Lab 203: Electric Potential and Electric Field

Name: Arsh Bhamla, Kevin Gettler,
Yosif Ismail **Group: G**

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Course: PHYS 121A 016 **Instructor: Subodh Dahal**

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1. INTRODUCTION

1.1 OBJECTIVES

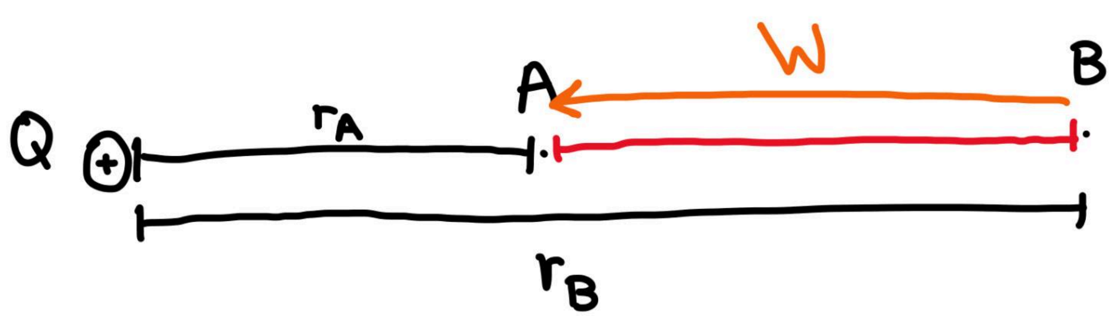
The objective of this lab was to view how equipotential surfaces are formed using different types of conducting sheets by measuring voltage at different regions. Given three experiments and Matlab code, we were able to learn about electric potential and its relationship to electric fields and equipotential surfaces.

1.2 THEORETICAL BACKGROUND

The first major area of background we received was electric potential, and by extension, electric potential energy. We start with the equation for work, which is:

$$W = -\int_{r_a}^{r_b} F\, dr$$

It’s best to assume work by using two particles. Particle one, the source charge, is a static positive charge that has an electric field in all directions surrounding itself. Particle two is another positive charge that is being moved closer to particle one, going against the electric field. Particles always follow electric fields, therefore by going against one, particle two is having work done on it.



In this diagram, we can see how the small dot charge has to do work as it moves towards Q as they are both positively charged and therefore it is moving against an electric field produced from charge Q. In the next couple of steps, we will be able to solve for the difference of potential and potential energy between points A and B.

Going back to the equation, we know the value of force in Coulomb's law, we can make a substitution for F with the following:

$$F = k|\frac{q1q2}{r^2}|$$

$$W = \int_{ra}^{rb} k(\frac{q1q2}{r^2})\, dr$$

What we can notice is that the formula for work is also the formula for potential energy. Solving for the integral, we get an equation of:

$$U = k\,\frac{q1q2}{r}\,,\ Ua - Ub$$

Electric potential uses the formula for electric potential energy to create its own formula as follows:

$$V = \frac{W}{q2} = \frac{kq1}{r}$$

The value for r in this case is a difference between two points, ra and rb. In some cases, we assume that rb is infinite, which allows us to set that value equal to 0 and use only the value of ra in our equation.

The electric field can also be written in terms of electric potential, whereby the equation is as follows:

$$E = -\frac{dv}{dr}$$

The second important factor to consider are the equipotential surfaces, which are three-dimensional surfaces where every point has the same electric potential. In other words, they represent regions where the electric potential remains constant. These surfaces are perpendicular to the electric field lines, and the spacing between them indicates the strength of the electric potential: the closer they are to the source charge, the stronger the potential at that area. Charge cannot flow from within a single equipotential surface as the difference in potential is always 0 by the definition. However, charge can flow between several equipotential surfaces (between one another) because the voltage at each one is different in respect to the distance r from the source charge. While there is no formula for equipotential surfaces, we can take all points where the voltage is the same and form an equipotential surface as that satisfies the definition.

2. EXPERIMENTAL PROCEDURE

This experiment evaluates the electric potential produced by three distinct charge set-ups. For each set-up, a conductive plate that produced the desired charge set-up was attached to a field mapping board. This board was hooked up to a direct current power supply. A voltmeter was then added to the circuit such that the voltmeter read the potential present at the tip of a reader arm. A sheet of paper was then attached to the top of the field mapping board, and a stencil was used to mark the sections of paper that lied above the charged sections of the plate. The reader arm was then used to locate points on the board with specific voltage; the point's position and its particular voltage were then marked on the paper. The general aim was to map four to five points for each voltage, with the potentials spread out at 0.5 V intervals. After all points had been located and marked, the points were then used as a guide to identify the sign of charge on each charged section, as well as to draw equipotential lines in the voltage field produced. Software was used to model the ideal equipotential lines produced by each charge set-up, and these ideal diagrams were compared to the empirically produced ones.

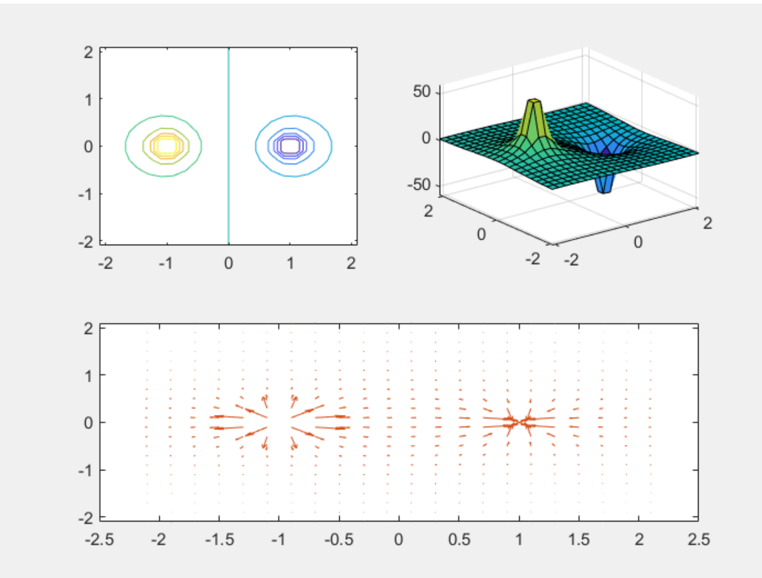
3. RESULTS

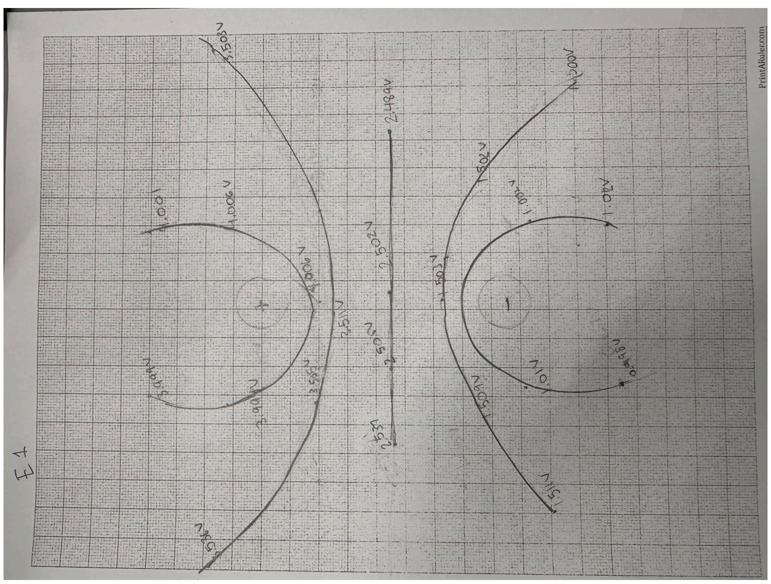
3.0 CODE

```
eps0 = 8.85e-12; k = 1/(4*pi*eps0);

% the code section for computing the potential field for each
% charge set-up is highly varied; the corresponding code used
% for each set-up is listed with its corresponding figures

%% Variable Code Section (see figures in Experimental Data section)
%
%
%

V = double(V1 + V2);
subplot(2, 2, 1); contour(x, y, V)
subplot(2, 2, 2); surf(x, y, V)

% added parameters for the vector field subplot, since the constants
% differ between set-ups; the exact values are defined separately in
% each code section
[px, py] = gradient(V, gradientScale, gradientScale);
subplot(2, 1, 2); quiver(x, y, -px, -py, vectorFieldScale)
```

3.1 **EXPERIMENTAL DATA**

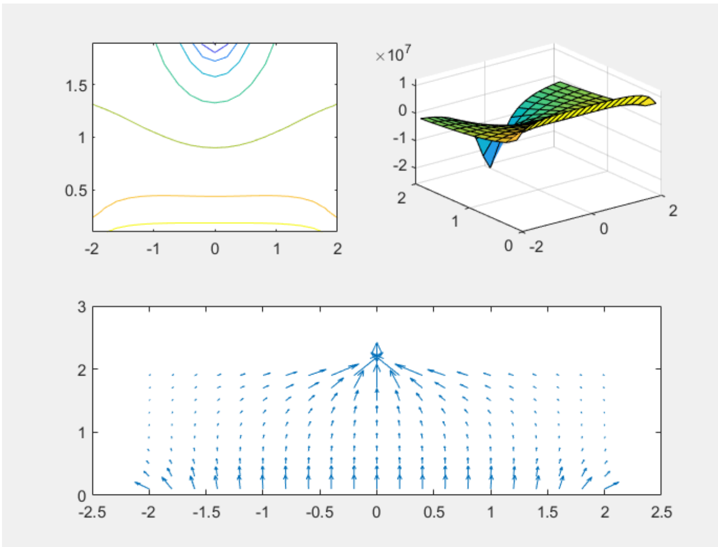
Figure 1. Observed and Calculated Electric Potential for Two Point Charges

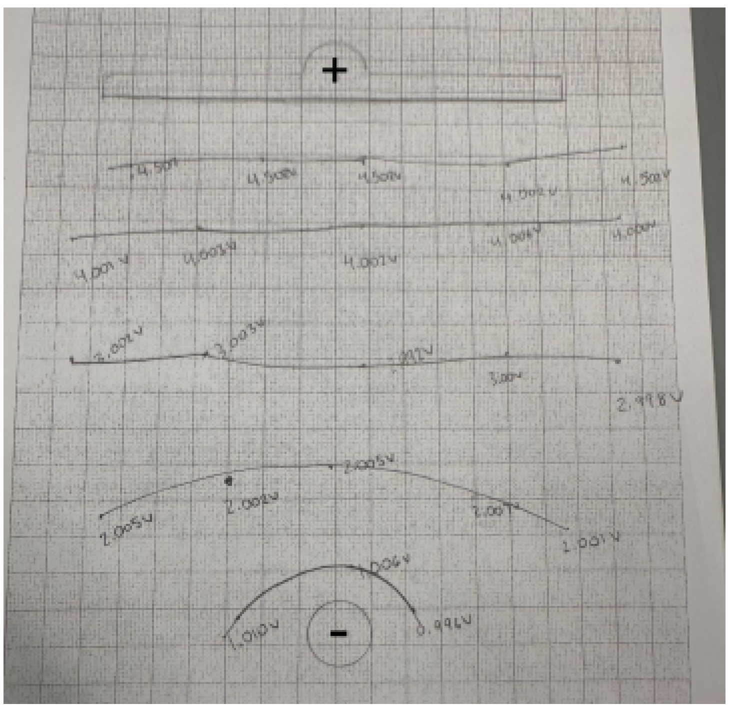




```
gradientScale = 0.01;
vectorFieldScale = 1;
[x, y] = meshgrid(-2.1:0.2:2.1,
-2.1:0.2:2.1);
ql = +1e-9;
q2 = -1e-9;
a = 1;
rl = sqrt((x+a).^2 + y.^2);
r2 = sqrt((x-a).^2 + y.^2);
V1 = k*ql./rl;
V2 = k*q2./r2;
```

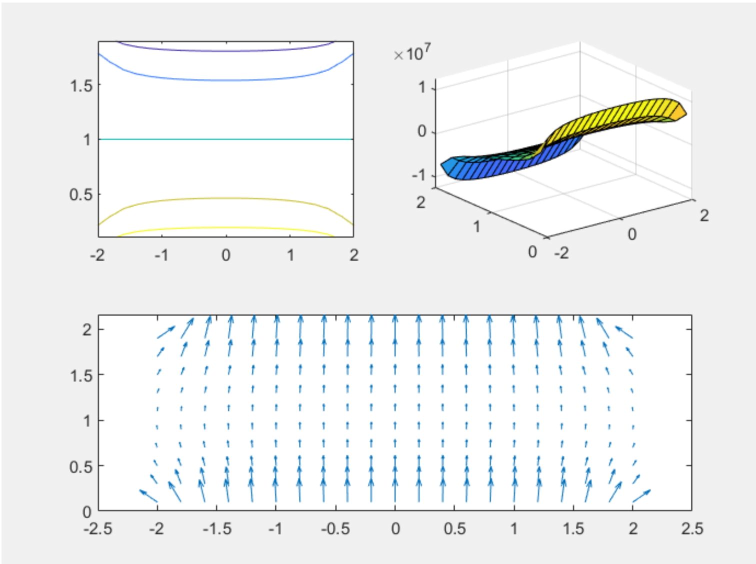
Figure 2. Observed and Calculated Electric Potential for Point and Line Charge

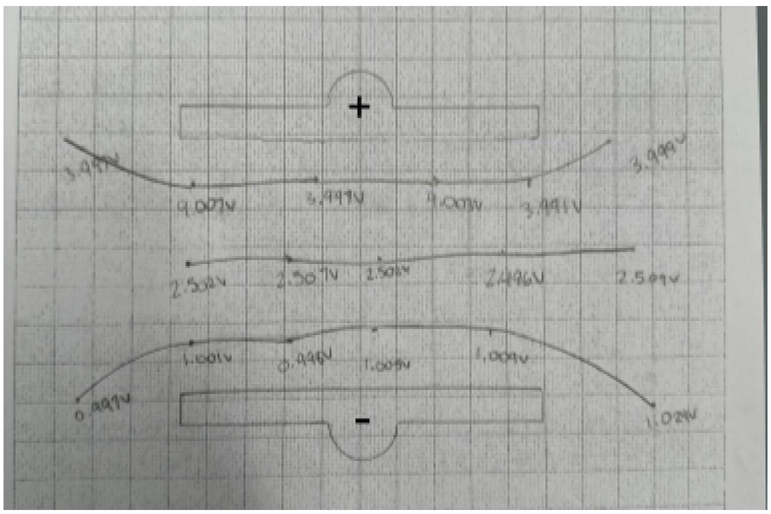




```
gradientScale = 0.1;
vectorFieldScale = 2;
[x, y] = meshgrid(-2:0.2:2,
0.1:0.2:2);
q1 = -1e-3; a = 2.2;
Q2 = +1e-3; L = 4; lambda =
Q2/L;
syms X;
r1 = sqrt(x.^2 + (y - a).^2);
r2 = sqrt((x-X).^2 + y.^2);
V1 = k*q1./r1;
V2 = k*int(lambda./r2, X, -L/2,
L/2);
```

Figure 3. Observed and Calculated Electric Potential for Two Line Charges





```
gradientScale = 0.1;
vectorFieldScale = 1;
[x, y] = meshgrid(-2:0.2:2,
0.1:0.2:2);
Q = +1e-3; L = 4; lambda = Q/L;
a = 2; b = 0;
syms X;
r1 = sqrt((x-X).^2 + (y-a).^2);
r2 = sqrt((x-X).^2 + (y-b).^2);
V1 = double(int(-lambda*k./r1,
X, -L/2, L/2));
V2 = double(int(+lambda*k./r2,
X, -L/2, L/2));
```

3.2 **CALCULATION**

This lab did not have any values to calculate. Instead, we used a multimeter in class to measure voltage.

4. **ANALYSIS and DISCUSSION**

This lab was a visual way to understand Electric potential and Electric field. Before we could input the code into MATLAB and make changes, we had to understand its purpose and the desired result. Furthermore, we had to understand how MATLAB works in order to properly create, edit, and print the figures. When the code structure is compared to the electric field formula and electric potential, each program produces a coordinate space in a straightforward manner. The first set of computations yielded equal electric potential values. The equipotential line in our graphs that is closest to the left electrode is obviously curved in some way. This line will always have a short course since it is so near to the electrode.But when the lines distance themselves from the electrode, they start to seem straight and lack any curvature. It would be simple to see that these lines would just be pursuing a much wider circular course if the paper were expanded. What occurs when an equipotential line approaches another electrode is depicted by the center line. Within a general region of each electrode, the lines start to wrap around them. The route taken by an electric field as it moves from one electrode to the next is depicted by the lines. They start to bend toward the second electrode after the first electrode in order to maintain the field's perpendicular to the equipotential lines. This experiment's outcomes confirmed the validity of its hypothesis. The electric field and equipotential lines curled around the electrodes on the paper and were perpendicular to one another as a result of following their predicted trajectories. The meeting of the two lines did, however, appear to be somewhat off from the perpendicular 90 degrees in some places. On the equipotential lines, every point was marked at the same voltage as the other points. We gained a lot of knowledge about potential and the operation of electric fields from this lab. Vectors make up electric fields. This implies that they can only add and subtract; they cannot cross. Hence, the fields between two oppositely charged particles or distributions will eventually cancel when they are near to one another. We also discovered that the electric field and voltage decrease with increasing distance from a charge. Additionally, we discovered that there is nearly no variation in the electric field between two lines of charge. The electric field arrows in the above graphic, which are the same size between both lines, serve as an illustration of this.

Questions

1- The answer is that two equipotential lines cannot intersect.Lines joining places with equal electric potential are known as equipotential lines. This indicates that the electric potential of any two places on the same equipotential line is equal. Since this would mean that two places at the line's crossing would have different electric potentials, it is thus impossible for two equipotential lines to cross.

2-There is no work done by the point charge since it is at an equilibrium state. In the meanwhile, $W=F*d*\cos\theta$ is the equation that defines the work. Given that the force and displacement values do not equal zero, $\cos\theta$ will equal zero and θ, the angle formed by electric forces and equipotential lines, will be 90°.

3-The electric field is oriented in the positive charge's direction. Due to the presence of both a positive and a negative point charge in this instance, the electric field is not uniform.

4- They are extremely similar but there is a small error due to human error.

5. **CONCLUSIONS**

In conducting this experiment, we learned about what electric potential and equipotential surfaces are, and how they relate to one another. It was a good learning experience to use an actual voltage and multimeter to see in real time how voltage changed, especially with the different types of conducting plates which affected how the equipotential lines changed. Furthermore, the Matlab coding part verified the results we were hoping to see, and provided additional insight into the mathematical equations being put in action. We learned specifically how voltage operates between the area of high potential (the 5V on one side) to go to the area of low potential (ground on the other). Furthermore, it gave us insight into how voltage distributes itself when it encounters breaks in the surface in the form of round or rectangular insulators. There were a few challenges in setting up the circuit for it to function and utilizing all the wires in the correct fashion. The Matlab code faced some challenges due to the expensive operations it was using, but ultimately we were able to make it run properly. If we were to do this lab again, we would recommend trying different shapes on the conductive plates and working with a different voltage level. Overall, this experiment enhanced our understanding of fundamental electrical principles and also demonstrated the relationship between voltage and equipotential surfaces in a real-world scenario.

6. **RAW DATA**

Figure 4. Coding Running to Produce Results in Figure 1

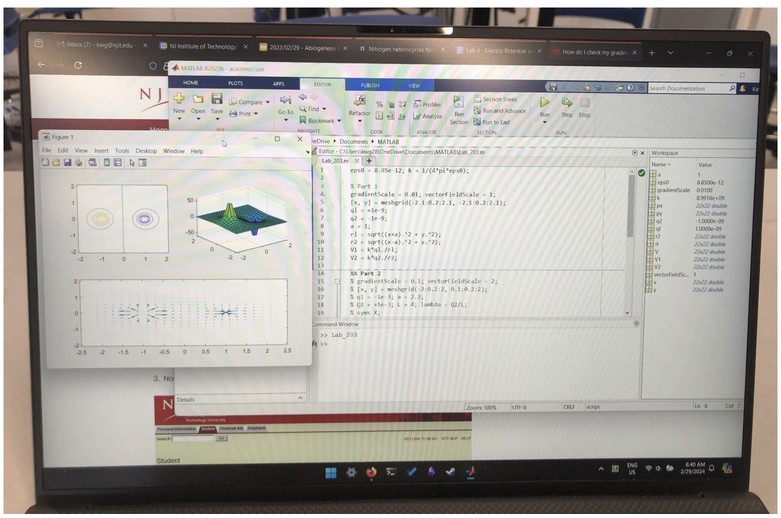


Figure 5. Coding Running to Produce Results in Figure 2

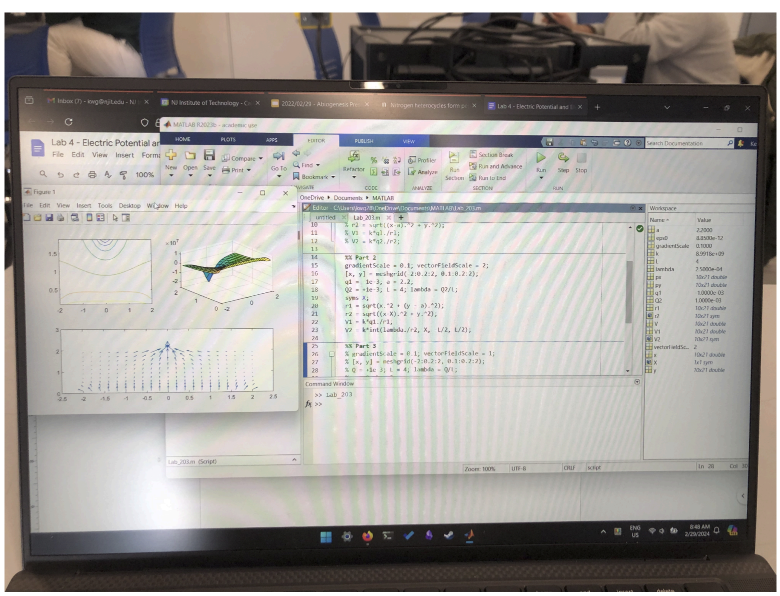
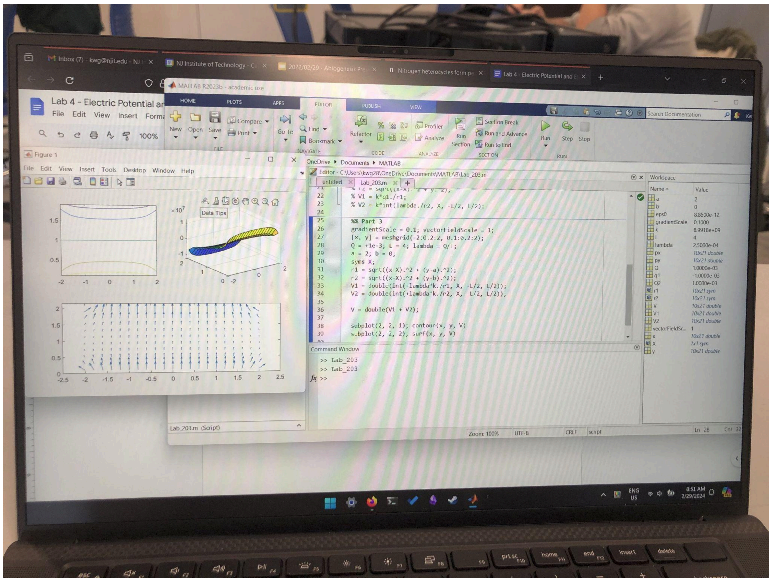


Figure 3. Coding Running to Produce Results in Figure 3


Lab 4 - Electric Potential and E
Figure 1
Editor - C:\Users\kwg28\OneDrive\Documents\MATLAB\Lab_203.m
untitled
Lab_203.m
% V1 = k*q1./r1;
% V2 = k*int(lambda./r2, X, -L/2, L/2);
%% Part 3
gradientScale = 0.1; vectorFieldScale = 1;
[x, y] = meshgrid(-2:0.2:2, 0.1:0.2:2);
Q = +1e-3; L = 4; lambda = Q/L;
a = 2; b = 0;
syms X;
r1 = sqrt((x-X).^2 + (y-a).^2);
r2 = sqrt((x-X).^2 + (y-b).^2);
V1 = double(int(-lambda*k./r1, X, -L/2, L/2));
V2 = double(int(+lambda*k./r2, X, -L/2, L/2));
V = double(V1 + V2);
subplot(2, 2, 1); contour(x, y, V)
subplot(2, 2, 2); surf(x, y, V)
Command Window
>> Lab_203
>> Lab_203
>>
Zoom: 100%
UTF-8
CRLF
script