INDIRECT MEASUREMENT Name_____
Rutherford Experiment Simulation Hour_____Date_____

How can you measure something you cannot touch or cannot see or even worse both? There must be some ways of doing this for things that are extremely large, incredibly small, or at unreachable distances.

Rutherford, in his famous gold foil experiment, discovered and measured what we now call the nucleus of the atom without ever seeing it or measuring it directly. This simulation will try to give you some idea of how the size of an object can be measured by indirect means.

PURPOSE:
SAFETY:
PRE-LAB QUESTION- How will your lab set up compare to Rutherford's Gold Foil experiment? (i.e- What do the wood frame, taped marbles and rolled marbles represent?)

PROCEDURE:

1. Obtain a wooden frame that has one side open when the other three sides are on a flat surface. Measure the size of the opening in the frame from side to side in centimeters. Record this as **W**, the width of the target area.

2. Place the frame on a large table or on the floor with 3-4 feet of open space in front of the opening, if the frame could be against a wall that would be even better. Tape 5 marbles inside the frame spaced randomly. These marbles should be stationary and must be returned to their locations if they should happen to become dislodged. Record the number of marbles you taped down as **n** in your data.

3. Using 2 other marbles you will be rolling one marble at a time from 3-4 feet in front of the frame directing the marble at all points of the opening in the frame. DO NOT AIM AT THE MARBLES IN THE FRAME! You will keep a count of how many rolls enter the opening of the frame.

4. Your partner will keep a count of how many times your rolled marble collides with a stationary marble inside the frame. There may be only one collision per roll; the rolled marble is considered a miss if it hits the frame first.

5. There will be a total of 500 rolls in this simulation. Record the number of collisions after the following rolls has been made, 10, 50, 100, 200, 300, 400 & 500. (this is continuous, you do not start over once you reach 10 etc). You and your partner may wish to change places after each 100 rolls.

6. To be able to verify the theoretical size of your marbles with an actual value, line up all of your marbles from a corner of the frame, count how many marbles you used and measure the distance for all of your marbles in centimeters. Record this with your data.

DATA (create a **DATA TABLE** that can include the following information):

Number of target marbles (n) _____ Width of opening (W) _____

Rolls	Collisions	Rolls	Collisions
10	_____	300	_____
50	_____	400	_____
100	_____	500	_____
200	_____		

Total number of marbles used in the lab. _____

Total distance for all marbles side by side. _____

CALCULATIONS (answers to the following 5 bullet points are all you need in your calculations portion of your lab report) (SEP 5 - MCT)

- collision rate equation (write a mathematical formula to calculate the collision rate….use variables)
- probability equation (write a mathematical formula to calculate probability…use variables)
- collision rate = probability (set collision rate equal to probability; write a mathematical formula….use variables)
- show calculations for theoretical size of marble for each set of data
- show calculations for actual size of the marble

Help for figuring out your formulas and calculations is below:

COLLISION RATE=

- First you must derive a formula for collision rate. The collision rate is equal to the number of collisions that occurred divided by the number of rolls you made at that point. **Write the collision rate as a mathematical formula in the calculations section (using variables). NO actual calculations here!**

PROBABILITY=

- Next you must derive a formula to figure out the probability that a collision might occur for any one marble rolled into the frame. This probability depends on several factors: the diameter of the marbles (d), the number of stationary marbles (n), and the width of the target area (W). The larger the diameter of the marbles the greater the probability of a collision so diameter (d) must be directly related to the probability. For a collision to occur, the rolled and stationary marbles must be within a lateral space no greater than if the marbles were located exactly side by side or a space of 2d. Now we have the factor **2d** which is directly related to the probability. The more marbles you have taped down in the frame (n) the greater the probability for a collision so the factor **n** is directly related to the probability. The larger the opening in your frame (W) the more spread out your marbles will be and the fewer collisions you will have. The factor **W** is inversely related to the probability. **Use the information above to write a mathematical statement for probability of a collision below in the calculations section (using variables). JUST a Formula! NO actual calculations here!**

COLLISION RATE= PROBABILITY

- Hopefully the actual collision rate and the probability of a collision should equal. **Using your equations from above set the collision equal to the probability as indicated below in the calculations section (using variables). JUST an equation! NO actual calculations here!!!!**

- **THEORETICAL SIZE OF MARBLE: Solve the above equation for d** for each sample of rolls in your data (yes all seven of them). These calculated theoretical values will then be compared to the actual measured diameter of your marbles. (**DO actual calculations for this! show all work!)**

10	300
50	400
100	500
200	

DIAMETER OF MARBLE

- Calculate the actual diameter of one marble. You collected the length of all 7 marbles lying next to one another, how would you use that number to figure out the size of ONE marble without measuring just ONE? **(Do actual calculations here! Show all work!)**

CONCLUSION:

Post Lab Questions/Conclusion Prompts: Begin your conclusion with a short paragraph restating your **purpose** and **explain** how the results **support** the purpose. Answer the following questions after your conclusion paragraph.

1. Knowledge: Describe Rutherford's Gold Foil experiment including his observations and conclusions.
2. Comprehension: Revisit your answer to the pre-lab question. What do the wooden frame, taped marbles and rolled marbles represent? Explain the model's function and evaluate its accuracies and limitations.
3. Application: How would your theoretical values be different if one of the target marbles blocked contact with another marble? (Would the theoretical values be higher or lower?) Explain your reasoning.
4. What is the purpose of measuring the length of 7 different marbles side by side and not just directly measuring the diameter of ONE marble to find the actual size?

5. Synthesis: How does your “actual average value” compare with your 7 different calculated “theoretical values”? Why do you think your results show this difference based on experimental design?
6. Evaluation: Evaluate your 7 calculated theoretical values. Which do you think is the most accurate and why? What changes would you make in collecting and analyzing data to improve your results? Explain why you would change these things.