Question 4:

Log_grad.m code:”

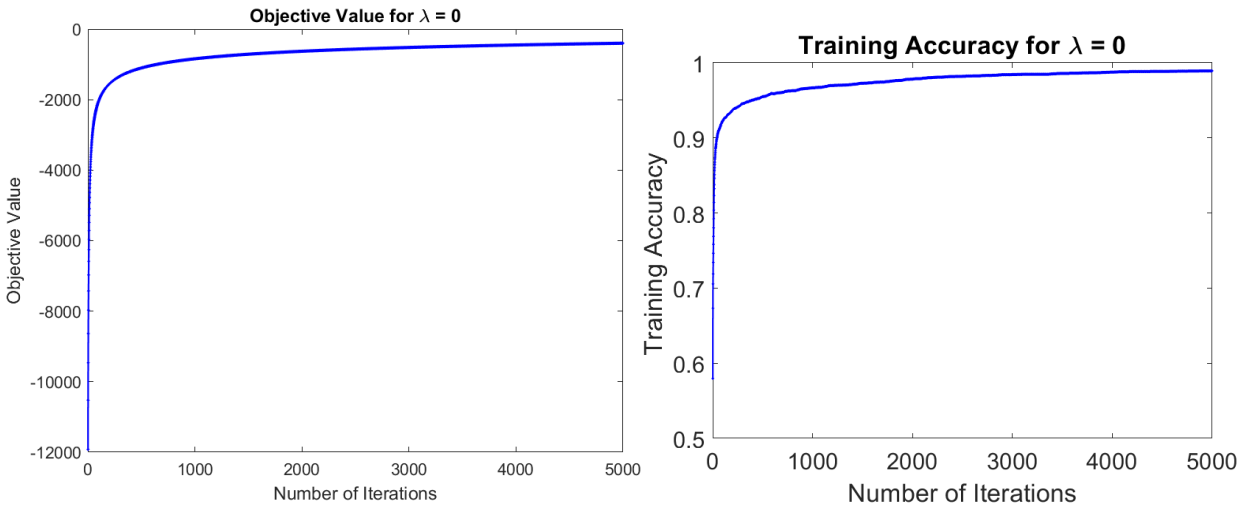
```
function G=log_grad(y, X, B)
    [n,d] = size(X);%n: number of samples, d: number of features
    K = size(B,2) + 1; %Total number of classes


%compute gradient
    XB = X * B;
    expXB = exp(XB);
    prob = expXB ./ (1 + sum(expXB, 2));


    prob = [prob, 1 - sum(prob, 2)];


    G = zeros(d,K-1);
    for k = 1:K-1
        indicator = (y == k);  % Indicator vector for class k
        G(:, k) = X' * (indicator - prob(:, k));  % Gradient for class k
    end



end
```

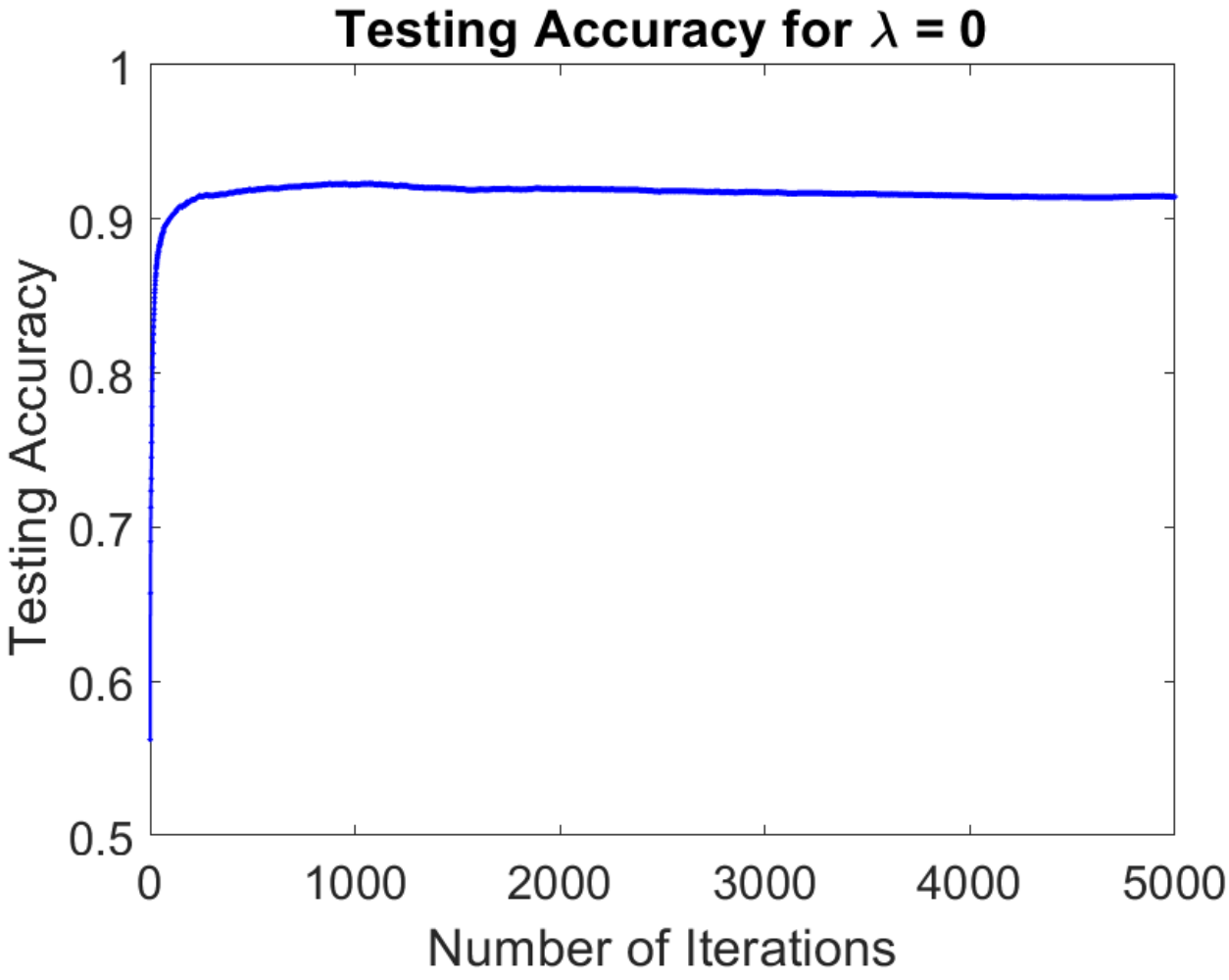
“

```
function G=log_grad(y, X, B)
    [n,d] = size(X);%n: number of samples, d: number of features
    K = size(B,2) + 1; %Total number of classes

%compute gradient
    XB = X * B;
    expXB = exp(XB);
    prob = expXB ./ (1 + sum(expXB, 2));

    prob = [prob, 1 - sum(prob, 2)];

    G = zeros(d,K-1);
    for k = 1:K-1
        indicator = (y == k);  % Indicator vector for class k
        G(:, k) = X' * (indicator - prob(:, k));  % Gradient for class k
    end


end
```

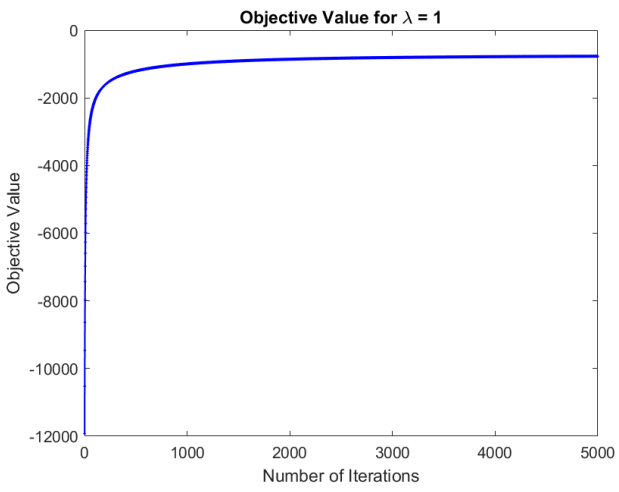
Following this code and implementing the logistic_classify .m and generate these graphs:

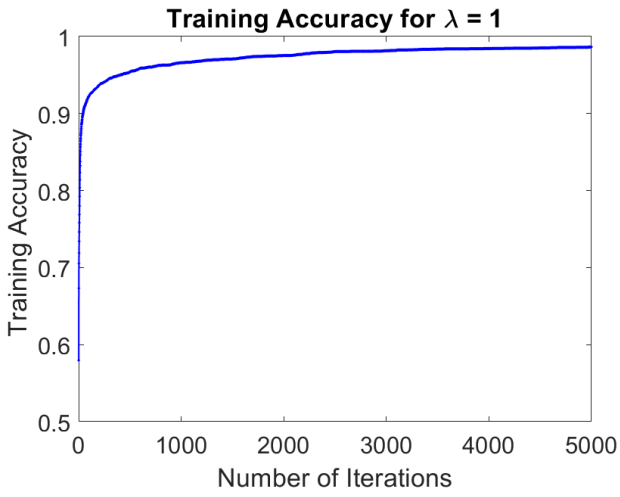
When lambda = 0

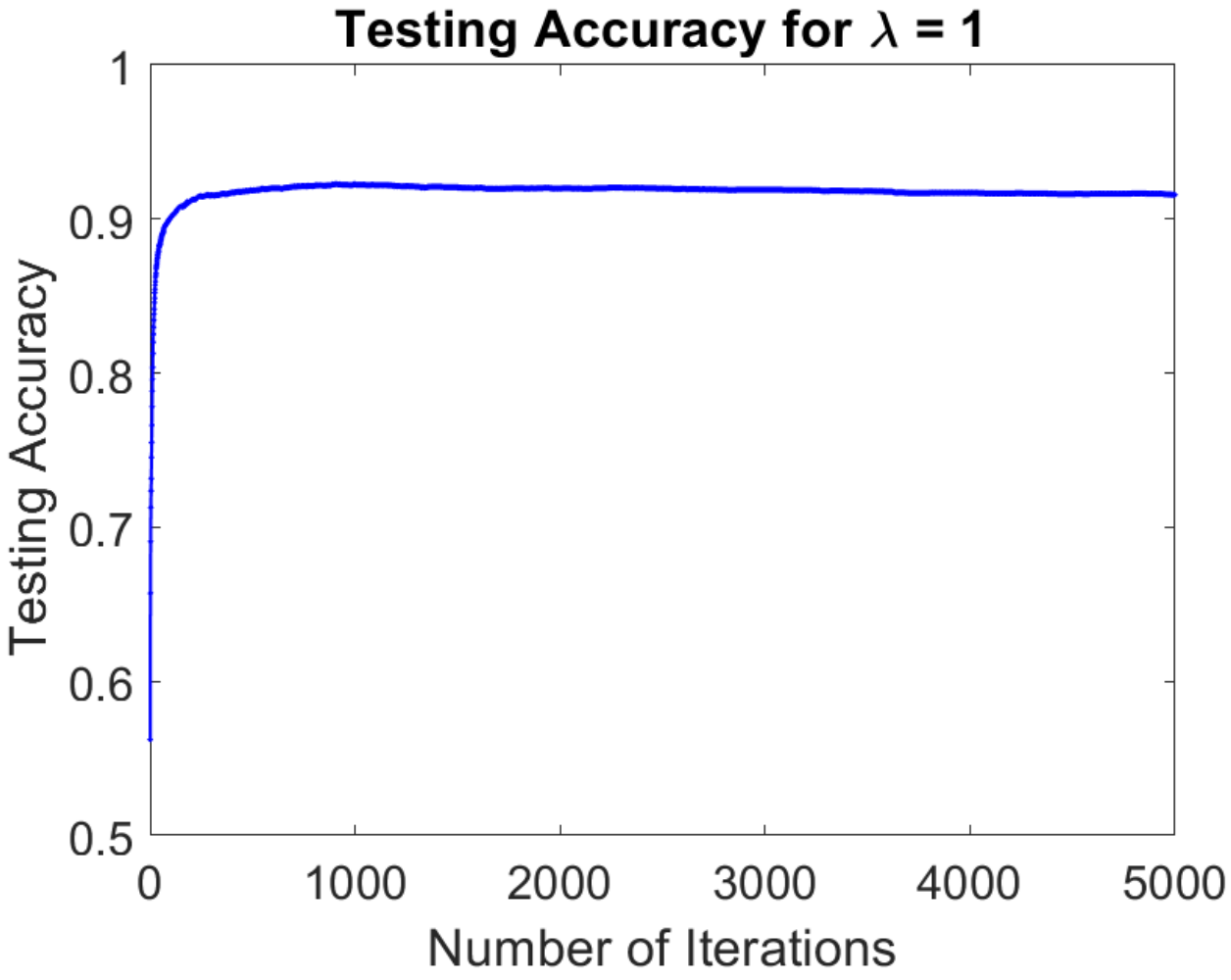




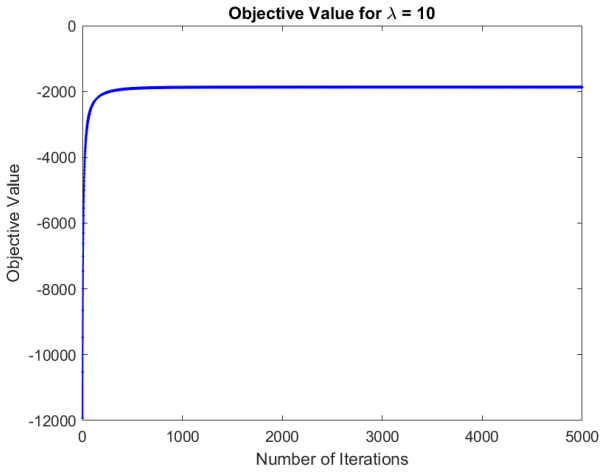

When lambda = 1

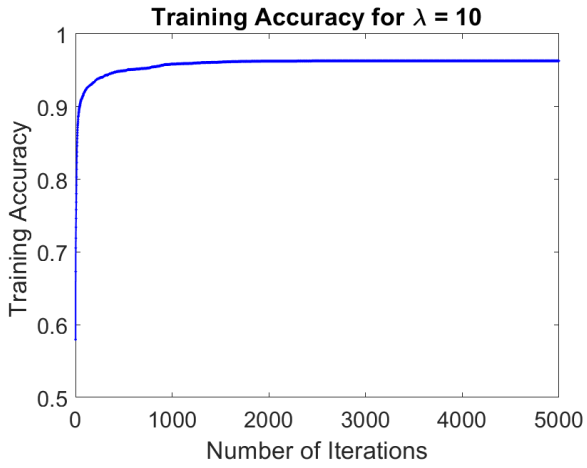


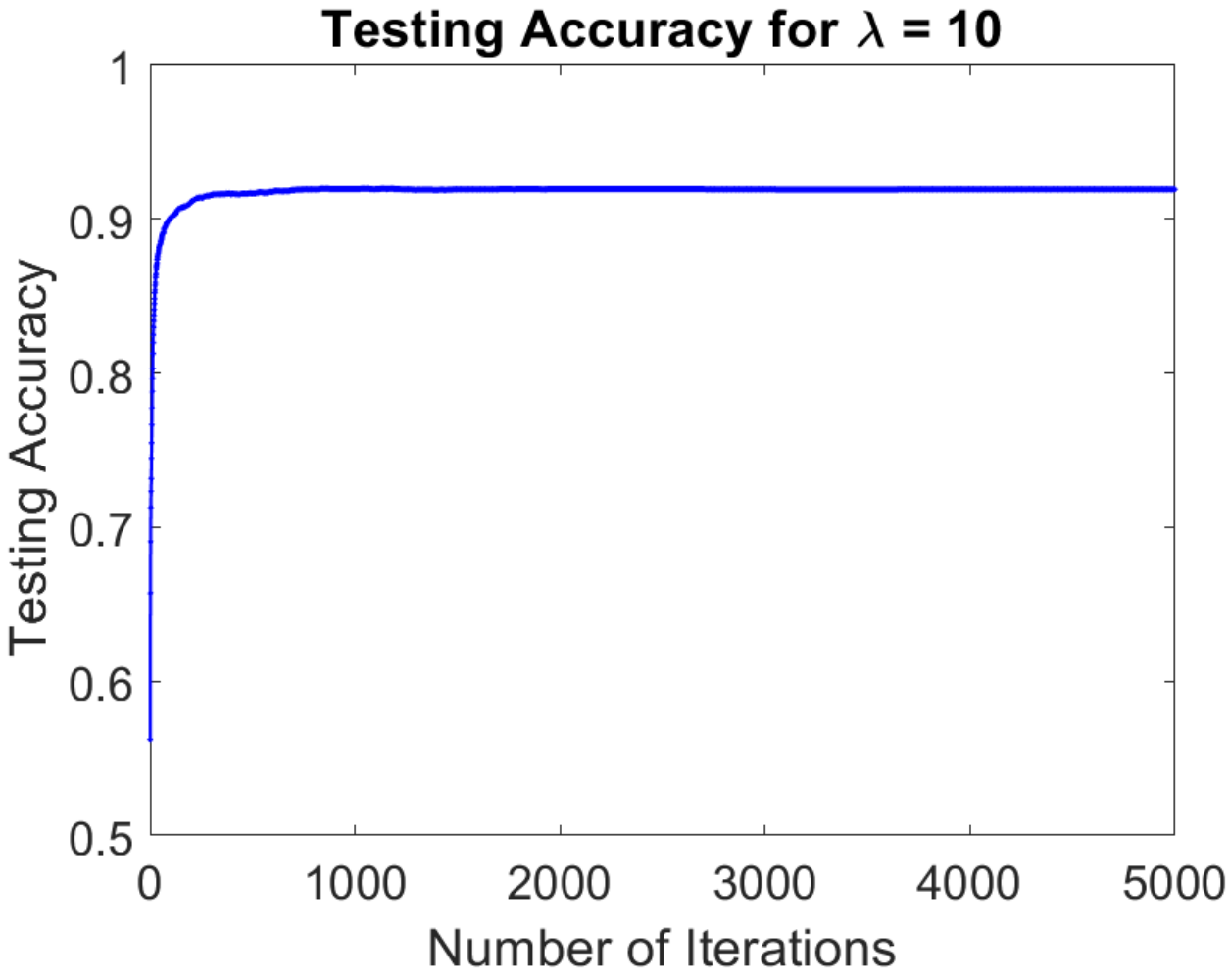





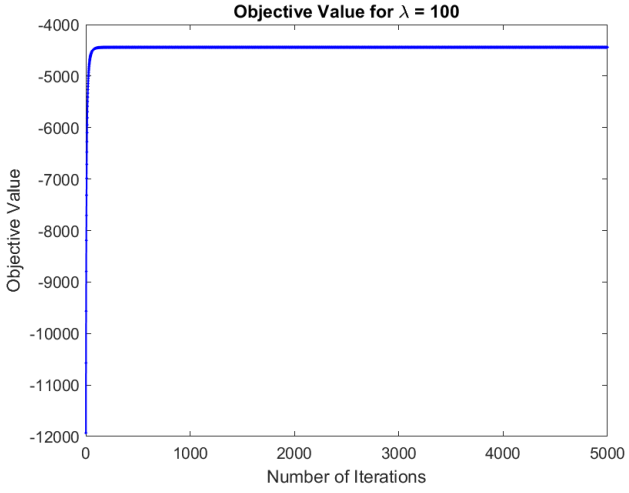

When lambda = 10

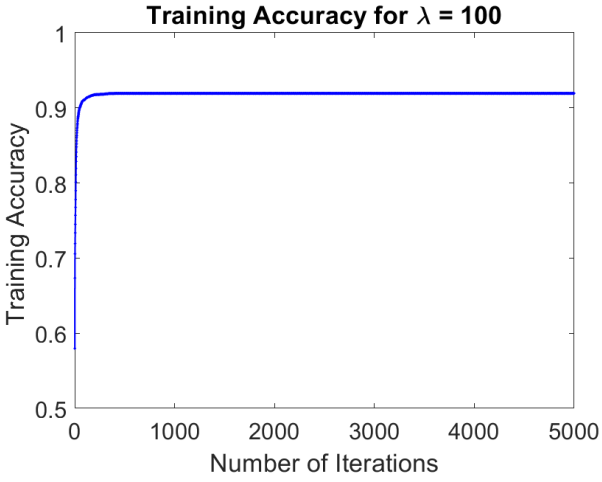


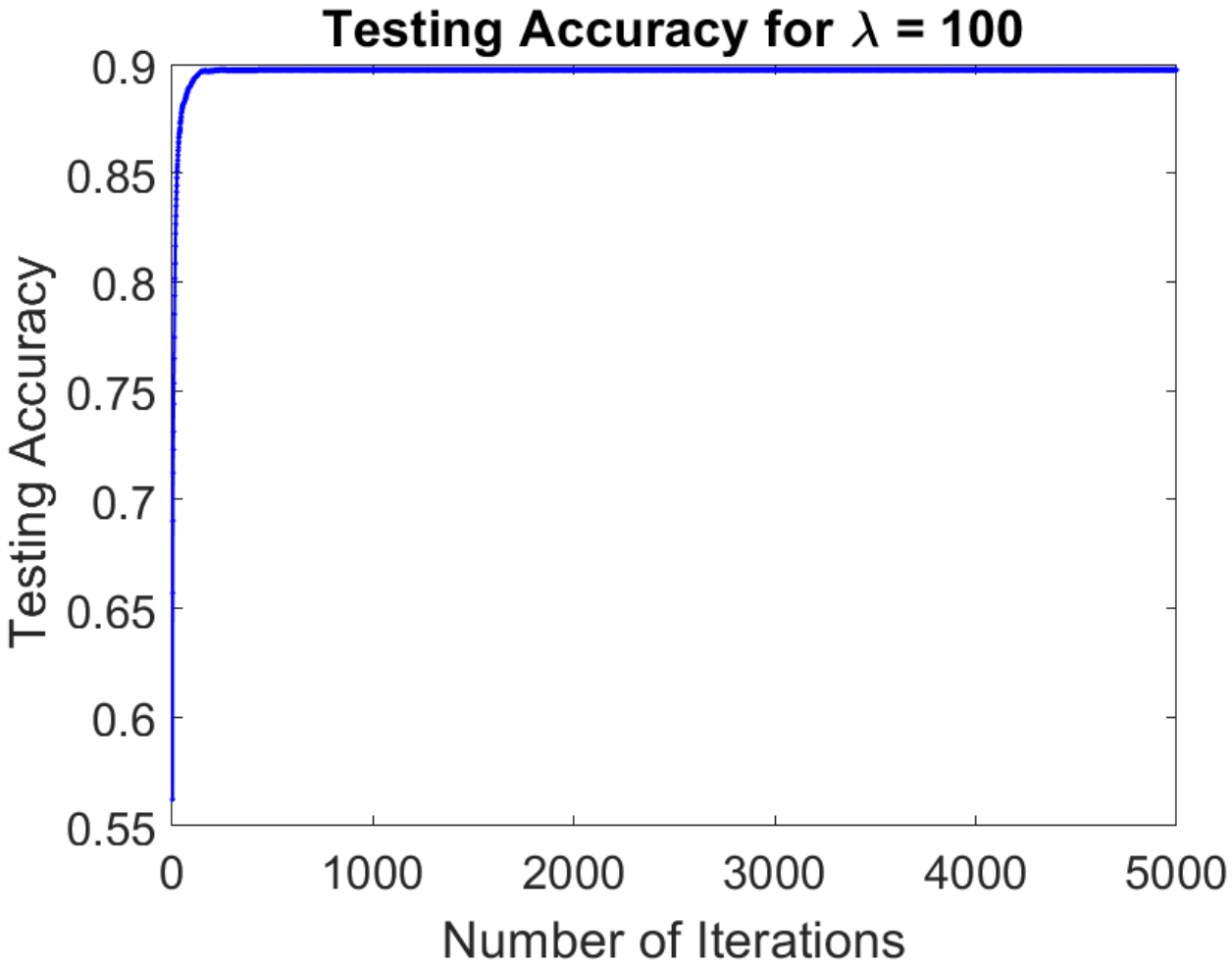





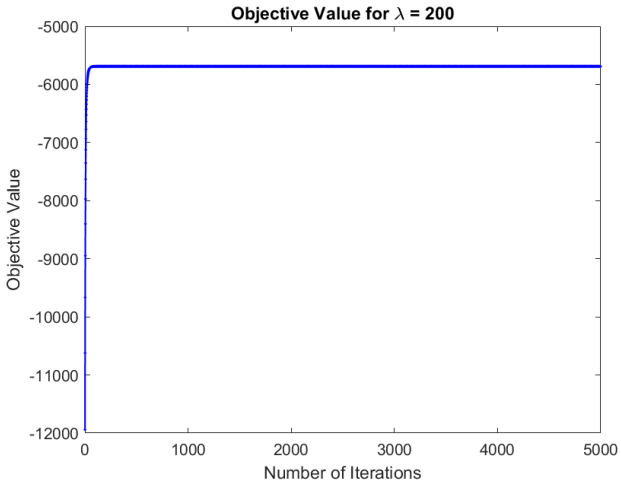

When lambda =100

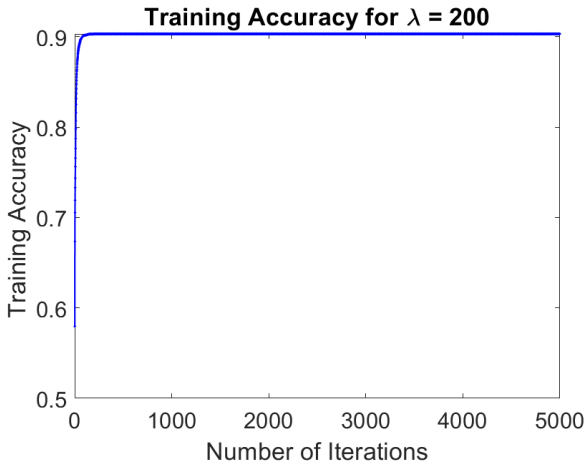


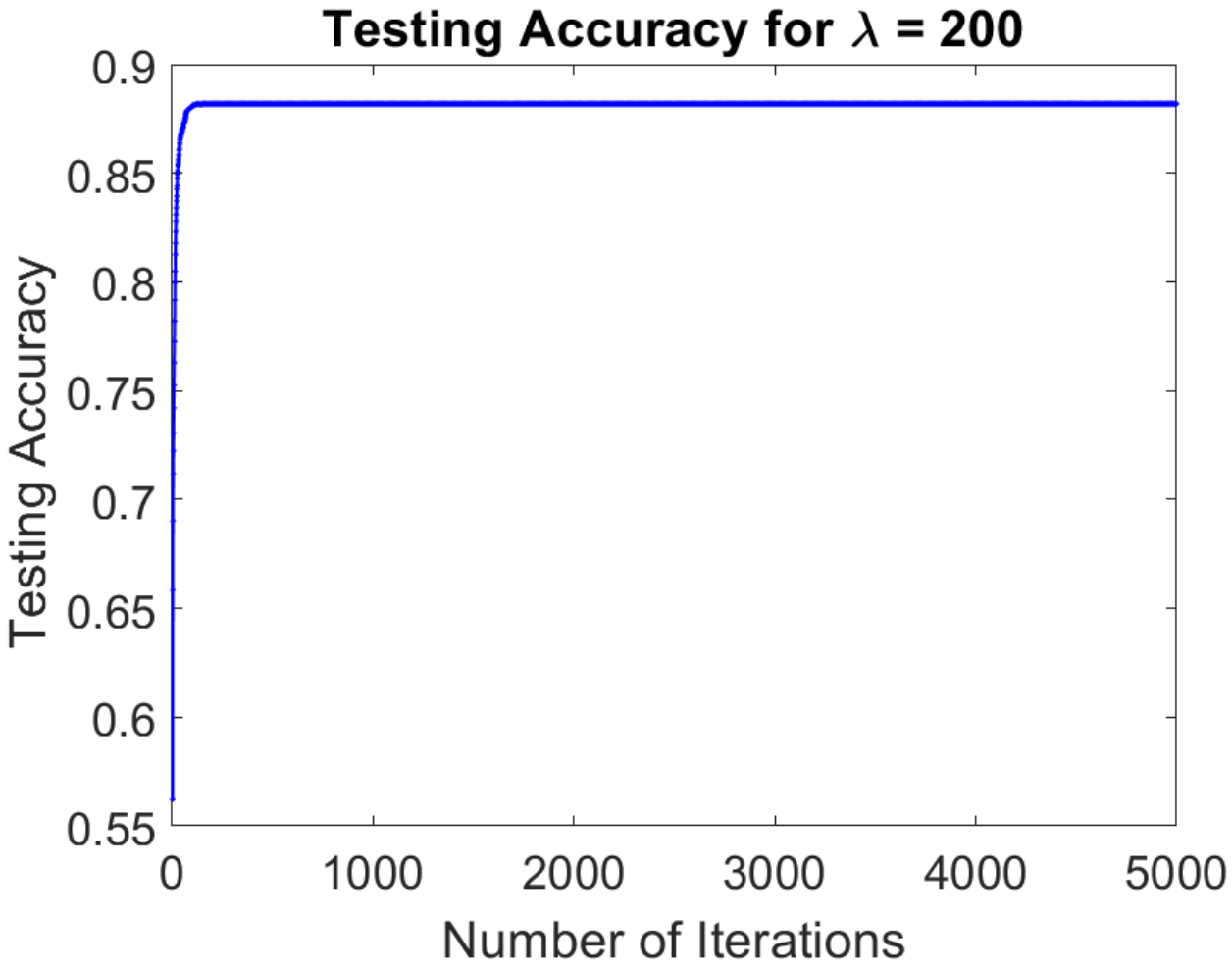






When lambda =200






From the above charts we recognize that:

- Objective value:
  - In general the obj value decreases over iterations, showing convergence for all lambda values.
  - While for smaller lambda values (lambda = 0), the convergence is faster and reach a lower final value.
  - And for larger values, the convergence is slower and the final obj is higher.
  - To wrap up: a moderate lambda balances fast convergence and regularization.

- Training Accuracy:
  - For smaller lambda values, training accuracy is higher as the model overfits to the training data. While for larger values, training accuracy decreases because the model becomes over regularized.
  - To wrap up, moderate lambda has in between better training accuracy.
- Testing Accuracy:
  - This improves with moderate values as the model geralization better to unseen data.

- While for small values, testing accuracy is lower since the model overfits to the training sets.
- And for larger values, it declines again due to underfitting since the model becomes too simplistic.