Teacher: James Buck	**Unit Title:** Creating an equation from a line using data on wind energy
Subject: Wind	**Lesson Title:** Ping Pong Ball Anemometers
Grade Level: Algebra Principles in the Bus World	**Lesson Length:** 90 minutes
Date(s):	

- **Learning Goal(s)**

  Students will be able to construct and calibrate an anemometer to measure wind speed. They will be able to create a graph and an equation of Angle vs. Wind Speed and use them to find wind speed or angle, given the other variable.

- **Energy Connection**

  This lesson is part of a larger unit on renewable energy, with examinations of wind, solar and biomass energy. Understanding wind speed is critical to understanding efficiency of wind turbines.

- **Connection to Standards**
  Colorado State Standards

  Science: High School
  Standard 3: Earth Systems Science
  5. There are costs, benefits, and consequences of exploration, development, and consumption of renewable and nonrenewable resources

  Math High School:
  Standard Patterns, Functions, and Algebraic Structures:
  1. Functions model situations where one quantity determines another and can be represented algebraically, graphically, and using tables
     Interpret functions that arise in applications in terms of the context. (CCSS: F-IF)
     i. For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. (CCSS: F-IF.4)
     ii. Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. (CCSS: F-IF.5)
  2. Quantitative relationships in the real world can be modeled and solved using functions
     b. Interpret expressions for function[s] in terms of the situation they model. (CCSS: F-LE)
  4. Solutions to equations, inequalities and systems of equations are found using a variety of tools

Create equations that describe numbers or relationships. (CCSS: A-CED)
Create equations and inequalities in one variable and use them to solve problems. (CCSS: A-CED.1)

a. Create equations in two or more variables to represent relationships between quantities and graph equations on coordinate axes with labels and scales. (CCSS: A-CED.2)

Math High School Standard:

3. Data Analysis, Statistics, and Probability

1. Visual displays and summary statistics condense the information in data sets into usable knowledge

b. Summarize, represent, and interpret data on two categorical and quantitative variables. (CCSS: S-ID)

i. Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data. (CCSS: S-ID.5)

ii. Represent data on two quantitative variables on a scatter plot, and describe how the variables are related. (CCSS: S-ID.6)

- Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models. (CCSS: S-ID.6a)
- Fit a linear function for a scatter plot that suggests a linear association. (CCSS: S-ID.6c)

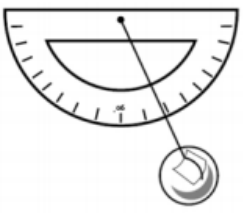
- **Materials and Resources**

Hand held digital anemometer
Two protractors
Tape
A fan capable of producing a range of wind speeds
Ping pong ball
Drinking straws
Kite string or fishing line

- **Procedure**

- Depending on student skill level this lesson may be modified for more or less scaffolding. Students should work in groups of 3 for best success.

1) Help the students to construct a ping pong ball anemometer similar to the one shown.



Construction tips

- Use two protractors to provide a "channel" for the straw to swing through
- Use extra straw to space the protractors apart so the device swings freely (no binding)
- Run a string through a straw section that is cut to length (~.5") to limit side-to-side motion at both the top and bottom of the protractor. Pass a string through the straw and protractor holes and tie tightly to hold in place.
- Run string from the top straw section through a new straw to the ping pong ball. Tape the string to the ping pong ball at the end of the straw.

2) Using a fan, students will use a digital anemometer to collect data on the wind speed in miles per hour. They will simultaneously use the constructed ping pong ball anemometer to measure the angle of displacement away from vertical when it is placed in the wind stream. Collect 5-7 pairs of data points (see measuring hints below).

Measurement tips
- Fans produce turbulent wind. Move the device around to find a strong steady spot
- Take anemometer and ping pong measurements from the same location. Have one student hold the digital anemometer and another hold the protractor anemometer next to each other to maintain consistency.
- Be sure to hold the protractor level (i.e. parallel with the ground)
- Be careful not to pinch the swing arm. It must swing freely on the pivot point
- Record the angle of displacement from vertical (i.e. away from 90 degrees)
- Shoot for a range of wind speeds between 0 and 25 mph
- Inexpensive box and desktop fans tend to be low speed. Students may be able to find different wind speeds by varying their distance or angle from the fan.
- Use high velocity floor drying fans for top speeds (e.g. squirrel cage fans). You may want to set this type of fan on a table to get better results.
- You can either measure the average wind speed or the maximum observed wind speed, but you must be consistent with whichever you choose. Max wind speed appeared to produce more consistent data.

3) Plot a graph showing the protractor angle displacement on the vertical axis and the wind speed in miles per hour on the horizontal axis.

a) For hand-drawn scatter plots, draw a best fit line, determine the *y*-intercept by observation and calculate the slope of the line to generate the equation for the line.

b) For computer-generated graphs, perform a linear regression to obtain the best fit line. Determine the equation of the line and the regression coefficient of the line.

4) Use the graph and equation to respond to the prompts on the worksheet. Complete the extension problems as directed.

5) Using the graph with the best fit line, students can now determine the wind speed outside today. Use the protractor to measure the angle, and then interpolate or extrapolate from the graph the speed of the wind. Compare class results.

6) Share the results of your outdoor wind speed measures with the class for discussion. If asked, report your data following the instructions given.

- **Technology Integration**

To incorporate additional technology, students may use a spreadsheet such as Excel to generate their graph. Students may also expand the experiment to include the iPhone wind speed app as available.

- **Checks for Understanding**

Students may to measure the wind speed of a novel source, e.g., HVAC vent in the classroom. Assign points based on how close they come to the accepted value (measured with a commercial anemometer).

- **Independent Practice**

Students can complete any of the worksheet questions they did not finish in class for homework.

- **Assessment & Closure**

Students will submit their worksheets with their data, calibration graph, equation and responses to prompts. Discussion of jobs in the wind energy industry will meet CTE requirements.