Mouse Trap Racer Scientific Investigations (Exemplar)

Online Resources at www.steminabox.com.au/projects

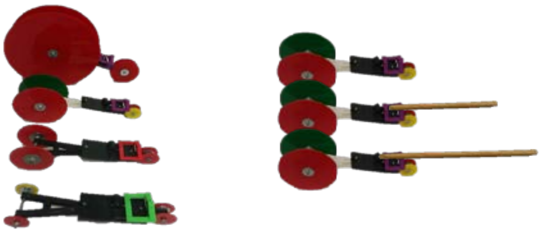
This Mouse Trap Racer Classroom STEM educational kit is appropriate for Upper Primary and Secondary School.

The Curriculum relevance is primarily Mechanics (study of Forces) and Working Scientifically. These student investigations are also relevant to the Technology and Mathematics Curricula. Full exemplars, worksheets and online support materials are provided for the following investigations:

Effect of Spring Arm Length on Displacement

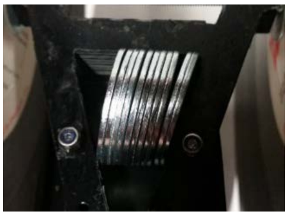
Effect of Wheel Diameter on Displacement

Optimal Vehicle Mechanical Advantage (Pooled Data)

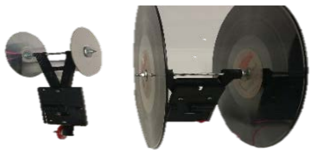


Effect of Wheel Friction on Displacement

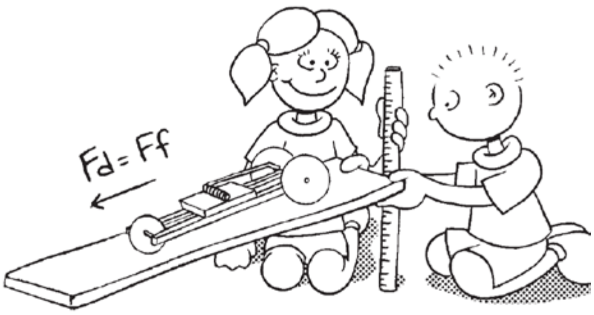
Influence of Vehicle Mass on Displacement



Influence of Chassis Design on Displacement



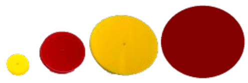
Determine Vehicle Kinetic Friction and Energy Efficiency



Effect of Wheel Diameter on Displacement

Aim: Determine which size diameter wheel (40mm, 80mm, 120mm, and 160mm) achieves the greatest horizontal displacement using the supplied mouse trap.

Hypothesis: A pair of 120mm diameter wheels will result in the greatest horizontal distance.



Method: A "fair test" method with the following variables and conditions:

The mousetrap racer will be started in similar conditions with the only difference being the size of the wheel diameter (40mm, 80mm, 120mm, and 160mm) with the resulting horizontal distance being recorded.

Type of Variable	Description	How it will be measured or controlled
Independent	Wheel Diameter	Wheel diameters of 40mm, 80mm, 120mm and 160mm
Dependant	Displacement	Front wheel to front wheel perpendicular to the start
Controlled	Spring Arm Length	Distance from spring fulcrum to string anchor point
Controlled	Wheel Friction	Same width acrylic wheels with same wheel/floor surface
Controlled	Air resistance	Same size, shape and launch conditions (wind etc)
Controlled	Spring Energy	Spring loaded back to same point
Controlled	Vehicle Mass	All vehicles weighted with washers to 270 grams

Results: Table 1 and Figure 1 shows results of the four different wheel diameters and resultant average displacement data.

Table 1. Effect of Wheel Diameter on Displacement

Wheel Diameter (mm)	Displacement (m)				Further Observations
	Trial 1	Trial 2	Trial 3	Av	
40	0.75	1.2	0.9	0.95	wheels slipped
80	4.3	4	4.5	4.27	
120	6.1	5.81	5.9	5.94	
160	7.8	7.64	7.53	7.66	

Controlled Variables: Spring Arm Length (200mm), Wheel Friction, mass

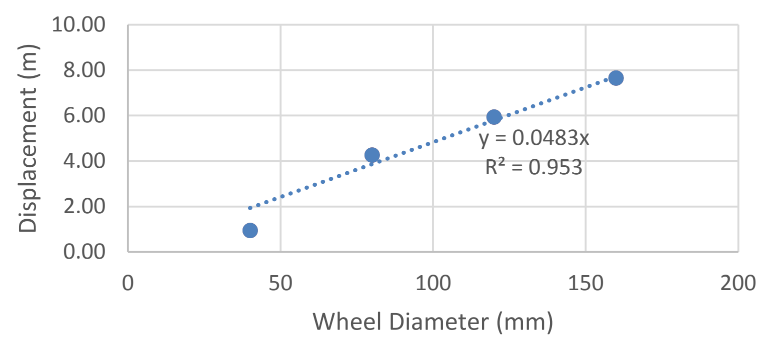
Discussion: Experimental results indicate that as wheel diameter increases horizontal displacement increases. Figure 1 illustrates this positive linear relationship. Linear regression analysis indicated the relationship as:

Displacement (m) = 0.0483 x Wheel Diameter (mm)

Additionally, this is a strong correlation with 95% of the variation in Displacement explained by Wheel Diameter (correlational coefficient R^2=0.953). [Extension]

The wheels spun with the 40mm wheels probably due to insufficient gearing leading to excessive torque at the wheels far in excess of wheel friction resulting in wheel spin. Larger wheels may produce greater displacement but at some point the vehicle will not have sufficient torque to overcome static friction. Further testing is required.

Fig 1. Wheel Diameter Vs Displacement



Conclusion: Experimental results show a strong positive relationship between wheel diameter and displacement i.e. larger wheels produced a greater vehicle displacement. Therefore the hypothesis must be rejected because the 160mm wheels produced the greatest displacement not 120mm as hypothesised.

Effect of Spring Arm Length on Displacement

Aim: Determine which length spring arm (50mm, 100mm, 200mm, 480mm, and 750mm) achieves the greatest horizontal displacement using the supplied mouse trap.

Hypothesis: A 200mm spring arm will result in the greatest horizontal distance.

Method: A "fair test" method with the following variables and conditions:

Type of Variable	Description	How it will be measured or controlled
Independent	Spring Arm Length	Distance from spring fulcrum to string anchor point (50mm, 100mm, 200mm, 480mm, 750mm)
Dependant	Horizontal Displacement	Front wheel to front wheel perpendicular to the start
Controlled	Wheel Diameter	The diameter of the drive (back) wheel
Controlled	Wheel Friction	Same width acrylic wheels with same surface
Controlled	Air resistance	Same size, shape and launch conditions (wind etc)
Controlled	Spring Energy	Spring loaded back to same point
Controlled	Vehicle Mass	All vehicles weighted with washers to 270 grams

The mousetrap racer will be tested in similar conditions with the only difference being the size of the spring arm (50mm, 100mm, 200mm, 480mm, 750mm) with the resulting horizontal distance being recorded.

Results: Experimental data indicates that the greatest displacement of 7.3m was achieved with the 480mm spring arm (Table 2).

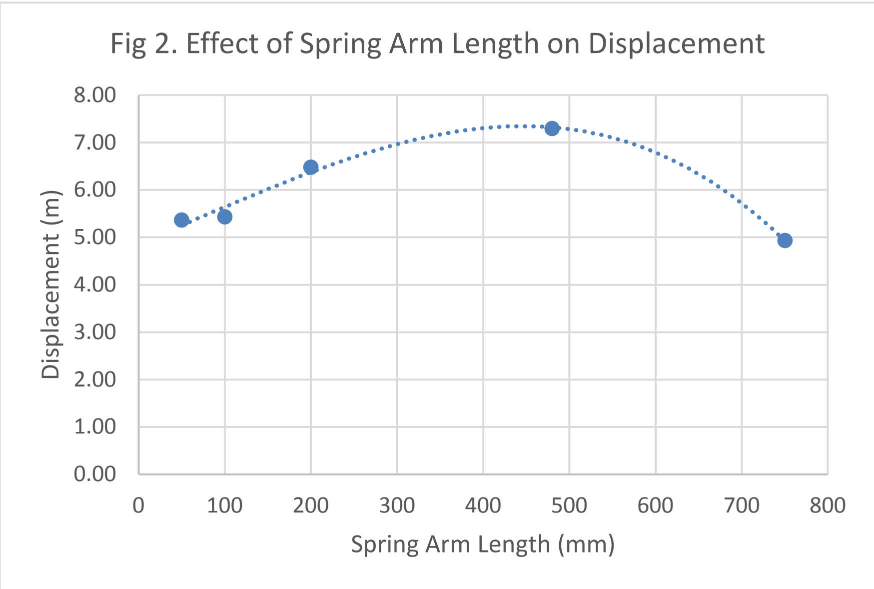
Discussion: Displacement was generally found to increase as spring arm length increases up to a spring arm length of 480mm. The 750mm spring arm resulted in a decreased displacement because the spring did not fully discharge. This was probably due to insufficient force to overcome rolling friction caused by a lower mechanical advantage (gearing ratio) due to the larger spring arm.

Table 2. Effect of Spring Arm Length on Displacement

Spring Arm Length (mm)	Displacement (m)				Further Observations
	Trial 1	Trial 2	Trial 3	Av	
50	5.5	5.7	4.9	5.37	
100	5.5	5	5.8	5.43	
200	6.5	6.75	6.2	6.48	
480	7.4	7.5	7	7.30	
750	5	4.5	5.3	4.93	Spring did not completely unwind

Controlled Variables: Wheel Diameter (160mm), Wheel Fiction, mass

Further testing is required because the optimal spring arm length could be any value between 480mm and 750mm, however based on test results 480mm maximises displacement.



Conclusion: The hypothesis that a 200mm spring arm maximises displacement must be rejected because the data indicates that a spring arm length of 480mm produces the greatest displacement.

Effect of Wheel Friction on Displacement

Aim: Determine which type of wheel surface produces the greatest horizontal displacement.

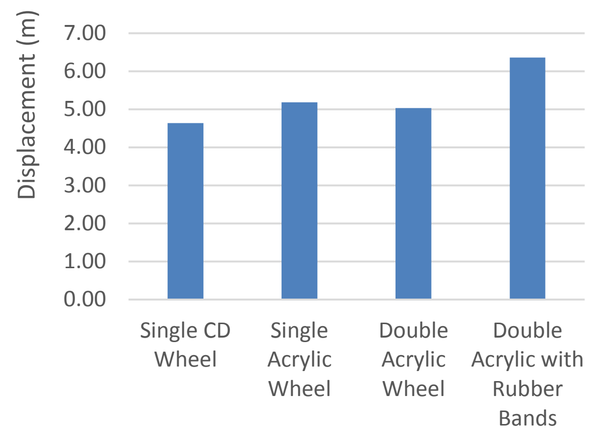
Hypothesis: A pair of single CD wheels will result in the greatest horizontal distance.

Method: A “fair test” method with the following variables and conditions:

Type of Variable	Description	How it will be measured or controlled
Independent	Wheel Friction	Wheel surface characteristics: single acrylic, single CD, double acrylic, double acrylic with rubber bands
Dependant	Displacement	Front wheel to front wheel perpendicular to the start
Controlled	Wheel Diameter	120mm diameter wheel used
Controlled	Spring Arm Length	200mm spring arm used
Controlled	Air resistance	Same size, shape and launch conditions
Controlled	Spring Energy	Spring loaded back to same point
Controlled	Vehicle Mass	All vehicles weighted with washers to 270 grams

Table 3. Effect of Wheel Friction on Displacement					**Further Observations**
	Total Horizontal Distance (m)				
Wheel Friction	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	
Single CD Wheel	4.6	4.4	4.9	4.63	wheels slipped
Single Acrylic Wheel	5.15	5	5.4	5.18	
Double Acrylic Wheel	5.6	5.5	4	5.03	
Double Acrylic with Rubber Bands	6.8	6.13	6.15	6.36	
Controlled Variables: Wheel Diameter (120mm), Spring Arm Length (200mm)					
This trial conducted on a very low friction polished floor.					

Fig 3. Wheel Friction and Displacement



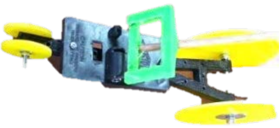
Results: Experimental results (Table 3) indicated that the greatest displacement was produced with the Double Acrylic wheels with rubber Bands.

Discussion: The single CD wheels racer resulted in the least displacement while the rubber band double acrylic wheels performed the best. This is because the CD racer lost traction on the polished floor at launch while the rubber band wheel afforded greater traction and ensured all spring energy was utilised.

Interestingly, testing on a higher friction floor showed the reverse results- probably because traction was not an issue with any vehicles so the best performer was the CD with the least wheel friction and the rubber band wheels produced the least displacement due to wastage of energy into heat from friction rather than kinetic energy.

Conclusion: Experimental and analysis indicates that the optimal wheel friction depends on the floor surface friction such that adequate traction is provided to transfer spring energy into movement, however, excessive traction (wheel friction) will retard displacement as energy is wasted as heat. For the polished floor surface studied, high traction wheels were found to be the best. Therefore we must reject our initial hypothesis. Further testing on different floor surfaces is required to more accurately detail the relationship between wheel surface friction and displacement.

Effect of Vehicle Mass on Displacement



Aim: Determine the relationship between vehicle mass and horizontal displacement.

Hypothesis: The lightest vehicle (0g added mass) will result in the greatest horizontal distance.

Method: A "fair test" method with the following variables and conditions:

Type of Variable	Description	How it will be measured or controlled
Independent	Extra Vehicle Mass	The amount of extra mass attached to the body of the vehicle
Dependant	Horizontal Displacement	Horizontal travel distance
Controlled	Wheel Diameter	The diameter of the drive (back) wheel
Controlled	Spring Arm Length	Distance from spring fulcrum to string anchor point
Controlled	Air resistance	Same size, shape and launch conditions
Controlled	Spring Energy	Spring loaded back to same point
Controlled	Wheel Friction	The friction the wheel exerts on the surface

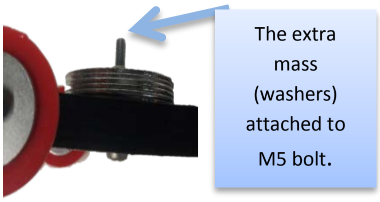


Table 4. Effect of Extra Vehicle Mass on Displacement

Extra Vehicle Mass (g)	Total Horizontal Distance (m)				Further Observations
	Trial 1	Trial 2	Trial 3	Average	
0	4.8	5.2	5.4	5.13	no extra mass
24	4.98	5.02	5.1	5.03	1 x 50mm washers
49	4.22	4.26	4.29	4.26	2 x 50mm washers
72	4.2	4.1	4.18	4.16	3 x 50mm washers
99	3	3.1	3.2	3.10	4 x 50mm washers

Controlled Variables: Wheel Diameter (120mm), Spring Arm Length (200mm)
This trial conducted on a very low friction polished floor.

Results:

Table 4 shows the displacement results when the racer is loaded with extra mass indicating a reduced distance with extra vehicle mass.

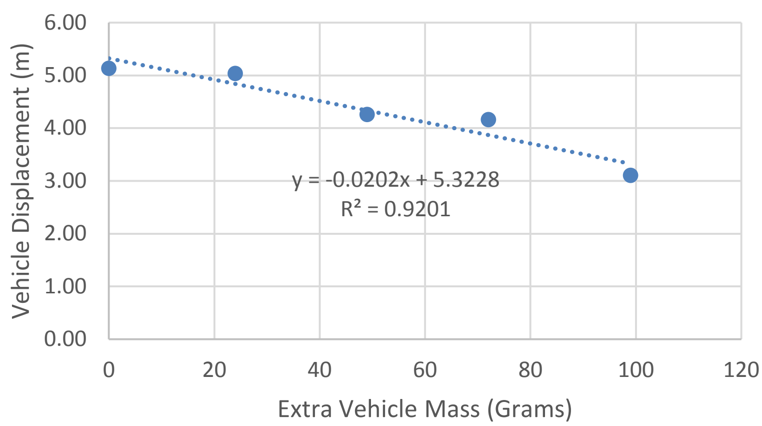


Fig 4. Effect of Vehicle Mass on Displacement

Discussion: Figure 4 illustrates that as the vehicle is loaded with extra mass the displacement declines. This is a negative linear relationship i.e. extra mass results in a proportional decrease in displacement. [Linear regression analysis indicated that for every extra gram added to the vehicle the resultant decrease in displacement would be 2cm (0.02m). This is a strong relationship with a correlation coefficient of 0.92 meaning that 92% of the displacement is explained by the vehicle mass i.e. only 8% is not explained by the linear regression model.][Extension]

The likely reason for the decrease in displacement as vehicle mass increases is that the increased mass leads to greater frictional forces caused by the combination of gravitational force and frictional forces of the wheels turning in the axle housing and on the floor surface. Additionally, extra energy is required to accelerate the larger mass from a standing start to its traveling velocity thus leaving less energy from the spring for forward movement (kinetic energy).

Conclusion: It is clearly evident from the experimental data that extra vehicle mass retards vehicle displacement. Therefore displacement is maximised with the least vehicle mass which is in agreement with our initial hypothesis that the lightest vehicle (0g added mass) will result in the greatest horizontal distance.

Influence of Chassis Design on Displacement

Aim: Compare the merits of a single and Double axle chassis design on vehicle displacement.

Hypothesis: The single axle design will have greater displacement.

Method: Record displacement data for the best double axle mouse trap racer (accessed from previous experiments) and the single axle racer with vinyl record album wheels. Variables that should be controlled but are not include vehicle mass and overall mechanical advantage. A complete "fair test" method cannot be done with the resources at hand however the following variables and conditions are noted for the test conditions:

Type of Variable	Description	How it will be measured or controlled
Independent	Chassis Design	Single or Dual axle
Dependant	Horizontal Displacement	Horizontal travel distance
Controlled	Spring Arm Length	Distance from spring fulcrum to string anchor point
Controlled	Air resistance	Same size, shape and launch conditions
Controlled	Spring Energy	Spring loaded back to same point
Controlled	Wheel Friction	The friction the wheel exerts on the surface

Results: The single axle "Record Album" racer travelled approximately twice as far as the best double axle racer with the same spring energy (Table 5)

Table 5. Effect of Chassis Design on Displacement

Vehicle Design	Total Horizontal Distance (m)				Further Observations
	Trial 1	Trial 2	Trial 3	Av	
Double Axle (CD wheels)	7.4	7.5	7	7.30	best run of double axle vehicles
Single Axle (Record Album Wheels	15.3	13.8	14.4	14.50	took longer to get up to speed but "free wheeled" about 6m

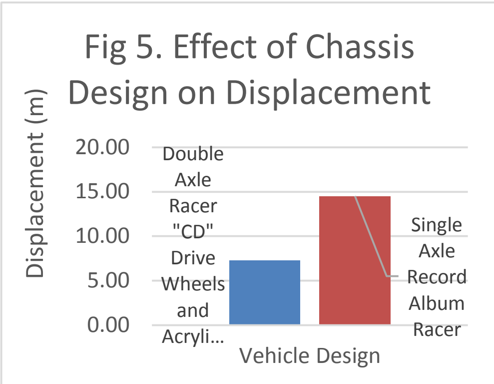


Fig 5. Effect of Chassis Design on Displacement

Table 6. Comparison of Design Features		
Design Feature	Engineering Issue	Significance
Single/Double Axles	Internal friction of drive train and wheel friction	Probably very significant as the front wheels on the double axle racer are simple not present on the single axle model thus at least halving friction
Vehicle mass	Friction	The mass of the single axle racer is much greater at 330g compared to 270g for the double axle racer, so this would increase friction for the heavier single axle racer but this influence is probably very small compared to the reduction in friction of having only one axle
Vehicle mass	Inertia	The record album wheels are significantly heavier than the CD wheels of the double axle racer which means that more spring energy is "stored" as inertial (both rotational and linear inertia) which means that the spring energy is effectively dissipated over a longer period of time which should improve its travel distance- however the extra mass means greater energy loss while accelerating up to travel velocity but this waste would be insignificant compared to the benefit of delivering energy over a longer period of time. So overall a positive influence for increasing displacement for the heavier record album wheels.

Conclusion: Eventhough this experiment was not a true fair test with all variables controlled these issues should not interfere significantly with making a valid conclusion based on the results. We can strongly conclude that the extra mass of the record album wheels and the reduced friction of the single axle model is more efficient design substantially improving linear displacement.