

# AP Physics 1 Fourth Quarter Project: The Line Rider Rides Again!

Rev. 1: Added alternate method for determining Wf Rev.2: Separate sections for both methods of determining Wf



*Line Rider* is an internet game, originally created in September 2006 by Boštjan Čadež (also known as "fšk"), a Slovenian student. Soon after its initial appearance on [DeviantArt](#), *Line Rider* became an internet phenomenon. The basic concept is to draw one or more lines with the **mouse** on which a boy (referred to as "Bosh" by the creator<sup>l</sup>) on a sled can ride after the player presses the "Play" button. The game includes simulated **physics**,

which means the track must be sufficiently smooth to prevent the character from falling off the sled. The author has said that he prefers the description "toy" to "game", as there is no goal to accomplish, nor does it have an end.<sup>[8]</sup> In spite of its simplicity, many complicated tracks have been created, which include loops and other stunts. New tracks can consist of unrealistic tricks such as "flings" and "manuals" both on and off the sled. Many tracks created by the community have been set to music, others use background art to fill their tracks with hand-drawn mountain slopes and trees. Tracks are typically shared among users by uploading a video to websites such as [YouTube](#).

## 1. Software Setup

- Go to <https://www.linerider.com/> and experiment by making some simple tracks and letting the little guy go sledding. (Note: There is a newer version located at <https://linerideradvanced.com/> but it only runs on Windows or Apple laptops. We are not going to use it for this project).
- There is also a good introductory video located at: <https://www.youtube.com/watch?v=DcjcTZRNoH8>. This shows one way to analyze some of the Line Rider physics, but we are going to use a better method.
- You will be recording your tracks using Screencastify. <https://www.screencastify.com/> Make sure you have it on your Chromebook.
- You will be using Vernier Video Analysis. There is a free trial available at: [www.vernier.com/video-analysis/](http://www.vernier.com/video-analysis/)
- The instruction manual for Video Analysis is at: <http://www2.vernier.com/manuals/video-analysis-manual.pdf>

## 2. Line Rider Practice

- Here are some hints on the drawing tools at the top of the screen:
  - There are 3 colors of lines. Blue is for a normal downhill track, red is an accelerator track (more on that later) and green is just for scenery artwork.
  - There are 3 types of drawing tools. The leftmost one is for drawing smooth curves, the middle one is for normal lines, and the right one is for straight lines.
  - The eraser is for, well, erasing. To completely start over, click on the small file icon on the left and select “new.”
  - The arrow tool is for making adjustments to drawn lines. Try it out.
  - The compass tool will move your track and rider up, down, left, or right.
  - The zoom tool will allow you to zoom in or out.
- Here are some hints on the playback tools at the bottom of the screen:
  - The timeline along the bottom records time in seconds:frames. There are 40 frames per second.
  - The basic play, pause, stop, step back, step forward are the first 5 icons
  - The flag allows you to set an intermediate starting point anywhere along your track.
  - The slow motion button slows down the action but still keeps accurate time
- Here are some hints on the file tools at the left side of the screen:
  - The top icon erases your entire track and gives you a blank screen
  - The up arrow allows you to load a saved track
  - The next icon down is to save a track file
  - The camera icon is for exporting a video. This feature does not work on this version of Liner Rider. No problem - we will use Screencastify instead.
  - The gear icon is to change some Settings. Click on Settings, then click on General, and make sure Smooth Playback is selected.
  - Go back to Settings and click on Riders. ***Very Important: Notice the slider bar called “Keep Rider In View While Scrubbing.” When this is selected (to the right), the background will move to keep the rider in the center of the screen. When it is deselected (to the left), then the background will remain stationary when you hold down the frame advance button (double right arrow). Make sure it is slid to the left. This is critical for the video analysis part of the activity!***

- The help and info icons are not very useful.

### 3. Screencastify Practice

- Here are some hints on how to use Screencastify:
  - Draw your track (or no track for free fall) in LineRider
  - Click on the Screencastify icon (looks like an arrowhead) at the top right of your screen. The Screencastify control box should open up.
  - Make sure “Browser Tab” is selected and click on Record. You will hear the countdown, and once it starts recording, the controls minimize and move to the bottom left of your screen.
  - Click and hold down the **double right arrows** in Line Rider. Do not use the single Play arrow! When the rider reaches the end of his ride, release the double right arrows.
  - In the Screencastify controls, click on Pause and then End Recording.
  - The Screencastify Video Details window will load automatically. On the right side, click on Download and then Export as mp4.
  - **Important: Click the box “Convert to Fixed Frame Rate” and type in 10 fps (frames per second). Click on Export.**
  - You will see the file conversion progress window in the lower right corner. When it is finished, click on Download mp4.
  - Select the folder to download the mp4 video file to. Give it a name that you will remember. It must end in “.mp4” or it will not be accessible in the video analysis step.

### 4. Vernier Video Analysis Practice

- Here are some hints on how to use Vernier Video Analysis
  - After you open the program, click on Import Video. Locate and select the .mp4 file that you saved in Screencastify.
  - Click on the gear in the lower right corner and make sure the frame rate matches what you saved from Screencastify, which should be 10 fps.
  - Click on the 3 rectangles in the top right corner. Turn off the data table and turn on 2 graphs. The first graph is the x and y position versus time, and the second is the x and y velocity versus time.
  - Click on the Scale button on the left. Move the two connected circles to the left end and right end of his sled. Enter 0.75 m in the box. Click anywhere outside the box for the new scale factor to take effect.

- Move the single circle (origin) to line up with the starting height of the rider.
- Use the clockwise arrow button at the bottom to step the video forward until the Line Rider starts to move
- Click on the Add button in the top left (it looks like a plus sign). Line it up with the center of his sled, and click once. A dot will appear, and the video will advance one frame.
- Continue to add points until the rider is no longer visible.
- Instructions on how to do the graphical analysis and how to save your files will follow in the “Your Challenge” section.

## 5. Your Challenge

The goal of this activity is to reverse-engineer the physics of Line Rider, specifically what is going on with **gravity, air resistance, and friction**. You may work by yourself or with one or two other students. One completed project report per group will be submitted to Google Classroom. More on your final report later.

- **Objective #1: Determine the Acceleration of Gravity and Air Resistance**
  - Make a Screencastify recording of the Line Rider in free fall. Make sure you use the double right arrows so that the rider moves, not the background!
  - Save your video as an mp4 file at 10 frames per second
  - Import your mp4 file into Vernier Video Analysis. Follow the steps above to add points to the video and create the position and velocity graphs
  - Make sure you set the scale. The length of the sled is 0.75 m.
  - Go to the position graph, and click on the 3-dot graph in the lower left corner. Select Apply Curve Fit, Quadratic, and Apply.
  - Look at the graph of  $y$  vs.  $t$ . Make sure the  $y$ -axis units are meters, not pixels. Look at the BLUE curve fit numbers. The curve fit gives the coefficients of the quadratic equation,  $ax^2 + bx + c$ .
  - Recall that for an object in free-fall,  $y = \frac{1}{2}gt^2$ . This means that the “ $a$ ” in your curve fit represents  $\frac{1}{2}g$ , where  $g$  is the acceleration of gravity. Solve for  $g$  and record your calculated values for  $a$  and  $g$  in your data.
  - Go to the velocity graph, and click on the 3-dot graph in the lower left corner. Select Apply Curve Fit, Linear, and Apply.
  - Look at the graph of  $y$  velocity versus  $t$ . The BLUE curve fit gives the coefficients  $m$  and  $b$  of the equation for a line,  $y = mx + b$ .

- Recall that acceleration is the slope of the velocity graph. This means that  $m = g$ , where  $g$  is the acceleration of gravity. Record your calculated value for  $g$  in your data.
  - Next, you will determine whether or not there is air resistance in Line Rider's world. Recall that in the presence of air resistance, objects in free fall eventually stop accelerating and reach a constant terminal velocity.
  - Look at your graph of  $y$  velocity versus time to determine if the Line Rider reaches terminal velocity. You may have to repeat your experiment by zooming out so that you can capture a greater number of frames before the rider drops off the bottom of the screen.
  - Save your video analysis files to Google Drive (they should end in .vmb1)
- **Objective #2: Determine the Coefficient of Kinetic Friction ( $\mu_k$ ) Between the Sled and Snow**
    - *Your challenge is to first determine the work done by friction, then the force of friction, and finally the coefficient of friction between the sled and snow.*
    - *Here are two methods that can be used to measure the work done by friction between the sled and the snow. Choose either one.*
    - Method A: The Half Pipe
    - One of the first things you notice is that he does not slow down when travelling on a level surface, but he will eventually slow to a stop if you put him in a half pipe (u-shaped track).
    - If the rider is placed at the top of a half-pipe, he has only potential energy. When he reaches the other side, he doesn't get as high.
    - Assume the rider has a mass ( $m$ ) of 20 kg (45 pounds) and the length of the sled is 0.75 m. Use your calculated value of  $g$  from Objective #1.
    - Using Video Analysis, measure the difference between his starting height and his final height (on the other side of the pipe). Calculate the work done by friction:  $W_f = \Delta mgh$
    - It is important that you make your half-pipe track as smooth as possible so that friction (not bumps) is the only force slowing him down
    - Take a screenshot of Video Analysis, showing the video screen on the left and two graphs on the right. Include the screenshot in your lab report.
    - Method B: The Ramp and Horizontal Surface
    - Instead of using a half-pipe, make a ramp that smoothly merges into a horizontal line.

- Using Video Analysis, measure the vertical height (h) of the ramp and calculate his PE = mgh at the top.
- Assume the rider has a mass (m) of 20 kg (45 pounds) and the length of the sled is 0.75 m. Use your calculated value of g from Objective #1.
- Measure the velocity (v) of the rider on the horizontal section, and from that calculate his kinetic energy:  $KE = \frac{1}{2} mv^2$ . Then, use  $W_f = PE \text{ (top)} - KE \text{ (bottom)}$ .
- Take a screenshot of Video Analysis, showing the video screen on the left and two graphs on the right. Include the screenshot in your lab report.
  
- Method A and B: Calculate the Coefficient of Friction Between the Sled and the Snow
  
- Recall that the work done by friction is equal to the force of kinetic friction (Fk) times the distance travelled (d), or  $W_f = F_k * d$ .
- You can use your Video Analysis graphs and the Pythagorean Theorem to calculate the distance travelled by the rider as he is sliding down the ramp or half pipe. You can now solve the equation  $W_f = F_k * d$  for Fk.
- Recall also that the force of kinetic friction (Fk) is equal to the coefficient of kinetic friction times the normal force, or  $F_k = \mu_k * F_n$ .
- The normal force (Fn) varies continuously as the rider slides down the ramp. Assuming a 45 degree angle, you can approximate it using:  
 $F_n = F_g * \cos 45$  or  $F_n = F_g * 0.707$  where  $F_g = mg$
- Assume the rider is 6 years old with a mass (m) of 20 kg (45 pounds). Use your calculated value of g from Objective #1.
- Make sure you save and show all your calculations in your report.
- Save your video analysis files to Google Drive (they should end in .vmb)
  
- **Bonus Objective #3: Make a Really Awesome Track and Share it with Your Classmates**
  - You can earn additional points if you make a really cool track for the Line Rider. Once you finish, record it with Screencastify and include a link to it in your lab report
  - Points will be awarded for including each of the following:
    - Jump with landing
    - Loop
    - Backwards sliding
    - Scenery
    - Cool crash at the end

- Music

## **6. Project Report**

- Use the AP Physics Lab Report template (attached below).
- Make sure you include your measured value for the acceleration of gravity, whether or not there is air resistance, and your calculated coefficient of friction between the sled and snow.
- Include screenshots of any relevant video analysis results
- Include links to any video files that you saved on Google Drive