Physics 142, Lab 3: Equipotentials and Electric Fields

Group
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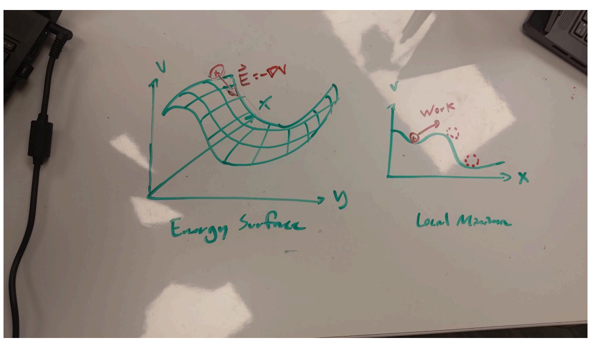
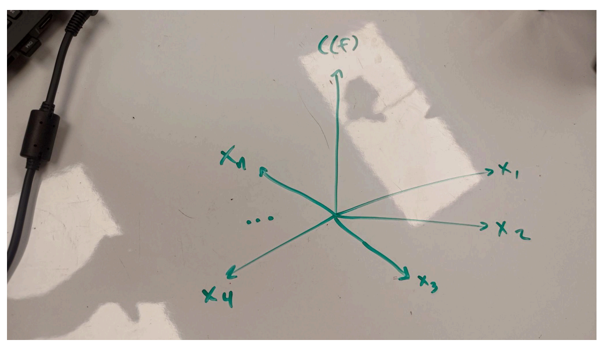
Introduction:

Measuring voltages at points on a piece of paper may seem initially a bit abstract and useless, but there can be a lot of parallels to other things in the real world. Equipotential Lines are visual representations of regions in space that have a constant electric potential (along the line). Such lines are important for determining trends in electric potential and for understanding electric fields within the same region. These ideas are commonly applied in areas such as electrical engineering and medical diagnostics. Specific applications of equipotential lines and electric fields include: defibrillators, electrocardiogram, air filters, lightning rods, and many more.

The electric potential can be viewed as an energy landscape. Charged objects follow the path of fastest energy loss, which is the *negative gradient* of the potential energy ($E = -\nabla V$). This principle can be applied to a majority of physics, chemistry, biology, and computer science. For example, following the negative gradient is useful for machine learning algorithms when minimizing the cost (error) of the specific parameters. The negative gradient, in that case, is for n-dimensions (e.g. 10k), where each dimension represents a single scalar parameter. This tells the training algorithm which adjustments to each parameter will reduce the error fastest. This is just one example where energy landscapes and fields can be applied to.



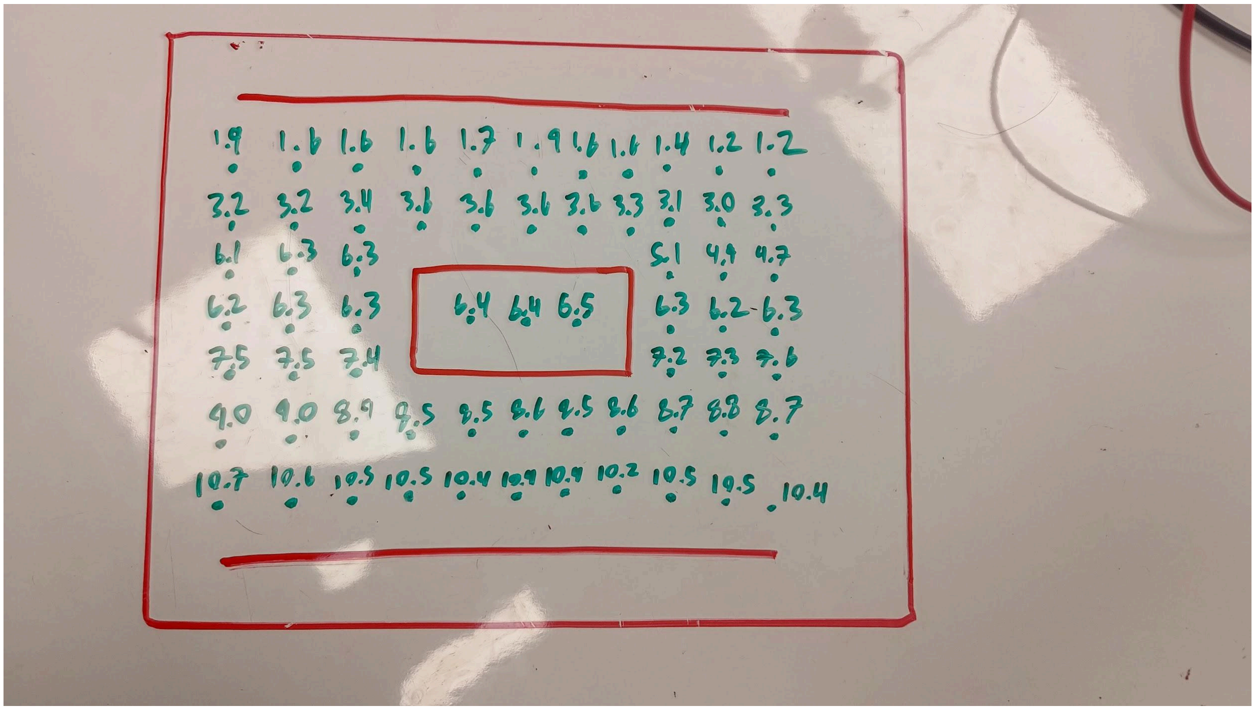


Procedure:

1. First plug in the cables into the power supply (into respective ground and + port)
2. Next plug the other side of the cable to the board being used
3. After that plug in the multimeter
4. Then turn on the power supply and set it to 12 volts
5. Now repeat measurements, taking the voltage at various points on the board and recording the data from the multimeter

Data:

Board 1:
Raw Data: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6.2 6.3 6.3 6.4 6.4 6.5 6.3 6.2 6.3
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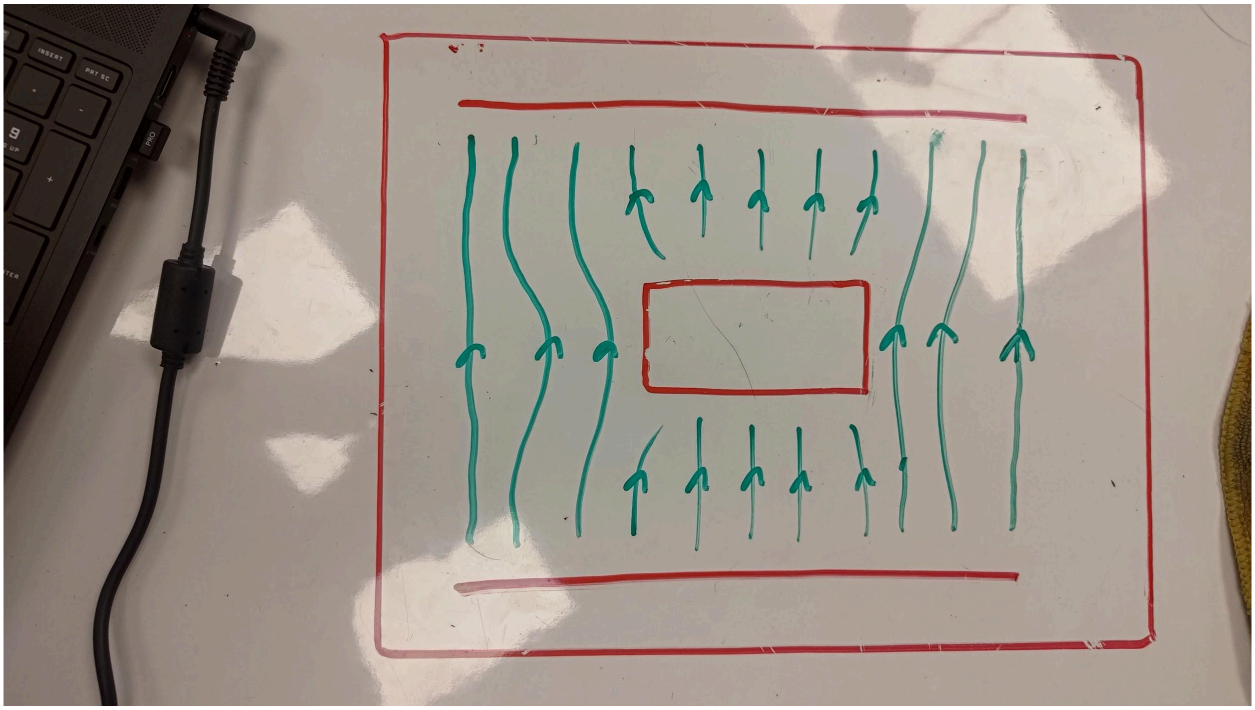
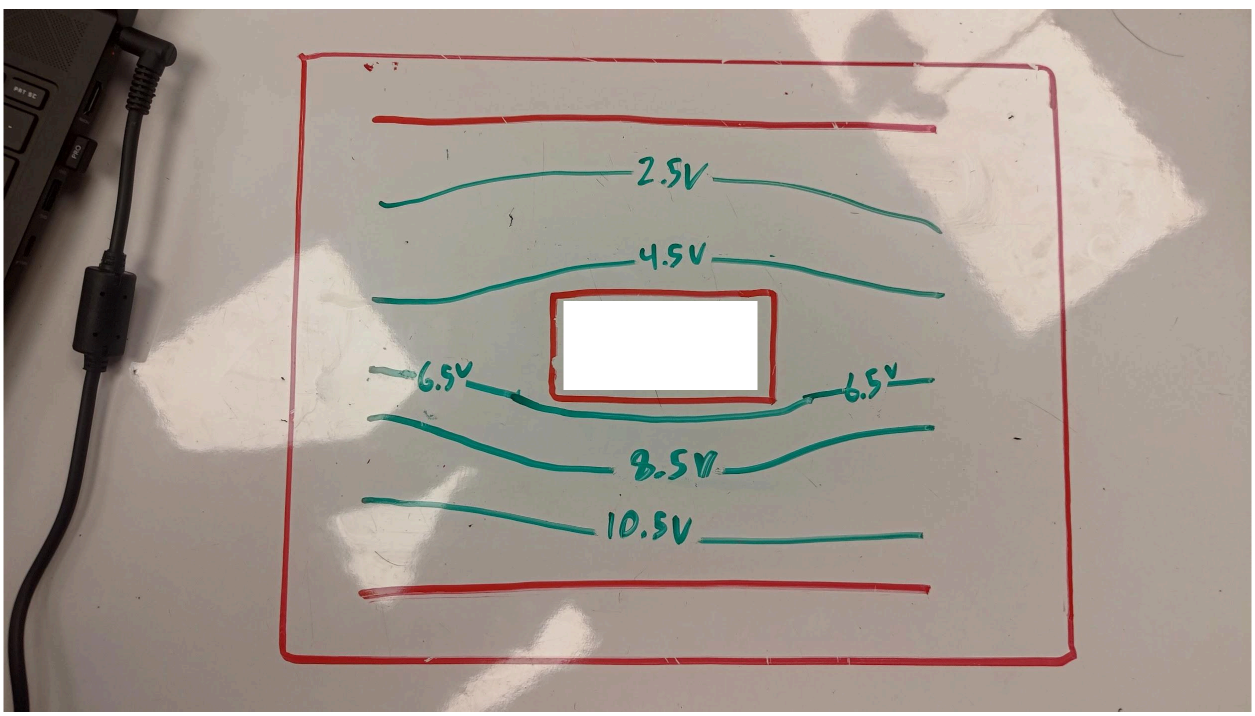
Field Lines:

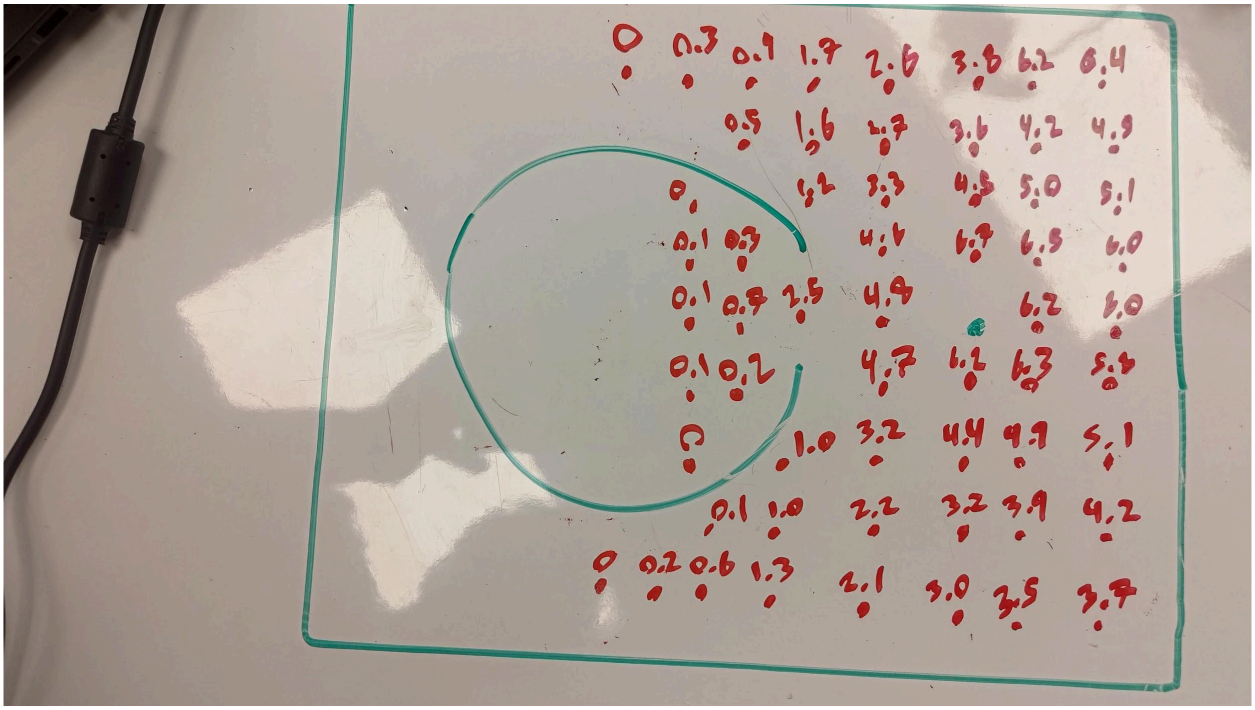


Equipotential Lines:

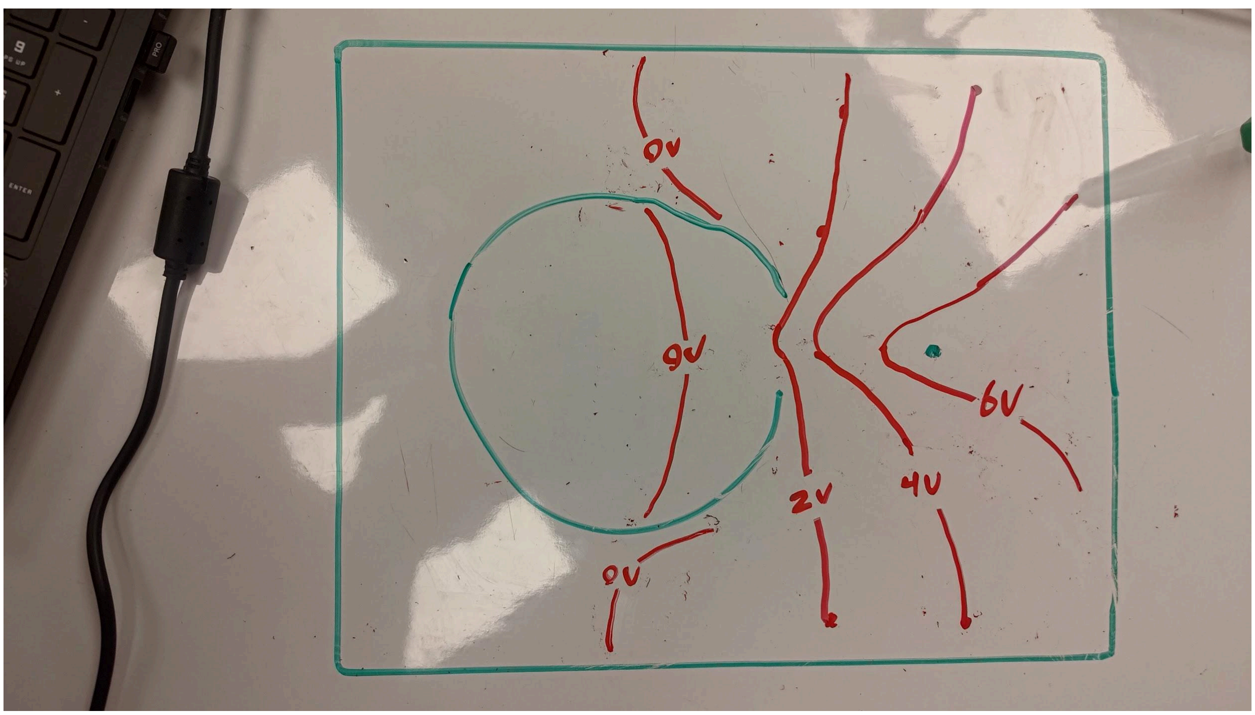


Board 2:

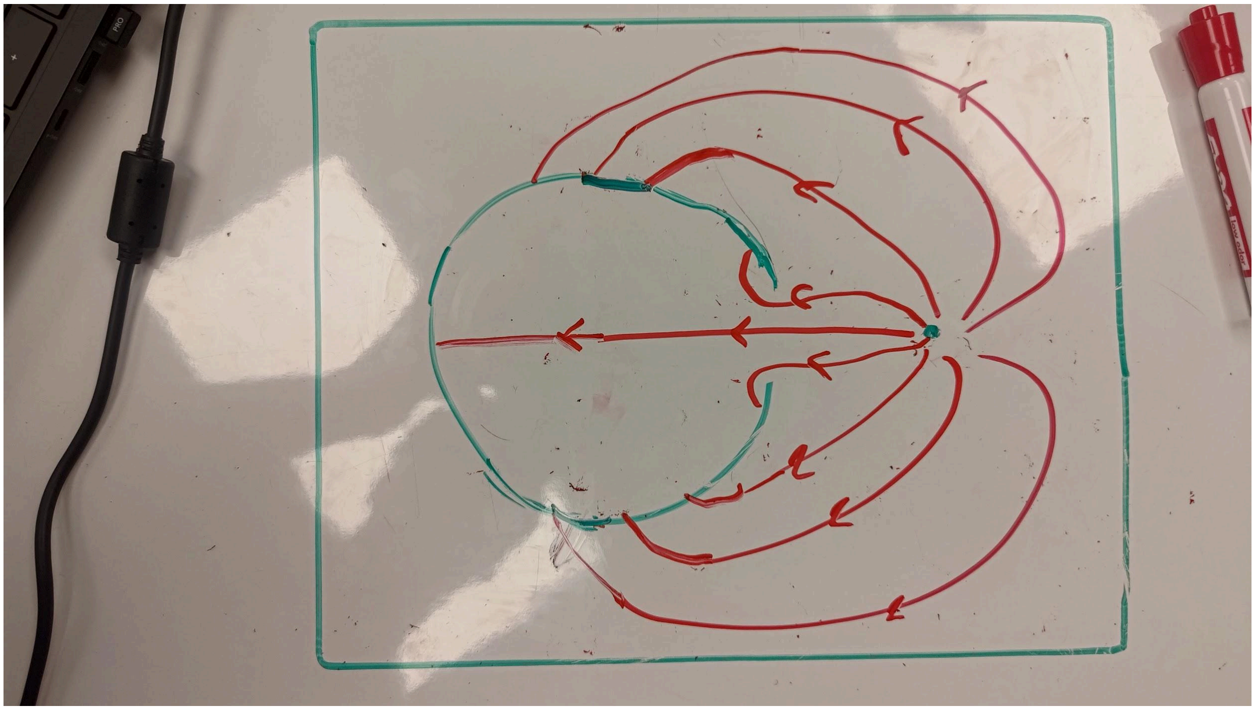
Raw Data:



Equipotential Lines:

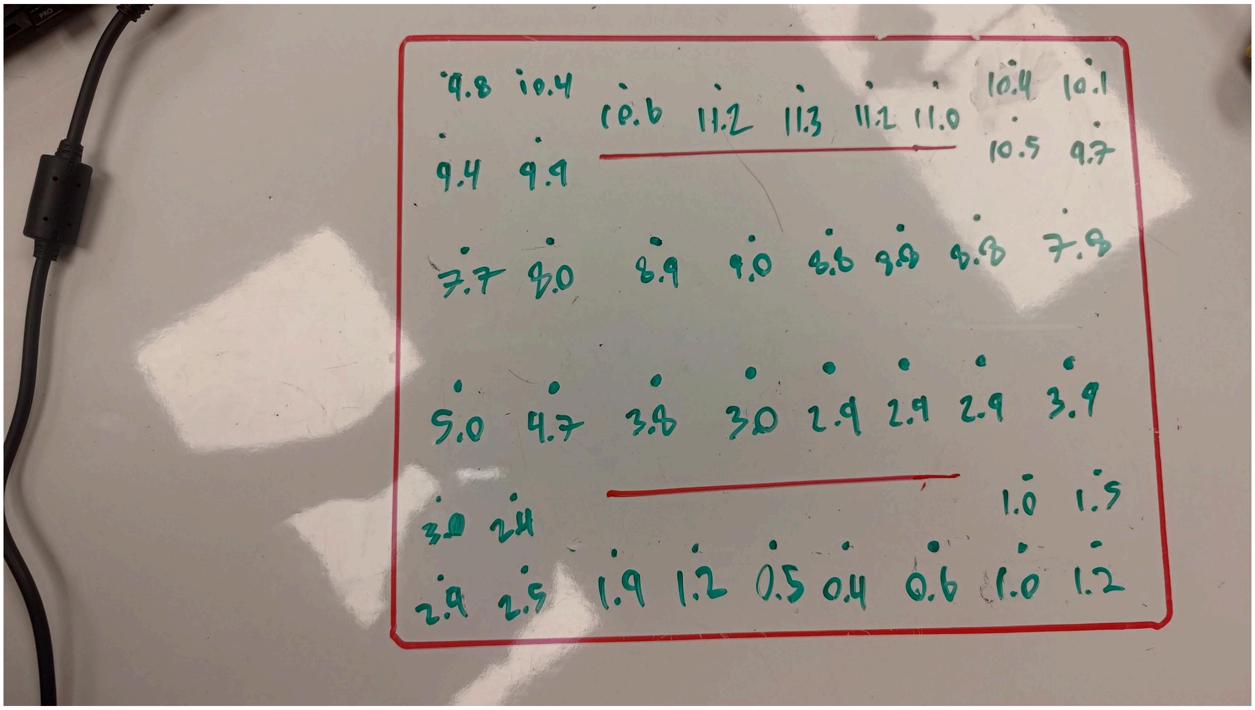


Electric Field Lines:

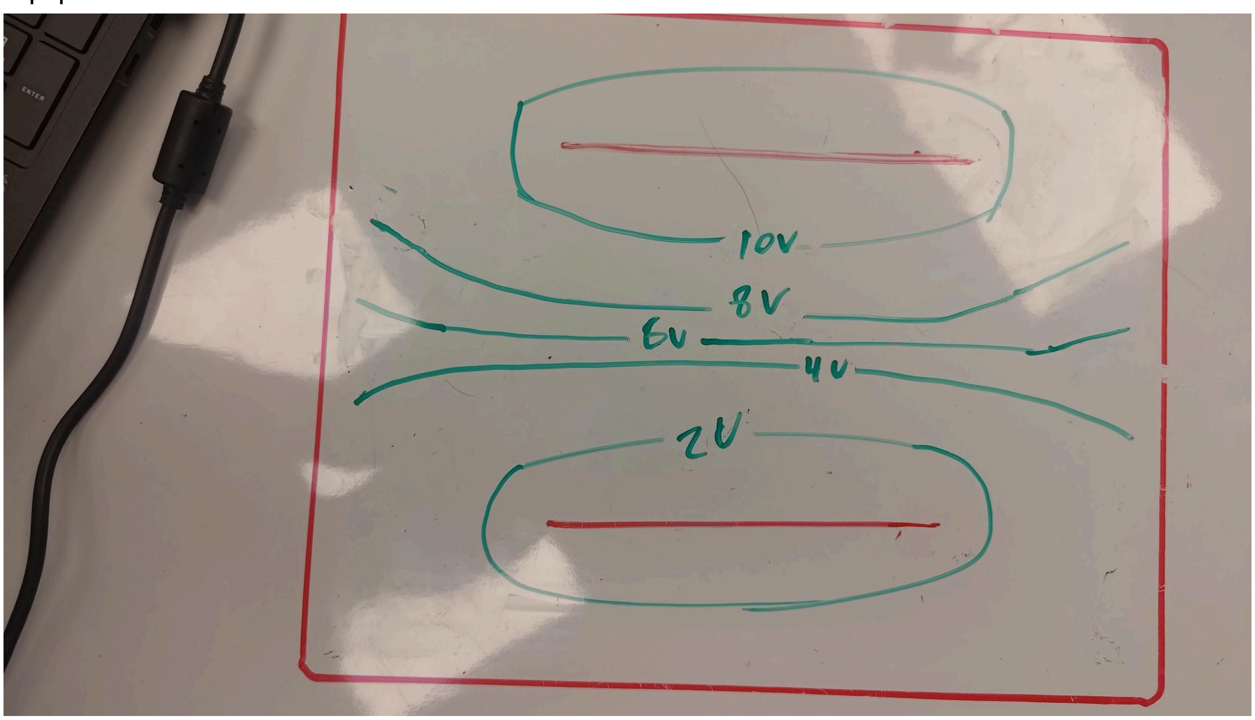


Board 3:

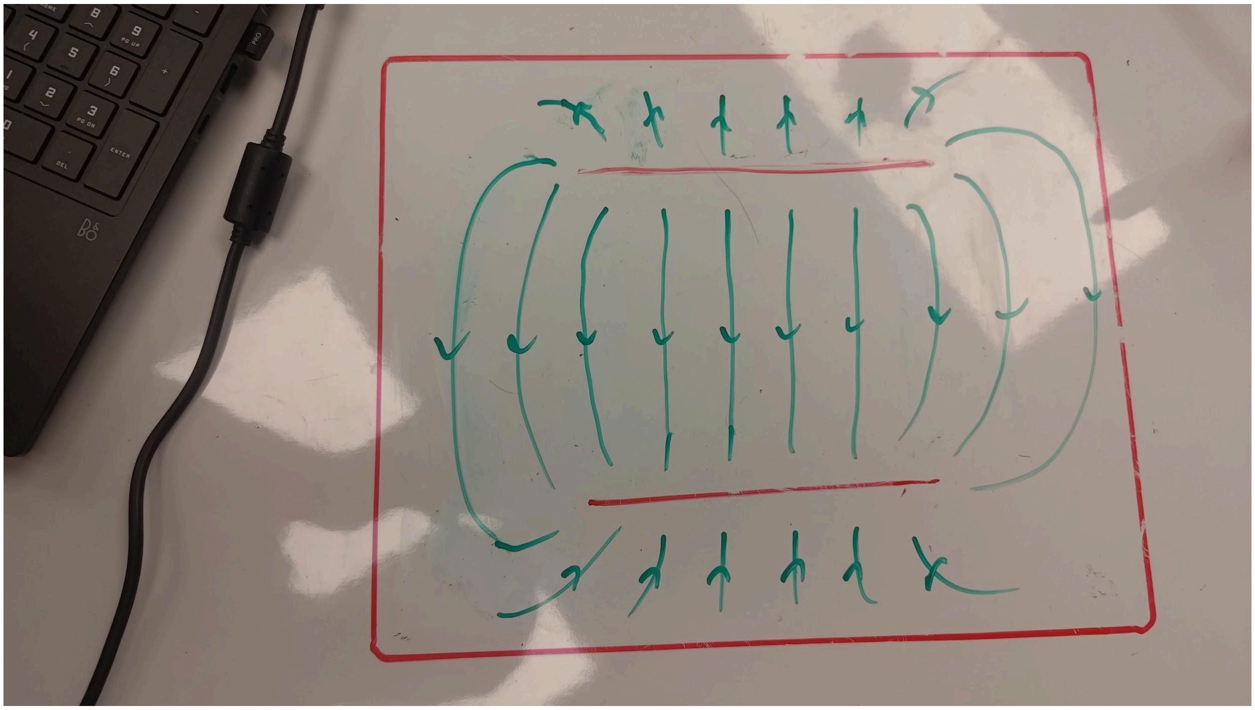
Raw Data:



Equipotential Lines:



Field Lines:



Data Analysis:

- For board 1, the equipotential lines curve slightly towards the ends, bending around the conducting box. The lines are also more concentrated where there is greater electric potential which also corresponds to a stronger electric field (electric field lines are also closer together here). The electric potential also decreases as the lines go from the positive to ground side of the board. The middle area is a faraday cage which means there is no electric field present in the area hence the absence of electric field lines (this is due to conductive material enclosing the area). The electric field lines also go into the conductor and terminate on the negative side and then resume on the top (positive) side and terminate to the top plate.
- For board 2, the equipotential lines are closer to one another near the positive source and space out/diminish as the reach they reach slightly past the cage/the cage itself. The electric field is the strongest to the left of the positive source and near the opening of the cage. It is weakest on the left side of the cage/parts within the cage. The electric field is weaker within the partial circle and zero at some parts. Since the field lines originate from the source and terminate on the surface of the cage, this would mean that the charges on the partial circle are concentrated on the surface (this makes sense as the partial circle is a conducting surface). The field is larger near the opening than well within the sphere since the field lines are more concentrated/closer together near the opening.
- For board 3, the potential is much greater in the region above (positive) compared to the below region (ground). This tells us that the field is much stronger above the top capacitor plate as opposed to below the bottom plate. The shape of the electric field lines near the ends curve outwards and around the plates. This relates to an ideal

capacitor (with two large plates very close together) since in an ideal situation we would want the field to be strictly concentrated between the two plates as opposed to around them. The equipotental lines surround both plates and then are spaced out between the plates and the region between the two plates (higher concentration here). This tells us that the electric field is stronger between the two plates. This relates to the landscape metaphor since topo lines closer together represent a greater gravitational potential and subsequent greater force applied. This corresponds to how closer together equipotential lines represent a greater electric potential and a greater force (hence a stronger field in the area).

Conclusion:

As seen in the lab, measuring voltages at just a few points can lead us to a lot of conclusions about how electric fields flow. In addition, we also discovered some fundamental properties of capacitors, such as that they have a nearly perfectly straight electric field in between the plates. This can be used in many areas of physics, such as in Cathode Ray tubes, particle accelerators, and more. It allows a constant force to be applied to a particle in the field. Overall, the main takeaway of this lab is *energy landscapes* and how particles follow the negative gradient of such surfaces, which apply to almost all physical phenomena.