FREDERIKSEN™ Scientific

Doppler-effect on airtrack- 258000

Product manual - AC 258000 Rev. 2024-12-16 / MRA

Product description

This equipment package makes it possible to work experimentally and quantitatively with the Doppler effect:

This means showing how the frequency of an audio signal changes as the light emitter moves in relation to the receiver.

The kit consists of a transmitter part (battery powered with rechargeable batteries) and a receiver part (powered by Electronic Counter - 200270).

An ultrasonic transmitter is used, which emits sound at a very constant frequency. Ultrasound is used because most noise sources emit audible sound, which in multiple attempts simultaneously produces "sound noise" - the ultrasonic signal is not heard, and measurements are not easily interrupted.

The transmitter is placed on an air cushion carriage that can move at an almost constant speed. The signal is picked up by a receiver which is at rest. The device emits ultrasound at a frequency of; f = 40 kHz (nom.) to create a sound reference in relation to the moving object.

The speed of the carriage is measured with a photocell, which also provides a start signal to the electrical counter, which measures the frequency of the measured signal from the ultra-receiver.

The measurement of data from the ultra-receiver and photocell is done with an electronic counter capable of performing fast and accurate frequency measurements. To ensure that the signal is "clean enough" to achieve an accurate measurement, a narrowband ultrasonic signal and electronic filtering are used, which in combination virtually eliminates any unwanted noise influence.

Equipment package in 258000 - Doppler effect on air cushion bench

a. Transmitter and battery unit
b. Receiver
c. 398610 - USB 2.0 cable, A male to USB C male
d. (97850117) - Clamping pin Ø10

Accessories for 258000

a. 200270 - Electronic counter (2x modular cables included)
b. 000600 - Tripod base, tripod
c. 197560 - Photocell with modular connector
d. 195050 - Air cushion rail

Set-up

Set up Doppler effect experiment on air cushion bench.

The setup of the Doppler Effect experiment can be done following the same instructions as in the product image above.

The process starts by adjusting the air cushion rail so that it is completely horizontal.

Next, the kit with transmitter and battery unit is placed on the trolley included in air cushion bench 195050. The kit is "locked" with a "tab" that is placed on top of the trolley. The tab has a well-defined width (e.g. 25 mm) and acts as a switch for the photocell's light beam when passing.

Place the transmitter on the supplied pole in a stable base so that it points unobstructed towards the receiver.

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Mounting brackets for the photocell are placed at the 55 cm mark.

Measurement

When the carriage is set in motion past the photocell, two things happen:

1) Frequency measurement starts, and the carriage travels a predefined distance.

2) Measure the passage time of the tab through the photocell

The latter of these results (along with the tab width) is used to calculate the vehicle speed. To measure the resting frequency (reference value), the vehicle must be held still - then a "normal frequency measurement" is read on the electronic counter by simulating a pass on the photocell with your index finger.

Connection

Connections to Electronic counter (200270):

1. Connect *Photocell* (197560) with modular connector to the "Gate" input (Input **A**).
2. Set up in a tripod (000600) *the Doppler Effect Receiver* at the 5 cm mark on the air cushion bench
3. Connect *the Doppler effect receiver* to the "frequency" input (Input **B**).
4. Place the receiver in a tripod (000600) or air cushion bench bracket at a random location after the 55 cm mark on the air cushion bench.

Experimentation

Exploring the Doppler effect: *We will show how the frequency of a sound signal changes when a sound emitter moves in relation to the receiver*.

Theories

The speed of sound v_L is temperature dependent. Calculate it from this formula, where the temperature T should be inserted in degrees centigrade:

$$v_\mathrm{L} = 331{,}37\frac{\mathrm{m}}{\mathrm{s}} + 0{,}588\frac{\mathrm{m}}{\mathrm{s}\cdot{}^\circ\mathrm{C}}\cdot T$$

The theory of the Doppler effect for sound can be summarised in the formula below:

$$f \;=\; f_0\cdot\frac{v_\mathrm{L} - v_\mathrm{M}}{v_\mathrm{L} + v}$$

- where

v is the speed of *the transmitter* relative to the air - positive speed: **away** from the receiver

v_M is the speed of *the receiver* relative to the air - positive speed: **away** from the transmitter

v_L is the speed of sound

f_0 is the frequency emitted by the transmitter

f is the frequency, which is the measured value recorded by the receiver unit

(The Doppler effect can also be experienced with electromagnetic radiation (*light, radio waves, radar*, etc.) - the formula above does not cover this case!)

In our case, the speed of the receiver is zero; $v_M = 0$. The formula describing the frequency change can then be rewritten as follows:

$$\Delta f = f - f_0 = f_0\cdot\frac{-v}{v_L + v}$$

Execution

When the tab on the trolley breaks the light beam of the photocell, two things start in the electric counter:

The length of time the photocell is shadowed is timed and a frequency measurement is initiated over a fixed period (gate time - can be set on the electric counter).

When both measurements are complete, the result can be read in the display. (To avoid misunderstandings: *The gate time* is **not** the same as *the passage time* in the photocell).

We need to measure *very small* changes in frequency and even though the transmitter is designed to output a fixed frequency, you still need to measure the frequency at rest f_0 before each measurement of the offset frequency f (with the vehicle in motion). The transit time Δt is the third value to determine for each measurement point.

Repeat at different speeds - both away from and towards the receiver.

Sign of the movement: We count the speed as **positive** in the direction **away from the receiver**. The measurements where the carriage moves towards the ultrasound receiver are noted with negative Δt.

Execution (sequence)

1. Use the setup and connections from the previous section "Connection"
2. Measure the tab on the trolley and make notes in the chart Δs (see below)
3. Follow the menu on the electronic counter:

   a. Find reference frequency and notes in chart - Select from main menu - ***Frequency***
   b. Switch on the transmitter (push button at the back of the transmitter).
   c. Notice that an LED is now lit on the Receiver (Note: May flicker a little when the vehicle is at its furthest distance).
   d. Hold the carriage still and measure f_0 by running a finger through the photocell
   e. Select from the main menu - ***Frequency, gated***.
      (Reset (press **X**) the measurement in the menu under ***Frequency,*** gated
   f. Set the trolley in motion
   g. Measurement is taken when the vehicle passes the photocell with direction towards the receiver.
   h. Note the measured value of f and Δt in the counter in the table below
   i. Reset (press **X**) the measurement in the menu under ***Frequency, gated*** and repeat the above process

The results can be entered in a table as shown. (As formulas are involved, a spreadsheet would be an advantage.

Finishing

For each measurement, the speed is determined as

$$v = \frac{\Delta s}{\Delta t}$$

- where the sign of the velocity follows from that given for Δt.

Expand and fill the table with these new columns: v meas / f meas / f theo / diff..

Note the sign of the two frequency changes; they should both be *negative* when the cart is travelling in a positive direction, i.e. *away from* the receiver - and vice versa. The deviation between measured and theoretical frequency change is given in per cent.

Discussion and evaluation

Describe the agreement between the theoretical and measured frequency changes.

Is there a correlation between the deviations and the magnitude of the speed? If so, please provide an explanation.

	A	B	
1	Run 1		
2	v sound	340	
3			
4	f o	40,00023	
5	f meas	40,04673	
6			
7	Δs	25	
8	Δt	8,429	
9	v meas	2,965950884	=E7/E8
10			
11			
12	f theo	40,35224	=E4*E2/(E2-E9)
13	diff	0,7629%	=E12/E5-1
14			