Physics of the Familiar
(and inexpensive)

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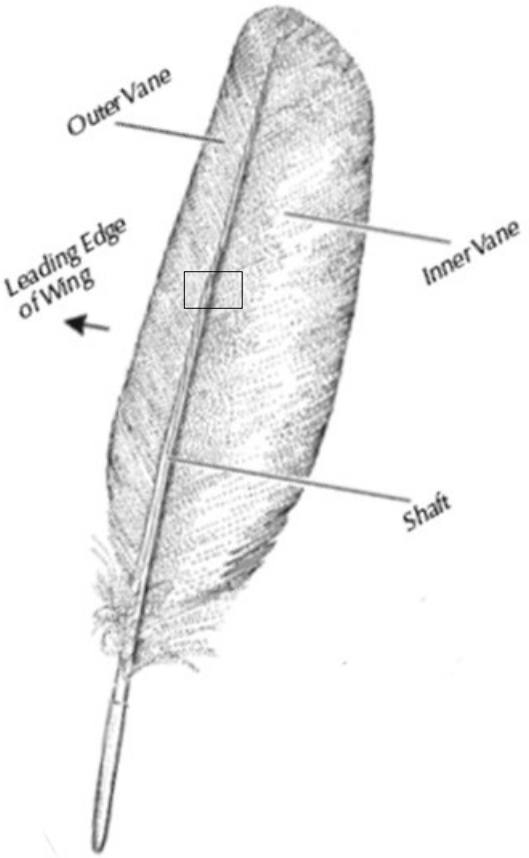
Gratings in a Pigeon Feather

SEM micrograph of feather

Barbule diffraction spots

left side right side

of shaft



It's Important to Use Familiar Materials

because...

- Classical Physics is a study of the familiar around us

- Today's technology obscures the underlying causes and mechanisms beneath layers of sensors, micromechanics, and software

- Familiar stuff demystifies the concepts

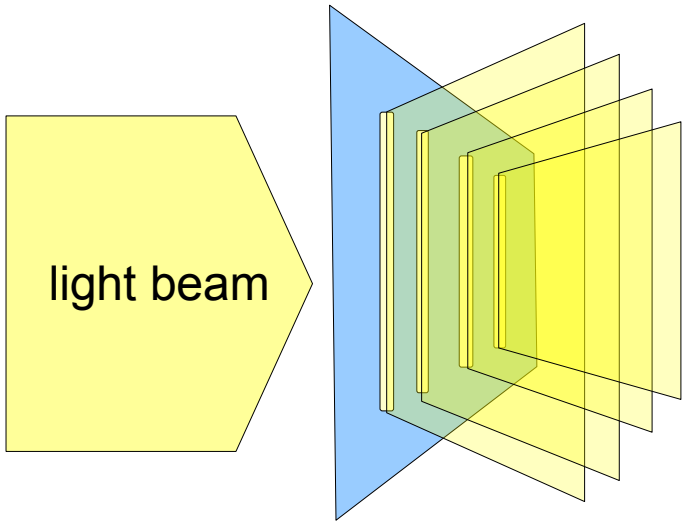
- Student says, after making a loudspeaker from a magnet, piece of paper, and a coil:

  "You mean – that's *all* it is?"

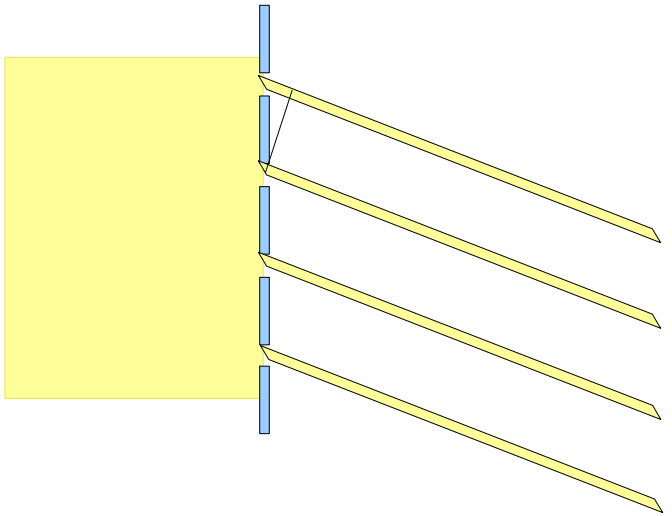
- Low Cost

Grating Diffraction

vertical slots



VIEW FROM ABOVE



Beams radiating from the many openings in the grating interfere constructively towards certain directions.

Vertically oriented slots diffract the light in horizontal directions

As spacing decreases, diffraction angle increases

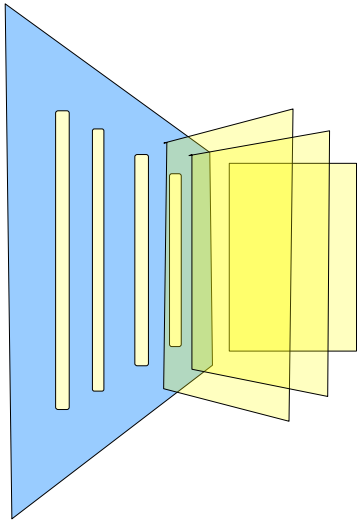
Equation:

$d \sin \theta_n = n\lambda$

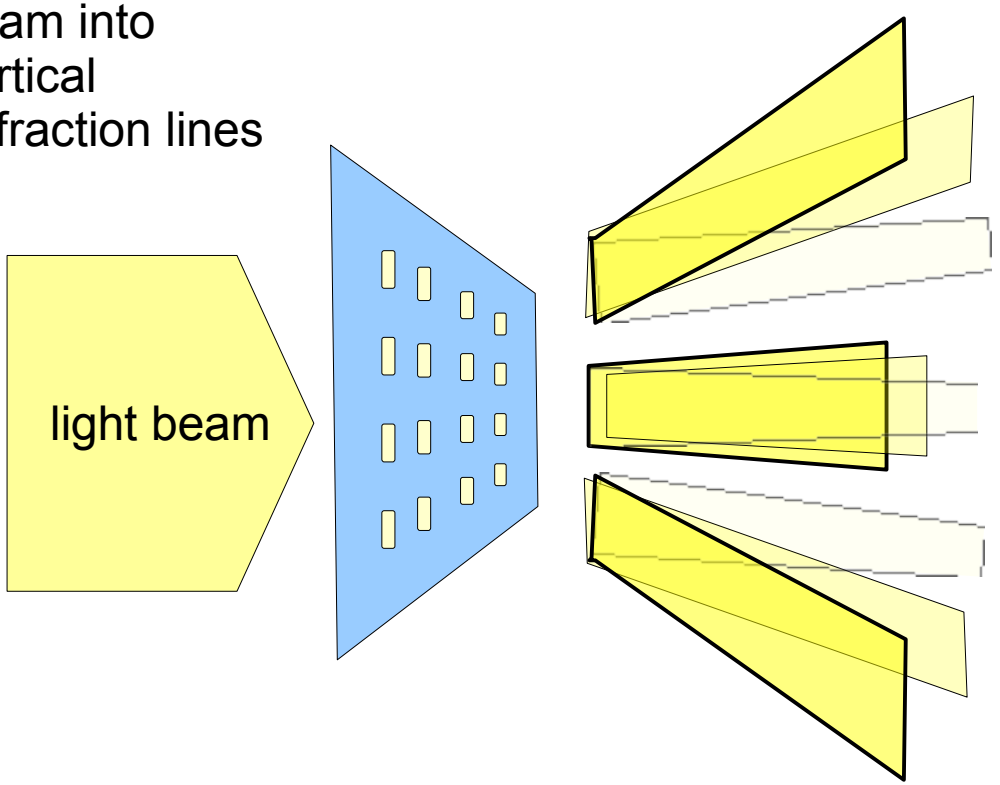
grating spacing d
wavelength λ

Barbule spacing:
$d = \lambda/\sin \theta = 650 \text{ nm}/.037$
$= 0.018 \text{ mm}$

Array Diffraction



Multiple slits diffract light beam into vertical diffraction lines

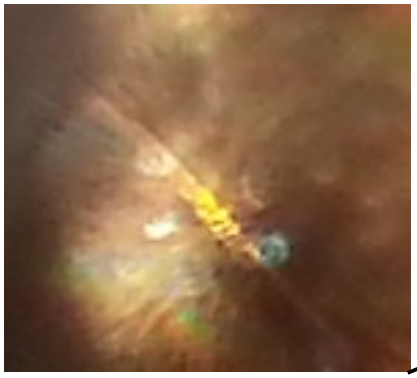


If the multiple slits are restricted in the vertical direction, diffraction lines break up in the vertical direction

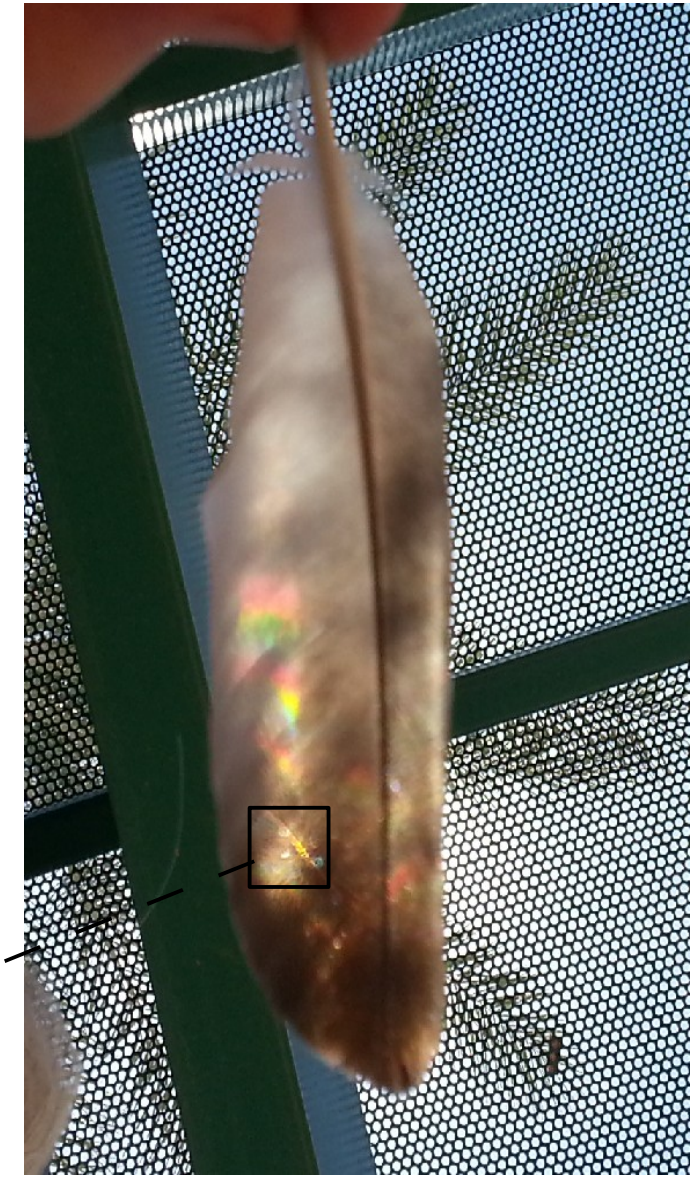
Feather Diffraction Separates Colors

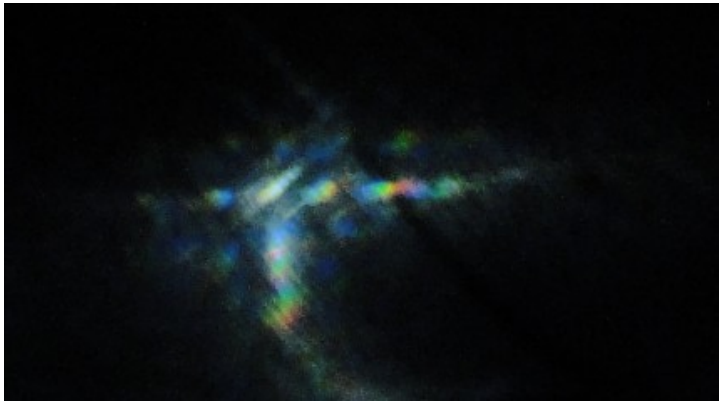
Superposition of

- Barb diffraction pattern
  - Vertical barbule diffraction pattern
  - Horizontal barbule diffraction pattern
    - Crossed barbule diffraction pattern

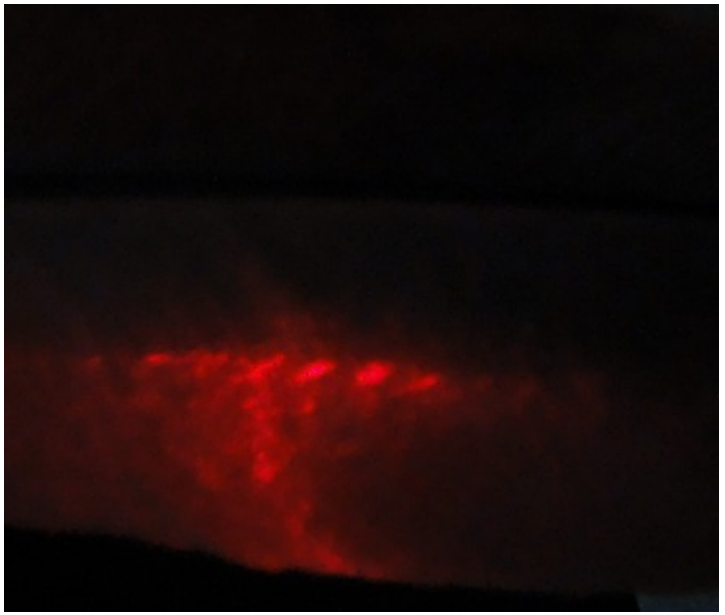


Barb diffraction

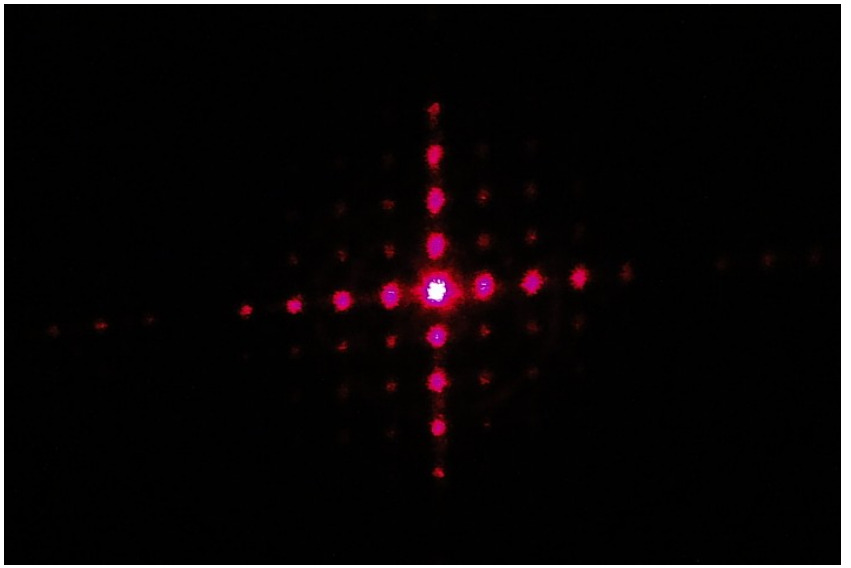




White LED multiple orders from feather



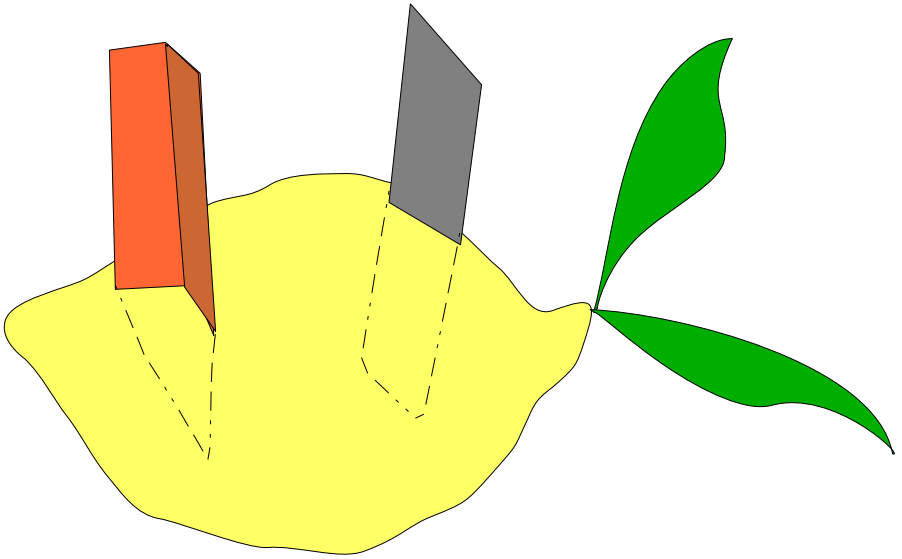
Red LED multiple orders from feather



Laser / fine wire screen

Lemon Batteries

Cut points on copper flashing and zinc (galvanized steel) strips and push into lemon



With a multimeter:

- Measure the voltage V between electrodes
- Measure the short-circuit current I by changing multimeter scale to milliamps

Example Data

Voltages (V) from different lab groups	Currents (ma) from different groups
0.91	0.237
0.86	0.121
0.90	0.328
0.85	0.179
0.93	0.201

The voltage appears to be an **intrinsic** property of lemon batteries – depends on the metal difference

The current is an **extrinsic** property – depends on sizes, shapes and distances between metal strips in the lemons

Electromotive Series

Chemistry students *may* recognize this table of metals:

1. Determines which metals will react with acids to produce H_2 gas

2. The voltage difference $V_{Zn} - V_{Cu} \approx$ to the battery voltage

TABLE I - ELECTROMOTIVE SERIES

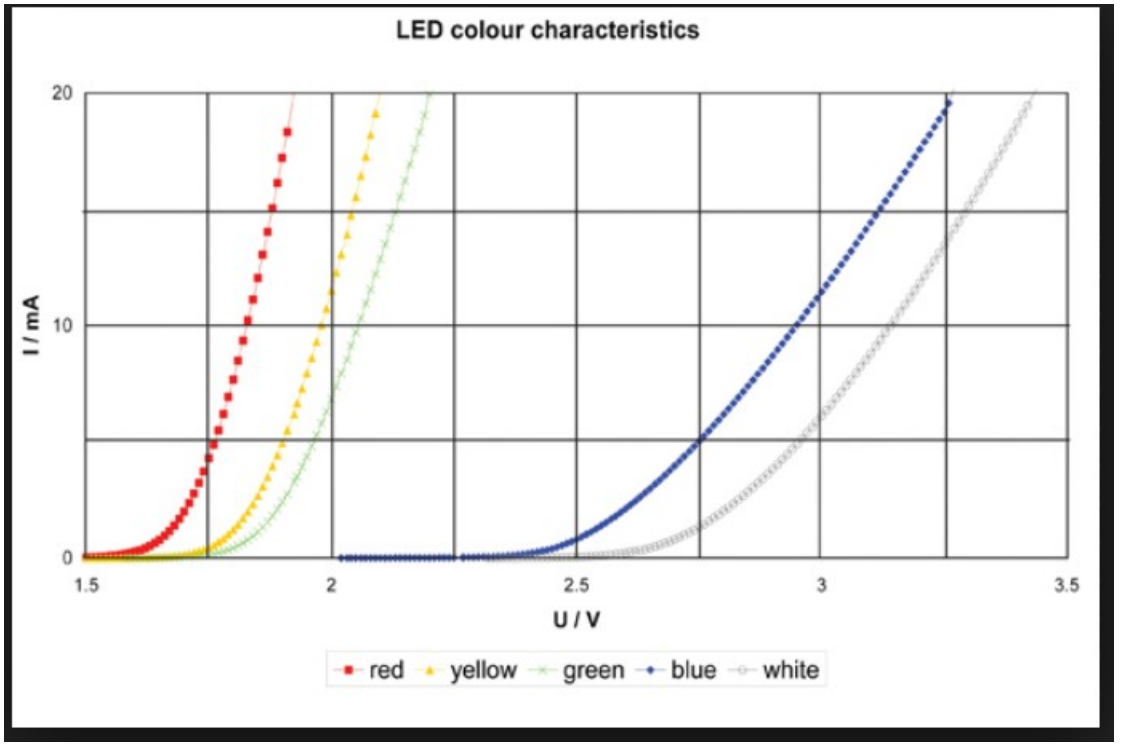
METAL	NORMAL ELECTRODE POTENTIAL* (Volts)
Gold	+ 1.4
Platinum	+ 1.2
Iridium	+ 1.0
Palladium	+ 0.83
Silver	+ 0.8
Mercury	+ 0.799
Osmium	+ 0.7
Ruthenium	+ 0.45
Copper	+ 0.344
Bismuth	+ 0.20
Antimony	+ 0.1
Tungsten	+ 0.05
Hydrogen	+ 0.000
Lead	- 0.126
Tin	- 0.136
Molybdenum	- 0.2
Nickel	- 0.25
Cobalt	- 0.28
Indium	- 0.3
Cadmium	- 0.402
Iron	- 0.440
Chromium	- 0.56
Zinc	- 0.762
Niobium	- 1.1
Manganese	- 1.05
Vanadium	- 1.5
Aluminum	- 1.67
Beryllium	- 1.70
Titanium	- 1.75
Magnesium	- 2.38
Calcium	- 2.8
Strontium	- 2.89
Barium	- 2.90
Potassium	- 2.92

*The potential of the metal is with respect to the

LED Current – Voltage Characteristics

Students learn red LED requires 2 lemons in series

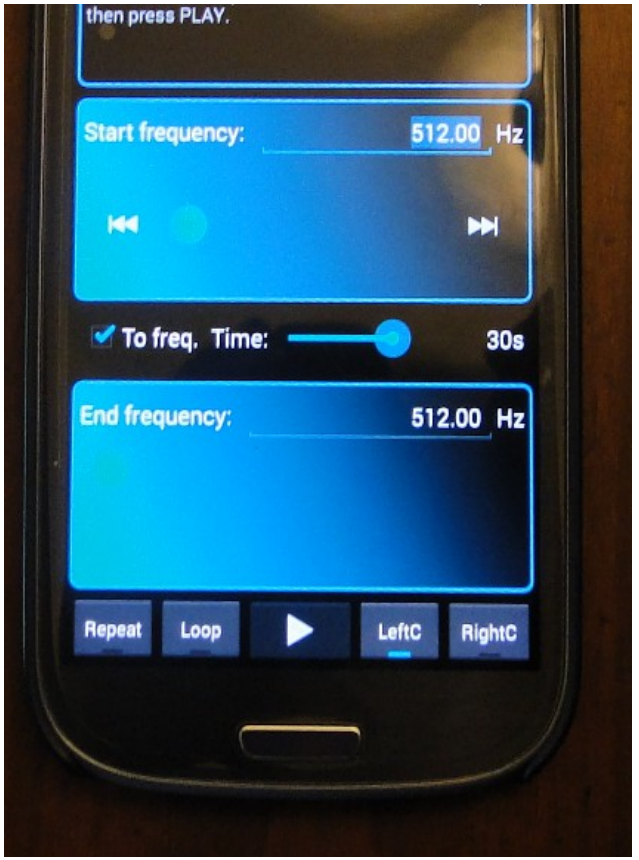
Longer lead is +,
attach to Cu terminal



Student discovery: White LED required 3 lemons in series!

Cell Phones have frequency meter and tone generation apps

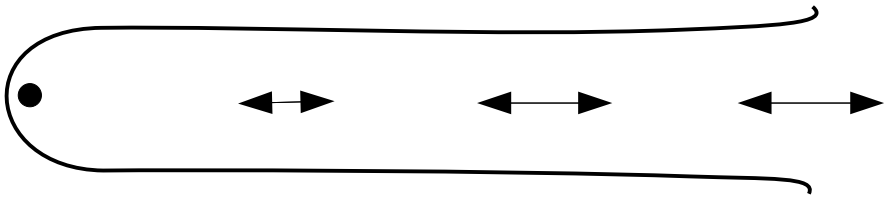
PitchLab et cetera



FG Tone Generator

Cell phones have great possibilities for low-cost experiments

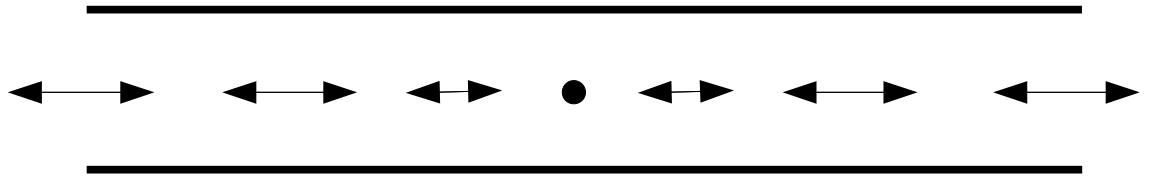
Measure speed of sound



For a closed-end tube, the fundamental resonance occurs when λ = 4 x length of tube.

So find the resonance, then determine speed of sound from
frequency * wavelength = speed

Measure speed of sound



Distance between nodes or antinodes is λ/2

For an open-ended tube, the fundamental resonance occurs when λ = 2 x length of tube.

So find the resonance, then determine speed of sound from
frequency * wavelength = speed
790Hz * 0.413 m = 326 m/s

Resonant tubes and chambers used to amplify musical vibrations

Other Low Cost / Familiar Physics Experiments

- Coulomb Force measured on a 0.1 gram electronic balance
- Magnetic Force on a wire loop measured on a 0.1 gram electronic balance
- Magnet, Paper, Coil, Cellphone Loudspeaker
- Cellphone velocity measurement for velocity/acceleration experiments
- Plexiglass and Pins Snell's Law Experiment

Uses for Familiar Physics

- Low Budget Community Colleges
- Most Public High Schools
- Most Charter Schools
- Foreign Countries

List of Materials

Feathers – dove feathers are great and available on the ground during cool months – best for sunlight. Chicken feathers very good for laser pointer.

.005” Copper – flashing from Industrial Metal Supply Co.,
5150 S. 48th Street
Phoenix, AZ 85040

Zinc – galvanized strips from Home Depot for strapping wooden framing

LED's – Radio shack

Tone Generator App - “FG” on

Frequency measuring App - “PitchLab”