Doppler Paper

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Introduction

We present a novel activity to demonstrate the Doppler Shift of a sound wave incident, at an angle, upon a moving reflector. This activity is intendend for use in an introductory physics laboratory focused on preparing students for the health and medical fields. The activity is designed to simulate Doppler velocity measurments from ultrasound imaging.

This activity has the following objectives. First, to demonstrate to students how the Doppler shift can be used to determine the speed of an object in the specific cases of a stationary sound source and reciever and a moving reflecting surface. Second, to demonstrate how this model can be built upon to accommodate an angled reflecting surface.

Laboratory activities appropriate for the first objective have been discussed in the literature already, see Gómez-Tejedor, Castro-Palacio, and Monsoriu (2014), and references therin. The second objective, however, is novel, and directly

At non-relativistic speeds the change in frequency of a wave observed at a moving reciever from the initial frequency emitted at a moving source is given by

$$f' = \frac{c + v_r}{c + v_s} f_0.$$

Where f' is the measured frequency, c is the speed of sound, v_r is the speed of the reciever, v_s is the speed of the source, and f_0 is the emitted frequency.

To mimic measuring blood flow speed with ultrasound, we use an apparatus that contains a stationary initial sound source, a moving reflector, and a stationary receiver located near the initial source. We can consider the the final frequency measured at the receiver to be the result of two Doppler shifts. The first Doppler shift results from the moving receiver reflecting the intial sound pulse

$$\begin{aligned} f' &= \frac{c + v_r}{c + v_s} f_0 \\ &= \frac{c + v_r}{c} f_0 \end{aligned}$$

since $v_s = 0$. The second Doppler shift results from the reflected wave now being "emitted" from the moving reflector with a frequency of f'. This reflected pulse will then be measured at the receiver with a frequency

$$\begin{aligned} f'' &= \frac{c + v_{r'}}{c + v_{s'}} f' \\ &= \frac{c + v_{r'}}{c + v_{s'}} \frac{c + v_r}{c} f_0 \\ &= \frac{c}{c - v_r} \frac{c + v_r}{c} f_0 \\ &= \frac{c + v_r}{c - v_r} f_0 \end{aligned}$$

since, $v_{s'} = -v_r$.

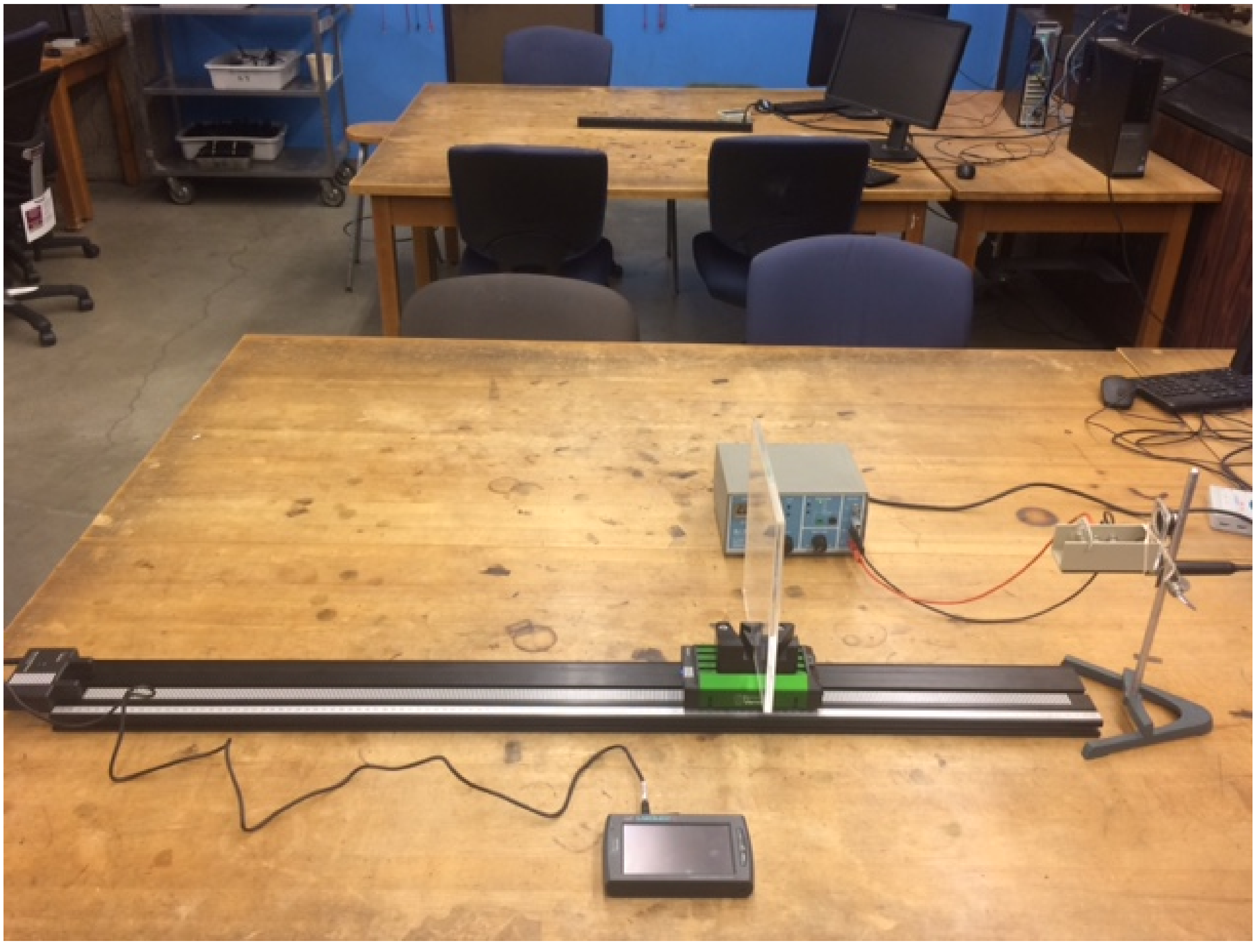


Figure 1: Figure: Test setup

Apperatus

This activity makes use of commercially available equipment data aquisition software commonly used in introductory laboratories. The equipment includes a motion encoding cart, receiver and track, with a custome made plastic reflector to attach to the cart. The sound source is generated with a function generator and a speaker, and recieved with a microphone. The LabQuest Mini and LabQuest 2, both devices from Vernier, and the Logger Pro software were used to aquire and log the data.

Experiment 1

The first experiment is a measurement of the velocity of a cart using a Doppler shifted echo. A cart with an attached re

University of Colorado lab exercise using a sound source moving on a track.

Uncertainty in Experimental methods.

- Consistant cart speed throughout experiment
- means adjusting the level of the track
- How uncertain can the experiment be and still measure the effect of having the reflector

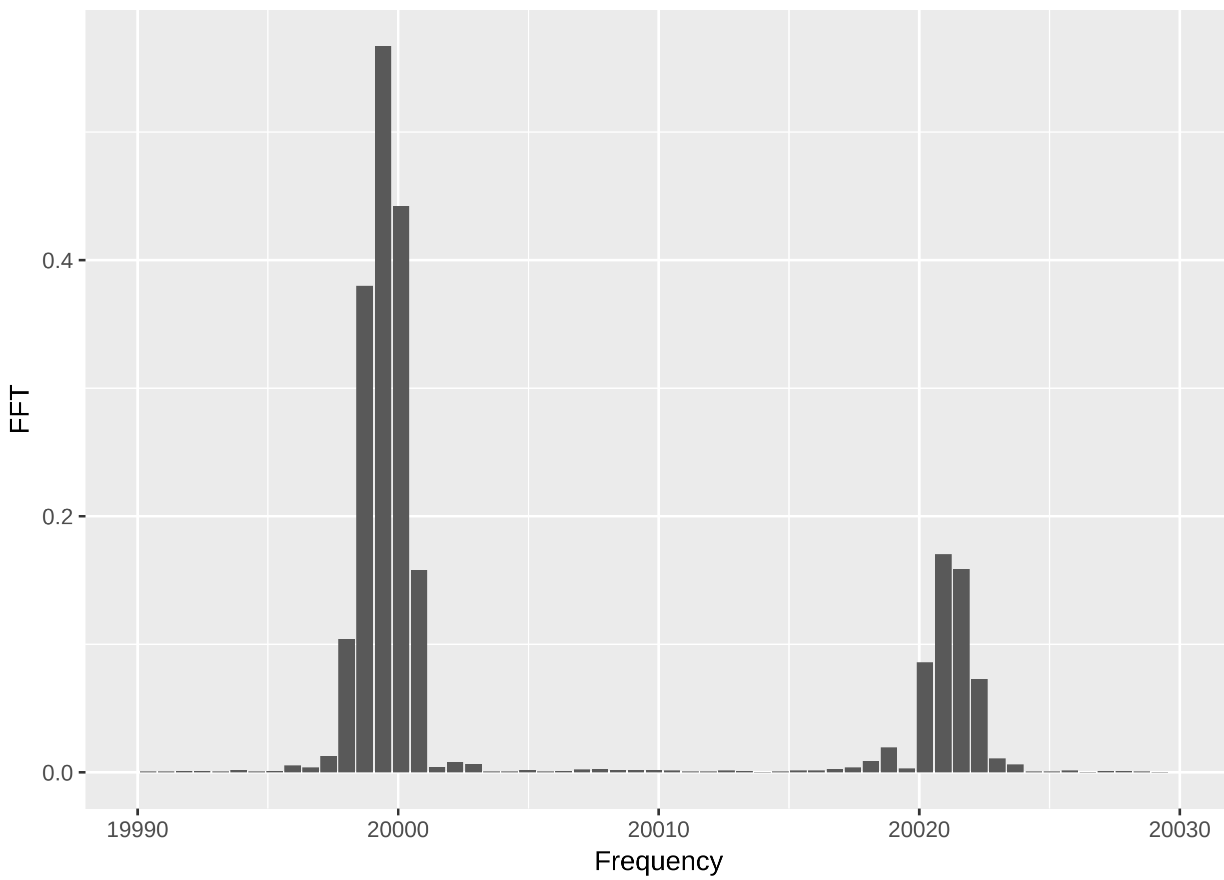
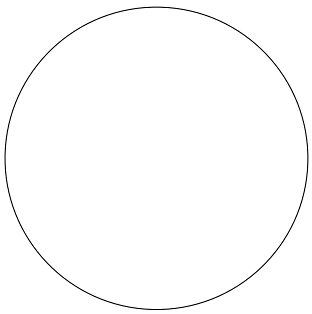


Figure 2: Figure: Results of experiment 1

Citation (Meltzer and Thornton 2012).

TikZ picture

- Here is a TikZ picutre



Appendix

- LoggerPro profile
- LoggerPro/LabQuest2 Images
- Mention the slope in the velocity graph as the cart slows down due to the track being level.

REverse axis on LabQuest for

Gómez-Tejedor, José A., Juan C. Castro-Palacio, and Juan A. Monsoriu. 2014. "The Acoustic Doppler Effect Applied to the Study of Linear Motions." *European Journal of Physics* 35 (2): 025006. doi:10.1088/0143-0807/35/2/025006.

Meltzer, David E., and Ronald K. Thornton. 2012. "Resource Letter ALIP–1: Active-Learning Instruction in Physics." *American Journal of Physics* 80 (6): 478–96. doi:10.1119/1.3678299.