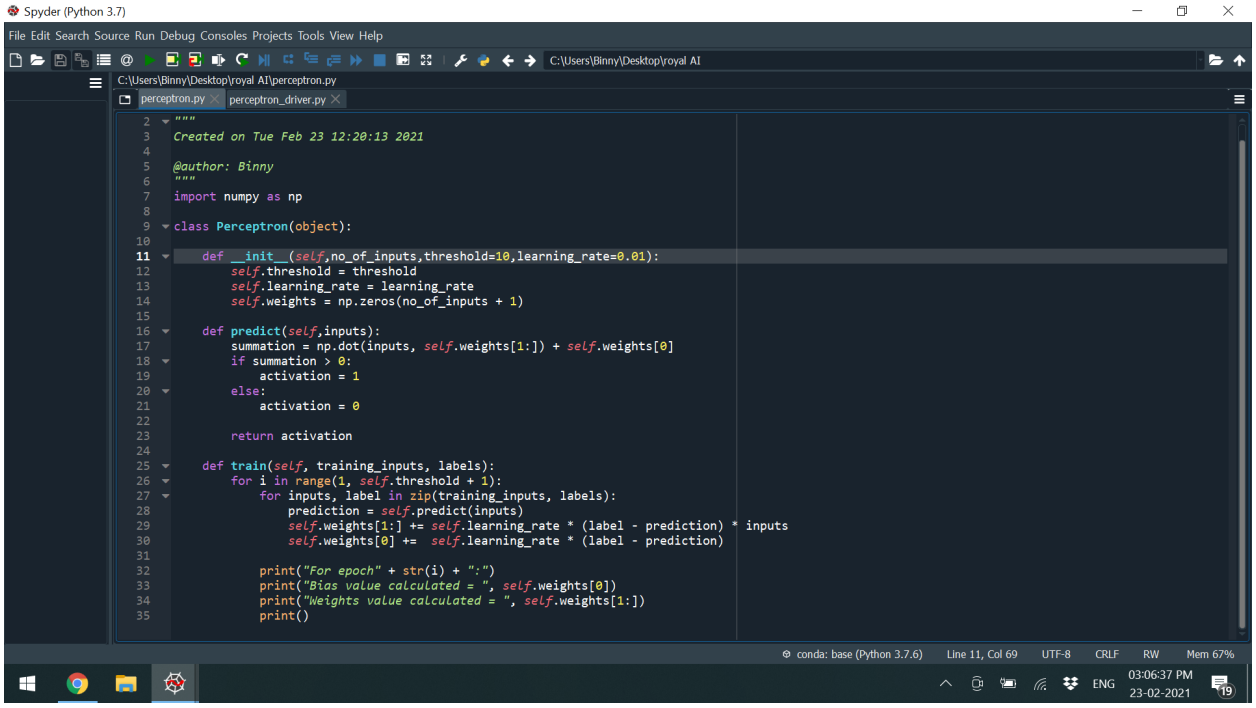

Fig 1. Skeleton code

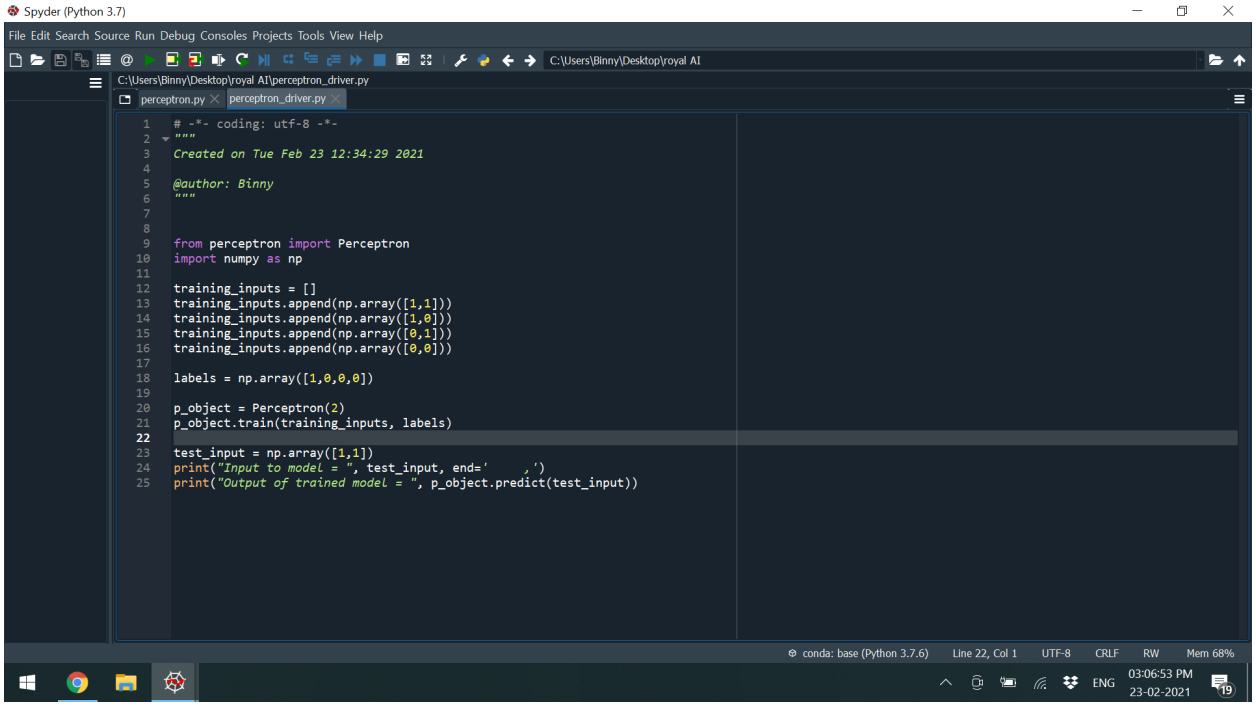

Fig 2. Driver code

The following is the output generated:

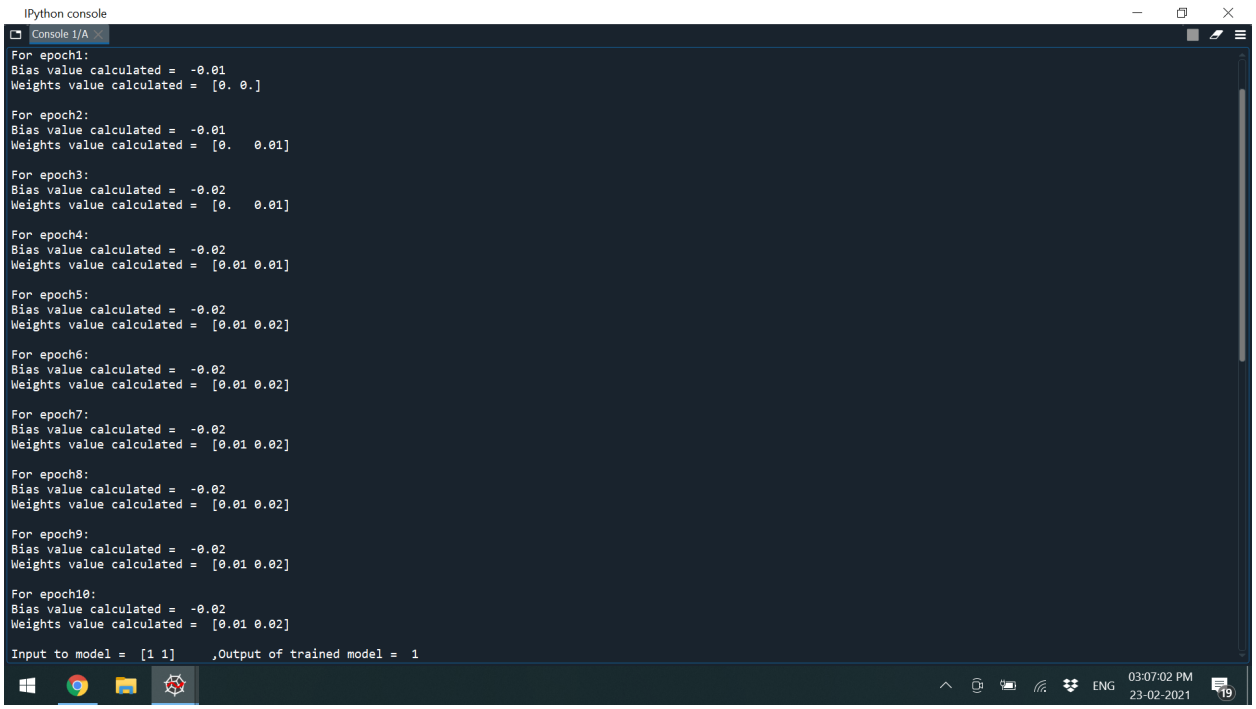

Fig 3. Output of model with threshold = 10 & learning_rate = 0.01

In fig 3, I have printed the bias and weight vector for individual epochs, along with the test input given to the model and the corresponding output generated by the model.

Further, moving on to determine the minimum threshold required to get the correct output, we can observe in the above output that after epoch 5, we get constant values for bias and weights. So, it can be inferred that the minimum threshold required to train the model is 5.

In order to prove this, let us check the output for threshold = 4.

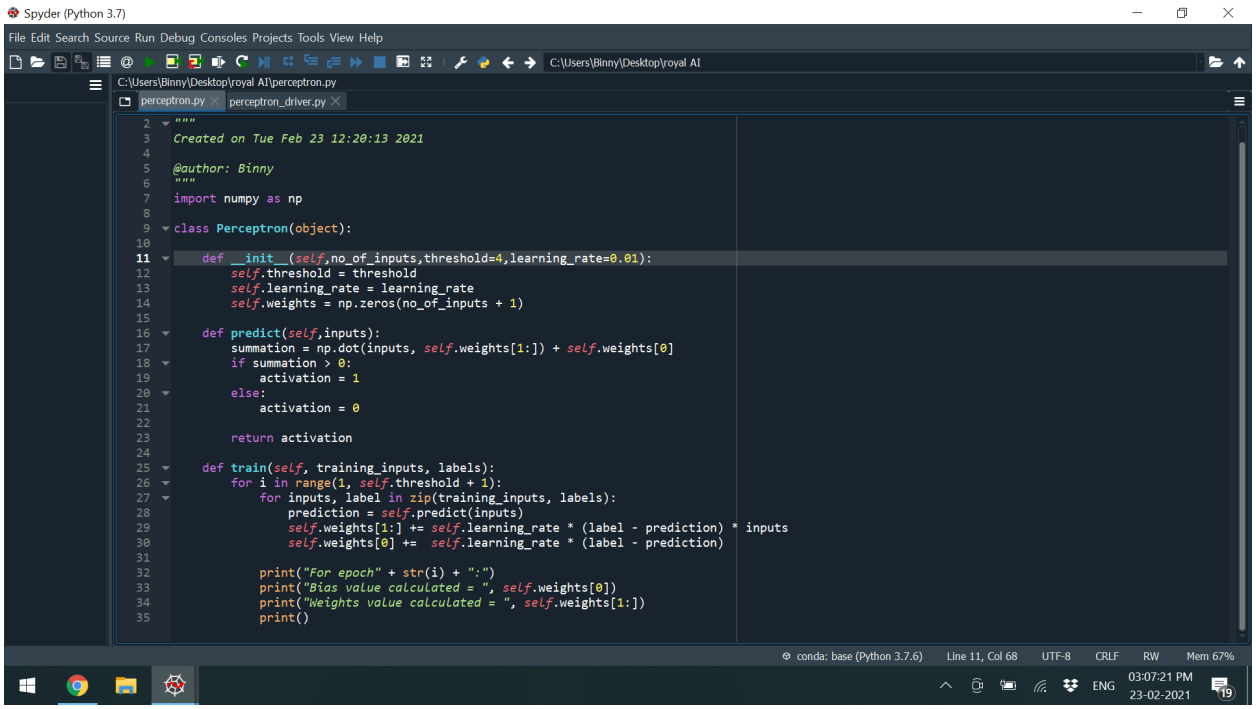

Fig 4. Code with threshold 4

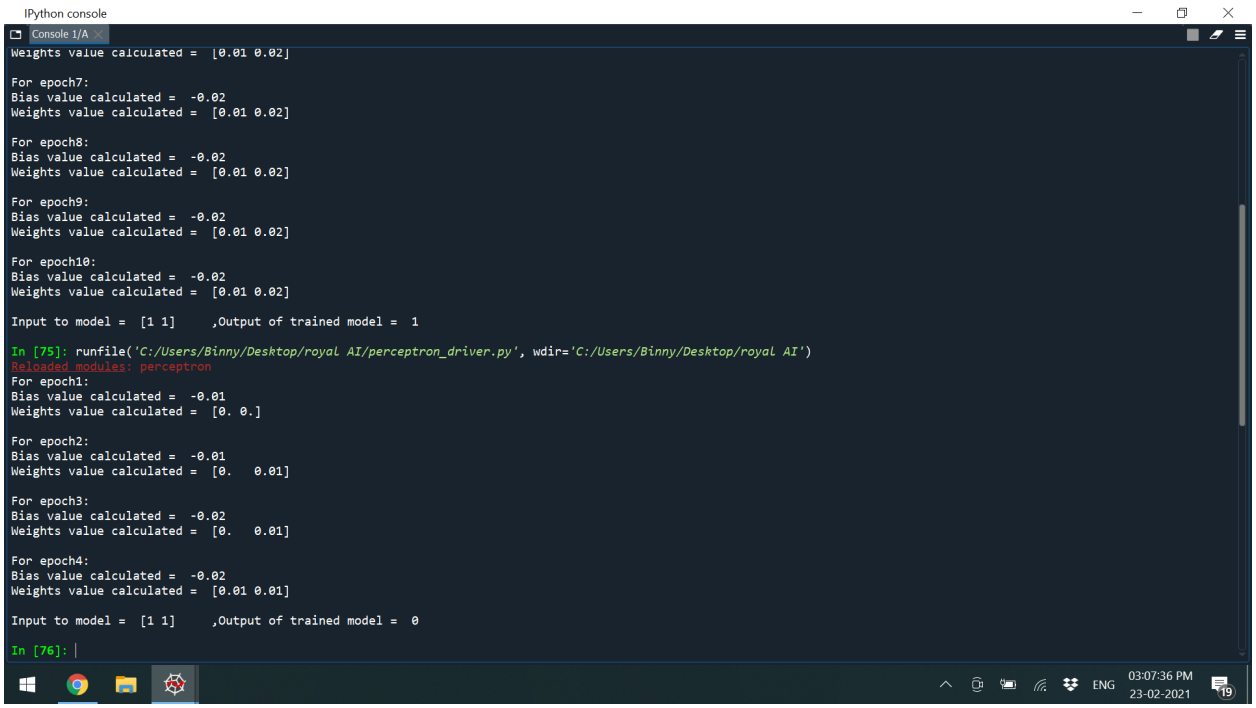

Fig 5. Output with threshold 4

It can be seen in fig 5 that for input (1,1) the output generated by the model is 0, which is the wrong output.

Thus, the minimum threshold required to train the model to produce the correct output is 5.

Now, moving on to observe the behavior of outputs upon changing the learning_rate.

In the subsequent section, I'll be illustrating the outputs produced for different learning_rates.

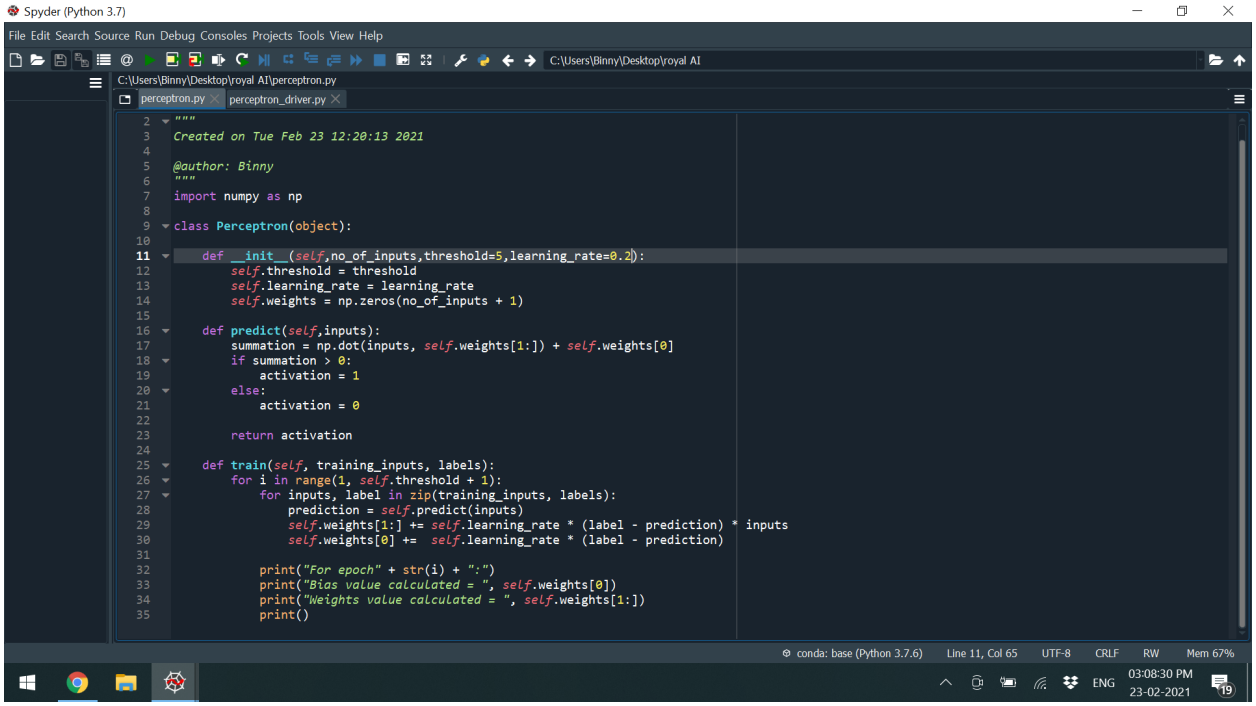

Fig 6. Code with threshold = 5 and learning_rate = 0.2

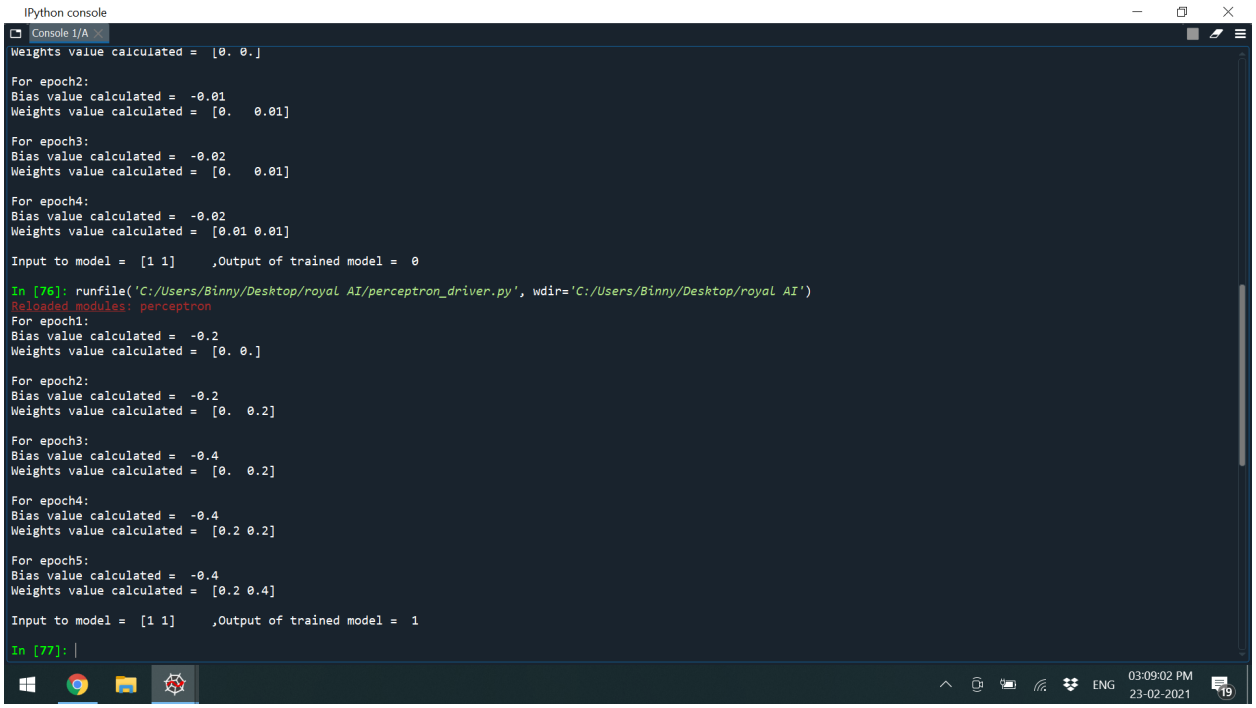

Fig 7. Output of model with threshold = 5 and learning_rate = 0.2

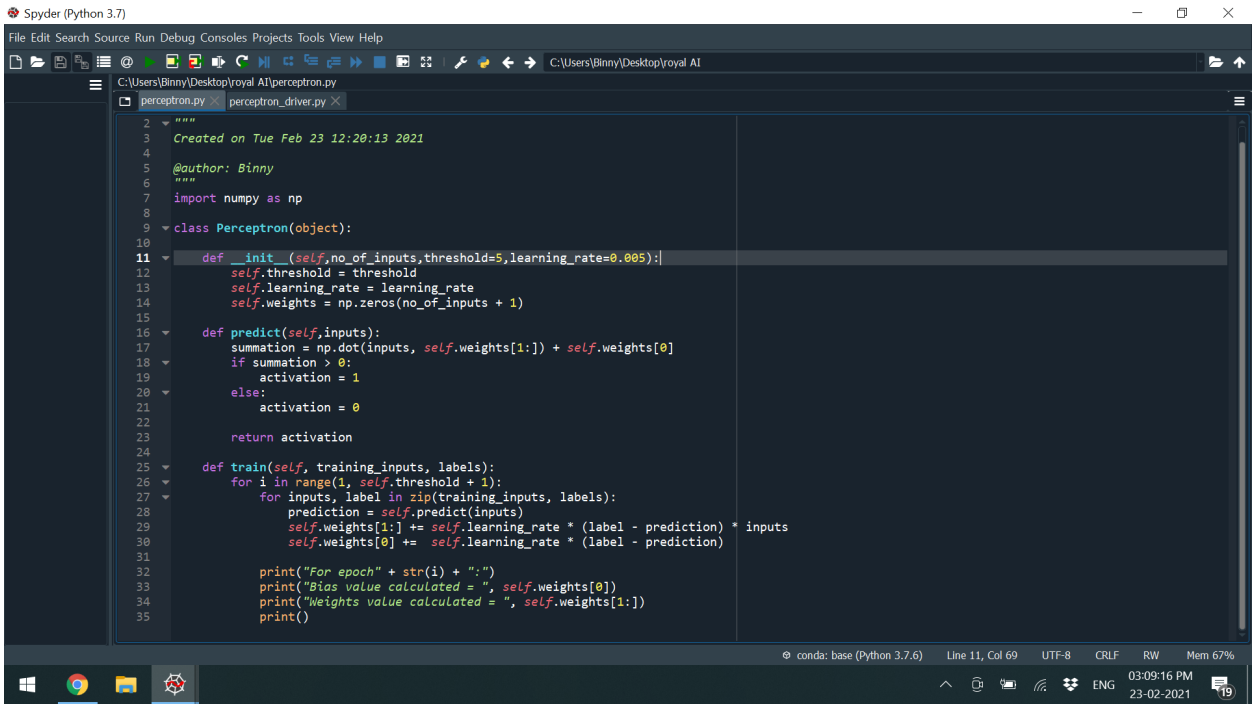

Fig 8. Code with threshold = 5 and learning_rate = 0.05

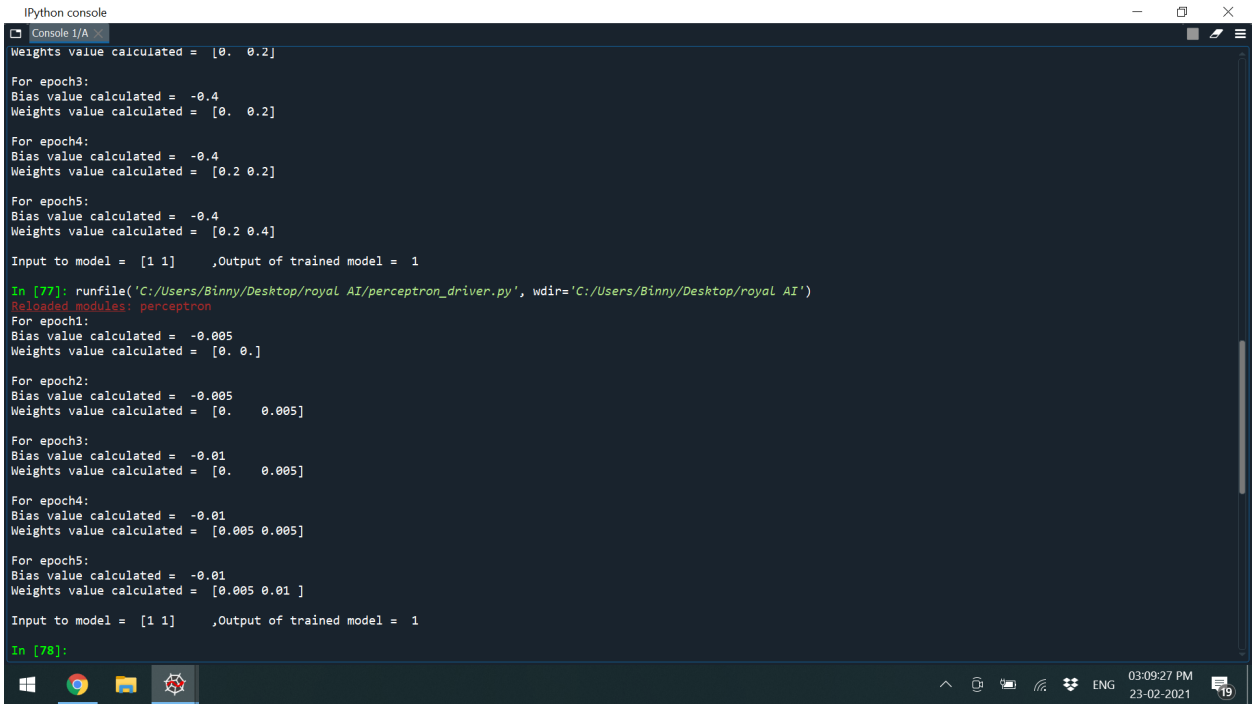

Fig 9. Output of model with threshold = 5 and learning_rate = 0.05

It can be analyzed from Fig 6-9, that by changing the learning_rate; the values of bias and weights change. However, there is a notable relation observed between the learning_rate(α), bias(w_0), and weights(w_1, w_2) which can be represented as follows:

$$w_0 = 2 * \alpha$$
$$w_1 = \alpha$$
$$w_2 = 2 * \alpha$$

Further, as per my analysis, for this particular perceptron with the implementation of AND gate, changing the learning_rate does not change the minimum threshold value of 5. It only changes the values of bias and weights, giving the correct output at epoch 5.