<u>Experimental Design</u>
Rotational Inertia

Rotational inertia is defined as the quantity that determines the torque needed for a desired angular acceleration about a rotational axis of a rigid body. The rotational inertia of a mass may be found using the equation $I = mr^2$.

Your Task: Design and conduct an experiment on the topic of <u>Rotational Inertia.</u> You must use at least two of the items provided.

Materials:
1 m of string
3 balls of varying sizes
3 washers of varying sizes
2 rulers
1 plastic cup
3 popsicle sticks

Provided at station:
Electric scale
Scotch tape

Good luck 😃

Experimental Design
Capillary Action

Capillary action is defined as the tendency of a liquid or absorbent material to rise or fall due to surface tension. It is a result of the adhesion to walls of a surface being stronger than the cohesive forces between liquid molecules which causes an upward force of the liquid.

Your Task: Design and conduct an experiment on the topic of Capillary Action. You must use at least two of the items provided.

Materials:
3 sticks of celery
1 bottle of food dye
Salt
Sugar
Dish Soap
3 plastic cups
Water

Provided at station:
Hot plate
Ice water

Good luck 😃

Experimental Design

Momentum

Momentum is defined as the quantity of motion of a moving object which is measured as a result of its mass and velocity using the equation *P=mv*. Momentum may be angular or linear depending on the plane of movement of a mass.

Your Task: Design and conduct an experiment on the topic of Momentum
You must use at least two of the items provided.

Materials:
3 rulers
Timepiece
1 tiny wood ball
1 golf ball
1 ping pong ball
1 tennis ball
2 wooden blocks
1 m of string
1 roll of 3M tape
1 large wood ball

Provided at station:
Electronic scale
Scotch tape

Good luck 😃

A. Statement of Problem (4 pts.)

B. Hypothesis (8 pts.)

C. Variables (20 pts.)

D. Experimental Control (4 pts.)

E. Materials (6pts.)

F. Procedure (12 pts.)

G. Qualitative Observations (8pts.)

H. Quantitative Observations (12pts.)

I. Graphs (10 pts.)

J. Statistics (6 pts.)

K. Analysis and Interpretation of Data (8pts.)

L. Possible Experimental Errors (6pts.)

M. Conclusion (8pts.)

N. Applications and Recommendations for Further Use (8pts.)

Sample Write-up Momentum

Hypothesis:

We hypothesize that if objects have a higher mass then they will take less time to travel 30 cm from the base of a ramp in an indirectly proportional relationship. This is because objects with a higher mass have higher kinetic energy in the form of greater velocity which leads to a higher momentum.

Variables:

Independent- The independent variable is the mass of the objects measured in grams. The levels are: 2.72 g (tiny wood ball), 3.79 g (marble), and 8.62 g (large wood ball).

Dependent- The dependent variable is the amount of time taken to travel 30 cm from the base of the ramp and is measured as precise as a hundredth of a second using a timepiece.

Control-

-Height of the ramp

-Distance traveled

-Material of ramp

-Material of flat surface

Standard of Comparison:

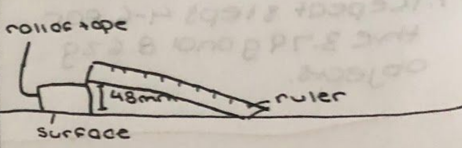
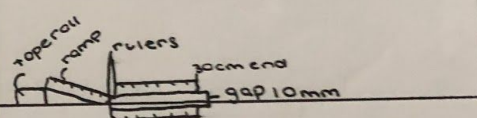
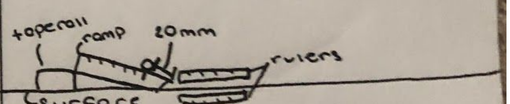
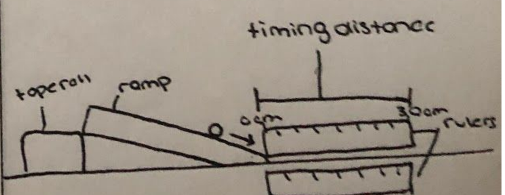
The standard of comparison is the tiny wood ball with a mass of 2.72 g. This is the standard of comparison because it is the mass being tested which is closest to the hypothetical 0 g. This mass will have the least amount of kinetic energy so it should take the longest to travel 30 cm. The larger masses will either take more or less time than the standard and create an observable trend between time and mass.

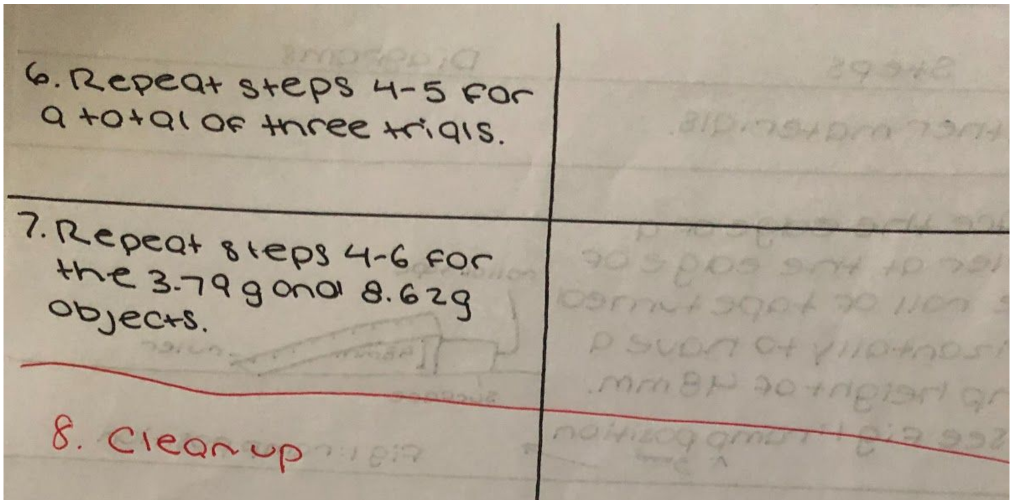
Materials:

- 3 rulers
- Timepiece
- Roll of 3M masking tape
- 2.72 g tiny wood ball
- 3.79 g marble
- 8.62 g large wood ball

Procedure:

Procedure

Steps	Diagrams
1. Gather materials.	
2. Place the edge of a ruler at the edge of the roll of tape turned horizontally to have a ramp height of 48 mm. See fig 1: ramp position ↑ good	 Fig 1: ramp position
3. Place 2 rulers at the end of the ramp parallel to each other with a 10mm gap between them. See fig 2: ruler position	 Fig 2: ruler position
4. Place the 2.72g 20mm from the base of the ramp (end near surface). See fig 3: ball position	 Fig 3: ball position
5. Allow the object to roll down the ramp and time the amount of time taken to travel from the base of the ramp to the 30cm mark as denoted by the rulers. See fig 4: timing distance	 Fig 4: timing distance

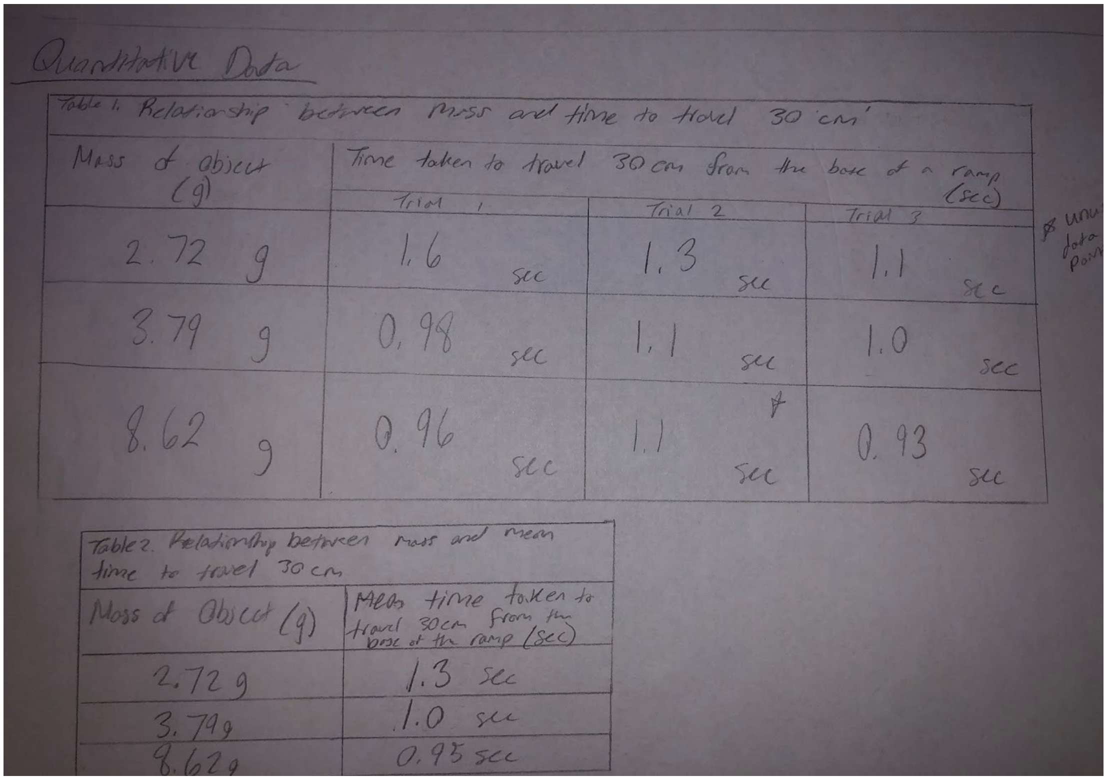


6. Repeat steps 4-5 for a total of three trials.	
7. Repeat steps 4-6 for the 3.79g and 8.62g objects.	
8. Clean up	

<u>Qualitative Observations:</u>

Two observations related to the given results are that balls with a higher mass appeared to travel 30 cm after falling down the ramp in less time and the different diameters of the balls did not appear to have a significant impact on the time measured to travel 30 cm. Two observations related to the procedure and deviations are that not all balls were positioned in the exact same place before they were allowed to roll down the ramp and that the same person timed every trial in order to ensure consistency in timing. Two observations about results that are not directly related to the variables include that in some trials the balls appeared to wobble from side to side as they moved down the ramp and that some balls bounced once they came into contact with the flat surface. Two observations made throughout the course of the experiment include that consistency in timing increased as trials progressed and that after several trials the ramp began to slide downward.

Quantitative Observations:



Quantitative Data

Table 1. Relationship between mass and time to travel 30 cm

Mass of object (g)	Time taken to travel 30 cm from the base of a ramp (sec)		
	Trial 1	Trial 2	Trial 3
2.72 g	1.6 sec	1.3 sec	1.1 sec
3.79 g	0.98 sec	1.1 sec	1.0 sec
8.62 g	0.96 sec	1.1 ✱ sec	0.93 sec

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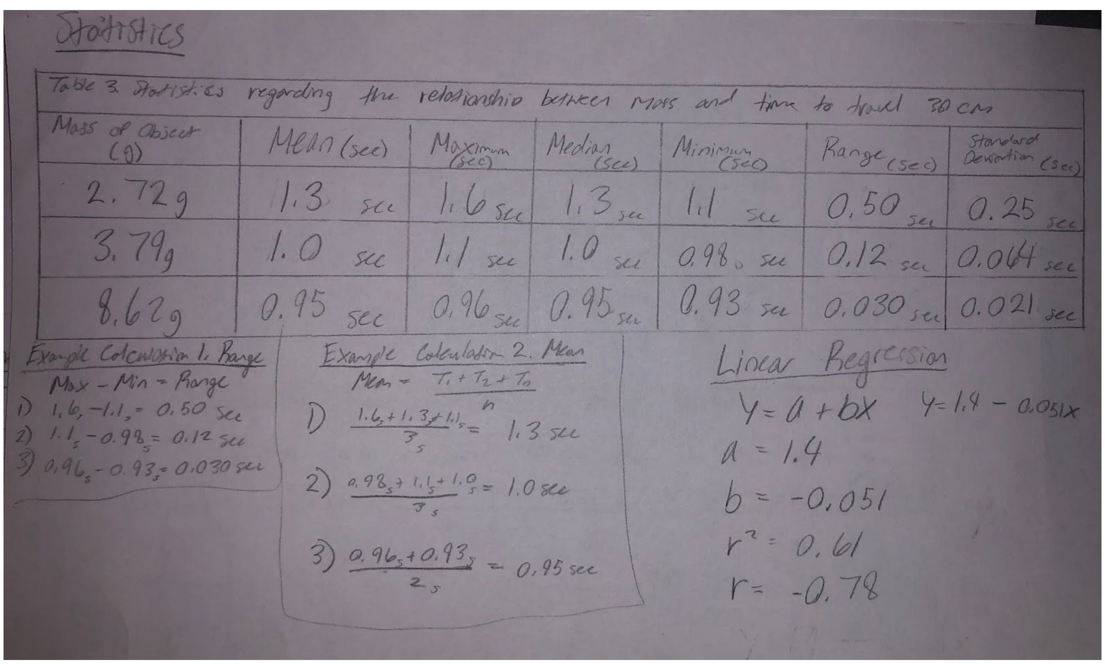
Table 2. Relationship between mass and mean time to travel 30 cm

Mass of Object (g)	Mean time taken to travel 30cm from the base of the ramp (sec)
2.72 g	1.3 sec
3.79 g	1.0 sec
8.62 g	0.95 sec

Statistics:



Statistics

Table 3. Statistics regarding the relationship between mass and time to travel 30 cm

Mass of Object (g)	Mean (sec)	Maximum (sec)	Median (sec)	Minimum (sec)	Range (sec)	Standard Deviation (sec)
2.72 g	1.3 sec	1.6 sec	1.3 sec	1.1 sec	0.50 sec	0.25 sec
3.79 g	1.0 sec	1.1 sec	1.0 sec	0.98 sec	0.12 sec	0.064 sec
8.62 g	0.95 sec	0.96 sec	0.95 sec	0.93 sec	0.030 sec	0.021 sec

Example Calculation 1. Range

Max − Min = Range

1) $1.6_s - 1.1_s = 0.50$ sec
2) $1.1_s - 0.98_s = 0.12$ sec
3) $0.96_s - 0.93_s = 0.030$ sec

Example Calculation 2. Mean

Mean = $\frac{T_1 + T_2 + T_n}{n}$

1) $\frac{1.6_s + 1.3_s + 1.1_s}{3_s} = 1.3$ sec
2) $\frac{0.98_s + 1.1_s + 1.0_s}{3_s} = 1.0$ sec
3) $\frac{0.96_s + 0.93_s}{2_s} = 0.95$ sec

Linear Regression

$y = a + bx$ $y = 1.4 - 0.051x$

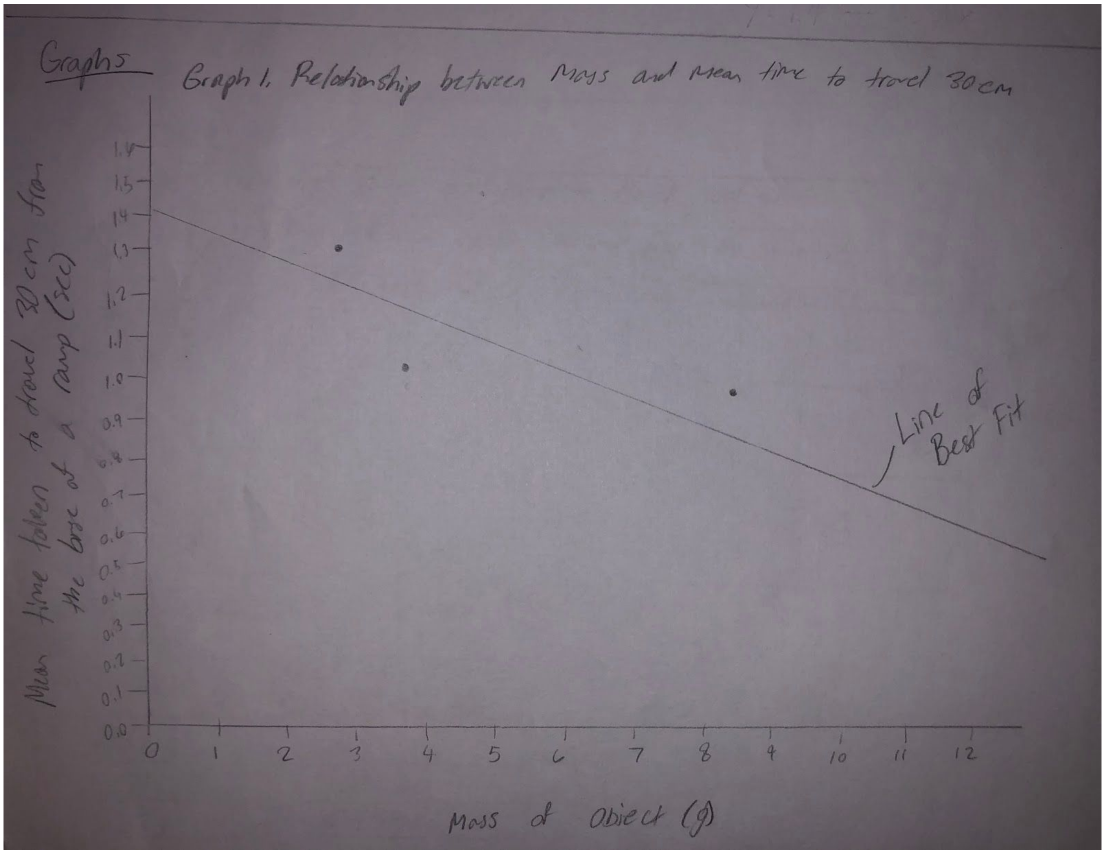
$a = 1.4$

$b = -0.051$

$r^2 = 0.61$

$r = -0.78$

Graphs:



Analysis and Interpretation of Data:

After analyzing raw quantitative data that was collected and is displayed in Table 1, a negative correlation was found between the increase in mass of an object and the time taken to travel 30 cm from the base of a ramp. This is shown by the line of best fit in Graph 1 and the r value of -0.78. The reason that time decreased as mass increased is because objects with a higher mass have higher kinetic energy of motion which is observed as higher velocity and is measured as taking less time to travel a constant distance. The higher velocity leads to higher momentum because momentum is found as the mass multiplied by velocity. Therefore, a greater mass will equate to greater momentum when all other factors are controlled. This is because momentum is defined as a linear relationship between mass and velocity, so changing one factor, being either mass or velocity, will cause a proportional change in the actual momentum of the object. The standard deviation and range decreased as trials went on (Level 1 SD= 0.25, R= 0.50; Level 2 SD=0.064, R= 0.12; Level 3 SD= 0.021, R= 0.030) which suggests that accuracy in timing increased throughout the experiment. There was an unusual data point in the second trial of the third level due to timing errors by human. This data point skewed the mean to be higher and was therefore excluded to ensure accuracy in results.

Possible Experimental Errors:

A possible source of error throughout this experiment was introduced by error in reaction time while timing trials. This random error caused by decreased accuracy in results. Using an automated timepiece may reduce this source of error . The effect in having slow reaction time caused by human timing was evident in the second trial of the third level, as there was error stopping the timepiece which caused the recorded value to be higher than the determined trend. An additional error is that calculations did not take into account the effect of friction and air resistance which caused the velocity to decrease. Had these factors been accounted for, the value of velocity would have been greater

Conclusion:

Our initial hypothesis that objects with a higher mass will take less time to travel 30 cm from the base of a ramp is supported by the results collected through our experiment. Therefore, we failed to reject the hypothesis. Overall, the objects with a higher mass took less time to travel 30 cm from the base of a ramp. As can be seen in Table 2, the ball with a mass of 2.72 g had a mean time of 1.3 seconds, the 3.79 g ball had a mean time of 1.0 seconds, and the 8.62 g ball had a mean time of 0.9 seconds to travel 30 cm from the base of a ramp. The relationship is further illustrated in Graph 1 where a line of best fit illustrates an inversely proportional relationship between mass and time taken to travel a set distance. The trend observed can be explained by the conservation of energy and momentum which explains that balls with a higher mass have more potential energy which can be transformed into more kinetic energy. Greater kinetic energy is related to higher velocity which was observed by decreased time to travel the same distance. Since momentum is equal to mass times velocity, balls with higher mass had higher velocity and therefore higher momentum. When considering that momentum is related to the quantity of motion in a mass, it is evident that greater mass would have greater momentum.

Suggestions for Further Research

Ways to improve this specific experiment include using balls with the same diameter that have different densities in order to vary mass. Also, have multiple individuals timing to improve the accuracy of results. Other ways to look at this same hypothesis include changing the distance traveled from 30 cm to a longer distance such as 90 cm in order to evaluate the conservation of momentum. Also, the same distance can be kept but ramp height can be raised to 96 mm in order to increase potential energy in order to allow a greater energy conversion. Suggestions for future experiments include using an electronic timer to avoid the possibility of human error as well evaluating the effect different ramp height has on momentum by keeping the same mass and changing the height of the ramp to evaluate the potential to kinetic energy conversion. A practical application of this experiment is in the construction of cars in which mass must be considered in order to avoid cars from going down hills too quickly. Also, in the construction of wheelchairs in which the wheelchair ramps must not be made too high to avoid too much potential energy that would cause an increase in momentum and the chairs going too fast.