Unit 2 Homework Problems

Learning Goals:

F.2 Given a set of data, calculate the average and standard deviation (in Excel), the standard deviation of the mean, and determine how to write the best result to the correct number of significant figures.

A.2 Distinguish and apply the practical meanings of the standard deviation, the standard deviation of the mean, accuracy, precision, and systematic error.

2-1) Linda and Edward calculated the averages and SDMs for several types of measurements. They got into a rote mood and copied all the digits that appeared on their scientific calculator. Please boil these down to the "correct" number of significant figures and state how many significant figures is being reported for each best estimate.

(a) 5.666666667 ± 0.028314389 Volts
(b) –18.25723 ± 2.31684 degrees Celsius
(c) 0.0373749738 ± 0.005174523 meters
(d) 3546.78349 ± 188.549763 seconds (express this answer with and without scientific notation)
(e) Explain why the result of rounding off in part (d) is ambiguous unless scientific notation is used.

2-2) Suppose Linda and Edward each use a slingshot to shoot 5 pellets at a target. The holes in each of their targets are shown in the figure on the next page.

(a) Each student is trying very hard to hit the bull's-eye each time. Without doing any calculations yet, discuss in essay form which of the two students has the least *uncertainty* associated with his or her shots and is thus *more precise*. Which of the students is *more accurate*. Does either student have a *systematic error* associated with his or her shots? What factors like eyesight and coordination might cause one to be more precise and another more accurate?

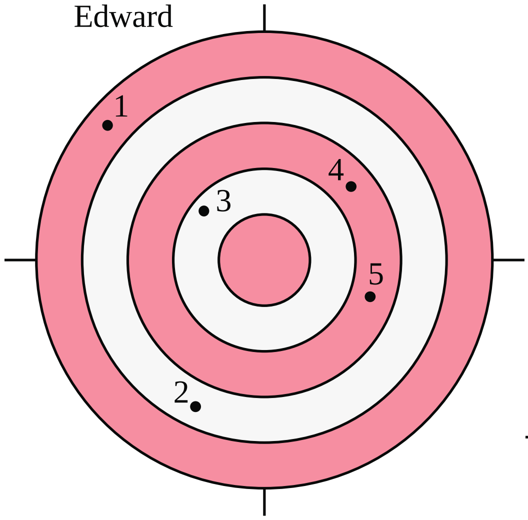
(b) Use the spreadsheet average function to calculate Edward's average distance from the center of the bull's eye. Also calculate Linda's average distance.

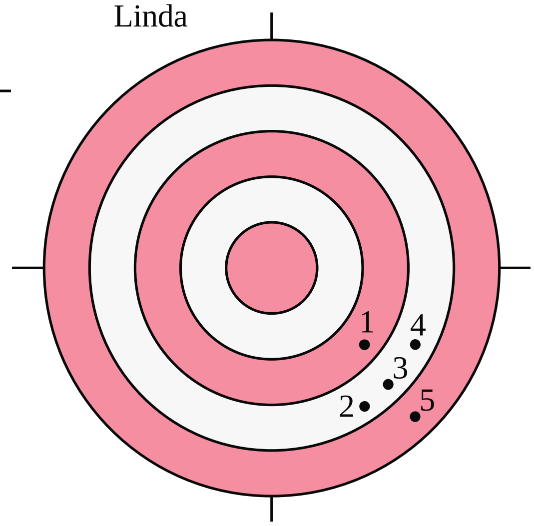
(c) Use your spreadsheet STDEV function to calculate the standard deviation of both Edward's set of shots and Linda's set of shots.

(d) Which standard deviation is larger? Is that what you expected? Explain.

(e) Calculate the standard deviation from the mean (or SDM) for Edward and for Linda. Explain the difference between the standard deviation and the standard deviation from the mean (SDM). Hint: See the Workshop Physics Activity Guide Section 2-5 and 2-6, or Appendix C, p. A-21.

(f) In view of the values of the SDM, express Edward's average and Linda's average *to the correct number of significant figures.*





Edward

Pellet	***r* (m)**
1	0.271
2	0.212
3	0.102
4	0.150
5	0.148

Linda

Pellet	***r* (m)**
1	0.159
2	0.220
3	0.217
4	0.208
5	0.273

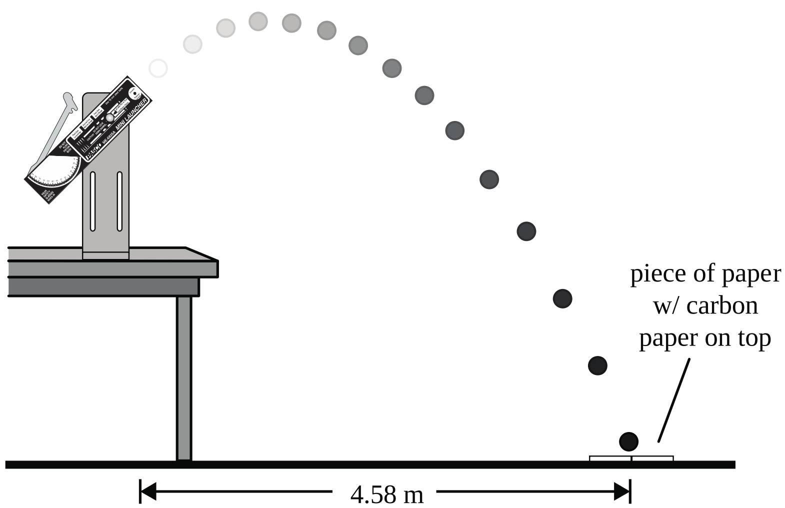
2-3) Linda and Edward are studying projectile motion and they have derived a theoretical equation that allows them to determine how far a projectile should land from the launcher as a function of its angle of launch, height above the floor, and initial speed. Each of them agrees that for the initial angle of launch, height above the floor and speed of the ball that they measured, the theoretical distance for a launched ball ought to be 4.58 meters. To verify the theoretical equation, Edward tapes the center of a piece of paper at a horizontal distance of 4.58m from the point of launch and shoots the projectile six times. He puts a piece of carbon paper on top of his other paper so that each time the projectile hits the paper it leaves a smudge. Linda thinks she can get less variation in her data by steadying the table and adjusting the angle of launch more carefully. She does these things, puts down a clean paper, and launches the projectile four more times.

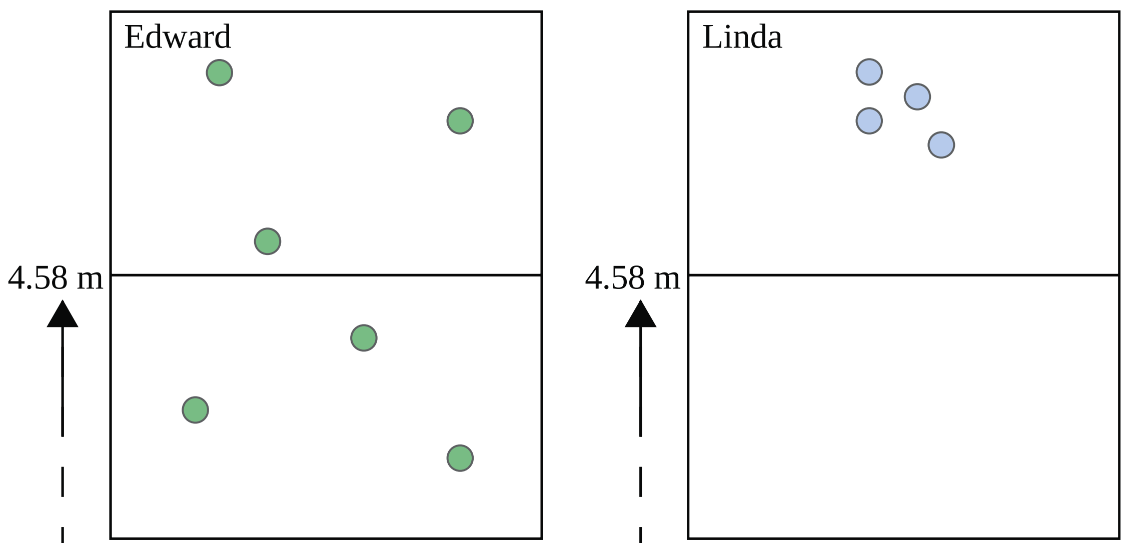
(a) Assuming that the picture of each piece of paper that follows on the next page is its actual size, what is the average distance of Edward's six launches **from the launcher** (not from the paper centerline)? What is the average distance of Linda's four launches? What is the standard deviation (σ_{sd} or SD) and standard deviation of the mean (SDM) of each set of measurements? (*Hint*: You'll need to print the next page and use a ruler. If you've done your measurements and calculations correctly, you should get that Linda's closest projectile landed 4.596 m from the launcher (1.60 cm away from the centerline).) Please include your spreadsheet (as a separate Excel file) when you submit your homework.

(b) Discuss in essay form which of the two students has the least uncertainty associated with his or her launches and is thus more precise. Which one of the students is the most accurate in the sense of having a best estimate that closely matches the theoretical calculation. Which one of the students appears to have a systematic error associated with his or her launches? What factors in the experimental technique used by each student might cause one to be more precise and another more accurate?

(c) If Linda took *one more measurement*, between which two distances would you expect the ball to land? How often should the ball land within that range?

(d) If Linda conducted the whole experiment all over again, in exactly the same way, in what range would you expect her *average* distance to fall? How likely is her new average to fall within that range?





2-4) On January 28th, 1986, the space shuttle Challenger exploded shortly after it was launched, killing all seven astronauts who were on board, including Dr. Ronald E. McNair, whom our McNair Scholars Program is named after. Within days after the tragedy, Richard Feynman, a well-known Nobel Laureate in Physics, was asked by the head of the National Aeronautics and Space Agency, NASA, to serve on a panel to investigate the circumstances of the accident. In a fascinating autobiographical work entitled *What Do You Care What Other People Think?* (Bantam Books, 1989, pp. 164-166), Dr. Feynman describes his investigative work for NASA. It appeared at the time that the explosion was caused by the failure of a rubber O-ring to expand rapidly enough to prevent hot gases from leaking out of one of the booster rockets needed to lift the shuttle into its flight path. If the temperature was too low prior to the launch, then it would be possible to conclude that the O-ring could have failed. One of the crucial issues was to make sense of the temperatures in the vicinity of the shuttle during the morning of the launch. Please read Richard

Feynman's account of his attempt to reconstruct as accurately as possible what the temperature readings were before the launch and answer the following questions:

(a) Even before Dr. Feynman started his investigation the original temperature readings were considered to be too low to be accurate. Why?

(b) Was the inaccuracy of the readings due primarily to systematic error or to statistical error, i.e. uncertainty? Explain your answer.

2-5) Problem 2.7 from the Activity Guide.

2-6) Remember from reading the syllabus that you have a yellow 8.5" $\times$ 11" piece of paper that you can write your own notes on for use with the Foundational and Advanced Skill assessments. Based on completing the Activity Guide and the homework for Unit 2, what key notes, equations, definitions, etc. will you add to your equation sheet for this unit? (Remember you'll need to fit 13 units worth of notes onto the front/back of the paper.)