Flying Hot Wheels

**Topic:** Projectile Motion

**Key Concepts:**
- Horizontal velocity is constant
- There is a point at which the vertical velocity is zero
- Mass does not affect projectile motion
- The higher from the ground the takeoff point, the farther the distance traveled
- Human error
- Equations:
  a. Horizontal distance: \( x = V_x t \)
  b. Horizontal velocity: \( V_x = V_{x_0} \)
  c. Vertical distance: \( y = V_{y_0} t - \frac{1}{2} gt^2 \)
  d. Vertical velocity: \( V_y = V_{y_0} - gt \)
  e. [https://formulas.tutorvista.com/physics/projectile-motion-formula.html](https://formulas.tutorvista.com/physics/projectile-motion-formula.html)

**Materials (per group):**
- Three Hot Wheels of similar size
- Small weights
- Scale (weigh cars)
- Hot Wheels tracks
- Tape measure (measure height of takeoff point and distance traveled)
- Tape (mark where it hits the floor and also to tape on the weights to the cars)
- Large blocks (raise track)
- Stopwatch
- Pencils or stick to hold car at top of ramp
Safety Concerns:
- Students getting hit by/throwing materials

Data:

<table>
<thead>
<tr>
<th>Mass of Car (g)</th>
<th>Distance Traveled (in.)</th>
<th>Time to land (s)</th>
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<thead>
<tr>
<th>Height (in.)</th>
<th>Distance Traveled (in.)</th>
<th>Time to land (s)</th>
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Activity:

1. Initial testing of the variables (~5 minutes):
   a. Write the question on the board:
      i. How can we change the distance and time it takes for a car to launch and hit the ground?
   b. Tell students that they will be launching cars off a ramp in order to answer the previous question.
   c. Provide the students with the necessary materials, listed above.
   d. Break the students into groups of 2-4, and tell them that this is the group they will be in for the remainder of this exercise.
e. *What safety concerns should we consider before starting to launch the cars?*

f. Allow students ten minutes or so to play with the cars, and encourage them to change the variables in order to test how they affect how far the car goes. Tell them to write down their observations in their notebooks.

2. **Discussion of variables (~10 minutes):**

   a. Have students sit down around their setups in their separate groups.

      Discuss the variables that they think can affect projectile motion. List student’s answers on a board. Have students write down their answers (hypotheses) in their notebooks.

      i. *What variables could we change?*

         1. Wait time I and II

      ii. *Of the listed variables, which do you think will affect the projectile motion the most? How will they affect the motion?*

         1. Wait time I and II

   b. Guide students towards mass and height.

      i. *How might the height of the ramp affect the distance the car goes?*

      ii. *How might the mass of the car affect the distance the car goes?*

   c. Have students write down how they think each variable will affect the distance and time the car travels, then discuss in their groups, then discuss as a class. Have them write down their answers for future reflection. *Teachers should be walking around, asking open-ended questions to bring student misconceptions to light. They should also note when student conversations halt, and move on to the next section.*

      i. *How do you think mass/height/ will affect the projectile motion?*

      ii. *What exactly is mass? How can you change it?*

      iii. *How can you change the height of the ramp?*

3. **Write up the methodology of the experiment -- 15 minutes:**
a. Have each group choose one variable for the experiment (mass of car, height of ramp). With the students around their setups, ask: What might be the best way to test your chosen variable?

b. Tell students to write down the exact steps they would take in order to test their variables in their notebooks. They should each write them down in separate notebooks.
   i. What independent and dependent variables are we testing?
   ii. How can we best test this variable, in relation to time and distance?
   iii. What would be the best way to record your results?
   iv. How many trials should be done for each variable?
   v. They might not remember to include time… Remind them to. Ask them when they think they should start recording the time.
      1. What if you test the car with two different masses, but both tests hit the same spot? How do you account for the difference in flight path? (Answer: you want to record time in flight)

c. Also encourage them to draw a diagram of what they want their setup to be. *Walk around and see what students are thinking. Ask questions to guide their methods. Focus on only asking questions and not giving answers.*

d. Once they write down their methods, discuss as a class.
   i. What kind of table might you draw to record your data?

e. Have them each draw tables in their notebooks somewhat similar to the ones shown above.

4. Secondary testing of variables -- 20 minutes:
   a. Have students systematically test each variable (mass of car or height of ramp). Encourage them to draw a diagram of their set up throughout each iteration. Also have them write down their data in the datatables they made.
i. Why is it important to change only one variable at a time?

b. As students test their methodology, walk around the room to ask questions to see where any gaps in knowledge might be.
   i. Why did you decide to start the timer at this point? (letting go of car vs. leaving the ramp)
   ii. How are you going to record when the car hits the floor?
   iii. How do you think you can improve your methods?
   iv. How do you think gravity is affecting the car?
   v. How do you think your variable affects distance and time?

c. Have students write their data on the board. Discuss the data.
   i. What’s a good visual way to look at the data? (Graphs)
   ii. Which variables appear to affect projectile motion?

d. As students are testing, write the equations above on the board. Label each variable. *If students ask what the equations mean, ask them, What do you think the equations mean?*

5. Discussion of Equations -- 20 minutes:

   a. Once students are done, have them sit down and look at the board.

   b. Have students talk in their groups about what they think each equation means for a few minutes. Then, have them share their ideas for each equation with the class. Write down their ideas verbatim underneath each equation, and go over each statement and how they might differ or accentuate what the equations mean.

   i. Why does gravity not affect the X-direction in the case of this experiment? What direction does gravity go in?
   ii. How can you calculate the velocity of the car?

   iii. Calculating velocity (speed):

      1. What units of speed are there? (car-miles per hour->distance over time->inches/cm over sec)
      2. What unit is velocity? (m/s)
3. What are the units for each variable in the equations?

c. Once they understand how distance and time affects velocity, ask them, 
*How do you think you can calculate the distance a car might go?*

d. Go over an example problem with them:

i. A car launches off of a ramp with a horizontal velocity of 10 m/s and a vertical velocity 15 m/s. The ramp is 50 m above the ground. How far (horizontal distance) will the car travel before it hits the ground?

\[
\begin{align*}
\Delta y &= 0 \\
\Delta t &= 0 \\
\Delta x &= 0 \\
V_x &= 10 \text{ m/s} \\
V_y &= 15 \text{ m/s} \\
y &= 50 \text{ m} \\
g &= -10 \text{m/s}^2 \\
\end{align*}
\]

1. Why do we get a negative time?

ii. Have them try to solve the problem in their groups. Walk around and help each group solve the problem. Then, once the group figures the example out, they can go onto the next part.

6. Application of variables -- 15 minutes:

a. Put a piece of tape on the ground somewhere in the path of the track.

b. Have students use the projectile motion equations to calculate how to use their chosen variable to allow them to hit the piece of tape with the car. They will do this in individual groups. *Teachers should walk around and help the groups through solving these equations.*

c. Give the students as many attempts as they need to launch a car and hit the piece of tape by changing only their chosen variable, while keeping velocity constant.
d. Whoever gets it on the first try gets candy or something! Or a car!

6. Discussion -- Rest of class:
   a. Ask a series of questions to solidify the information the students have just learned. *Teacher should be sitting down with the students, preferably at a long table or on the floor. The teacher should also restrain from answering or asking too many questions, purely leading the discussion.*
   b. Questions to ask:
      i. How does everyone think this experiment went?
      ii. How did you end up organizing your data?
      iii. Do you think your methods were the best way to approach this problem? What do you think you did well? What could you have done differently?
      iv. How do these different variables (time, velocity, mass) relate to each other?
      v. Which variable affects distance the most?
      vi. How did your understanding of the effect of mass and height change from before and after the lesson?
      vii. Why doesn’t mass alter the projectile motion?
      viii. Why does ramp height affect the projectile motion?
      ix. What other situations can projectile motion be applied to?
         1. Throwing a baseball
         2. Catapult
         3. Jumping
         4. Shooting a basketball
      x. What is in common between each of those situations? (defining a projectile)
         1. Anything that travels under the influence of gravity only
Learning Cycle Questions:

Exploration

1. How does the opening activity stimulate students’ interest and create a need to know?
   a. We are allowing them to explore the exercise prior to explaining what it is actually for. This allows for them to become engaged in the exercise and create their own questions. They are allowed to work with each variable and decide which one they want to test for the remainder of the class.

2. What is the activity’s core question?
   a. *What are the principle characteristics of projectile motion?* We want to try to help the students understand how height and mass affect the way an object moves throughout space using methods from social learning theory.

3. To what extent does the experience help students make predictions, think about their thinking, and become aware of their own preconceptions regarding some aspect of the activity?
   a. The activity is very simple, with only a few variables being changed. This will allow students to look at the idea of projectile motion from a very simple standpoint and understand how motion is affected, which many students might have misconceptions or preconceptions about. By allowing students to engage in the activity from the beginning to the end, they are continuously making predictions, trying to alter their thinking to grasp the concepts in front of them, and becoming aware of their ideas.

4. How are students encouraged to share their initial predictions regarding some aspect of the activity?
   a. Students are encouraged to share predictions inside of their groups and with the class. They also are told to write down their hypotheses in their notebooks.

5. To what extent are students engaged in physically manipulating materials?
a. Students are very engaged because they are manipulating the cars and ramps/tracks and making observations on their own. They are in charge of their own work stations.

6. To what extent are students making decisions and assessing the outcomes of their decision-making?
   a. Students don’t make all of their decisions for themselves, the lesson is guided to where they are given variables to investigate, but they can investigate those variables however they want given the materials they have. They are allowed to choose the variable they want to test, and they create their own method for how to test it.

7. How are students encouraged to make accurate observations and document those observations?
   a. Students are given measuring tools (tape measure, stopwatch) to make measurements. They are given the freedom to explore their materials, and come up with ways in their groups and in the whole class for how to test variables.

Concept Introduction

1. How are students encouraged to compare their predictions to what was actually observed?
   a. After collecting data on each of the variables, the students are encouraged to share their data with the class and discuss the results and how they compared to their predictions. They are also given equations and asked to make their own calculations in order to test their experiment. This compares theoretical and observational methods.

2. To what extent do students share their results with the class/group?
   a. Students discuss their results in individual groups after each step, and then share their results with the class. The teacher also then writes down
what the students have discussed and written in their notebooks verbatim on the board.

3. How are students helped to make sense of the activity?
   a. Students are given the opportunity to understand projectile motion on their own. During each step, the teacher is walking between groups and asking open-ended questions in order to gauge student understanding and misconceptions (Clough, 2008).

4. How is the scientific vocabulary linked to the students' work?
   a. Very little jargon is used throughout the lesson. The students first get to experience the experiment themselves, and then are introduced to scientific vocabulary later in the lesson that relates the experiment that they have been performing.

5. To what extent are students encouraged to re-enter the lab to explore emerging ideas relevant to the scientific concept(s) being taught?
   a. The students constantly move in and out of hands-on and minds-on activities. They flip between working with the materials and talking to fellow students about what they are learning.

6. How is the scientific concept that make sense of the activity introduced so that students can link the two?
   a. The scientific concept is introduced towards the end of the activity through equations, after students have already worked with materials and made an experiment. That way, the students have a physical understanding of what they are testing, and when we introduce the scientific concept later, the students can build off their experience with the experiment and understand the concept better.

7. When students' thinking is at odds with the introduced scientific concept, how are students mentally engaged in wrestling with and resolving incongruence?
   a. The teacher only asks questions back to students and have them figure it out themselves.
8. How are other materials used to help students understand the scientific concept?  
   a. We use materials specific to the experiment that will best demonstrate parabolic motion.

Application

1. What questions or activity is provided to determine whether or not students can apply the scientific concept in unique situations?  
   a. The activity of having students use the equations to try and have the car hit a specific spot has students apply their knowledge on how each variable affected the distance that the car travelled.

2. How are students encouraged to pursue their questions that follow from the concept introduction phase?  
   a. After concept introduction, students then have to perform another experiment in order to solidify the concept we are teaching.

3. To what extent does the application phase eventually lead to an exploration regarding a new, but related, scientific concept thus beginning the learning cycle once again?  
   a. We ask questions at the end that push students to apply their knowledge gained from the experiment, and from concept introduction.
MATERIALS LINKS

- Three Hot Wheels of similar size (8 groups, so 24 hot wheels cars)
  - 5 of the below link
  - https://www.amazon.com/Hot-Wheels-Avengers-Die-Cast-Exclusive/dp/B00KJB0JUG/ref=sr_1_8?ie=UTF8&qid=1542158201&sr=8-8&keywords=hot +wheels+cars+3+pack

- Two small weights
  - 1 order of below
  - https://www.amazon.com/CK-Auto-Adhesive-EasyPeel-Chrysler/dp/B072JXSN9P/ref=pd_sim_263_18?_encoding=UTF8&pd_rd_i=B072JXSN9P&pd_rd_r=99c972d3-e7ab-11e8-9ae7-f7bd06e3c933&pd_rd_w=AncJK&pd_rd_wg=S3ZRg&pf_rd_i=desktop-dp-sims&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=18bb0b78-4200-49b9-ac91-f141d61a1780&pf_rd_r=QE6W815T7A3XZQ2H7BY5&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&psc=1&refRID=QE6W815T7A3XZQ2H7BY5

- Scale (weigh cars)
  - 8 orders of below
  - https://www.amazon.com/American-Weigh-Scales-AWS-600-BLK-Nutrition/dp/B000O37TDO/ref=sr_1_5?s=kitchen&ie=UTF8&qid=1542158975&sr=1-5&keywords=small+scale

- Hot Wheels tracks 40 ft
  - 1 order of below
  - https://www.amazon.com/Hot-Wheels-Track-Builder-Straight/dp/B00IVL1C1O

- Tape measure (measure height of takeoff point and distance traveled)
  - 1 order of below
  - https://smile.amazon.com/Blisstime-Tailor-Sewing-Flexible-Measure/dp/B00UFG1HXS/ref=sr_1_14?ie=UTF8&qid=1542158774&sr=8-14&keywords=tape+measures
• Tape (mark where it hits the floor and also to tape on the weights to the cars)
  ○ 1 order of below
• Large blocks (raise track and change takeoff angle)
  ○ 1 order of below
  ○ https://www.amazon.com/Glitz-Star-Painting-Supplies-Children/dp/B01MXW7578/ref=sr_1_2_sspa?ie=UTF8&qid=1542158687&sr=8-2-spons&keywords=wooden+blocks&psc=1
• Protractor (measure takeoff angle)
  ○ 1 order of below
  ○ https://www.amazon.com/eBoot-Degree-Plastic-Protractors-Measurement/dp/B072L2R52P/ref=sr_1_1_sspa?ie=UTF8&qid=1542158805&sr=8-1-spons&keywords=protractors&psc=1
• Stopwatch
  ○ 1 order of below
  ○ https://www.amazon.com/BSN-Sports-Mark-Stopwatch-Color/dp/B00428AMHC/ref=sr_1_6?ie=UTF8&qid=1542158856&sr=8-6&keywords=small+stopwatches
• Stick to hold car at top of ramp
  ○ 1 order of below
  ○ https://www.amazon.com/Loew-Cornell-1021173-Woodsies-Dowels-Pkg/dp/B0033F4GSQ/ref=sr_1_4?ie=UTF8&qid=1542158908&sr=8-4&keywords=thin+sticks