Acmeville Water Slides

PROJECTILE MOTION FOR THE LOW-CLEARANCE CLASSROOM

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Project Summary

This project is designed to allow students to experiment with projectile motion without having to launch a projectile. This is very beneficial for areas with low ceilings. The variable in this experiment is the initial velocity rather than the initial firing angle. Fischertechniks sensors and the RoboLab software will be used to measure the initial velocity of the projectile.

This project can be completed by students in grades 9-12, but will probably be easer for students in at least grade 11. It will be completed as part of the Dynamics/Kinematics component of the Principles of Engineering course. Students should have a basic understanding of trigonometric and algebraic functions. Students also need to have previously learned how to use the Fischertechniks and RoboLab software. This project can either replace or supplement the Ballistic Device project, depending on the needs and time frame of the course.

The *Acmeville Water Slides* project gives students an idea of how the engineering principles they are learning can be applied to real life, in this case the design of a thrill ride at an amusement park. Most students have probably visited an amusement park. They will be able to relate the issues of safety and adventure relating to thrill rides.

This project consists of a PVC pipe ramp that is supported on a truss framework of Fischertechnik parts. A release mechanism, a measuring system, and an angle adjusting mechanism are also constructed from Fischertechnik parts. A marble rolls down the ramp and into a PVC pipe chute. Sensors will record the velocity as it rolls through this chute. The velocity will change depending on the angle of the ramp. The students will need to calibrate the angle mechanism and the sensors to get accurate measurements.

At the end of the project, the students must be able to hit a target located a specific horizontal and vertical distance away from the chute. They will use principles of physics and mathematical formulas to determine the necessary velocity to hit the target. This project will provide an interesting and engaging activity for the students to learn about trajectory motion and ballistics.

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Problem Statement/Specific Aims

The study of ballistics and projectile motion is very important. Whether it's throwing a ball, playing horseshoes, or going to Mars, projectile motion is all around us. The study of ballistics is also becoming increasingly more important as space exploration and homeland defense become major issues. But ballistics and projectile motion also play a major part in recreation, especially as extreme thrills become more and more popular.

If you have ever ridden on a water slide at a water amusement park, chances are, you have been a projectile. The velocity of a person going down the slide is given careful consideration in the designs of these rides in order to provide a safe, yet enjoyable ride. If a person travels too fast, serious injury or even death can occur. Yet if the ride is too slow, it will not provide the desired exhilaration.

You will work in design teams of two or three to construct a device that will simulate a water slide. You will use a marble to simulate a rider on the slide. You will collect and analyze data to calibrate your measuring devices and to determine the best velocity for the marble. As part of this project, each team will:

- Be able to launch a projectile at different initial velocities.
- Record data for initial velocity.
- Determine the angle of the ramp that produces a given velocity.
- Keep a log of all design ideas, tests, data, results, analyses, and design changes in your engineering notebook.
- Use mathematical formulas and physics principles to predict what velocity is needed to hit a certain point.

Scenario

Water amusement parks are becoming an increasingly popular attraction. In 2003, over 70 million people visited the over 1000 water parks in North America. The combination of cool water, thrilling water slides, and leisurely swimming make these water parks a great activity for the heat of the summer.

As more and more people ride water slides, safety becomes a major concern. Injuries can be caused from falling, colliding with objects or people, or drowning/near drowning, resulting in sprains/strains, open wounds, fractures, head injuries, and even death. Water slides and other thrill rides must be designed to **safely** provide a fun and exhilarating experience.

The city of Acmeville is building a municipal water park to increase tourism and provide summer recreation for residents. The plan for one of the water slides includes a long, angled chute leading into a shorter, level chute. The level chute ends with a drop off into a swimming pool below. Riders gain velocity as they slide down the angled chute. After sliding through the level chute they are launched into the air. They land safely in the swimming pool below where they will then exit the ride.

Your engineering design team has been selected to create a design for the slide. The ride needs to be fast, but also safe. You will determine which angle will provide the best rider velocity. You will also need to determine the size and position of the pool at the bottom. The rider needs enough clearance to safely land in the water without hitting the sides of the pool. The pool also needs to be small enough to minimize the amount of swimming needed to exit the pool.

In order to design the slide, you will need to make a model to analyze data. Since it would not be very feasible to build an actual water slide to test, your model must be small and accurately simulate the water slide. Using materials provided by the teacher, you will create a small version of the slide with a chute that has an adjustable angle. You will use a marble to roll down the chute. This will allow you to measure the differences in velocity for a given angle. A system of measuring the velocity of the marble will be set up on the level chute.

You will conduct ten trial runs for each of six given angles. On each run you will record the velocity in feet per second. You will use Microsoft Excel to graph the average velocity at each angle. The graph, in combination with the formula for projectile motion, will be used to determine the final angle of the slide and the placement and size of the pool.

As a final test to determine the accuracy of your data, the teacher will place a 6 inch square target on the floor at a specific distance from the end of your level chute (which will be on a desk or table). You must measure the vertical and horizontal distances from the end of your chute to the target. Using these measurements and the formula for projectile motion, you will determine the velocity needed to hit the target with the marble. You must be able to set the top chute to the angle necessary to achieve that velocity. Because of different variables in your model that can affect the velocity of the marble, you will have three tries to hit the target, **<u>but you cannot adjust the angle!</u>**

Concepts and Standards

ITEA Standards of Technological Literacy

3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
8. Students will develop an understanding of the attributes of design.
9. Students will develop an understanding of engineering design.
10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
11. Students will develop the abilities to apply the design process.
12. Students will develop the abilities to use and maintain technological products and systems.
18. Students will develop an understanding of and be able to select and use transportation technologies.

National Mathematics Standards

Students will:

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
- Understand meanings of operations and how they relate to one another.
- Compute fluently and make reasonable estimates.
- Understand patterns, relations, and functions.
- Represent and analyze mathematical situations and structures using algebraic symbols.
- Analyze change in various contexts.
- Understand measurable attributes of objects and the units, systems, and processes of measurement.
- Apply appropriate techniques, tools and formulas to determine measurements.
- Recognize and apply mathematics in contexts outside of mathematics.

National Science Standards

- Systems, order, and organization.
- Evidence, models, and explanation.
- Change, constancy, and measurement.
- Abilities necessary to do scientific inquiry.
- Understandings about scientific inquiry.
- Motions and forces.
- Abilities of technological design.
- Understandings about science and technology.

Assessment

The following rubric will be used to assess the students' progress and understanding of the material:

Model Construction	Ramp adjustability	10
	Angle automatically measured	20
	Velocity determined by sensors and program	20
	Release mechanism	10
	Sensors calibrated and accurate	20
	Ramp and chute secure and stable	20
	Total Points for Model	**100**
Worksheet	10 trials for each of 6 angles	15
	Scatter Chart	15
	All steps of worksheet completed	20
	Total Points for Worksheet	**50**
Engineering Notebook	Test results recorded	20
	Initial design ideas	20
	Changes to design and reason for changes	30
	Final design	10
	Analyses and conclusions	20
	Total Points for Notebook	**100**
	Total Points for Project	**250**

Schedule/Timeline

This project should take 5 days to complete. They will be broken down into the following;

- Day one- Lecture describing the project and teaching projectile motion and free fall, breaking them into their X Y components, and the math involved.
- Day two and three- Divide into groups to design and build their water slide simulator using Fischer Techniks and pvc pipe provided by teacher. During this time students will collect data to calibrate their "timer eyes" and the angle measurement of the ramp.
- Day four- Teach in about 10 minute lesson how to use Microsoft Excel, then groups will work on their worksheet, collecting data of the velocity of the ball.
- Day five- Challenge day! Teacher will place the target on the floor within and students will measure it's location in relation to their simulator, calculate the necessary velocity, and use their chart from the Microsoft Excel worksheet to determine the angle setting for their simulator to hit the target.

Materials and Equipment

A computer per group with the following software;

- Robopro
- Microsoft Excel

A Standard Fischer Technik kit for Project Lead the Way per group with a minimum of the following;

- 2 motors
- 2 lamps
- 2 phototransistors
- 1 potentiometer

4 rubber bands per group

A 16" length of ¾ pvc pipe per group with two 1/8" dia. parallel holes drilled on pipe centerline. The first hole 1" from an end and the second 12" from the first. 2" of the top half needs to be cut off of the other end.

A 24" length of ¾ pvc pipe per group with a .159 (drill #22) hole drilled 1/2" from an end and offset from pipe centerline. Other holes or cutting may be necessary to fit ball release mechanism on other end.

A ½" ball per group

A Protractor per group

Band saw or hand saw for notching pipe

Drill press or hand-held drill

1/8 drill bit

#22 drill bit (may vary depending on potentiometer shaft.)

Tape measure

Literature Cited

[1] "Waterpark Facts," <www.waterparks.com/funfacts.asp>, accessed April 25, 2006.

[2] Recreational Water Injuries," <www.ausport.gov.au/fulltext/1998/qld/qisuissue51.pdf>, accessed April 25, 2006.

Project Description

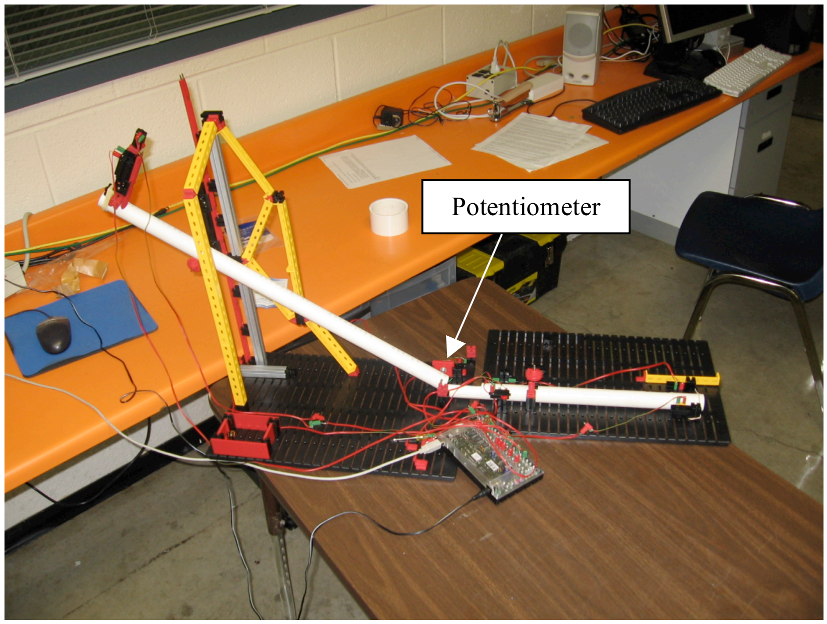
The goals of this project are;

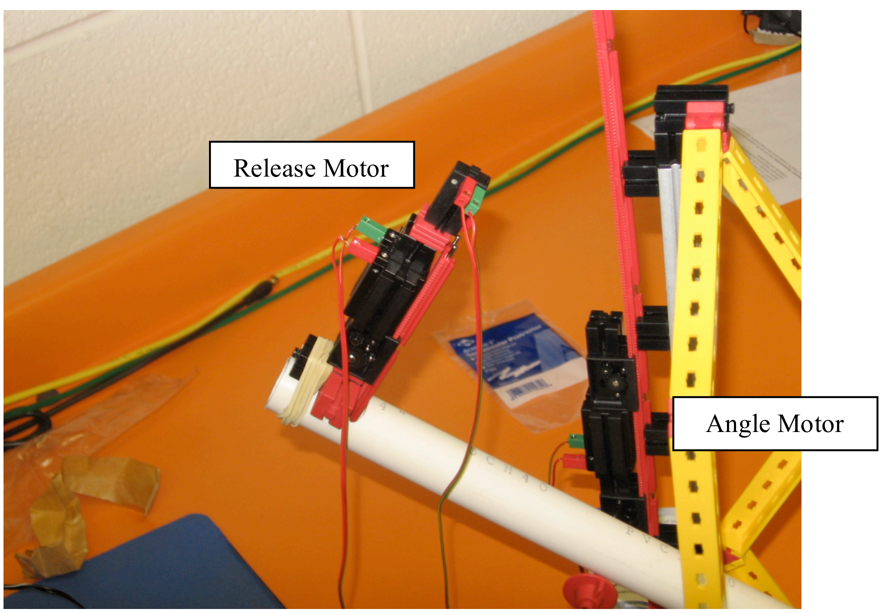
- To help students improve their design skills
- Students will learn about projectile motion and how to separate it into XY components for calculations
- Students will learn how to use a spreadsheet to manipulate data and to represent it with a chart.

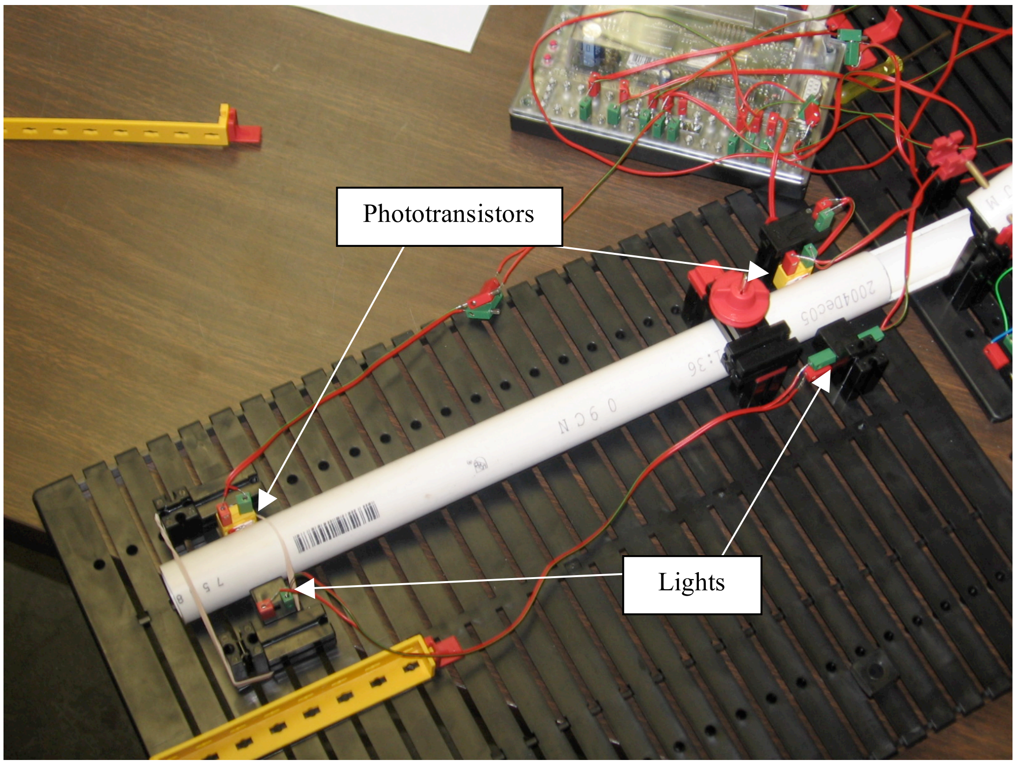
The equations that will be used in correlation with this project are;

- $y = mx + b$ where $y =$ resistance (R), $x =$ angle (A) such that $R = mA + b$. This will be used to calibrate the ramp angle with the variable resistor.
- Inches/counts * counts/seconds
- $x = Vt$ where x is the projectile travel in the x axis, V is the initial velocity when the ball leaves the simulator, and t is time between leaving the simulator and hitting the target.
- $y = Gt^2$ where y is the projectile travel in the y axis, G is the acceleration due to gravity (386 in/sec^2), and t is time between leaving the simulator and hitting the target.

The following pictures provide ideas for constructing the project.

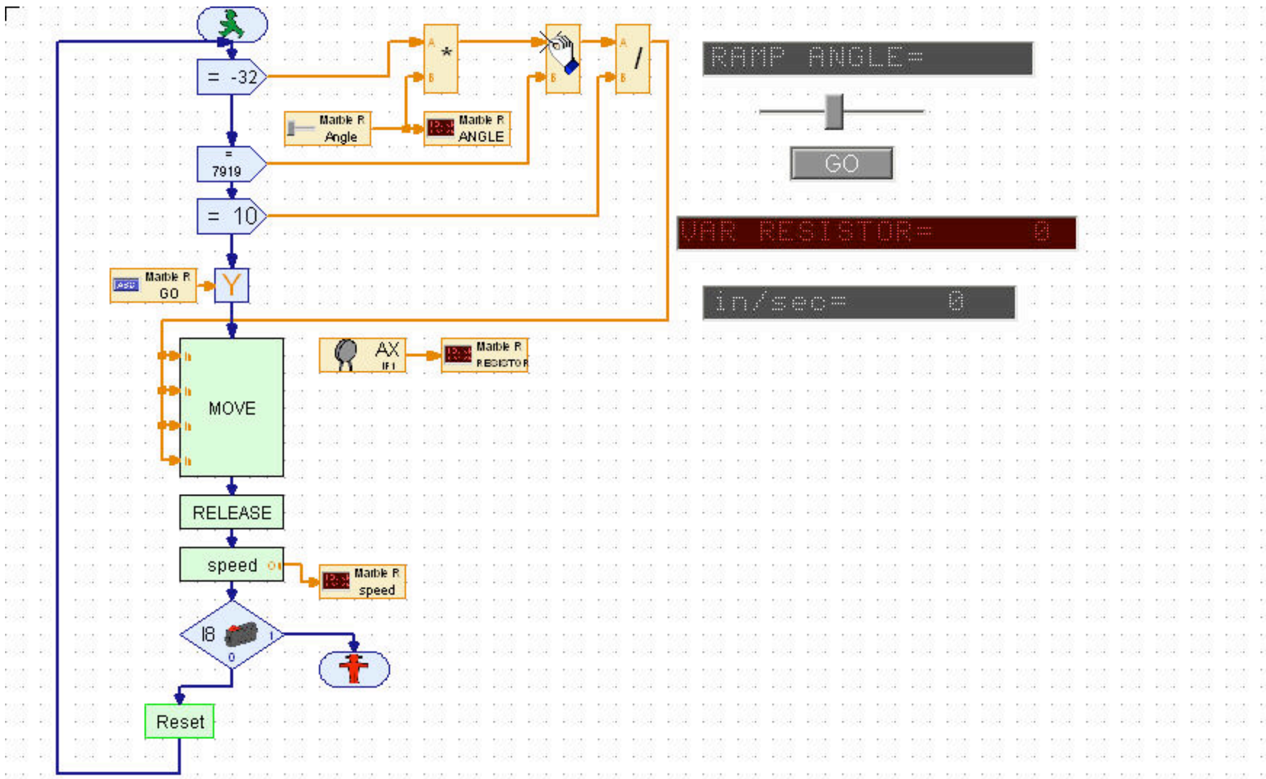




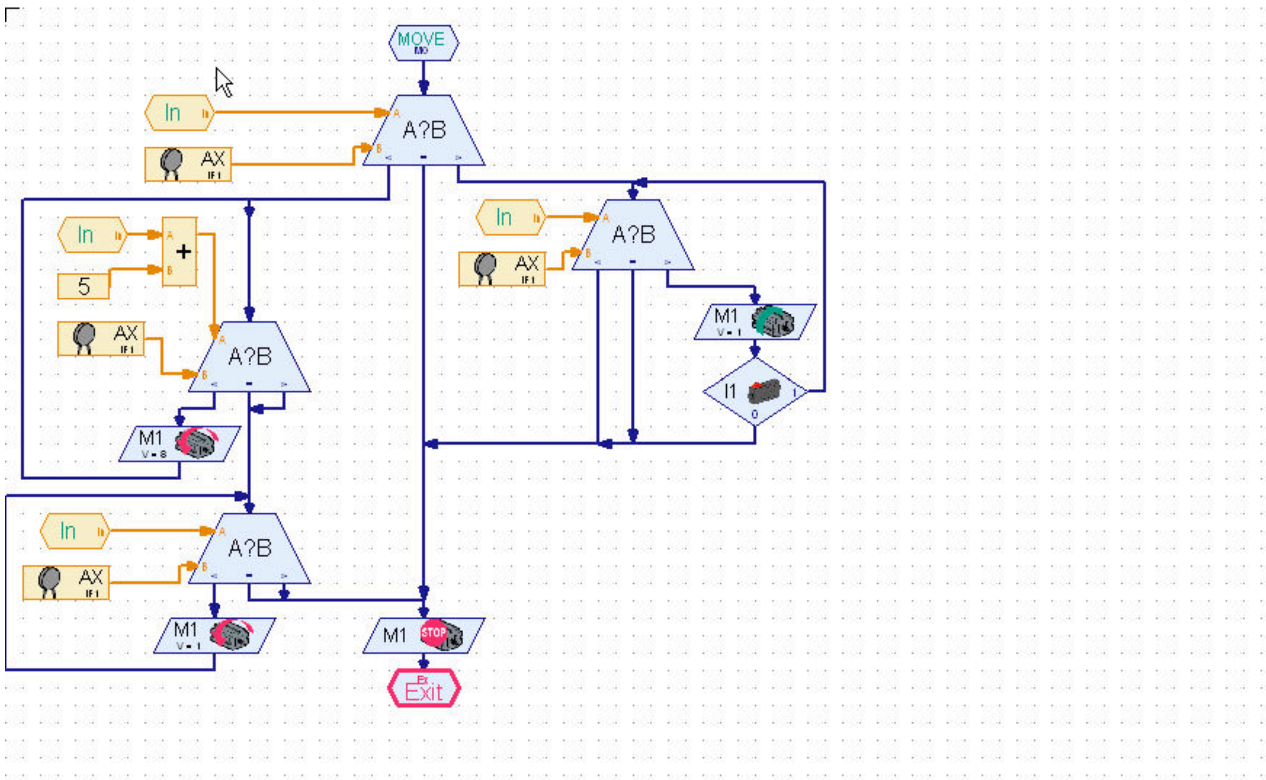

Phototransistors
Lights

Use the following RoboPro programs for ideas on how to write the program.

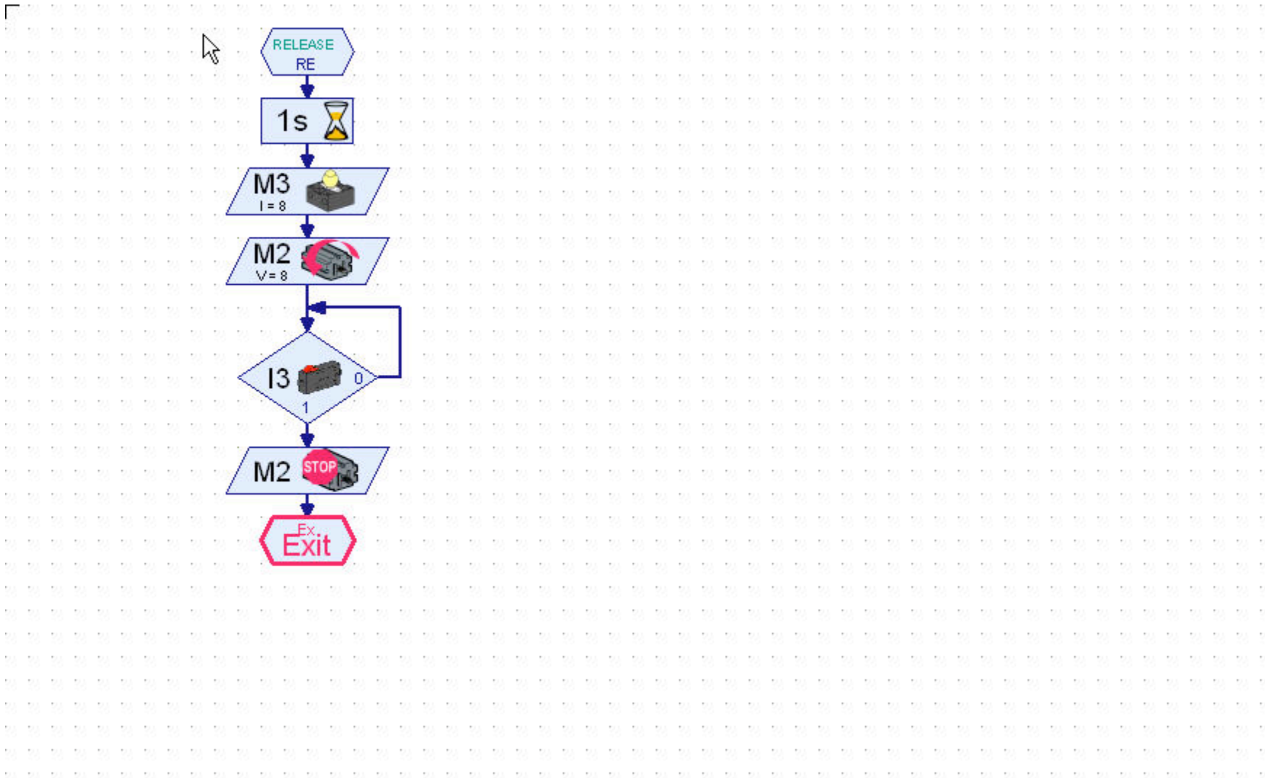
Main Page



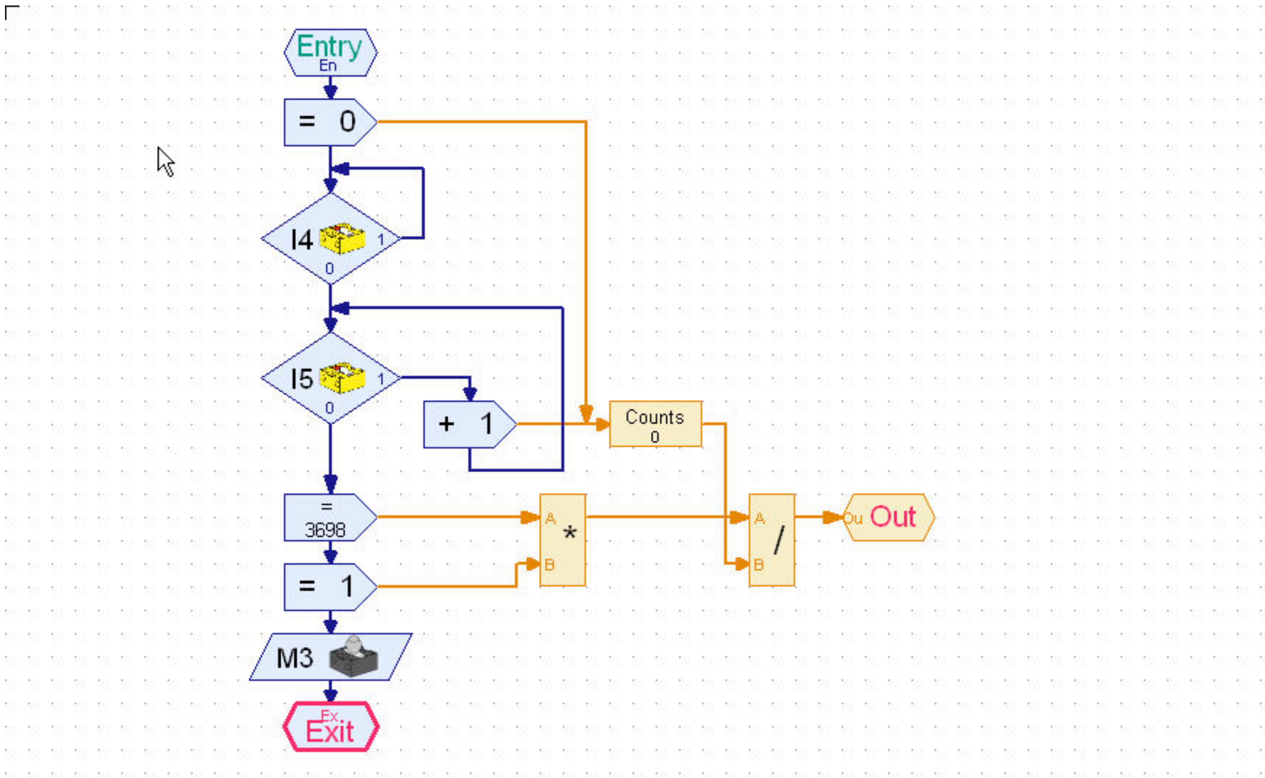
Move



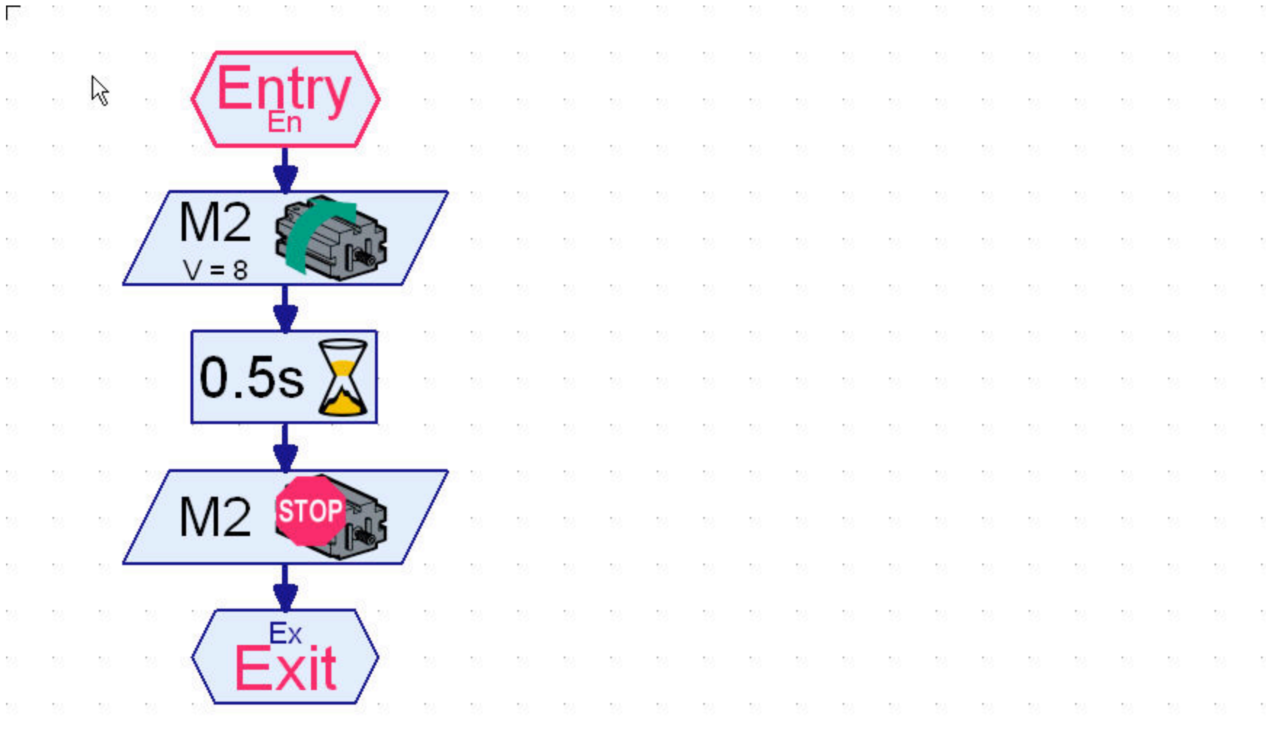
Release



Speed



Reset



Microsoft Excel/Water Slide Worksheet

1) Open a new spreadsheet in Microsoft Excel.
2) In A2 – A11 type **TRIAL 1, TRIAL 2, TRIAL 3**, etc.
3) In B1 type **5 DEGREES.**
4) In B2 – B11 enter data collected from 10 trials with the ramp at 5 degrees.
5) Repeat steps 4 and 5 for column C setting the ramp at 10 degrees, column D with 15 degrees, column E with 20 degrees, column F with 25 degrees, and column G with 30 degrees.
6) In A12 type **AVERAGE.**
7) In A13 type **STANDARD DEVIATION.**
8) Highlight B12 and select ***fx*** under toolbar.
9) In pop-up window select **AVERAGE.**
10) With the **Function Arguments** window open, highlight B2 –B11 and click **OK**.
11) Highlight B13 and select ***fx*** under toolbar.
12) In pop-up window select **STDEV.**
13) With the **Function Arguments** window open, highlight B2 –B11 and click **OK**.
14) Repeat steps 8 – 13 for columns C – G.
15) Copy row 12 into row 17
16) In A18 type **ANGLE**.
17) In B18 enter **5**, in C18 enter **10**, in D18 enter **15**, etc
18) Highlight B17 – G18 then select Chart Wizard from the toolbar.
19) Select **XY (Scatter)** and **Scatter with data points connected by smoothed Lines**, then select **Next** twice.
20) Under the **Titles** tab type **ANGLE AND VELOCITY** in the **Chart title** field. Type **ANGLE** in the **Value (X) axis** field. Type **VELOCITY** in the **Value (Y) axis** field.
21) Under the Gridlines check all boxes of **Major** and **Minor gridlines,** then select **Finish.**
22) Position the chart below the other information. This chart will be used to predict the degree setting to hit the target.