CNS Institute for Physics Teachers

Title:	**Stunt Car Challenge!**
Original: **Revision:**	28 October 2007 9 January 2009
Authors:	Buzz Putnam
Appropriate Level:	High School Physics (New York State Regents-Level)
Abstract:	A projectile motion lab is required for the NYS Regents Physics classroom and state standards require a qualitative and quantitative understanding of the horizontal and vertical displacements as a function of launch angle. In a fun and engaging way, students meet these standards with this lab. The lab apparatus consists of a launcher that includes three angle settings and a photogate placed to measure the initial launch velocity of the projectile. In Part I, the lab team will qualitatively experiment with a projectile motion simulation, working through the launch angle vs, d_v and d_h. In Part II, they calculate their car's initial velocity from the photogate time and car length. After calculating the horizontal and vertical distances for the different launch angles, the lab team will attempt to hit a landing pad and have their car fly through the dreaded "Ring of Fire."
Time Required:	Two 40 minute class periods
NY Standards Met:	• The path of a projectile is the result of the simultaneous effect of the horizontal and vertical components of its motion; these components act independently. (5.1f, 5.1i, 5.1ii, 5.1vii) • A projectile's time of flight is dependent upon the vertical components of its motion. (5.1g, 5.1vii) • The horizontal displacement of a projectile is dependent upon the horizontal component of its motion and its time of flight. (5.1h, 5.1vii)
Special Notes:	**Stunt Car Challenge** is a kit available from the CIPT Equipment Lending Library, www.cns.cornell.edu/cipt/.

Behavioral Objectives:

Upon completion of this lab, a student should be able to:

- Qualitatively determine the horizontal and vertical displacements through the use of a projectile motion simulation that allows them to vary launch angles.

- Conceptually visualize the relationship between the launch angle and the resulting horizontal and vertical displacements.

- Quantitatively determine the horizontal and vertical displacements for a project launched with a given angle and velocity.

Class Time Required:

For the complete Projectile Motion lab experiment, the students will need a minimum of two-40 minute lab periods or one period if on a "Block" schedule.

Teacher Preparation Time Required:

Total prep time - ~20 minutes, longer if you are not familiar with the photogates

- For Part I, the set-up requires only a computer station and the "PhET simulation" either installed or Internet capability.

- For Part II, the teacher must set up the launch apparatus with accompanying photogates.

- Teachers must observe heightened awareness of safety throughout this lab. This lab requires the launching of objects at high speeds. Be certain to have supervision and practice safety precautions such as safety glasses at all times.

Materials Needed:

- "PhET simulation" available free through…http://phet.colorado.edu/simulations/projectilemotion/projectile.swf

- "Jump Track" set-up

- Photogates (Vernier, Pasco or Arbor Scientific)

- "Darda" toy car (pull-back car)

- Fish nets

- Protractor/Metric tape measure/meter stick

- Carbon paper

- Calculators

Assumed Prior Knowledge of Students:

Very little prior knowledge of projectile motion is required for using the computer simulation in Part I, which is intended to be discovery/inquiry-based activity for exploring the relationship between the launch angle and the resulting horizontal and vertical distances for projectile trajectories in vacuum and air. Part II can only be done after the student is introduced to the following mathematical concepts of projectile motion: determination of the velocity components, the vertical and horizontal times of flight, and the horizontal and vertical distances for the projectile as a function of launch angle.

Background Information for Teacher:

- The teacher should have complete conceptual knowledge of qualitative and quantitative determinations of d_h, d_v and the angle vs. d_h and d_v relationship. Despite the simulation illustrating the ideal conditions, the teacher should be aware that the application of projectile motion in a real-life situation leads to some deviation from the "perfect" answers that will result in this lab. The "Jump Track" set-up and "Darda" toy car (pull-back car) are affected by friction variables and will not result in true textbook accuracy depending on conditions. Students will ask why the angles are not at higher settings as exhibited in the simulation. Real-life car and motorcycle jumps are accomplished at angles less than 30 degrees. Remember that each set-up may vary in its launch velocities and a number of experimental trials will result in truer calculations.

- The crucial point of this lab is the set-up of the photogate at the end of the track. The photogate determines the time the entire car passes through its detectors. Numerous photogate set-ups have been tested and manipulated at Cornell to achieve the highest degree of precision in measuring the car's velocity at its take-off point. Be certain that the photogate is placed as seen in the attached photo at the end of this lab. Through trials at CIPT, it was found that vertically-arranged photogates provide the best measurements for the car's velocity leaving the track. Photogates can also be set-up on ring stands prior to the students' experiments if the teacher prefers, but pre-test all set-ups prior to the lab.

- The "Stunt Car Track" set-up has been designed to accept most photogate types. Each type of photogate MUST be arranged vertically in order to clearly detect the length of the car. Horizontally mounted photogates are too inconsistent in their readings, consequently causing the data/calculation of the car's initial velocity to render the lab conclusions vague and meaningless. The track has adaptations for Arbor Scientific and Vernier/Pasco photogates. (See included schematic of the track assembly.)

If using **<u>Vernier Photogates</u>**:

- For the Vernier photogates, you will need a Vernier *LabQuest* or a Vernier LabPro.
- Attach the patch cord from the photogate to the *LabQuest* or *LabPro* and plug the power cord.
- Turn on your *LabQuest/LabPro* and this will activate the photogate.
- The measurement read by the *LabQuest* is the total time the photogate is blocked by the car.
- Before you launch your car, your partner must prepare to catch the car as it leaves the ramp using the fish net.
- The Vernier photogate timer will record the time that the entire toy car body passes through the photogate.
- The resulting velocity of the car can be found by calculating the length of the toy car divided by the time the car takes to pass through the vertically-arranged photogates. **$v = d/t$**

If using **<u>Arbor Photogates:</u>**

- Attach a single Photogate to the Arbor Timer.
- Screw the Photogate on the track vertically (see diagram) to capture the motion of the car as it passes through. The car will block the light beam as it passes through the gate.
- Use the Mode button to choose "Gate Mode."
- Launch the car through the Photogate.
- Find the car's velocity by dividing the car length (the distance traveled) by the measured time (the time it took to travel that short distance).--> **$v = d/t$**
- The student can view each trial of data collection if they wish by viewing "Memory in One Gate Mode". Normally all data collected can be viewed by pressing the Memory button to "step" through all data results. When using the One Gate, the timer starts counting when a phototgate is interrupted the first time and continues to count until a second interruption of the photogates occurs. If the timer is in its counting cycle it is not possible to view data in memory. You must either press the reset button to exit the cycle or turn off power to the unit.

  Directions in using the Arbor Photogate in additional modes can be found at www.arborsci.com or calling 1-800-367-6695.
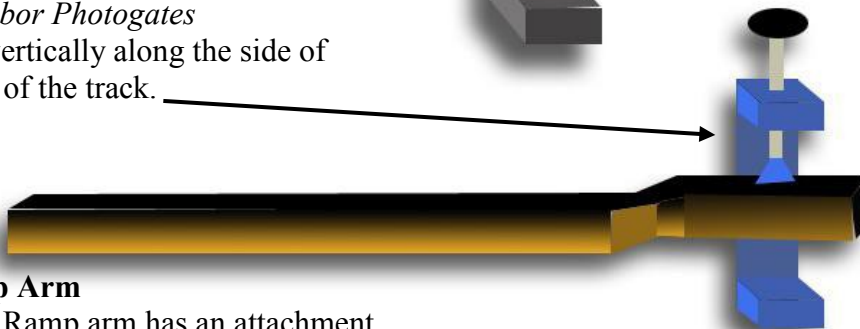
For use with the Vernier Photogates
This plate screws into the photogate arm of the ramp and has a thumb screw attachment that uses the attachment hole provided in the photogate.

Screw attachment to ramp arm.

For use with the Arbor Photogates
Photogate clamps vertically along the side of the ramp at the end of the track.

Top View of Ramp Arm
New mod to Speed Ramp arm has an attachment bracket that allows for the photogate to be clamped in a vertical position over the end of the track.

Plastic Track

- Prior to the students actually launching their cars for this lab, the students are required to calculate the Horizontal Displacement (d_h) and the Vertical Displacement (d_v) for their individual car/track set-up. The cars' velocities and the track specifications differ slightly for each individual lab set-up, but the results between all lab set-ups are similar, with some slight deviations. Below is a data table of five (5) launched car trials at the 10°, 20° and 30° angles, the velocity of the car as it leaves the ramp, and the resulting d_h and d_v values. The actual calculations for the horizontal and vertical displacements at the given angles are shown below as a reference for the teacher. The calculation method uses $\mathbf{d = v_i t + \frac{1}{2} a t^2}$ for both vertical and horizontal motion. Remember to keep the horizontal and vertical motion calculations of the car during its flight completely independent from each other. The vertical motion of the launched car does not affect the horizontal motion of that same launched car while in flight, no matter what the initial velocity or angle of launch is!

- **Helpful Equations**

  General Equation for Projectile Motion → $\qquad$ $\mathbf{d = v_i t + \frac{1}{2} a t^2}$

  For **Vertical** Motion only ---------------→ $\qquad$ $\mathbf{d_v = v_{iv} t_v + \frac{1}{2} a_v t_v^2}$

  For **Horizontal** Motion only -------------→ $\qquad$ $\mathbf{d_h = v_{ih} t_h + \frac{1}{2} a_h t_h^2}$

  For determination for time of flight ------→ $\qquad$ $\mathbf{a = \Delta v / t}$

  For determining the vertical and horizontal
  components of the car's velocity ---------→ $\qquad$ $\mathbf{c^2 = a^2 + b^2}$

  $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ **Sine, Cosine, Tangent functions**

- **Steps in solving an angled projectile motion problem**
  - Find the vertical (v_v) and horizontal (v_h) components of the car's velocity.
  - Find the time (t_v) it takes the car to reach its highest vertical displacement; its "halfway point" during its flight.
  - Multiply the t_v by 2 to find the horizontal time (t_h).
  - B using the Velocity data ($v_{v\ \&\ }v_h$) and the Time data (t_v & t_h), the the Horizontal Displacement and the Vertical Displacement of the launched car can be found.
  - For finding Vertical Displacements, use the equation, $\mathbf{d_v = v_{iv} t_v + \frac{1}{2} a_v t_v^2}$, where…

    $\mathbf{d_v}$ = Vertical Displacement

    $\mathbf{v_{iv}}$ = Initial Vertical Velocity

    $\mathbf{t_v}$ = Vertical Time

    $\mathbf{a_v}$ = Vertical Acceleration
  - For finding Horizontal Displacements, use the equation, $\mathbf{d_h = v_{ih} t_h + \frac{1}{2} a_h t_h^2}$, where…

    $\mathbf{d_h}$ = Horizontal Displacement

    $\mathbf{v_{ih}}$ = Initial Horizontal Velocity

    $\mathbf{t_h}$ = Horizontal Time

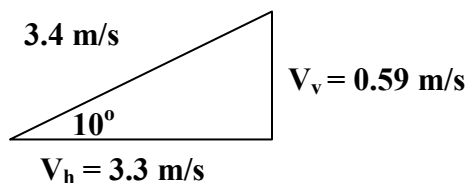 $\mathbf{a_h}$ = Horizontal Acceleration

Remember that the Horizontal Acceleration of a projectile is zero, meaning the object is moving at a constant velocity resulting in zero acceleration of the object (Dynamic Equilibrium).

- **Sample Calculations**
  - The cars have been tested for their reliability and consistency in launch velocity results. Each car will have its own launch velocity due to the manufacturing of the car's mechanics, but numerous tests have found the cars' average launch velocities to be 3.4 m/s. Your individual results will vary with each lab set-up, but for the **3.4 m/s** as the Initial Launch Velocity of the car.
  - The track allows three (3) angle settings for the students in their experiments; 10°, 20° and 30°. The sample calculations for all three angles are shown below. Your students' calculations will vary from set-up to set-up, with slight variation resulting from friction, car manufacturing, student error and other factors.
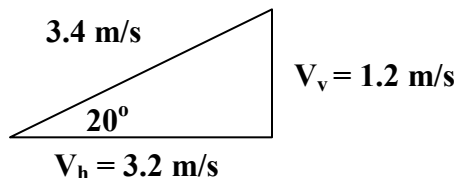
Car Launch #1 at 3.4 m/s with 10°
1. Find Vertical Velocity (V_v) Component →   Sin 10°=V_v/3.4 → 0.59 m/s
2. Find Horizontal Velocity (V_h) Component →   Cos 10°=V_v/3.4 → 3.3 m/s
3. Find the Vertical Time (t_v) → a = Δv/t   -9.8 m/s^2 = $\underline{0\text{ m/s} - 0.59\text{ m/s}}$ → 0.060 sec
                                                                        t
4. Find the Horizontal Time (t_h) → 0.060 sec X 2 = 0.12 sec
5. Find Vertical Displacement (d_v) →   **$d_v = v_{iv}t_v + \frac{1}{2}\ a_vt_v{}^2$**
                                        d_v = (0.59 m/s)(0.060 sec) + ½ (-9.8 m/s^2)(0.060)^2
                                        d_v = 0.017m
6. Find Horizontal Displacement (d_h) → **$d_h = v_{ih}t_h + \frac{1}{2}\ a_ht_h{}^2$**
                                        d_h = (3.3 m/s)(0.12 sec) + ½ (0 m/s^2)(0.12)^2
                                        d_h = 0.40m

3.4 m/s

V_v = **0.59 m/s**
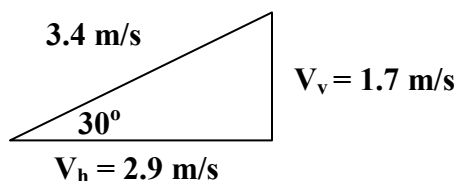
10°

V_h = **3.3 m/s**

Car Launch #2 at 3.4 m/s with 20°
1. Find Vertical Velocity (V_v) Component →   Sin 20°=V_v/3.4 → 1.2 m/s
2. Find Horizontal Velocity (V_h) Component →   Cos 20°=V_v/3.4 → 3.2 m/s
3. Find the Vertical Time (t_v) → a = Δv/t   -9.8 m/s^2 = $\underline{0\text{ m/s} - 1.2\text{ m/s}}$ → 0.12 sec
                                                                        t
4. Find the Horizontal Time (t_h) → 0.12 sec X 2 = 0.24 sec

5. Find Vertical Displacement (d_v) → $\quad$ $\mathbf{d_v = v_{iv}t_v + \frac{1}{2}\,a_v t_v^{\,2}}$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_v}$ = (1.2 m/s)(0.12 sec) + ½ (-9.8 m/s^2)(0.12)^2

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_v = 0.073m}$

6. Find Horizontal Displacement (d_h) → $\quad$ $\mathbf{d_h = v_{ih}t_h + \frac{1}{2}\,a_h t_h^{\,2}}$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_h}$ = (3.2 m/s)(0.24 sec) + ½ (0 m/s^2)(0.24)^2

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_h = 0.77m}$

3.4 m/s

V_v = 1.2 m/s

20⁰

V_h = 3.2 m/s

Car Launch #3 at 3.4 m/s with 30⁰

1. Find Vertical Velocity (V_v) Component → $\quad$ Sin 30⁰=V_v/3.4 → 1.7 m/s
2. Find Horizontal Velocity (V_h) Component → $\quad$ Cos 30⁰=V_v/3.4 → 2.9 m/s
3. Find the Vertical Time (t_v) → $\;$ a = Δv/t $\quad$ -9.8 m/s^2 = $\underline{0\ m/s - 1.7\ m/s}$ → 0.17 sec

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ t

4. Find the Horizontal Time (t_h) → $\qquad\qquad$ 0.17 sec X 2 = 0.34 sec
5. **Find Vertical Displacement (d_v) →** $\qquad$ $\mathbf{d_v = v_{iv}t_v + \frac{1}{2}\,a_v t_v^{\,2}}$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_v}$ = (1.7 m/s)(0.17 sec) + ½ (-9.8 m/s^2)(0.17)^2

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_v = 0.15m}$

6. **Find Horizontal Displacement (d_h) →** $\qquad$ $\mathbf{d_h = v_{ih}t_h + \frac{1}{2}\,a_h t_h^{\,2}}$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_h}$ = (2.9 m/s)(0.34 sec) + ½ (0 m/s^2)(0.34)^2

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathbf{d_h = 0.99m}$

3.4 m/s

V_v = 1.7 m/s

30⁰

V_h = 2.9 m/s

Extension(s) for the Teacher (As a follow-up to the lab experience)

- Using the Movie "Speed," you can use the concepts gained from this lab and apply it to Hollywood and its application to "real" Physics. From the movie clip of the runaway bus jumping the "gap" in the highway, the student is able to gather important data to solve whether the bus would actually be successful in its jump or is Hollywood skewing its science to thrill the viewer. The questions are shown on the following page.

- As a conceptually-higher level (such as Honors or AP), the teacher can have the students predict the d_h at DIFFERENT launch and landing heights. Using the ramp on the floor without providing the SAME landing area height or launching from a lab table and making quantitative predictions in landing on the floor. (Be certain to use a "soft" landing area for the fragile cars!)

Teacher Extension Question

In the movie "Speed," a bus must jump a gap in an unfinished highway. The bus JUST makes it, but are the movie makers accurate? Collect your data from the movie clip and use your knowledge of Angled Projectile Motion, find out if the bus SHOULD make it or fall short into disaster.

Movie Facts
Launch Velocity [v] of Bus _____
Launch Angle [θ] _____
Length [d_h] of "gap" in road _____

_____ How far does the bus jump?

Conversion →
MPH/2.2 = m/s
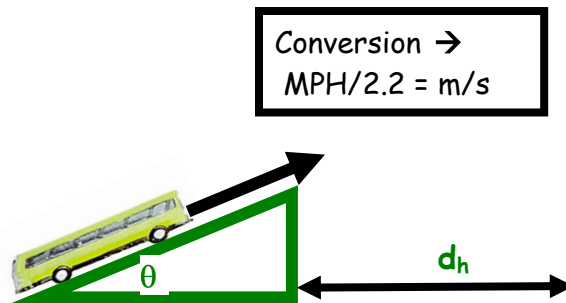
Answers to Questions: *send request for answers to cipt_contact@cornell.edu*

References:

- http://phet.colorado.edu/simulations/projectilemotion/projectile.swf
- http://www.nysed.gov/
- Physics, 5th edition, Giancoli, Prentice Hall 1998
- College Physics, A Strategic Approach, Pearson/Addison-Wesley 2007

Equipment List

Not shown:
 9 Carbon paper
10 Bolt and nut connector for track
11 Tape measure
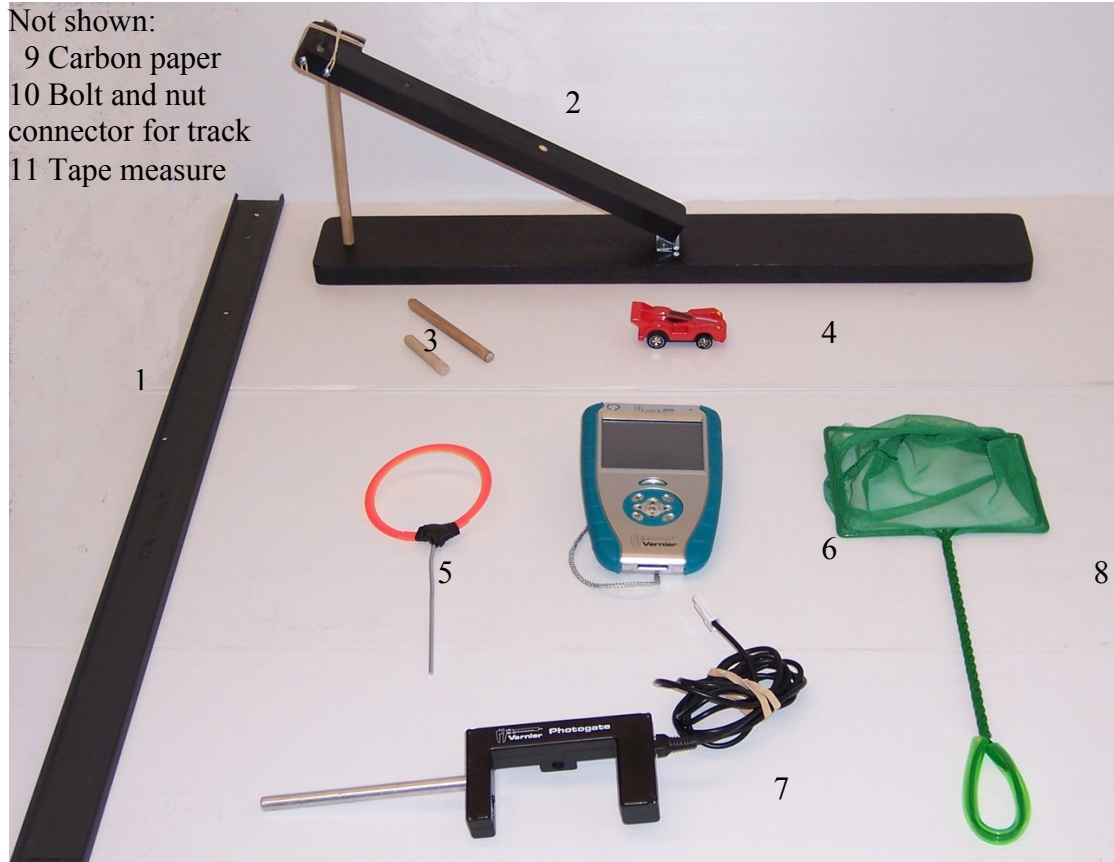
Item Number	Quantity	Item
1	1	2m track (two pieces with Velcro conntector)
2	1	"Jump Track" ramp
3	3	Variegated length dowels for supporting ramp
4	1	Darda car (pull back car)
5	1	Ring of Fire
6	1	LabPro
7	1	Photogate
8	1	Fish net
9	1	Sheet of carbon paper
10	2	Bolt, washer and nut connector for track
11	1	Tape measure or meter stick

STUNT CAR CHALLENGE!

Introduction:
We see examples of Projectile Motion in every aspect of our lives; a football punt or kick, a home run in baseball, a 9-iron golf shot, or a stunt driver driving his car off a ramp. In this lab, you will find out how projectiles fired at different angles behave and use real-world applications to confirm your calculations of distances and times.

Part I - Projectile Motion Simulator

Materials:
- computer (Windows Systems, Macintosh System OS 10.3.9 or later, Linux Systems, Microsoft Windows 98SE/2000/XP)
- Macromedia Flash 7 or later
- projectile motion simulation software
- calculator

Procedure:
- Open the *Projectile Motion* simulation at the website…
   http://phet.colorado.edu/simulations/projectilemotion/projectile.swf
- You can experiment with various factors that affect the flight of your projectile including the:
   - height of the cannon
   - location of the cannon
   - angle of the cannon
   - initial speed of the projectile
   - air resistance
   - range, height and time during the flight

- A tape measure is present in the simulation to help you measure heights and distances. Use the simulation to test your ideas about the things that affect the landing spot of a projectile.

- You may experiment with the choice of projectiles (tank shell, golf ball, baseball, bowling ball, football, pumpkin, adult human, piano or Buick) provided in the Projectile Motion Simulation.

- Get familiar with the simulation and its controls. Now vary <u>ONE</u> variable at a time to determine how that variable affects the projectile's motion (how far it goes, how high it goes, how long before it hits the ground, etc.).

- Using the simulation, answer the following questions by experimenting with the variables in the "green" box. Remember, you can either type in the angle you desire or click on the cannon and the tape measure to vary distances, heights, etc.
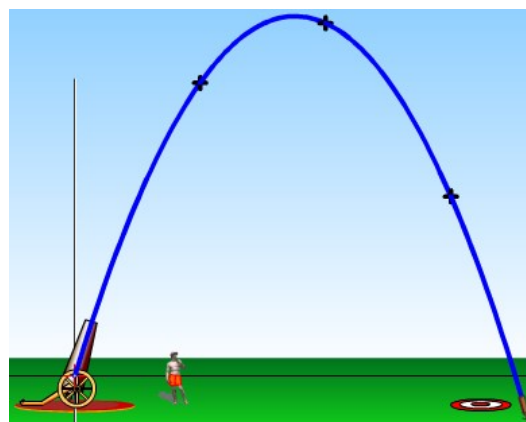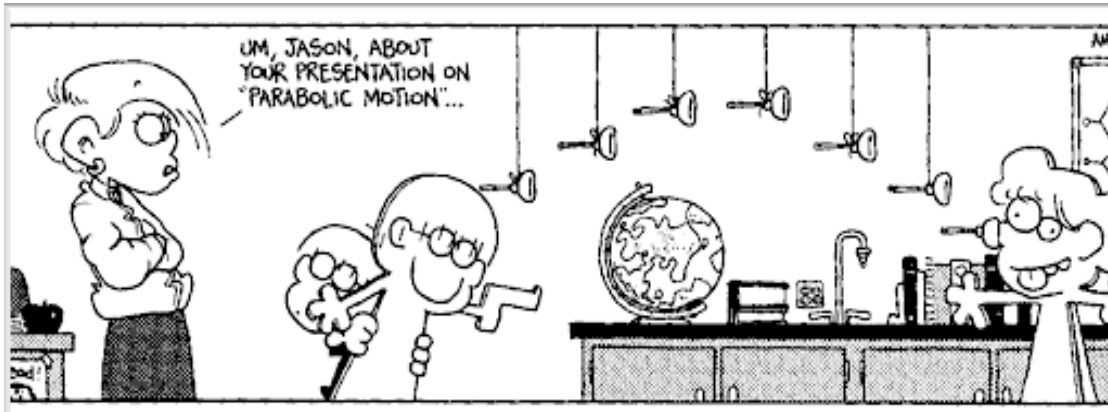
(reprinted with permission from Bill Amend)

Part I Questions:

1. Keeping the "Initial Speed" and "Projectile Type" constant and the "Air Resistance" unchecked, what angle results in the longest horizontal distance?

2. Keeping the "Initial Speed" and "Projectile Type" constant and the "Air Resistance" unchecked, what angle results in the highest vertical distance?

3. Keeping the "Initial Speed" and "Projectile Type" constant and the "Air Resistance" unchecked, launch a projectile at 30°. What angle results in the same horizontal distance?

4. Keeping the "Initial Speed" and "Projectile Type" constant and the "Air Resistance" unchecked, launch a projectile at 75°. What angle results in the same horizontal distance?

5. What "rule" could you make concerning the launch angle and the resulting horizontal distance?

6. Sketch the path of a true projectile (no air resistance) fired at 50°. What shape is it?

7. How does the mass of a projectile affect the horizontal distance if fired at the same initial speeds?

8. Fire a projectile of your choice at 45°. Leave the traced path on the simulation. Turn on the "Air Resistance". Fire the same projectile at the same angle. What happens to the vertical and horizontal distances?

9. What angle should you launch a projectile to make it travel the farthest horizontal distance with air resistance?

10. For our last experiment with the simulation, set the following conditions PRIOR to firing… (No air resistance)
> • Set the angle to 65°.
> • Select the "Buick" projectile
> • Set the Initial Speed to 20 m/s
> • Show your work for the calculations below:

10a. Calculate the total time of flight. _____ sec

10b. Calculate the vertical height of the Buick at its highest point of its trajectory. _____ cm

10c. Calculate the horizontal distance the Buick travels. _____ cm

• Before you "fire" the Buick, set the red target where you have pre-calculated it should land. Now launch… "FIRE IN THE HOLE!"

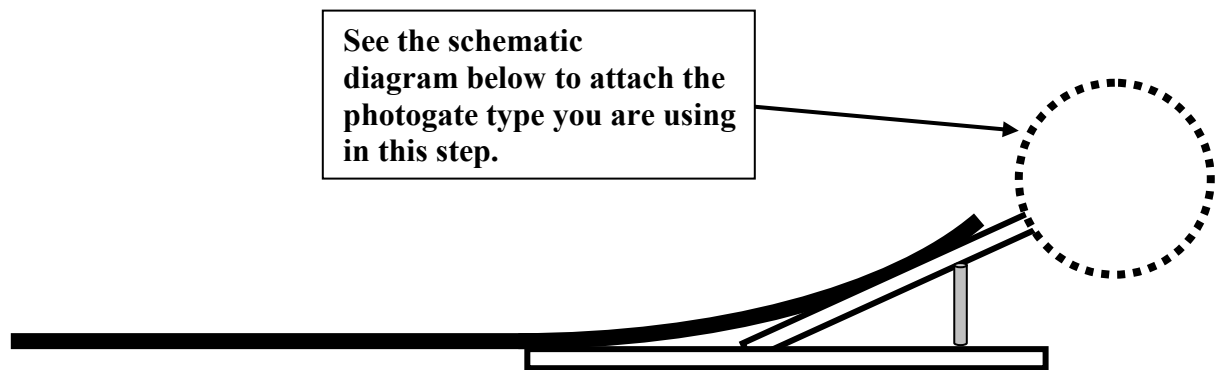## Part II- Stunt Car Challenge!

Materials:
- Darda car
- Jump track
- ramp assembly
- 3 angle posts (3 different length dowels)
- "ring of fire"
- photogate
- meterstick
- carbon paper
- protractor
- calculator

Procedure:
- Set up your jump track assembly on lab tables, on the floor in the classroom or hallway. If your ramp is not pre-assembled for you, attach the track to the ramp assembly using the screws provided. Be careful not to strip the screw holes but be certain to tighten them so they are as flush as possible with the track surface.

- Each ramp assembly has three angle posts which are used to set the angle of the launch ramp. Because of the wood construction, perfect precision is not possible so expect error of + 1% in the ramp angle. The longest post will set the ramp at 30°, the next smallest at 20° and the smallest post at 10°. Be certain to insert the dowel with the round end UP and the flat side DOWN securely into the ramp assembly. Only SLIGHT pressure is necessary to properly seat the angle post. The dowel rods (10°, 20° and 30°) correspond to the holes in the track and MUST be set perpendicular to the base of the track.

- Your teacher will assign your "stunt team" a launch angle. Set your launch angle using the dowel rod in either the 10°, 20° or 30° hole in the launch track and measure the actual angle of the track from the horizontal to provide accuracy in your calculations.

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  - Turn on your *LabQuest/LabPro* and this will activate the photogate.
  - The measurement read by the *LabQuest* is the total time the photogate is blocked by the car.

- Before you launch your car, your partner must prepare to catch the car as it leaves the ramp using the fish net.
- The Vernier photogate timer will record the time that the entire toy car body passes through the photogate.
- The resulting velocity of the car can be found by calculating the length of the toy car divided by the time the car takes to pass through the vertically-arranged photogates. $v = d/t$

- For **Arbor Photogates:**
  - Attach a single Photogate to the Arbor Timer.
  - Screw the Photogate on the track vertically (see diagram) to capture the motion of the car as it passes through. The car will block the light beam as it passes through the gate.
  - Use the Mode button to choose "Gate Mode."
  - Launch the car through the Photogate.
  - Find the car's velocity by dividing the car length (the distance traveled) by the measured time (the time it took to travel that short distance).--> $v = d/t$
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See the schematic diagram below to attach the photogate type you are using in this step.

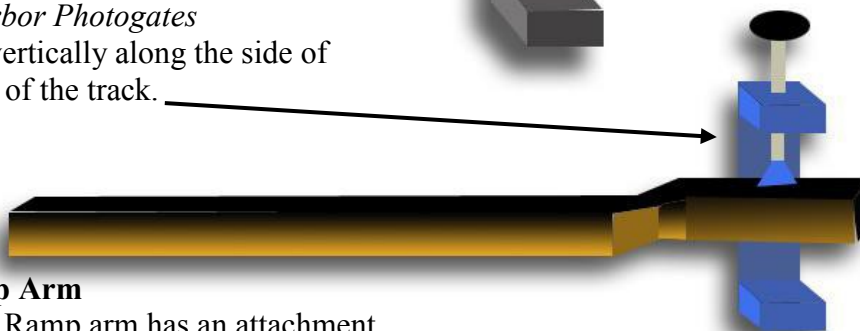*For use with the Vernier Photogates*
This plate screws into the photogate arm of the ramp and has a thumb screw attachment that uses the attachment hole provided in the photogate.
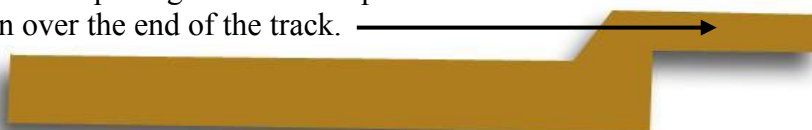
Screw attachment to ramp arm.

For use with the Arbor Photogates
Photogate clamps vertically along the side of the ramp at the end of the track.

Top View of Ramp Arm
New mod to Speed Ramp arm has an attachment bracket that allows for the photogate to be clamped in a vertical position over the end of the track.

Plastic Track

- Attach the cord from the photogate to the timer and plug in the timer. Turn on your *LabQuest* and this will activate the photogate. The measurement read by the *LabQuest* is the total time the photogate is blocked by the car.

- Before you launch your car, your partner must prepare to catch the car *just* after it leaves the ramp using the fish net. The photogate timer will record the time that the entire toy car body passes through the photogate.

- For the "Darda" pull-back car to provide a consistent launch speed for each trial, ***carefully and gently*** push down on the toy car and pull back until you hear a loud click. Make sure the wheels don't spin for consistent measurements. When you are ready to launch, release the car (or tap it lightly on the roof) and it will accelerate down the track. You MUST launch the car from the end of the track; the SAME starting position each time! Have your partner ready to catch the car EACH TIME just as it exits the ramp with the fish net.

PLEASE BE GENTLE WITH THE DARDA PULL-BACK CARS!
**THEY CANNOT TOLERATE ROUGH HANDLING!**

- Now you are ready to launch your car to determine its speed at the end of the launch track. Launch the car five times through the photogate and record the times in seconds.

BE CERTAIN TO CATCH YOUR CAR WITH THE FISH NETS!

Time measured by photogate in seconds

Trial #1 ____sec Trial #2 ____sec Trial #3 ____sec Trial #4 ____sec Trial #5 ____sec

Are the data consistent? If not, did the photogate record more than one event? Should that data count?
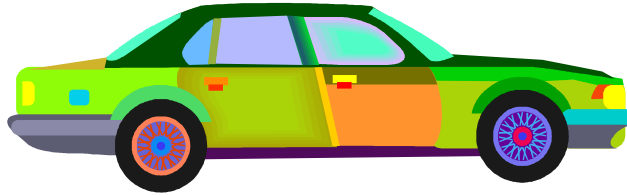
11. Calculate your average time through photogate: _____sec

12. What is your team's launch angle? _____degrees

13. What is the length of your toy car (in meters) _____m

14. Mark your measurement of the car's dimensions on the diagram above and explain those measurements in terms of your photogate/photodetectors and where they line up in relation to your car.

DO NOT LAUNCH YOUR CAR YET!

Calculations ⟶ *Use appropriate equations and show your work!*

15. Calculate the initial velocity **(vi)** of your car in **m/sec** as it leaves the ramp using the following equation: vi = car length/ave. photogate time: _____m/sec

16. Calculate the horizontal component of the vi: _____m/sec

17. Calculate the vertical component of the vi: _____m/sec

18. Calculate the time of flight for your toy car: _____sec

19. Calculate the horizontal distance your car will travel: _____ m

20. Calculate the maximum vertical height your car will travel: _____ m

- On the diagram, indicate the following
  - Launch Angle
  - Initial Velocity of your car
  - Your calculated prediction of the car's Horizontal Distance
  - Your calculated prediction of the car's Maximum Vertical Height
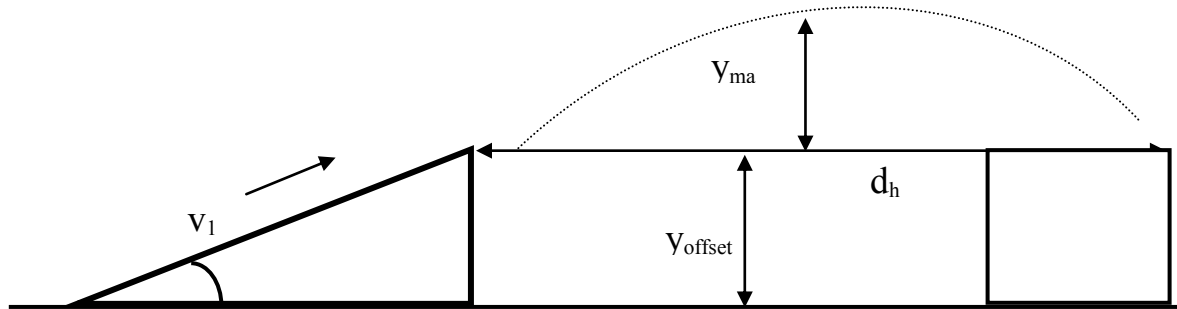
Ladies and Gentlemen … Start Your Engines!

- Place a white sheet of paper where you have predicted the car's horizontal landing spot. IT IS IMPORTANT TO HAVE THE LANDING HEIGHT THE SAME AS THE LAUNCH HEIGHT! Stack your textbooks to create a landing spot with the SAME height as the launch height. Tape the white paper to the textbook and PLACE A MARK AT YOUR CALCULATED HORIZONTAL DISTANCE. Place a piece of carbon paper on top of the white paper.

- Place the "Ring of Fire" assembly at the d_h **midpoint** and adjust the ring so that it correlates with your maximum vertical height prediction.

- **Launch the car** from the SAME starting position as in the earlier trials and observe the mark made by the car striking the carbon paper on the landing pad. If the car hits the carbon paper, there should be a mark on the paper where your partner can measure the actual horizontal distance the car traveled. Record this distance below.
    - Calculated Horizontal Distance (meters) _____
    - Experimental Horizontal Distance (meters) _____

22. Calculate the <u>Percent Difference</u> between the calculated horizontal distance (Calc) and your experimental horizontal distance (Exp) using the equation below:

$$\frac{Exp - Calc}{Calc} \times 100 = \%Difference = \underline{\hspace{2cm}}$$

23. How well did your calculated results compare with the actual launch results?

24. If there was significant error, discuss some of the factors attributing to the fluctuations in the values?

Part II Additional Questions:

25. A cannon is fired at 100m/sec at an angle of 30 degrees. Find the:
    a. time in the air_____
    b. maximum height of the cannonball_____
    c. how far the cannonball travels horizontally_____
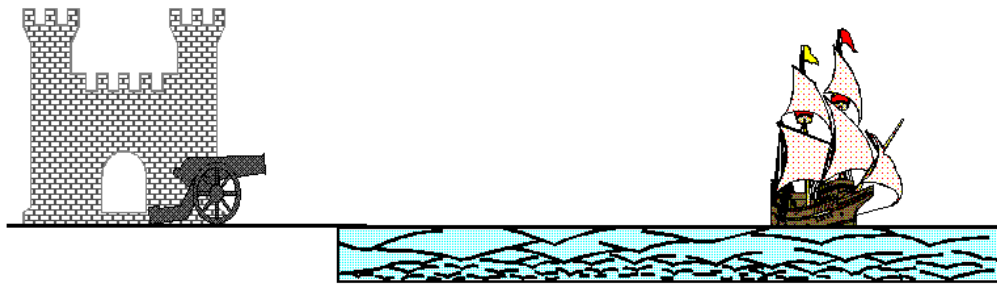
26. Using a six-iron (45° loft) and the same launch velocity as on Earth (70 m/s), how far horizontally did Apollo 14 Astronaut Alan Shepard drive a golf ball on the Moon? _____
[Hint… to find the time of flight, use g = 1.6 m/s2 for the Moon.]