**Video Physics: Hot Wheels® Loop-the-Loop**

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***Introduction***

Many toys that have initially been designed for very young children to play with are now proving to be of tremendous value in the physical science and physics classroom. One of these toys, introduced by the toy maker Mattel in 1968, is Hot Wheels®. One of the many items in this product line is the classic Dash & Crash™ Speedway Track Set, which includes cars, launchers, and a track for constructing a loop-the-loop. Interfacing Hot Wheels with Vernier Video Physics™ provides a great way for students to study both the kinematics and dynamics of loop-the-loop physics in the classroom.

***The Investigation Setup***

Figure 1 shows the loop-the-loop with a car coming in from the left. A ring stand is used to support the top of the loop so that it will be stable and not act like a spring when the car negotiates the loop. A meter stick is placed as close as possible to the plane of the track so that a scale can be set in Video Physics.



*Figure 1*

Figure 2 shows the launcher with the car ready for launch. A tiny LED with constant white light is attached to the top of the car with a small piece of Scotch® permanent clear mounting tape. The purpose of the LED, which is quite bright, is to make it extremely easy to locate the car while adding points in Video Physics. The LED is available from www.thatscoolwire.com as a product called Constant LED “Power Dots”for about a dollar each. The tape is strong enough to keep the LED from falling off the car during the rapid ride around the loop, yet it does allow removing the LED so that it can be turned on and off as desired.



*Figure 2*

***Video Physics Considerations***

In order to obtain the most detailed graphs from Video Physics, it is suggested that the camera be set to slow motion (slo-mo) when capturing the video. This will result in a frame rate of 120 fps for an iPhone 6, and can even go as high as 240 fps for the iPhone 8. The resulting video will be somewhat darker at the higher frame rates, but that is not an issue when adding points in Video Physics, as the LED is quite bright. The total time for the car to negotiate the loop is on the order of ½ second, so using the movie option to advance the movie by two frames after adding a new point works best with a frame rate of 120 fps. Note that if you use slo-mo at a data rate of 120 fps, you will need to right-click on the video in Logger *Pro*®, select Movie Options, and change the frame rate from the default 30 fps to 120 fps.

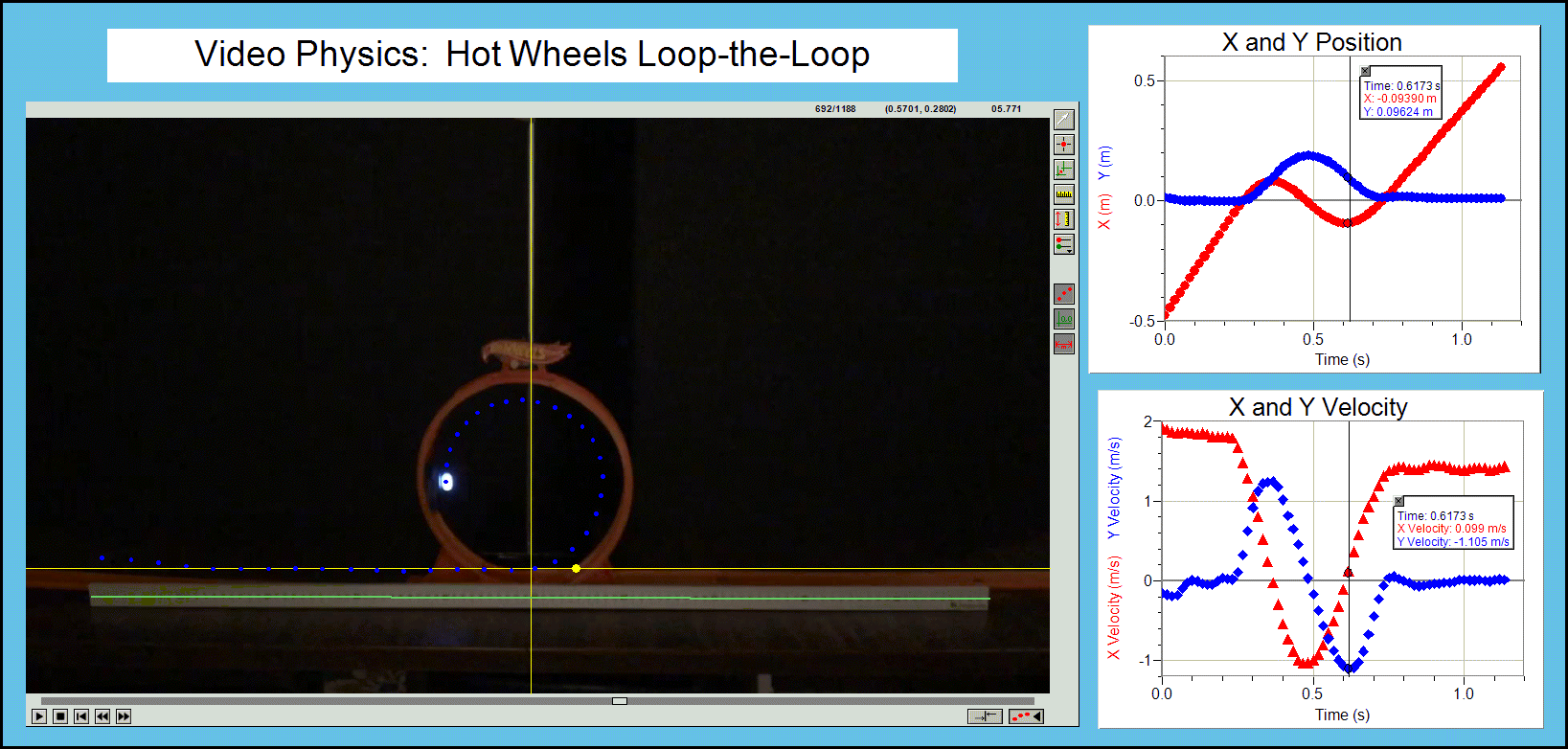
Two videos accompany this document. One was taken with the default video frame rate of 30 fps, and the other was taken with a slo-mo rate of 120 fps. The slo-mo video is especially nice for viewing as the motion is slowed down by a factor of four, and there is also less blur from the LED. If desired and you don’t have access to Hot Wheels, teachers are welcome to use these videos for students to do their own video analysis.

***Results***

Figure 3 shows a screen capture from Logger *Pro* after analyzing a video captured at 120 fps. The green line shows that the scale was set to the length of the meter stick. The yellow grid lines intersect at the origin, taken as the location of the car (coming from the left) just as it enters the loop. The trail of blue dots contains points that are spaced 1/60th of a second apart (every other frame in the video).

The graphs on the right side of Figure 3 contain X and Y position and X and Y velocity as functions of time—red for X and blue for Y. The two vertical “examine” lines at 0.6173 s refer to the somewhat blurred white LED shown in the video on the left of Figure 3. At this location, the X position is at its maximum negative (when the car is inside the loop). The Y position is midway between the highest and lowest points in the loop. Since there is no horizontal motion at that point, the X velocity is zero. The Y velocity is at its maximum negative value at that point.

Two Logger *Pro* files accompany this document. One is for a loop-the-loop video at standard 30 fps, and the other is at 120 fps.



*Figure 3*

***Extensions***

1. Instead of using the launcher for the car, let the car, starting at rest, roll down the track from a height *h* above ground level, as shown in Figure 4. At what minimum height does the car need to be placed to negotiate the entire loop without losing contact with the loop? What is the ratio of *h/r* when this condition is met?

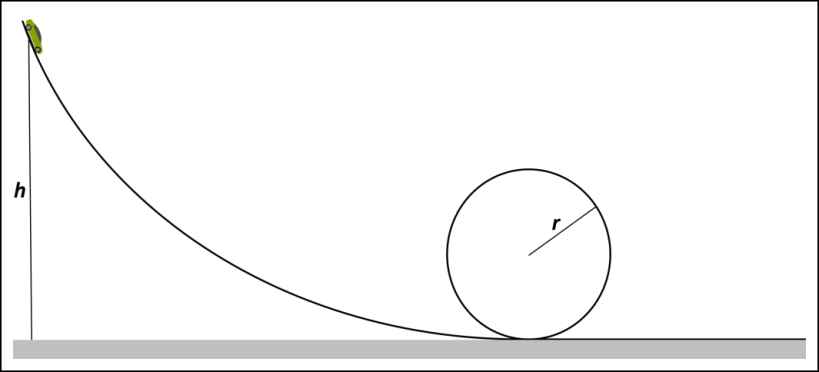


Figure 4

1. Now imagine that a block slides down a frictionless ramp from a height *h* and enters a loop of radius *r*. With the aid of free body diagrams and conservation of energy, derive an expression that specifies the height *h*, in terms of *r*, at which the block negotiates the entire loop without losing contact and falling. Hint: To determine the minimum height to keep the block from falling off the track, the normal force would be zero at the top of the track. *[Answer: h = 5r/2]*
2. Explain any differences between your experimental results and theory.