**Inertial Reference Frames Student Worksheet**

**Tools Needed for Activity:**

1. Watch, stopwatch, clock, or smartphone timer.
2. The inertial reference frame simulation, which can be accessed at the web address: https://nerdydandaman.github.io/

**Activity Time:**

Approx. 40 minutes.

**Notes About Known Issues:**

1. There are animations in this simulation that depict a box falling from a truck. The box takes longer to fall than it should due to an animation slowdown issue. Once the box reaches the ground the animation will play at the correct speed.
2. Browser Support: Currently, only the Google Chrome and Microsoft Edge web-browsers are confirmed to work with the simulation.
3. Mobile Support: The simulation will not display or work correctly on mobile or tablet devices.
4. Resolution Support: Due to the way the animations had to be defined while making this simulation, only a limited amount of screen resolutions are supported. The simulation will display properly on 4K (3840 x 2160), 1080p (1920 x 1080), and 720p (1280 x 720) resolution screens. Support for ultrawide monitors is not included. If you do not have a screen that is one of the listed resolutions, you can temporarily set your computer to display at those resolutions by going into your system settings and changing the display resolution setting (on Windows systems).
5. Screen Zoom-in/Zoom-out Support: Even if displayed on a screen displaying at one of the three supported resolutions listed above, if the web-browser window or screen itself is zoomed-in or zoomed-out, the simulation will not display properly. Please set your browser to a normal 100 percent zoom option when using the simulation. If you are still experiencing issues displaying the simulation, check the system settings of your computer to make sure the scale and layout setting is set to 100 percent.

**Section 1: Introduction**

Understanding the concept of reference frames will be an important skill for you to develop as you continue your studies in physics. To help you further your understanding, this simulation can be used. It depicts a box falling off of the back of a pickup truck in two different reference frames, both of which are from a side-on view. The first frame depicts the physics from the perspective of a bystander on the side of the road, while the second frame depicts the physics as if viewed from the perspective of the driver of the pickup truck. Open the simulation to get started. Do not click on anything yet.

**Section 2: Bystander Frame**

1.) When you open the simulation, you will be viewing the bystander’s reference frame. Before clicking on anything, notice that the box has yet to fall off of the back of the truck. Make a prediction about which direction the box will fall and slide when it falls out of the back of the truck. Will it move forward (to the right) or backward (to the left)? Explain why you think so.

2.) At the top of the simulation there is a slider that can be used to select a velocity. Drag the black bar along the slider to select a velocity. This will set the truck’s velocity to the one you selected and trigger the animation of the box. Was your prediction correct? Explain why it was or was not correct.

3.) What effect does the truck’s velocity have on the time it takes for the box to fall and slide to a stop? Measure the time it takes for the box to fall and slide to a stop for three different pickup velocities. Start your measurement the moment the box leaves the truck. Make a table of your measurements. Briefly comment on how increasing or decreasing the pickup’s velocity affects the time it takes for the box to come to a stop.

**Section 3: Pickup Frame**

The following questions will require you to view the simulation from the pickup truck driver’s reference frame. Select “Pickup-Truck” from the drop-down menu at the top of the simulation. Do not click on anything else yet. In this reference frame, the physics of the system is displayed as if viewed from the driver of the pickup truck, despite the side-on view.

4.) In this reference frame, the truck driver views themselves as sitting still while the world around them moves by. Before selecting a new velocity, predict once again which direction the box will travel when it falls off the back of the truck. Will it slide forward or backward?

5.) Test your predictions again by selecting a velocity using the slider. Based on what you see, are the physics displayed in this reference frame the same as those displayed in the bystander frame? How can you tell?

6.) Make a new table of velocities and times for this reference frame. Using the same three velocities as in question 3, measure the time it takes for the box to fall and reach a full, constant velocity, starting your measurement from the moment the box falls off the truck. Allowing for a margin of error, compare your new results with the results from problem three. What do they tell you? Are both of the reference frames depicting the same physics? Explain how your measurements support your answer.

**Section 4: Inertial and Non-Inertial Reference Frames**

7.) Are the bystander and pickup truck driver reference frames inertial or non-inertial reference frames? Give your personal definition of reference frames to support your answer.

8.) Notice that it appears as though the box is accelerating as it slides along the ground in both reference frames. Does this mean that both reference frames are non-inertial reference frames? Defend your answer by explaining why the box’s acceleration does or does not affect this.

**Section 5: Feedback Survey**

1. If you experienced any issues/bugs with the simulation such as slowdown, displaying improperly, failing to load, or something else, please describe them here.
2. Were any of the questions on the worksheet confusing or poorly worded? If so, please list the question and explain what your question/confusion was.
3. Was the simulation intuitive enough for you to use with only the instructions given in the worksheet, or did you feel like a user’s would have been useful?
4. Were the known issues such as the slow box fall speed or limited resolution scaling distracting, confusing, or overly problematic for you?
5. Did you have any difficulty with the accessibility of the simulation? Examples might include visibility issues for font-size or the animated elements.
6. Do you feel like using the simulation alongside the worksheet helped you to learn about reference frames better than a homework question, textbook, or lecture would have helped you? If you already had been taught about inertial reference frames in some capacity, did this simulation help to improve your understanding?