ROLLING THUNDER

A Study Of Various Principles Of Engineering Using An Inclined Plane And A Hot Wheels Car

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PROJECT SUMMARY

The objective of this project is to teach students basic concepts regarding energy (kinetic and potential), acceleration, velocity, friction and vectors. The project will require instruction on some basic principles of physics. In addition it will teach them how to perform a scientific experiment and how to measure and record the resultant data.

For the experiment students will be broken up into teams of two (2). Each team will be given the materials needed to build an adjustable ramp that is 18 inches long. The students will have access to a measuring device and a computer. The students will supply one Hot Wheels® car of their choosing. The object of the project is to determine how far the car will roll out after reaching the bottom of the ramp. All cars will start with their rear end at the farthest point back on the ramp, and the roll out will be measured from the bottom of the ramp to the back end of the car. The students will gather data about the ramp triangle and the roll out distances for various chosen ramp angles and a series of trial runs. A minimum of five (5) trial runs and a minimum for five (5) ramp angles will be required. The students will record their data in a computer spreadsheet of their design, and will analyze this data using formulas that they will write for the spread sheet.

A competition will be held on the final day of the project. The instructor will name a specific roll out distance and each team will have one try, using the calculations from there spread sheet, to reach the given distance. The team that comes closest to the distance will receive an award. This competition can be altered to more than one distance trial and the team with the lowest average is determined to be the winner.

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PROBLEM STATEMENT

If you have ever traveled along an interstate or highway, you may have noticed gravel roads that seem to veer off from the main highway after a particularly steep downgrade. These runaway truck ramps have the potential to save lives. A semi or vehicle traveling at an uncontrollable speed following a downgrade in the road can utilize such a ramp to control their speed and eventually bring the vehicle to a safe stop. Each ramp must be individually designed for each set of circumstances. Data collected from experiments using models can help determine the specifications for things such as runaway truck ramps. An experiment that determines a car's run out after reaching a specific velocity is one example. Students will have the opportunity to conduct this experiment in groups of two and record their data.

Each team will construct an inclined ramp. The ramp angle will be adjustable to raise or lower the height of the incline. An example of such a ramp is provided in Appendix C. The ramp will accommodate a Hot Wheels®™ car. The objective will be to accurately judge the distance that the car will travel after leaving the bottom of the incline. Students will need to find each vehicle's unique physical properties such as weight and speed from various heights. Students will calculate the velocity of the cars. They will set up a spreadsheet to keep this information. All data will be recorded using the variables provided in the drawing in Appendix D. A sample spreadsheet is provided in Appendix E. The final presentation will be documented in a notebook and will include all diagrams, data calculations, spreadsheets, and histograms. During the demonstration phase of the project, students will pick a ramp angle that will allow the car to reach a distance that is specified by the instructor.

PROJECT DESCRIPTION/ SCENARIO

This project is designed to teach the student about the concept of inclined planes and the mathematical principles involved with a vehicle descending this inclined plane. For the purposes of these projects calculations we will assume there is no friction involved with the descending vehicle and the inclined plane. Later we will discuss friction and how it affects the car and roll out distances.

The first session of the project we will briefly discuss kinetic and potential energy, gravity, acceleration, velocity, friction, and vectors. Review of these principles will be found in Appendix A. We will then move on to a more in depth study of inclined planes and the information in Appendix B will be given to the students for reference.

The second session of the project will be building the ramp. All materials will be provided by the instructor and must be built according to the design given. Failure to do this will result in a significantly different data set and will not conform to other groups. Although, one non conforming ramp would be an interesting experiment to compare the non conforming data and to demonstrate the differences in the ramp design

The third session of the project will be used to collect the data of various angles given by the instructor. A minimum of five trials per angle should be performed for a good average. The students should understand that they must achieve a good consistent run. The car must not deviate from its projected path by turning left or right. If the car does deviate from its project path, that trial must be scratched and reproduce until the car runs its projected path.

The forth session of the project will be used to create a spreadsheet for the data collected and using formulas learned in previous sessions to solve for velocity, friction, and acceleration.

The fifth session of the project will be used for the competition. To start the competition a distance will be given to the groups. The group that gets their car closest to that distance wins. Note: Students must find the angle their ramp must be set to through calculations derived from their data.

CONCEPTS AND STANDARDS

Essential Engineering Principles:

- Gravity and the rate of fall
- Potential and Kinetic Energy
- Time -- Speed -- Distance calculations
- Scalar and Vector Quantities
- A bonus option will be to figure out the friction components of the system.

Standards for Technological Literacy:

- **Standard 2:** Students will develop an understanding of the core concepts of technology.
- **Standard 8:** Students will develop an understanding of the attributes of design.
- **Standard 9:** Students will develop an understanding of engineering design.
- **Standard 12:** Students will develop the abilities to use and maintain technological products and systems.
- **Standard 20:** Students will develop an understanding of and be able to select and use construction technologies.

National Mathematics Standards:

- **NM-GEO.9-12.1** Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- **NM-DATA.9-12.1** Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer
- **NM-PROB.PK-12.1** Build new mathematical knowledge through problem solving
- **NM-PROB.COMM.PK-12.4** Use the language of mathematics to express mathematical ideas precisely

National Science Standards:

- **Standard 9: Understands the sources and properties of energy (Level IV)** Knows that all energy can be considered to be either kinetic energy (energy of motion), potential energy (depends on relative position), or energy contained by a field (electromagnetic waves)
- **Standard 10: Understands forces and motion (Level IV)** Knows that laws of motion can be used to determine the effects of forces on the motion of objects (e.g., objects change their motion only when a net force is applied; whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object; the magnitude of the change in motion can be calculated using the relationship F=ma, which is independent of the nature of the force)
- **Standard 13: Understands the scientific enterprise Level IV)** Understands that individuals and teams contribute to science and engineering at different levels of complexity (e.g., an individual may conduct basic field studies; hundreds of

people may work together on a major scientific question or technological problem)

ASSESSMENT

Grading Rubric

Grading Items	Points	Criteria				
		Diagrams	Calculations	Spreadsheets	Histograms	Clarity
Notebook	500	100	100	100	100	100
		Organized	Group participation			
Oral Report	200	100	100			
		Engineering Principals	Use of formulas			
Demonstration	150	75	75			
		Acurate Measurments	Ramp Quality			
Ramp Construction	150	75	75			
Total Points Possible:	**1000**					
Extra Credit:						
Competition Champions	50					

SCHEDULE/TIMELINE

	Start	Finish		DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
Instruction	**DAY 1**	**DAY 1**						
Kinetic energy								
Potential energy								
Gravity								
Acceleration								
Velocity								
Friction Vectors & Time								
Spreadsheets								
Pass out ramp materials								
Assign work areas / questions								
Build Ramps	**DAY 2**	**DAY 2**						
Build ramps & take measurements								
Record data from trials	**DAY 3**	**DAY 3**						
Run trials and record data								
Build spreadsheet & solve formulas	**DAY 4**	**DAY 4**						
Build spreadsheet and transfer data								
Add formulas and solve for velocity, friction etc								
Competition	**DAY 5**	**DAY 5**						
Hold the competition								

Class period #1

Cover kinetic and potential energy, gravity, acceleration, velocity, friction, vectors, time.
Go over the use of spreadsheets.
Pass out ramp materials.
Assign work areas and answer questions about the project.

Class period #2

Teams work on building the ramps and taking ramp measurements.

Class period #3

Teams start running trials and recording data.

Class period #4

Teams build spreadsheet programs and transfer data to spreadsheet.
Add formulas to the spreadsheet and solve for velocity, friction, and acceleration.

Class period #5

Hold the competition. If all teams have completed their data tables, identify the distances for the competition and conduct the competition.

FACILITIES EQUIPMENT AND OTHER RESOURCES

Supplies List:

- Hot Wheels® car supplied by the student team (1 for each team)
- Ramp supplies supplied by the instructor: (1 set for each team)
    - 2 boards 1ft 6in X 4in X .6875in
    - 1 brass piano hinge cut to 4in in length (with brass screws)
    - 1 plastic protractor
    - 1 ramp extension sheet 1ft 6in X 4in (Outdoor Home For Sale Sign is good for this)
    - 3 Pan head wood screws # 6 X 3/4in
    - Extension post 1in X 1ft 6in X 1/4in
- Scale to weigh cars supplied by the instructor
- Tape measure supplied by the instructor (1 for every 3 teams)
- Stop watches (1 for every 2 teams)
- Shop equipment for construction: (If the Instructor cannot do this check with the school shop instructor for help and guidance. The shop students could be assigned to cut and/or build the ramps for an assignment)
    - Table saw
    - Router
    - Screwdriver (flat blade #2)
    - Screwdriver (Phillips head #2)
    - Brad Nailer (or brads and hammer)
    - Rulers
    - Squares
- Engineering lab notebook supplied by the students
- Formula sheet
- Short nap carpet strip 1ft by 6ft (check carpet stores for remnants)

TEACHER'S GUIDE DESCRIPTION

Class period 1
State some examples of this type of use for the inclined panel. You could use the example used in the problem statement as one of these. Using Appendix A, briefly go over the definitions of the principles that will be introduced during this project. Some will already be familiar to the students; others will have to be explained in more depth. Use Appendix B to explain the concepts of the inclined plane and to introduce the formulas that will be used in this project. Cover the use of a spreadsheet and how it will be used to aid the student during this project. Formulas, graphs and charts should also be introduced at this time. This part of the project may spill over into day 2 because there is a lot of information contained here in. If time allows, pass out the ramp materials, assign team members to the various teams, assign work areas to the students and try to answer any questions that may come up.

Class period 2
Continue with any assignments from day 1 that you were unable to cover. Go over the construction information in Appendix C, D and E and start the teams on their projects. Today they will work on building their individual ramps and taking any measurements that may be required. The instructor will be occupied with mentoring students progress during this class period keeping the students motivated, and answering question that may come up.

Class period 3
Today teams will start their trials using the cars that they have brought in. They will use a minimum of 5 runs down their ramp. They will then adjust the angle of the ramp and repeat the process. This will be done for a minimum of 5 different angles. The students will record the run out distance and angle used for each trial, on their work sheet. The cars need to be weighed and the weight converted to Kilograms. Once again the instructor's assignment will be to monitor the student's progress and to answer any question that will arise.

Class period 4
Today the teams will take the data obtained during the last session and build their spreadsheets using this information and the formulas sheets supplied to them. Their spreadsheets need to solve for Normal Force, Acceleration, and Initial Velocity (at the bottom of the ramp). All data needs to be converted to meters for the calculations. The students will take the spreadsheet information and have the software build a scatter XY chart of this information. If time allows and the students are so inclined they may use the data to solve for the time it takes for the car to stop during a roll out when given a specific coefficient of friction. The students will research this work on their own as this is for extra credit. Work close with the students on this day because there will be a lot of questions on spreadsheet applications and about the use of formulas.

Class period 5

Today will be for project presentation and competition. Each team will be allotted 10 min. to describe and demonstrate their ramp and explain their findings. The team oral report should explain their use of the engineering design process to build their ramp. It should also include any engineering principles that they used and explanations of how various formulas were applied to their data.

For the competition phase of the day the instructor will have picked out, in advance, some rollout distances that will be used to test the student's data collection skills. The instructor will announce a distance and the students using their data charts will try to figure out which angle on their ramp would be the best choice to achieve the roll out distance given. The team coming closest to the prescribed distance will be determined the winners and will be awarded a prize chosen by the instructor.

At the end of the class, the teams will hand in their notebook, which the instructor will use to assess the project. The notebook will include all diagrams, data calculations, spreadsheets, and histograms. Each page of the notebook must be numbered and signed by both team members. The pages are to be written in pen.

SUPPORTING MATERIALS

APPENDIX A

CONCEPT DISCRIPTIONS

Potential Energy is the type of energy a body possesses by virtue of its position. Thus if a weight of "**w**" lbs. is raised to a height of "**h**" feet, it can be stated that this object possesses Potential Energy in the amount of **w** x **h** foot-pounds.

Kinetic Energy is the type of energy a body possesses by virtue of its motion. An object traveling at a velocity "**v**" has kinetic energy proportional to the square of its velocity.

Friction is the force exerted between two objects, which prevent one object from moving over the other. If the object is in motion, friction will impede this motion and slow the object down. The two types of friction are Sliding Friction and Rolling Friction.

Velocity is the speed an object is moving relative to some other object—usually a stationary one.

Acceleration is the rate of change of an object's velocity due to some externally applied force. For falling objects the applied force is gravity (which results in an acceleration of 9.81 meters per second squared).

SCALAR AND VECTOR QUANTITIES

A scalar is a quantity which has magnitude, such as mass, density, energy, or temperature. A vector is a quantity and has magnitude and direction, such as force, velocity or acceleration.

APPENDIX B

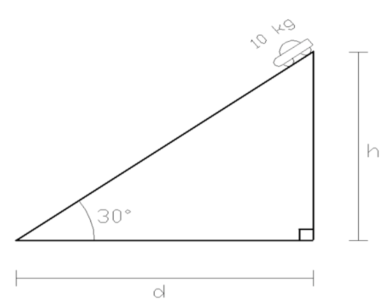
The information in this appendix comes from an instruction article taken from the Barnes & Noble Spark Notes Webpage (2) and has been modified for our "car and ramp" project.

INCLINED PLANES

What we call wedges or slides in everyday language are called inclined planes in physics-speak. From our experience on slides during recess in elementary school, sledding down hills in the winter, and skiing, we know that when people are placed on slippery inclines, they slide down the slope. We also know that slides can sometimes be sticky, so that when you are at the top of the incline, you need to give yourself a push to overcome the force of static friction. As you descend a sticky slide, the force of kinetic friction opposes your motion. In this section, we will consider problems involving inclined planes both with and without friction. Since they're simpler, we'll begin with frictionless planes.

FRICTIONLESS INCLINED PLANES

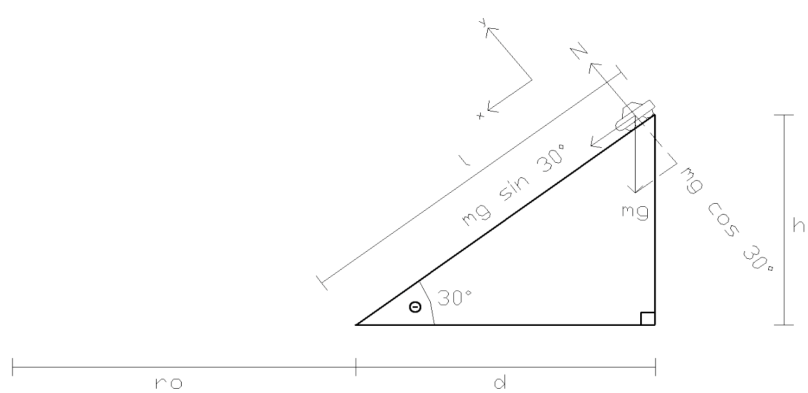
Suppose you place a 10 kg car on a frictionless 30º inclined plane and release your hold, allowing the car to roll to the ground, a horizontal distance of *d* meters and a vertical distance of *h* meters.



Before we continue, let's follow those three important preliminary steps for solving problems in mechanics:

1. **Ask yourself how the system will move:** Because this is a frictionless plane, there is nothing to stop the car from sliding down to the bottom. Experience suggests that the steeper the incline, the faster an object will slide, so we can expect the acceleration and velocity of the car to be affected by the angle of the plane.

2. **Choose a coordinate system:** Because we're interested in how the car rolls along the inclined plane, we would do better to orient our coordinate system to the slope of the plane. The *x*-axis runs parallel to the plane, where downhill is the positive *x* direction, and the *y*-axis runs perpendicular to the plane, where up is the positive *y* direction.
3. **Draw free-body diagrams:** The two forces acting on the car are the force of gravity, acting straight downward, and the normal force, acting perpendicular to the inclined plane, along the *y*-axis. Because we've oriented our coordinate system to the slope of the plane, we'll have to resolve the vector for the gravitational force, ***mg***, into its *x*- and *y*-components. Knowing you can break ***mg*** down into a vector of magnitude cos 30º in the negative *y* direction and a vector of magnitude sin 30º in the positive *x* direction. The result is a free-body diagram that looks something like this:



Decomposing the ***mg*** vector gives a total of three force vectors at work in this diagram: the *y*-component of the gravitational force and the normal force, which cancel out; and the *x*-component of the gravitational force, which pulls the car down the slope. Note that the steeper the slope, the greater the force pulling the car down the slope.
Now let's solve some problems. For the purposes of these problems, take the acceleration due to gravity to be $g = 10\ m/s^2$. Like SAT II Physics, we will give you the values of the relevant trigonometric functions: cos 30º = sin 60º = 0.866, cos 60º = sin 30º = 0.500.

HANDOUT FOR PROBLEM SOLVING PRACTICE

1. What is the magnitude of the normal force?

2. What is the acceleration of the car?

3. What is the velocity of the car when it reaches the bottom of the slope?

4. What is the work done on the car by the force of gravity in bringing it to the bottom of the plane?

PROBLEM SOLUTIONS

1. What is the magnitude of the normal force?

The car is not moving in the *y* direction, so the normal force must be equal to the *y*-component of the gravitational force. Calculating the normal force is then just a matter of plugging a few numbers in for variables in order to find the *y*-component of the gravitational force:

$$
\begin{aligned}
N &= mg\cos 30^o \\
&= (10kg)(10m/s^2)(0.866) \\
&= 86.6N
\end{aligned}
$$

2. What is the acceleration of the car?

We know that the force pulling the car in the positive *x* direction has a magnitude of *mg* sin 30. Using Newton's Second Law, $F = ma$, we just need to solve for *a*:

$$
\begin{aligned}
ma &= mg\sin 30^o \\
a &= g\sin 30^o \\
&= (10m/s^2)(0.500) \\
&= 5m/s^2
\end{aligned}
$$

3. What is the velocity of the car when it reaches the bottom of the slope?

Because we're dealing with a frictionless plane, the system is closed and we can invoke the law of conservation of mechanical energy. At the top of the inclined plane, the car will not be moving and so it will have an initial kinetic energy of zero ($KE_{initial} = 0$). Because it is a height *h* above the bottom of the plane, it will have a gravitational potential energy of $U = mgh$. Adding kinetic and potential energy, we find that the mechanical energy of the system is:

$$E = KE + U = 0 + mgh = mgh$$

At the bottom of the slope, all of the car's potential energy will have been converted into kinetic energy. In other words, the kinetic energy, $\frac{1}{2}mv^2$, of the car at the bottom of the slope is equal to the potential energy, *mgh*, of the car at the top of the slope. Solving for *v*, we get:

$$
\begin{aligned}
v &= \sqrt{2gh} \\
&= \sqrt{2(10m/s^2)h} \\
&= 4.47\sqrt{h}
\end{aligned}
$$

4. What is the work done on the car by the force of gravity in bringing it to the bottom of the inclined plane?

The fastest way to solve this problem is to appeal to the work-energy theorem, which tells us that the work done on an object is equal to its change in kinetic energy. At the top of the slope the car has no kinetic energy, and at the bottom of the slope its kinetic energy is equal to its potential energy at the top of the slope, *mgh*. So the work done on the car is:

$$\begin{aligned} W &= mgh = (10kg)(10m/s^2)h \\ &= 100h \end{aligned}$$

Note that the work done is independent of how steep the inclined plane is, and is only dependent on the object's change in height when it rolls down the plane. The work is measured in Joules.

APPENDIX C

RAMP CONSTRUCTION

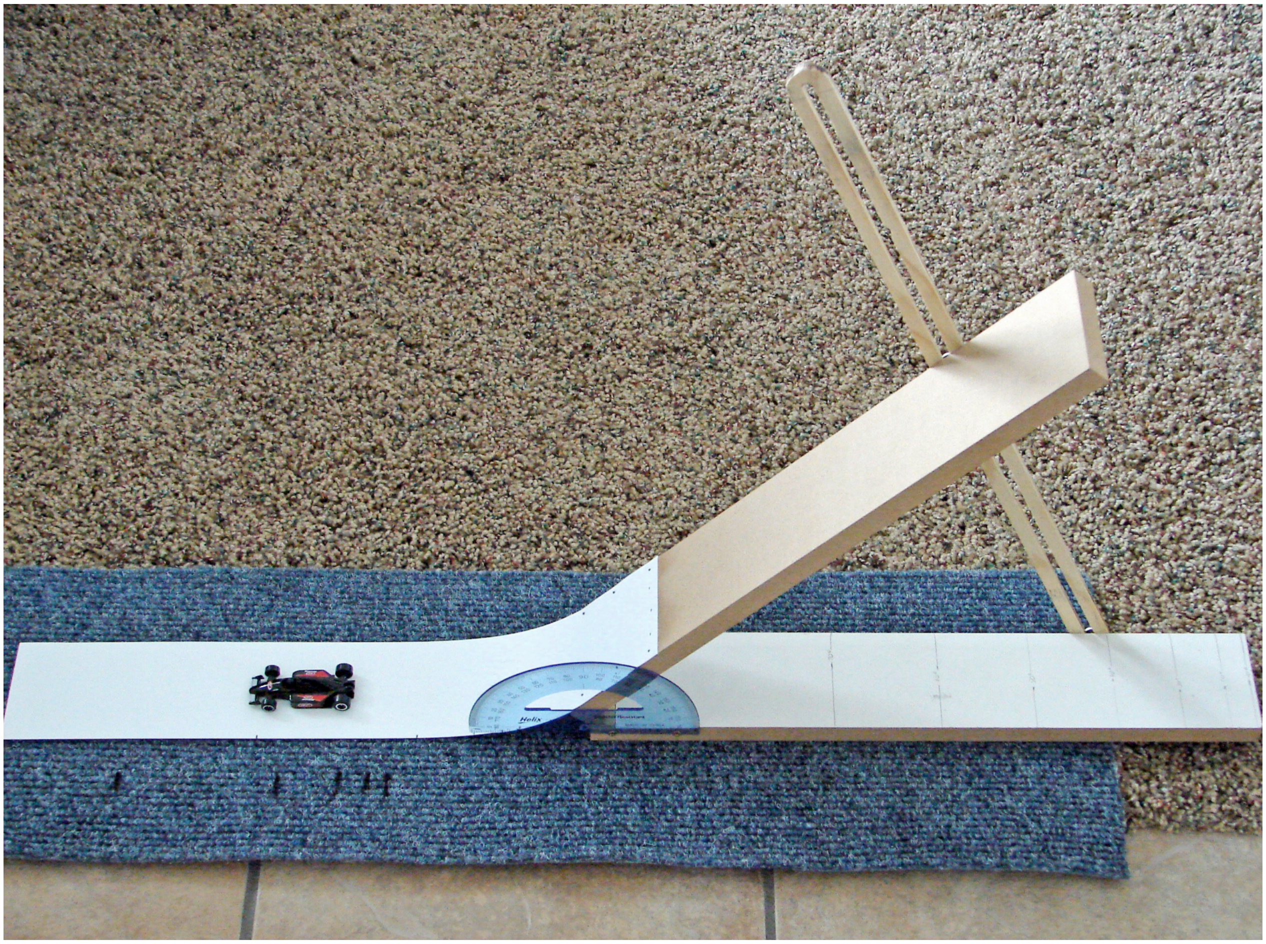


Fig. 1
Ramp Overview
Showing car, extension, protractor, outrun carpet, ramp boards and lift extension
(this is just one idea for the lift extension depending on skills)

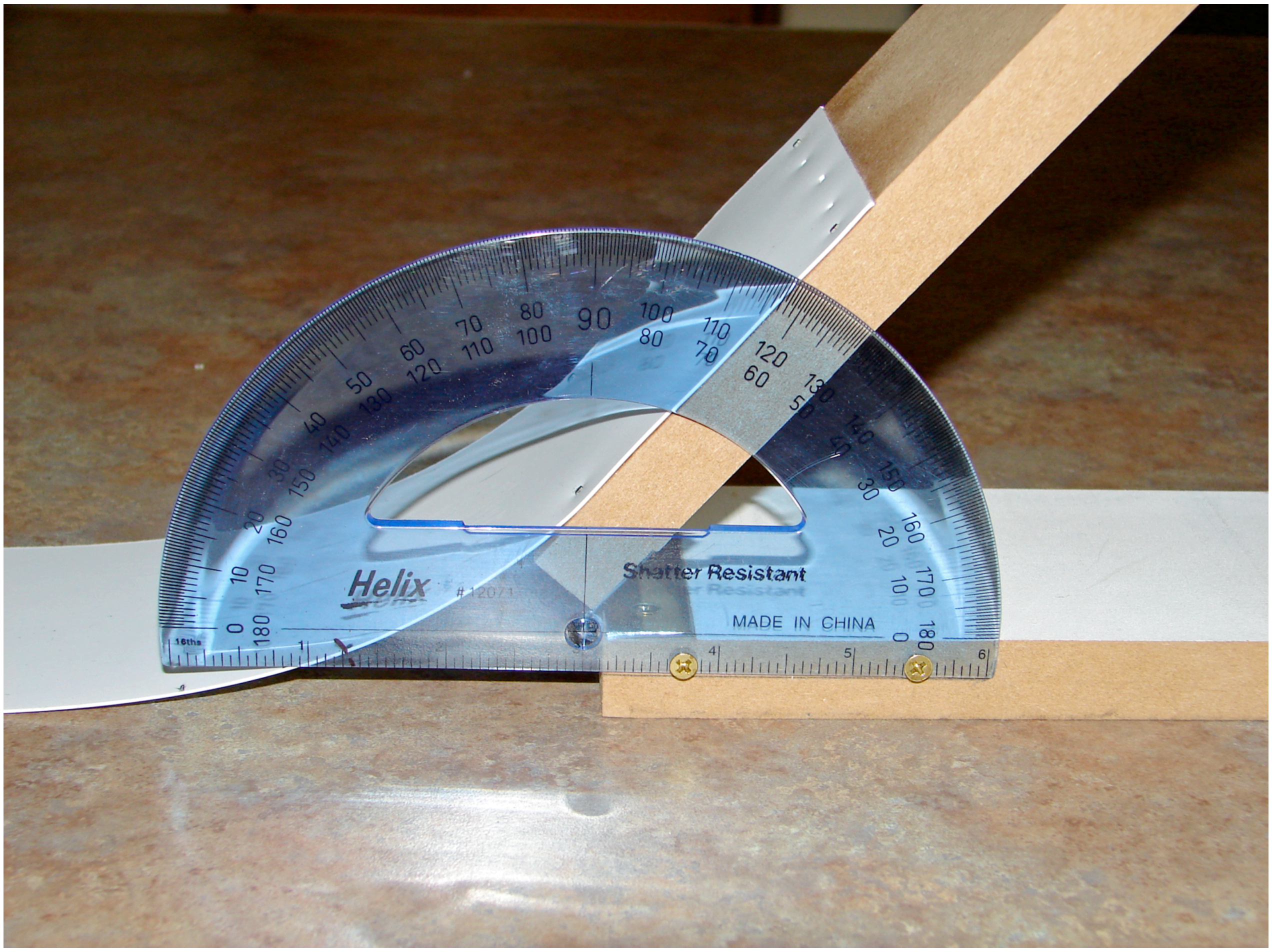


Fig. 2
Ramp Close Up
Showing a close up of the protractor mounting

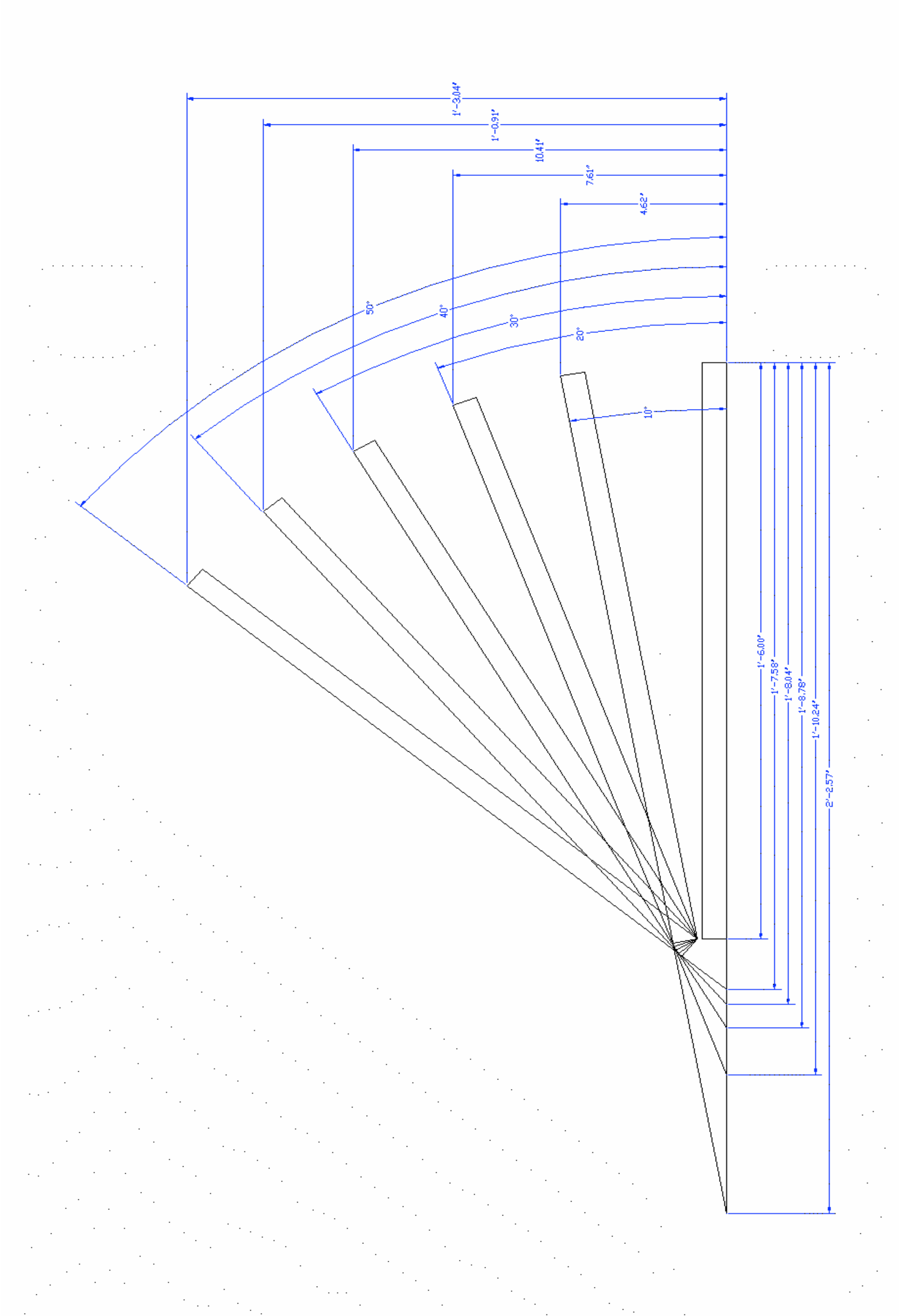


Fig. 3
Ramp angle and distances

APPENDIX D

VARIABLES USED

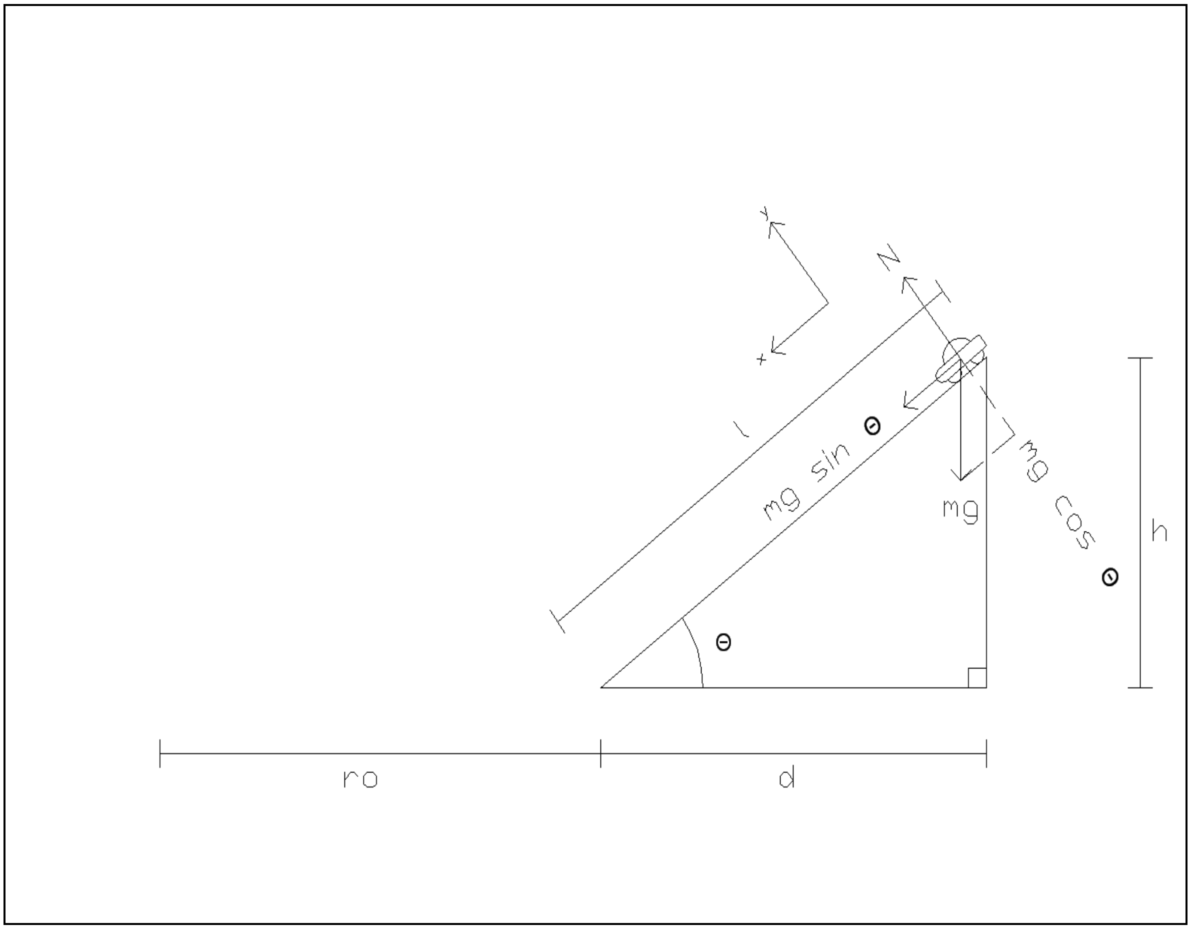


Fig 4
Reference for variables used

FORMULA WORKSHEET

t = time	E = mechanical energy	KE = kinetic energy
PE = potential energy	v = velocity	v_f = final velocity
v_o = initial velocity	W = work	N = normal force
F = force	m = mass	g = gravity ($9.8\, m/\sec^2$)
GPE = gravitational potential energy		a = acceleration
h = height	d = distance	l = length
f = friction	μ = coefficient of friction	

$F_{gy} = FN_y = mg(Cos\theta)$	$F_{gx} = FN_x = mg(Sin\theta)$	$F = ma$
$ma = mg(Sin\theta)$	$PE = mgh$	$E = KE + PE$
$v = \sqrt{2gh}$	$W = mgh$	$W = Fx$
$v = v_o + at$	$KE = \frac{1}{2}mv^2$	$GPE = Wh$
$a = (v_f - v_o)/t$	$F_f = F_{gx} - ma$	$F_f = \mu FN$

SOH ... **s**in = **o**pposite/**h**ypotenuse

CAH ... **c**os = **a**djacent/**h**ypotenuse

TOA ... **t**an = **o**pposite/**a**djacent.

TRIG TABLES

Angle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sin	0.017	0.035	0.052	0.07	0.087	0.105	0.122	0.139	0.156	0.174	0.191	0.208	0.225	0.242	0.259
Cos	1	0.999	0.999	0.998	0.996	0.995	0.993	0.99	0.988	0.985	0.982	0.978	0.974	0.97	0.966
Tan	0.017	0.035	0.052	0.07	0.087	0.105	0.123	0.141	0.158	0.176	0.194	0.213	0.231	0.249	0.268
Csc	57.299	28.654	19.107	14.336	11.474	9.567	8.206	7.185	6.392	5.759	5.241	4.81	4.445	4.134	3.864
Angle	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Sin	0.719	0.731	0.743	0.755	0.766	0.777	0.788	0.799	0.809	0.819	0.829	0.839	0.848	0.857	0.866
Cos	0.695	0.682	0.669	0.656	0.643	0.629	0.616	0.602	0.588	0.574	0.559	0.545	0.53	0.515	0.5
Tan	1.036	1.072	1.111	1.15	1.192	1.235	1.28	1.327	1.376	1.428	1.483	1.54	1.6	1.664	1.732
Csc	1.39	1.367	1.346	1.325	1.305	1.287	1.269	1.252	1.236	1.221	1.206	1.192	1.179	1.167	1.155
Angle	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Sin	0.276	0.292	0.309	0.326	0.342	0.358	0.375	0.391	0.407	0.423	0.438	0.454	0.469	0.485	0.5
Cos	0.961	0.956	0.951	0.946	0.94	0.934	0.927	0.921	0.914	0.906	0.899	0.891	0.883	0.875	0.866
Tan	0.287	0.306	0.325	0.344	0.364	0.384	0.404	0.424	0.445	0.466	0.488	0.51	0.532	0.554	0.577
Csc	3.628	3.42	3.236	3.072	2.924	2.79	2.669	2.559	2.459	2.366	2.281	2.203	2.13	2.063	2
Angle	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Sin	0.875	0.883	0.891	0.899	0.906	0.914	0.921	0.927	0.934	0.94	0.946	0.951	0.956	0.961	0.966
Cos	0.485	0.469	0.454	0.438	0.423	0.407	0.391	0.375	0.358	0.342	0.326	0.309	0.292	0.276	0.259
Tan	1.804	1.881	1.963	2.05	2.145	2.246	2.356	2.475	2.605	2.747	2.904	3.078	3.271	3.487	3.732
Csc	1.143	1.133	1.122	1.113	1.103	1.095	1.086	1.079	1.071	1.064	1.058	1.051	1.046	1.04	1.035
Angle	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Sin	0.515	0.53	0.545	0.559	0.574	0.588	0.602	0.616	0.629	0.643	0.656	0.669	0.682	0.695	0.707
Cos	0.857	0.848	0.839	0.829	0.819	0.809	0.799	0.788	0.777	0.766	0.755	0.743	0.731	0.719	0.707
Tan	0.601	0.625	0.649	0.675	0.7	0.727	0.754	0.781	0.81	0.839	0.869	0.9	0.933	0.966	1
Csc	1.942	1.887	1.836	1.788	1.743	1.701	1.662	1.624	1.589	1.556	1.524	1.494	1.466	1.44	1.414
Angle	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Sin	0.97	0.974	0.978	0.982	0.985	0.988	0.99	0.993	0.995	0.996	0.998	0.999	0.999	1	1
Cos	0.242	0.225	0.208	0.191	0.174	0.156	0.139	0.122	0.105	0.087	0.07	0.052	0.035	0.017	0
Tan	4.011	4.331	4.705	5.145	5.671	6.314	7.115	8.144	9.514	11.43	14.301	19.081	28.636	57.29	
Csc	1.031	1.026	1.022	1.019	1.015	1.012	1.01	1.008	1.006	1.004	1.002	1.001	1.001	1	1

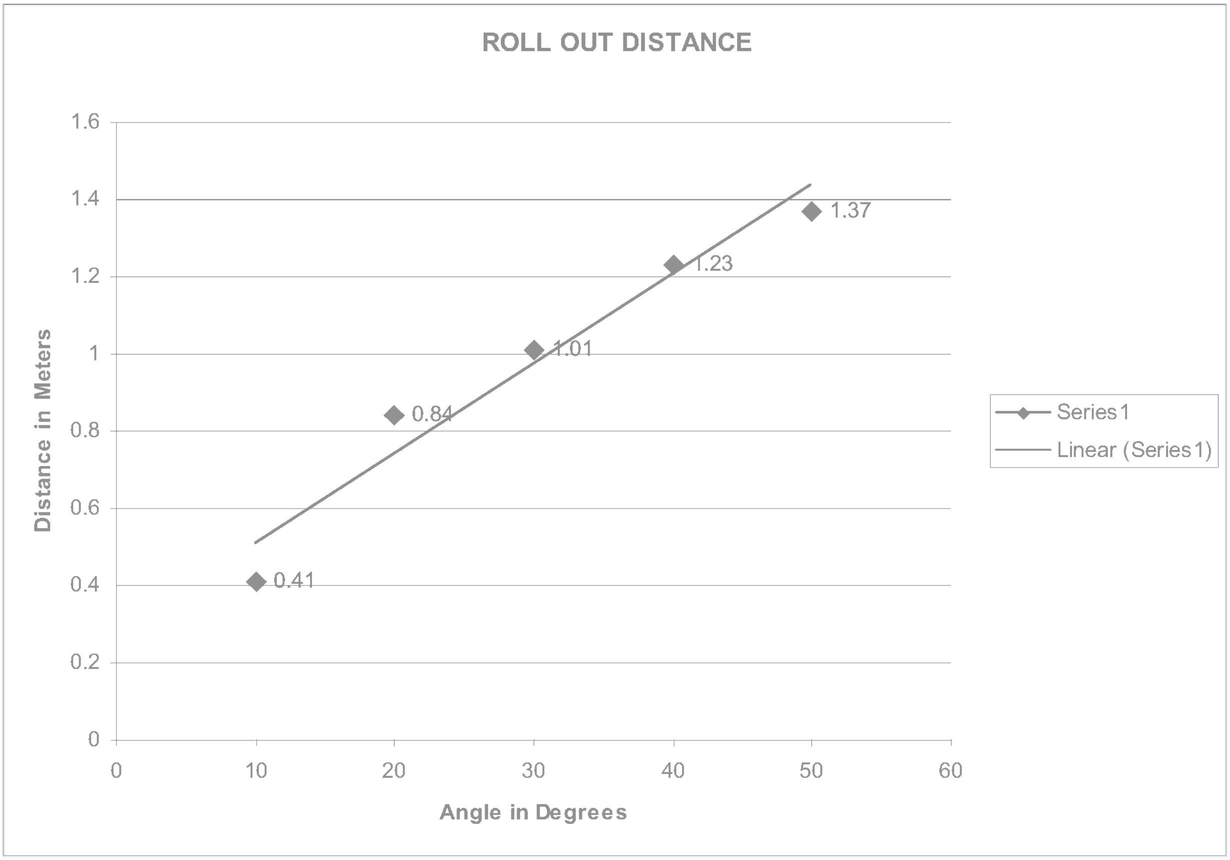
APPENDIX E

CAR RAMP DATA

Length (l) in meters	Normal Force in Newtons	Acceleration in m/s^2	Initial Vel. at base of ramp
=SQRT(#REF!^2+#REF!^2)	=#REF!*(#REF!)*COS(RADIANS(#REF!))	=#REF!*SIN(RADIANS(#REF!))	=4.47*SQRT(#REF!)
=SQRT(#REF!^2+#REF!^2)	=#REF!*(#REF!)*COS(RADIANS(#REF!))	=#REF!*SIN(RADIANS(#REF!))	=4.47*SQRT(#REF!)
=SQRT(#REF!^2+#REF!^2)	=#REF!*(#REF!)*COS(RADIANS(#REF!))	=#REF!*SIN(RADIANS(#REF!))	=4.47*SQRT(#REF!)
=SQRT(#REF!^2+#REF!^2)	=#REF!*(#REF!)*COS(RADIANS(#REF!))	=#REF!*SIN(RADIANS(#REF!))	=4.47*SQRT(#REF!)
=SQRT(#REF!^2+#REF!^2)	=#REF!*(#REF!)*COS(RADIANS(#REF!))	=#REF!*SIN(RADIANS(#REF!))	=4.47*SQRT(#REF!)

Test run #	Angle (?) in deg.	Length (l) in meters	Height (h) in meters	Dist. (d) in meters	Dist. (ro) in meters	Time in sec.	Normal Force in Newtons	Acceleration in m/s^2	Initial Velocity at base of ramp
1 (5 tries avgs.)	10	0.68	0.12	0.67	0.41	1.12	0.35	1.70	1.55
2 (5 tries avgs.)	20	0.59	0.19	0.56	0.84	0.57	0.33	3.35	1.95
3 (5 tries avgs.)	30	0.59	0.27	0.53	1.01	0.46	0.31	4.90	2.32
4 (5 tries avgs.)	40	0.61	0.33	0.51	1.23	0.35	0.27	6.30	2.57
5 (5 tries avgs.)	50	0.63	0.38	0.50	1.37	0.33	0.23	7.51	2.76

Weight of Car in Kg. 0.036
Gravity in m/s^2 9.8


ROLL OUT DISTANCE
Distance in Meters
Angle in Degrees
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
0.41
0.84
1.01
1.23
1.37
Series1
Linear (Series1)