Sample Unit Plan

Electrostatics Unit Plan

This unit plan meets or exceeds all requirements of the PHY 312 Unit Plan Scoring Rubric. Note that the instructional goals and student performance objectives come directly from the Modeling Method of Physics Instruction *Electricity and Magnetism* unit of second semester topics. Hints for using such resources will be found as footnotes throughout this document. This sample document was prepared with about four hours of effort.

I. Overview

The title of this unit is Electrostatics. The unit deals with static charges and serves as an introduction to flowing charges in circuits. It is part of the school's second semester topics in an introductory physics course. The content of the unit will extend to positive and negative charges, electric potential and fields, and interactions between charged bodies including charging by induction and conduction. Also addressed will be insulators, conductors, and capacitors. As a result of this unit, students should have improved scientific reasoning skills. The fun and excitement of this unit will redound to the lasting memory of the students with physics seen as both an interesting and useful field of study.

II. Rationale

The students taking this course will be mostly juniors plus a few seniors. The class is not expected to have any students with anything other than typical learning difficulties. One student currently has a broken leg and will be restricted to a wheel chair for the next 10-12 weeks. Students are from a mixed city/rural district, so there will lots of varied interests and career goals represented by those enrolled. City students likely will see this course as an important component of career preparation in the various science-related professions from doctoring to electrician. Rural students will likewise see this course as immediately useful to the extent that it will help the conduct farm-related tasks. Overall, the course will provide assistance to students who will elect careers that benefit society in any of a way array of professions, including the sciences. In addition, students will encounter various electrostatic phenomena on a day-today basis and will benefit from understanding these phenomena – from lightning to static cling to sparking doorknobs!

III. Materials/Technology/Resources

An inspection of the future student teaching site's classroom shows ready availability of teaching materials. For instance, for demonstrations there are multiple amber and glass rods with rabbit firs and silk cloths, pith balls on mounts, electroscopes, a Van de Graaff generator, different types of materials that can be used to generate charges, an electrophorus, wires, etc. Many of these materials are abundantly available and more than adequate in number to conduct lab activities with the course's 24 students working in 3-student groups. There are also multiple whiteboards, markers, and erasers for conducting Socratic dialogues. In addition I have access to worksheets and other teaching-related notes and guidelines for this unit readily available from the Modeling web site at Arizona State University – from which the student performance objectives and content outline were obtained for this project.

IV. Content Outline[1]

1. The electrical force is a result of charge

   - Charge is a fundamental property of matter (like mass).
   - Electric charge is a conserved quantity.
   - Electric charge is particulate in its behavior (as opposed to a fluid).
   - Only two types of charge (+ and -) have been observed.

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[1] See the Modeling Method of Physics Instruction web site at Arizona State University for ideas. http://modeling.asu.edu/. There is no reason to reinvent the wheel when it has already been prepared for you.

(Use of P and N may be appropriate here to avoid the confusion of mathematical signs)
- Charge carriers are microscopic constituents of matter.

2. The behavior of charged objects results from uneven charge distribution.

    - An attraction between two objects is evidence for an excess of charge on at least one object. Either:
        a. objects have excess charge of opposite type, or
        b. one charged object induces a charge imbalance in a neutral object (polarization).
    - Repulsion between two objects indicates that both objects have an excess of the same type of charge.

3. Explain differences between conductors and insulators in terms of a microscopic model.

    - In insulators charge carriers are more tightly bound, thus unable to engage in bulk flow.
    - In conductors charge carriers are less tightly bound, allowing bulk flow of charge carriers. The mobile charge carriers should be identified as "electrons" by an appeal to chemistry.

4. Compare and contrast electrical and gravitational forces.

    - Both are inverse square relationships between point particles (Law of Universal Gravitation vs Coulomb's law.)
    - Force arises from fundamental property of objects (mass vs charge)
    - Gravitational force only attractive, whereas electrical is also repulsive
    - Magnitude of the forces are vastly different.

5. The electric field is also a result of charge.

    - A field exists around every charged object
    - The field mediates the force between charged objects.
    - The electric field is a vector quantity; the length represents the strength of the field
    - Electric field vectors from multiple charges can be added (superposition)

6. Electric field lines are a representational tool

    - Field lines originate on positive charge and terminate on a negative charge.
    - Should be distinguished from electric field **vector** at a given location.
    - Field lines do **not** show path of a test charge; tangent to field line indicates direction of electric field vector at a given location.
    - Convention uses a positive test charge to determine direction.
    - Density of field lines represents strength of field at given location

V. Student Performance Objectives[2]

By the time students finish this unit, the should have demonstrated the ability to:

1. Distinguish between the two kinds of particles that are responsible for electric interactions.
    - When two objects are electrically attracted to each other, this does NOT confirm that both objects have a NET charge on them.
    - When two objects repel each other, this DOES confirm that both objects have a net charge on them, of the same type.

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[2] See the Modeling Method of Physics Instruction web site at Arizona State University for ideas. http://modeling.asu.edu/. There is no reason to reinvent the wheel when it has already been prepared for you.

2. Distinguish between conductors and insulators.

3. Explain charging by conduction, induction and polarization in terms of the movement of electrons.

4. Use Coulomb's Law to represent the relationship between electric force, charge and distance of separation. Given information about the quantity of charge on two bodies and the separation distance, determine the electrostatic force acting on the bodies.

5. Recognize the similarities and differences between Coulomb's Law and the Law of Universal Gravitation.

6. Recognize that an electric charge produces an electric field. Represent the electric field produced by point charges and charged plates.

7. Calculate the force exerted by a uniform electric field on a charged particle.

8. Draw parallels between the electric and gravitational fields.

9. Use the superposition principle to calculate the strength of the electric field produced by charge(s) at a given location.

10. Accurately relate the historical efforts of one scientist working in the area of electrostatics.

VI. Alternative Conceptions

A review of the literature suggests that several alternative conceptions relative to electrostatics appear to exist, but this area appears not to have been widely studied. One of a very few references to these alternative conceptions is that of William J. Beaty (http://amasci.com/emotor/stmiscon.html) who lists the following alternative conceptions relating to electrostatics:

- 'Static Electricity' is electricity which is static? No.
- Electric circuits use current, not 'static?' Nope.
- Friction causes 'static electricity?' Wrong.
- 'Static electricity' has nothing to do with High Voltage?
- 'Static electricity' is a buildup of electrons?
- Neutral objects have no charge?
- 'Electricity' is a form of energy?
- 'Charging' a capacitor fills it with charge?
- We don't used 'Static electricity,' it's too weak and feeble? Not exactly.
- 'Static' is a useless and rare event: sparks and dryer-cling?
- Clouds are charged by rubbing together?
- Ben Franklin's kite was struck by lightning?
- Electrostatics" is the study of electricity at rest?

VII. Inquiry-Oriented Activities[3]

This course will be taught using inquiry-oriented activities to the greatest extent possible. For instance, efforts will be made to include learning sequences based upon the Inquiry Spectrum: discovery learning, interactive demonstrations, inquiry lessons, and inquiry labs. Students will be required to construct knowledge based on their first-hand experiences. Socratic dialogues and whiteboarding will be used on a regular basis. Strategies from the

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[3] The Modeling web site, *Hands-on Physics Activities with Real-Life Applications* (Cunningham & Herr, 1994), *Teaching Physics for the First Time* (Mader & Winn, 2008) as well as many of the AAPT PTRA manuals contain excellent ideas. Make use of the library collection in the Physics Teaching Resource Center (MLT 307-A) to build your unit plan's activities.

Illinois Learning Standards' Applications for Learning – identifying problems, devising and conducting experiments, using technology, working in groups, making connections, and communicating results – will be included.

VIII. Assessments

The assessments associated with this unit will be multiple and varied, informal and formal, formative and summative. There will be:

- a traditional paper and pencil test aligned with both student performance objectives and associated activities,
- a written historical report dealing with the discoveries in electrostatics,
- an inquiry lab activity after which students will write a lab report that will be scored using a rubric,
- electrostatics worksheets from MMPI assigned on a near daily basis,
- end-of-class informal assessments to see if the student performance objects for the day have been met.

Results from these assessments will be used regularly to determine what needs to be re-taught and serve as a guide to revised instruction. Every effort will be made to achieve student mastery of the subject matter before moving on. Social, personal, and scientific dispositions will be assessed on in informal basis only and primarily though one-on-one interactions during laboratory activities.

IX. Internal Alignments

Student Objective[4]	Learning Activities[5]	Performance Assessments[6]
Distinguish between the two kinds of particles that are responsible for electric interactions.	Suspend an amber rod on a string and charge an amber rod and charge it. Then bring to it charged glass and amber rods noting both attraction and repulsion. Similarly, electroscopes can be used in the same way. Conduct Magic Tape activity from Mader & Winn (2008).	Students will, when presented with an example of electrostatic attraction or repulsion, accurately account for the forces on the basis of opposite and like charges respectively.
Distinguish between conductors and insulators.	A daisy chain of students will be arranged where a single shock can be felt by all. An insulating meter stick is introduced into the chain and a shock administered. No one beyond the meter stick will experience the shock. Replacing the meter stick with a metal conductor, all students will come to understand the meaning of the word.	Students will give examples of conductors and insulators; students will explain that conductors allow current to flow whereas insulators resist current flow.
Explain charging by conduction, induction and polarization in terms of the movement of electrons.	Demonstrate charging by conduction by touching a pith ball with a charge object. Also show what happens when the pith ball is not touched, merely induced polarization. Show how a charged comb and attract a stream of flowing water. Pick up tiny bits of paper and make a charged balloon stick to the wall.	Students will explain charging by conduction and induction, and explain polarization that results when induction is occurring. Students will explain why a charged balloon sticks to the wall and so on.
Use Coulomb's Law to represent the relationship between electric force, charge and distance of separation. Given information about the quantity of charge on two bodies and the separation distance, determine the electrostatic force acting on the bodies.	Students will develop basic concepts behind Coulomb's law by completing Modeling's Repulsive Balloon Lab activity.	Have students apply the formula $F=kq_1q_2/r^2$ to several situations.
Recognize the similarities and differences	Draw the self-evident parallels between $F=Gm_1m_2/r^2$	Students will answer a brief essay

[4] Copied here from Section V above.
[5] See Active Learning Strategies: http://www.phy.ilstu.edu/pte/311content/activelearning/activelearning.html
[6] See Alternative Forms of Assessment: http://www.phy.ilstu.edu/pte/311content/assess&eval/assess&evaluation.html

between Coulomb's Law and the Law of Universal Gravitation.	and $F=kq_1q_2/r^2$	question about this on a worksheet, quiz, or test.
Recognize that an electric charge produces an electric field. Represent the electric field produced by point charges and charged plates.	Use an internet-based electric field simulation in the areas around charged particles. Alternatively, conduct electric field mapping lab.	Students complete lab activity worksheet.
Calculate the force exerted by a uniform electric field on a charged particle.	Apply the formula F=qE to several different situations.	Students will apply the formula F=qE to specific situations on worksheets, quizzes, and tests.
Draw parallels between the electric and gravitational fields.	Compare F=mg with F=qE. Here g (gravitational field strength expressed not in m/s^2 but in N/m) corresponds to E; m corresponds to q. The parallels are obvious when g is expressed as field strength.	Students will correctly answer a brief essay question about this topic on a worksheet, quiz, or test.
Use the superposition principle to calculate the strength of the electric field produced by charge(s) at a given location.	Students use a computer simulation to determine the effect of including more than one charge (and difference charge sizes and polarities) on a test particle.	Students complete a series of calculations using the concept of vector forces to determine the net force on a test particle under a variety of conditions.
Accurately relate the history of one scientist working in the area of electrostatics.	Using internet resources, students will investigate the history of electrostatics by examining the work of one of the leading scientists such as Gilbert, Boyle, Franklin, von Guericke, Hauksbee, Faraday, Gray, Dufay, Desaguliers, Bose, Winkler, Cuthbertson, von Kleist, Galvani, or Volta.	Students will write a one-page essay about the electrostatics work of one scientist. Essays will be scored with the use of a formal scoring rubric.

X. Metacognitive Practices[7]

Here are some of the approaches that will be used to help students better meet the student performance objectives in addition to aligning student performance activities, class activities, and assessments:

- Daily reference to student performance objectives,
- Daily use of worksheets for in-class and homework activities,
- Daily use of formative assessment questions,
- Periodic use of one or more mid unit quizzes,
- End of unit use of sample examination questions,

XI. History and Nature of Science[8]

The history of electrostatics will be included as students work on historical research paper as one of the culminating summative assessments. The nature of science will be included in this unit using multiple methods such as background readings, case study discussion, inquiry lessons, and inquiry labs.

XII. Context of Science[9]

Generally a part of every lesson, I will attempt to explain how science relates to the daily lives and interests of students and the larger framework of human endeavor and understanding. For instance, we will start off the unit with a discussion of where electrostatic phenomena have on day-to-day living such as getting a shock from dragging one's feet over a carpet, to petting a cat, to taking clothes out of a dryer. Over the unit of study, students will learn about other important applications to everyday life such as the following:

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[7] See Supporting Metacognition and Self-Regulation at http://www.phy.ilstu.edu/pte/311content/supporting.htm for ideas.
[8] See *A Framework for Teaching the Nature of Science:* http://www.phy.ilstu.edu/pte/publications/teaching_NOS.pdf For inclusion of historical considerations, see PHY 312 historical vignettes.
[9] See *Hands-on Physics Activities with Real-Life Applications* (Cunningham & Herr, 1994) for many excellent teaching activities and connections between science and students.

- Electrically conductive truck tires
- Air purification
- Lightning and lightning safety
- Cathode ray tubes, monitors
- Particle accelerators
- Photocopiers
- Chemical bonds
- Electron microscope lenses
- Computer protection

XIII. Social Context

While electrostatics is something with which all students seem to be familiar, it would seem that there are few community or human resources locally that can be brought to bear on teaching science in social context at our school. However, after careful consideration and thinking more globally, the following have potential for helping my students learn about the importance and utility of electrostatics:

- Talk by a local weather forecaster about lightning and lightning safety including lightning rods.
- Using online resources to conduct simulations relating to electrostatics.
- Conducting a problem-based learning activity WebQuest in which students study the death of a softball pitcher from a lightning phenomenon that is not a direct strike.
- Make use of resources from the Electrostatics Society of America: http://www.electrostatics.org/ According to their web page, ESA is the central forum for technical interaction between scientists, engineers and educators involved in electrostatic phenomena.

XIV. Unifying Concepts

The unifying concepts of science will be addressed in the following ways. Systems, order, and organization will be addressed by introducing students to both natural and technological systems. Evidence, models and explanation will be addressed by having students construct scientific knowledge based on evidence using logic, evidence, and current knowledge. Change, constancy, and measurement will be addressed by having students apply mathematical skills of accuracy and precision to one or more lab activities. Analogies will be draw from among the other sciences. Evolution and equilibrium, and form and function will not be directly addressed in this unit.

XV. Alignment with State Standards[10]

This unit plan clearly addresses all Applications for Learning identified in the Illinois Learning Standards: solving problems, communicating results, using technology, working on teams, and making connections. These themes can be seen in the many learning activities in which the students will be engaged.

State Goal 11 (Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems) is addressed very well in terms of scientific inquiry as can be seen in the multiple and varied class activities, but not so well in terms of technological design.

STATE GOAL 12 (Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences) is addressed very well in this unit by teaching fundamental concepts associated with electricity, and by providing numerous examples of the application of electrostatic principles in real-life phenomena.

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[10] See *Illinois Learning Standards* for science: http://www.isbe.state.il.us/ils/science/standards.htm

STATE GOAL 13 (Understand the relationships among science, technology and society in historical and contemporary contexts) is addressed again by the many applications of electrostatics to technology, and includes historical contexts in terms of the essay that the students will write.

XVI. Legal, Safety, and Ethical Considerations

The active study of electrostatics does not pose a significant health threat to for most students; however, it does pose potential problems for those with known heart problems and those with “delicate” psychological constitutions. Even though voltages encountered in this unit will sometimes reach as high as 400,000 volts (Van de Graaff generator), these generally will not pose a significant health risk due to the exceptionally small amperages encountered in the mild shocks that result. However, students with known health risks such as heart problems will be excluded from these activities unless they use the thumb-to-palm approach. The other hazard in teaching this unit comes from a failure to consider ethical activities and the legal action that might follow under certain circumstances. Receiving an unanticipated shock from a Van de Graaff could cause any of a variety of psychological or social problems for “sensitive” students. For instance, an unanticipated shock might constitute a traumatic experience for some; others might be embarrassed from their public reactions to such a shock. In light of these considerations, I’ll always be certain to warn students of shock hazards and do everything possible to mitigate painful shocks (such as telling students to take a shock on the knuckles rather than on the finger tips or other sensitive portion of the body). No student will ever be required to receive any shocks.

Sample Lesson Plans (see attached)