Doppler Paper

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6/19/2018

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.

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

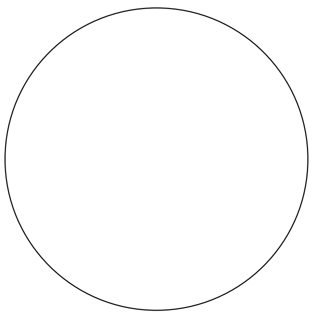
Experiment

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

Citation (Meltzer and Thornton 2012).

TikZ picture

- Here is a TikZ picutre



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.