Lesson Title	Estimation of Spherical Surface Area
Length of Lesson	1.5 hours
Created By	Justin Warren, William Funderburk
Subject	Physics
Grade Level	11-12
State Standards	Physics: 1 a, b, d, e
DOK Level	DOK 3
DOK Application	Use concepts to solve non-routine problems
National Standards	9-12: A
Graduate Research Element	Understanding the importance of measurement techniques and how error in measurement can effect conclusions drawn from data

Student Learning Goal:
Students will manually estimate the surface area of spheres of various sizes and ~~then~~ plot the data to determine a relationship between the radius and the surface area. In this way they will be introduced to entering and manipulating data in a computer spreadsheet. Another goal will be to understand that the quality of the measurement technique used determines the validity of collected data and the conclusions drawn from them. This is meant to be the first lab of an introductory physics course.

Physics: 1. Apply inquiry-based and problem-solving processes and skills to scientific investigations: a) Use current technology such as CD-ROM, DVD, Internet, and online data search to explore current research related to a specific topic, b) Clarify research questions and design laboratory investigations, d) Organize data to construct graphs, draw conclusions, and make inferences, e) Evaluate procedures, data, and conclusions to critique the scientific validity of research

National Science Education Standards of Content 9-12
A (Science as Inquiry): Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tool provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.

Materials Needed (supplies, hand-outs, resources):
Three spheres for each group made of Styrofoam or a similar material with appreciably different diameters, a length of string at least 10% longer than the circumference of the largest sphere, a black marker to draw lines on the spheres, ample supply of straight pins, ample plain, white computer paper, scissors, computer with Microsoft Excel or an equivalent program installed.

Lesson Performance Task/Assessment:
The students will determine the equator of each sphere and draw a line along it using the length of string as a guide. From this they will use their knowledge of the circumference of a circle to estimate and record the radius of the sphere. They will then draw two great circles through the poles 90^o apart in order to divide each sphere into 8 quadrants. See Figure 1 to view these lines.

Figure 1. Sphere divided into 8 quadrants

The student will then use the computer paper to draw and cut out triangles. They will be instructed to ensure their shapes are well formed so that there is little variability between them and that the area of each is known. These triangles will then be attached to the surface of the spheres using straight pins to completely cover one of the eight quadrants. See Figure 2 to view the shapes pinned on a quadrant.

Figure 2. Triangles pinned on one quadrant

The students will then use their knowledge of the area of each triangle to estimate the surface area of the quadrant and then extrapolate the surface area of the entire sphere. This procedure will be completed for each sphere. An x-y scatter plot will then be constructed in Excel or a comparable spreadsheet program with the estimated spherical surface area as the y-axis and the estimated radius of the sphere squared as the x-axis. They will then use the spreadsheet function to insert a trendline through the points plotted. If their measurements were correct, the slope of this line will be 4π.

The students will then be instructed to use the Internet to search for another method for estimating surface area of a shape that has been used in some current research effort and what error it produces.

Lesson Relevance to Performance Task and Students:
The student will become comfortable with using the basic functions of a computer spreadsheet to manipulate data. They will also gain an appreciation of how important quality measurement techniques are when conducting research.

Anticipatory Set/Capture Interest:
Show a YouTube video or put a picture on the projector screen of someone in a car getting a ticket from a police officer? Then explain that because the person bought new tires for their car that were a different diameter than the original ones, their speedometer no longer displayed the correct speed. This is to impart the importance of valid and meaningful measurement.

Guided Practice:
The instructor will discuss the lesson procedures and show a completed sphere separated into quadrants with one quadrant covered in triangles.

Independent Practice:
The students will carry out the entirety of the lesson on their own without direct instruction from the instructor in groups of two. The instructor will move around the room during the lab in order to answer any questions or offer advice if a group is obviously performing the lesson incorrectly.

Remediation and/or Enrichment:
It is expected that the relatively simple procedure and relationships involved in this lab will require a very limited amount of remediation if any. However, the instructor might discuss that a surface area estimation process similar to this could be done using Post-It notes to cover the entire surface of a car. A quick internet search for "cover a car with sticky notes" will bring up many links for the instructor to use to demonstrate the concept of surface area estimation.

The enrichment activity will be to further explore the other functions available in the computer spreadsheet program such as how to alter the characteristics of plots, import data from text files instead of entering it manually, etc.

Check(s) for Understanding:
The student will be required to discuss why the slope of their plot was not equal to 4π and what might be done to increase the accuracy of their measurement. The instructor will ask the student what would happen if the triangles were made smaller and smaller until their minuteness was unimaginable. Can the student then relate that idea to Calculus.

Closure:
Following the lab, the instructor will lead a short discussion on the importance in research of understanding how data is collected and of obtaining accurate and precise data. In my hypervelocity impact research, the time scale for an experiment can be on the nanosecond scale. This means that even a slight error in measurement can greatly affect the recorded data. For this reason, researchers strive to accurately measure data.

Here are a few provocative questions to ask the students after the lesson:

- Can you propose an alternative way to measure the surface area of a sphere?
- Can you think of a relationship between how we estimated the surface area in the lesson with fundamental Calculus?
- What was the significance of plotting our data such that the data points formed a straight line? How did that make the analysis more clear?

Possible Alternate Subject Integrations:
Calculation of the slope of a line given a data set; demonstration of the foundations of Calculus.

Teacher Notes:
Make sure students are comfortable using straight pins; if not, allow them to use tape or glue.

This is not intended to be a geometry lesson, but it could be altered to fit well into a geometry curriculum. This is meant as both an introduction to computer spreadsheet processing and the importance of quality data with a fun twist.

To save time, each group might only complete one sphere. The entire class' data could then be distributed and compiled in one plot for each group to manipulate.