Lab Project: Measuring the Mass of a Car

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ABSTRACT

This experiment uses concepts studied throughout the force unit to try and discover the mass of a car without weighing it. It does so by using free body diagrams expressing all forces present and their values, and the acceleration which was found by doing the experiment. Then, the two previous values could be plugged in the equation $\sum F = ma$ to find the mass m (in kilograms). At the end, the value of the mass of the car found was 1123.35 kg, which has a 9.70% error with the actual value of the car, which is 1244 kg.

INTRODUCTION

Firstly, Newton's Second Law of Motion explains the behavior of objects for which all existing forces are not balanced. This law states that the acceleration of an object is dependent upon two variables: the net force acting upon the object and the mass of the object. The acceleration of an object depends directly upon the net force acting upon the object, and inversely upon the mass of the object. As the force acting upon an object is increased, the acceleration of the object is increased. As the mass of an object is increased, the acceleration of the object is decreased. The equation used to define Newton's Second Law of Motion is $\sum F = ma$ (where the sum of forces $\sum F$ is in Newtons and 1 $Newton = 1\, kg \bullet m/s2$). Secondly, the net force is the vector sum of all the forces that act upon an object. An effective way to determine the net force of an object is to draw a Free Body Diagram to verify the existence of an unbalanced force for a given situation. Lastly, mass is a property of a physical body and a measure of its resistance to acceleration when a net force is applied. The objective of this experiment was to determine the mass of a car by using few materials to calculate the net force and acceleration of the car and finally use the equation $\sum F = ma$ to solve for m (the mass of the car in kg).

I. Proposed Equations:

Displacement:	$x = x_0 + v_0 * t + \frac{1}{2}at^2$
Newton's 2nd Law:	$F_{net} = m * a$
Friction:	$f = \mu N$

II. Proposed Equipment and its usage:

- Bathroom scale: measure force in *kg* applied by pusher(s) onto the car.
- Anemometer: one of the ways of measuring the car's instant velocity (v) at time interval *t.*
- Stopwatch: to measure time intervals.
- Position marker (stick notes or bean bags): mark the car's position after set time intervals
- Measuring tape

- Protractor
- Smartphone(s): with installed apps specialized for recording instant velocity – note that this is for cross-reference only.

III. **References and numbers:**

- We took reference from this site to know the gravitational acceleration in the Montreal region, which is 9.825 m/s^2:

http://www.wolframalpha.com/widget/widgetPopup.jsp?p=v&id=d34e8683df527e3555153d979bcda9cf&title=Gravitational%20Fields&theme=red&i0=Quebec&podSelect=&includepodid=Input&includepodid=GravitationalFieldStrength&includepodid=LocationOfTheGeographicalItemOfInterest

IV. Procedures and Methods:

a. Initial

Nominally: pushers – push the car, driver – drives the car, recorder – records car's position and keep the time.

1. Drive the car to a flat and open area and put the gas to neutral (N in most cases)
2. Two members position themselves behind the car to push, one is at the wheel to control the car, and the last one will observe the time and mark the car's current position.
3. Mark car's initial position at rest.
4. The members proceed to push the car with the bathroom scales in between them while making sure they are applying force as perpendicular to the car's rear as possible and maintaining the force constant throughout the displacement.
   a. **Solution to the perpendicular problem:** use a protractor and measure the angle made by the pushers' arms and the surface of the rear. Record that angle for later calculations.
   b. **Solution to the constant force applied:** push the car in increments of force until reach a pushing force that will move the car and maintain that force throughout. For example: 1st try: 30kg each – does not move; 2nd try: 50kg each – does not move; 3rd try: 60kg – move. Maintain 60kg throughout the experiment.
5. After a set time interval (e.g. 5s), the recorder drops a marker next to the car's front wheel.
6. Continue until place at least **10 markers**. Mark car's final position.
7. Using measuring tape, measure the distance between each marker and add the total distance traveled for later.
8. Make graph and plot Average velocity over time intervals and take slope, giving you the acceleration.

9. What we have after the trial, this part also explains nomenclature and symbol assignments:
    - From the bathroom scale: F_{raw} in kilograms per pusher
    - From measuring the distances between markers:
      Displacement between each time interval x_{n-th} → Total displacement Σx
    - We also have time intervals $\mathrm{t_{n-th}}$

b. Amendments:

4a. We decided to disregard measuring the angle of your applied force, as through the experiment, we already positioned ourselves as perpendicularly as possible.

DATA AND RESULTS

I. Data

Data tables: Distance, Displacement and Velocity to Time.

Trial 1:

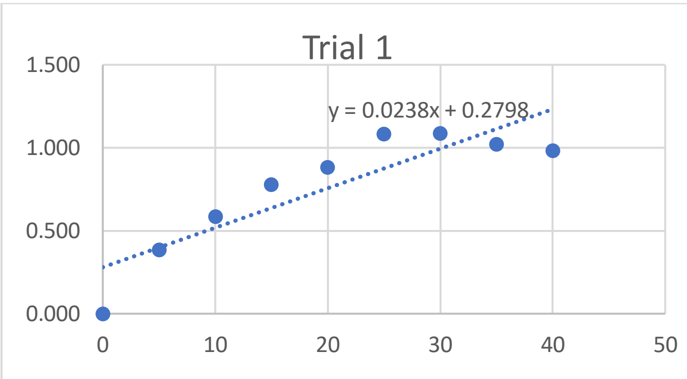
Time interval (s)	Trial 1 (F = 18 lbs/person)		
	Distance	**Displacement**	**Velocity**
0	0.000	0.000	0.000
5	1.930	1.930	0.386
10	3.920	5.850	0.585
15	3.830	9.680	0.645
20	3.970	13.650	0.683
25	3.400	17.050	0.682
30	2.550	19.600	0.653
35	3.180	22.780	0.651
40	3.530	26.310	0.658

Trial 2:

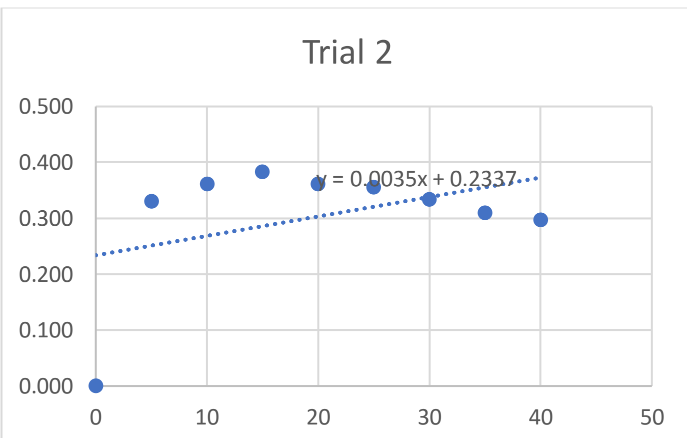
Time interval (s)	Trial 2 (F = 15 lbs/person)		
	Distance	**Displacement**	**Velocity**
0	0.000	0.000	0.000
5	1.650	1.650	0.330
10	1.960	3.610	0.361
15	2.130	5.740	0.383
20	1.470	7.210	0.361
25	1.680	8.890	0.356
30	1.120	10.010	0.334
35	0.810	10.820	0.309
40	1.050	11.870	0.297

Velocity vs. Time Graphs

Trial 1:



Trial 2:



II. Calculations:

a. Free-body diagram here:

b. Numbers:

$\boldsymbol{F_{applied}}$	$36\ lbs$
$\boldsymbol{otal\ Weight\ of\ 2\ people\ in\ car}$	$110kg$
$\boldsymbol{g\ (acceleration\ due\ to\ gravity\ in\ Montreal)}$	9.825

- Friction: $\mathrm{f} = \mu\mathrm{N} = \mu * \mathrm{m} * \mathrm{g}$
- Applied force by pushers: $F_{applied}\ (per\ 2\ people) = F_{raw} * g * 2$

<u>Calculating Mass</u>

We can find *global friction* (for both trial 1 and 2) looking at trial 2. Since the acceleration is very small, it's negligible.

The motion equation for trial 2 will be:

$$F_{applied\ 2} - f = m * a$$

$$\rightarrow F_{applied\ 2} - f = 0 \rightarrow F_{applied\ 2} = f$$

Solve for f with regards to trial 2 data:

$$f = 30\ (lbs) = 13.61\ (kg) = 13.61 * 9.825\ (N) = 133.70\ (N)$$

Going back to trial 1, we have the force applied by pushers:

$$F_{applied\ 1} = 36\ (lbs) = 16.33\ (kg) = 16.33 * 9.825(N) = 160.43\ (N)$$

we have the motion equation, $a = 0.012$ is taken from the slope of trial 1:

$$F_{applied\ 1} - f = ma$$

Substituting the data in:

$$\rightarrow\ 160.43 - 133.7 = m * 0.0238$$

Work out the m mass of the car:

$$\rightarrow 26.73 = m * 0.0238 \rightarrow m = 1123.35$$

DISCUSSION

Feedback for the other team:

We found your distance equation for linear motion to be an easier way to calculate the acceleration. However, that equation seems a bit too generalized for it does not account for the varied measurements.

We do appreciate your efforts, but it's preferable if you clearly divide between materials, methods and procedures like ours.

The sample situation does illustrate your idea clearly, however for an accurate reading, we would need more detail in how each individual should do in the experiment itself. Take for example, the lab manual's way of illustrating.

From our lab:

In our experiment, we explored the relationship between the net force (N)acting on an object and its corresponding mass (kg) multiplied by an acceleration (m/s^2) . These parameters are brought together using Newton's Second Law of motion $F_{net} = ma$. The point of this lab experiment was to find the experimental mass of a live-sized car using a few tools. The challenge of this was finding the other variables such as the corresponding net force acting on the car and its acceleration. In our 2nd trial, we assumed that the acceleration is 0 (very small number) since we were trying to push the car at constant velocity. In this trial, we could work out the global friction force. In our 1st trial, we push the car at constant force which means there is acceleration. Using the global friction from trial

2, we can work out the car's mass by analyzing $F_{net} = F_{applied} - f$. The acceleration is the slope found through graphing trial 1's results.

CONCLUSION

In conclusion, the mass of the car was found to be 1123.35kg. The theoretical result should have been 1244kg, which gave us a percent difference of 9.70%.