Lesson Title	Cars
Length of Lesson	45 minutes
Created By	Matthew Lee, William Funderburk, and Henry Stauffenberg
Subject	Physics
Grade Level	11-12
State Standards	Physics: 1 and 2b
DOK Level	DOK 4
DOK Application	Analyze, Draw Conclusions, and Develop a Logical Argument
National Standards	Physics B
Graduate Research Element	Data analysis, model fitting, estimating error.

Student Learning Goal:
The purpose of this lesson is to teach the students about collecting data and developing a model that explains a phenomenon. In this case, we will be studying toy cars

<u>Mississippi Standards:</u>
Physics: 1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.

a. Use current technologies such as CD-ROM, DVD, Internet, and on-line data search to explore current research related to a specific topic.
b. Clarify research questions and design laboratory investigations.
c. Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development).
d. Organize data to construct graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs) draw conclusions and make inferences.
e. Evaluate procedures, data and conclusions to critique the scientific validity of research.
f. Formulate and revise scientific explanations and models using logic and evidence (data analysis).
g. Collect, analyze, and draw conclusions from data to create a formal presentation using available technology (e.g., computers, calculators, SmartBoard, CBL's, etc.).

Physics: 2b Analyze, describe, and solve problems by creating and utilizing graphs of one-dimensional motion (e.g., position, distance, displacement, time, speed, velocity, acceleration, the special case of freefall).

<u>National Standards:</u>
Physics:
Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F=ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

Materials Needed (supplies, hand-outs, resources):
Two types of toy cars (wind-up and battery powered), stop watch, distance measuring tool (meter sticks, yard sticks, tape measure, etc.), tape for marking starting and finish lines on the floor, and about 2 square meters of floor space (carpet might not work with some cars).

The wind-up car will not have a constant velocity, but the battery powered car should have a constant velocity once it gets up to speed. The wind-up car can be one with a crank or one that they need to pull back to wind-up. Make sure the batteries are not running down, or they will not be able to get good data.

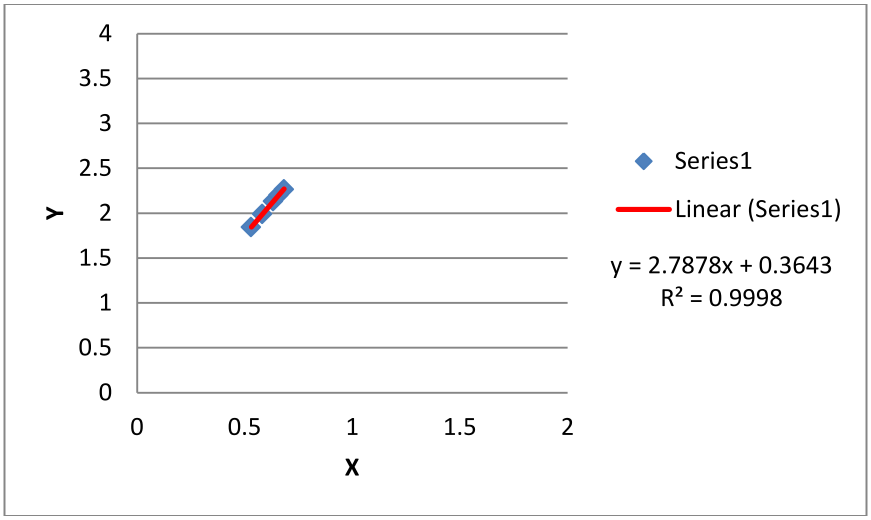
Lesson Performance Task/Assessment:
In this lesson, the students will be collecting distance vs. time data for both of their cars. The best way to do this is to set the distance and measure the time it takes the car to travel the distance, but I did not discourage the students from attempting to set the time and measure the distance the cars traveled in the time interval. However, almost all the students made the easiest choice. If they wind-up their cars the same way each time, and control all other variables carefully, they can get some good distance vs. time data for both cars. This can then be used to calculate velocity and acceleration. (The calculated values will most likely have a lot of noise.) The students will get measuring distance and time to get velocity and acceleration, but it is also a goal of this lesson to teach them about how they collect their data so they can describe the motion of the cars over a range of distances. In my experience, they don't get this easily, and some guided practice will be necessary to help them. If they understand this part of the experiment, then they will pick a lower and upper bound for their distances, and evenly space their distance vs. time sampling in that range. This will give them better, more accurate graphs of the data.

Lesson Relevance to Performance Task and Students:
The students will collect data, and attempt to develop a model for the physical behavior of the cars. If they make good sampling choices within their range, they will get better results.

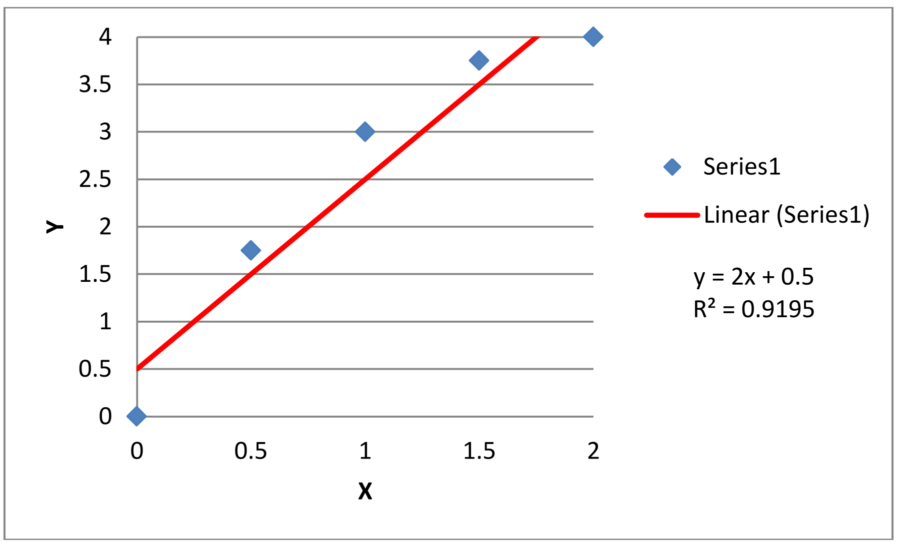
Anticipatory Set/Capture Interest:
The hook for this lesson is that they get to use/play with toy cars, and they will be applying their physics knowledge to understand the cars in ways they probably never did before.

Guided Practice:
It is probably a good idea to teach them the equations for computing velocity and acceleration before attempting this lesson.

When I used this plan with my students, most of them got how to compute velocity and acceleration, but few realized they needed to pick sample points that we evenly distributed in the range they were interested in. It is probably a good idea to teach them that they need to do this in order to get a good understanding of the motion of the cars. For example, if all their data points are something like the graph below, they may not realize that the function is not linear. (The function is really $y = -(x-2)^2 + 4$.)



However, if they spread their samples out, they will see that a linear trend-line is not appropriate.



Independent Practice:
The students will use the stopwatch, measuring stick, and tape to collect distance vs. time data for about five data points per car. In order to get better data, the students can repeat their data collection several times and average their results. You should tell them how many times they should replicate the experiment.

Remediation and/or Enrichment:
You can enrich the lesson by having the students compute trend-lines using Microsoft Outlook. There is a lesson plan describing how to do this, but you can also find information about it on the Internet.

Check(s) for Understanding:
The teacher can ask questions and observe the students during the lab. In addition, the distribution of the data the students collect will indicate that they understand how to distribute their data points.

Closure:
For closure, go over what the students observed about the motion of the cars. Ask the students some questions.

- Which car moves at a constant velocity?
- Which car moves at a non-constant velocity?
- If the cars were to race over a short distance, which one would win?
- If the cars were to race over a long distance, which one would win?

Possible Alternate Subject Integrations:
Math

Teacher Notes: