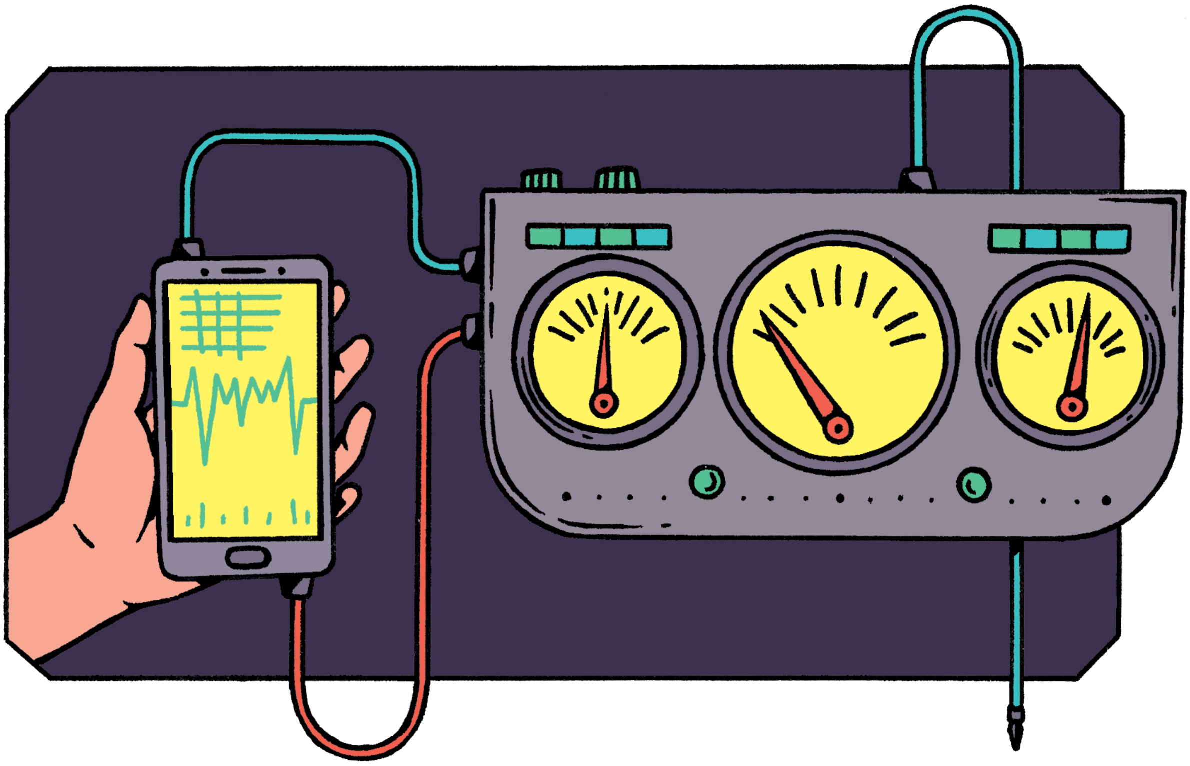
# SMARTPHONE & PHYSICS

*A set of sheets to convert his or her smartphone into a pocket lab.*
*Harness rigor and creativity to carry out these experiments...*



## *CREDITS*

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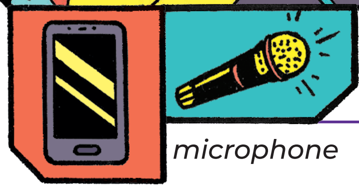


microphone

# RESONANCE OF A STRING

mechanics

## MATERIAL

– a guitar
– a smartphone

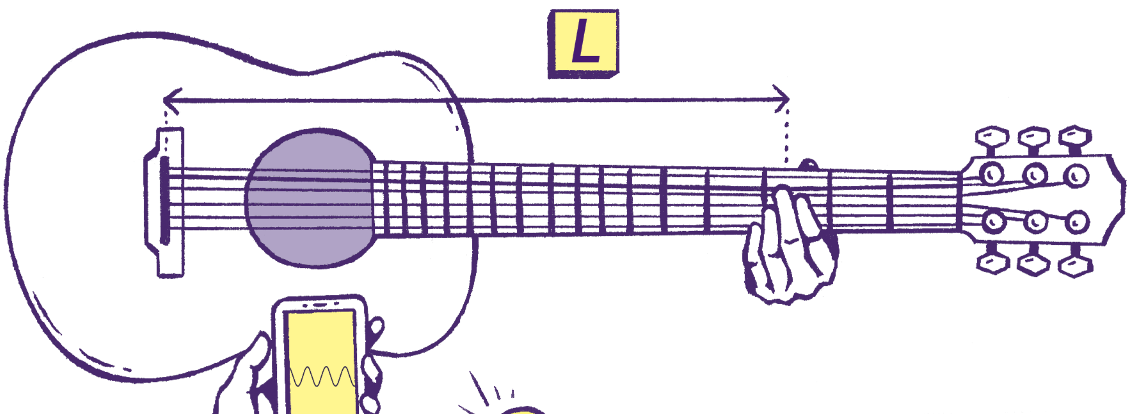
## CHALLENGE

Determine how the resonant frequency of a string varies with its length.

## OVER TO YOU

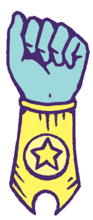
Choose a string (rather sharp) from the guitar to work on. Pressing the string at the handle creates a blocking point (a vibration node) that sets the length *L* of the string. While holding the blocking point, pinch the string to half its length: the note emitted corresponds to the fundamental mode of the string resonance.
Use your smartphone to measure its frequency *f* and characterize this note.

Determine how the frequency of the note emitted changes when you change the length of the string.



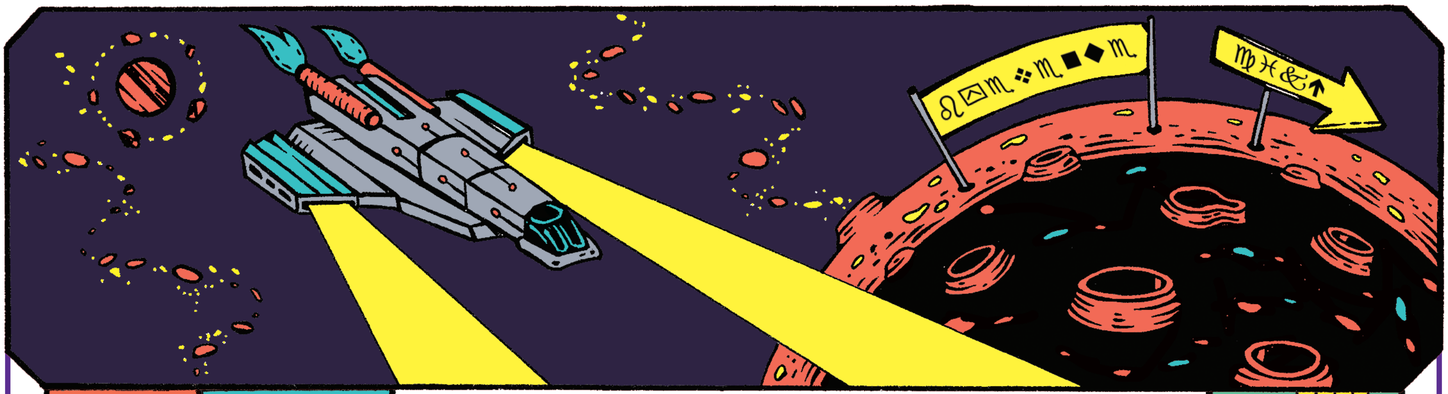

Plot *f* versus 1/*L* to demonstrate the relationship between these two quantities.

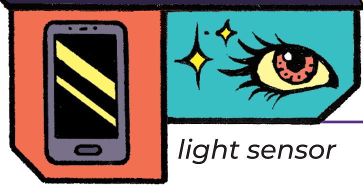
## THE ULTIMATE CHALLENGE



When you blow on the neck of a bottle, a note is emitted by resonance. By adding water in the bottle, the volume of air in the bottle is diminished. Determine the relationship between the frequency of the note the volume of air in that bottle.

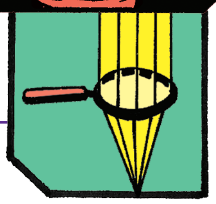
Which quantities should be plotted in order to do so (look for “Helmholtz resonance”)?





light sensor

# ILLUMINANCE



optics

## MATERIAL

– a smartphone
– a tape measure
– a light source (desk lamp, smartphone flashlight ...)

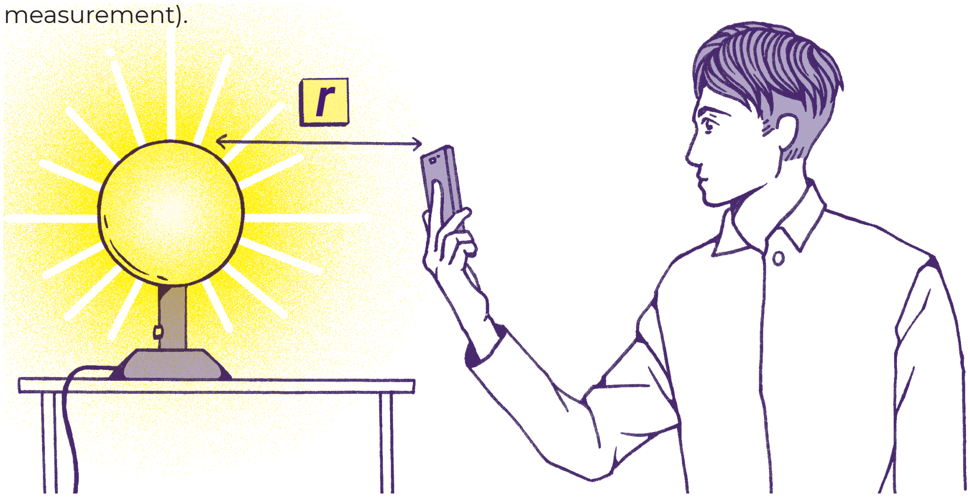
## CHALLENGE

Determine how the illuminance varies when moving away from the light source.

## OVER TO YOU

By working as much as possible in the dark, measure the variation of the illuminance measured by the smartphone in function of the distance between smartphone and light source. Determine the law that controls this variation.

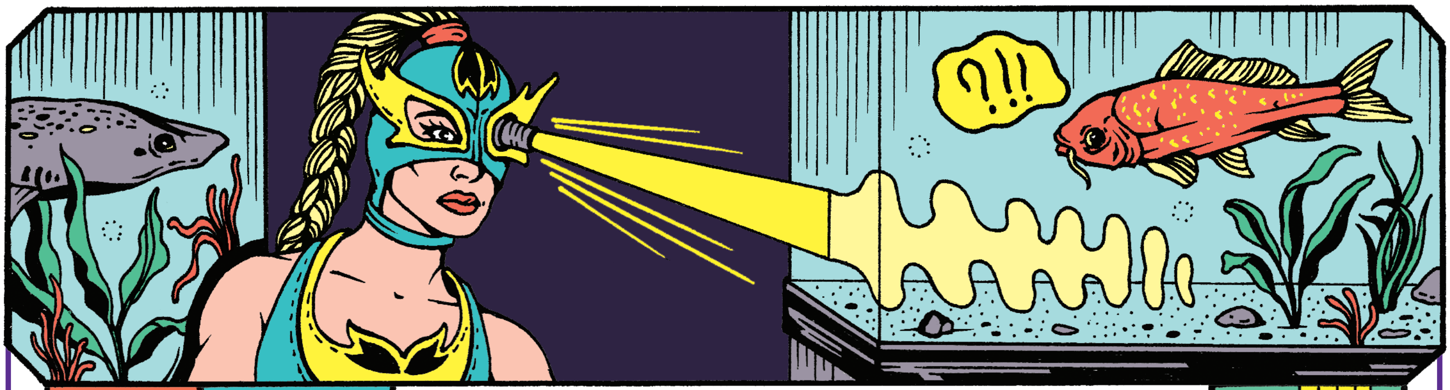
**Pro Tips:** Position the light source away from any reflective wall. Take a measurement when the light source is off to determine the contribution of ambient light to the illuminance (this contribution can be subtracted from the measurement).




Plot the logarithm of light intensity versus the logarithm of distance to determine the relationship between these two quantities.

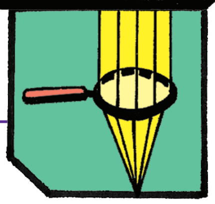
## THE ULTIMATE CHALLENGE

Forget light, determine how the measured sound intensity varies in function of the distance between the sound source (a loudspeaker) and your smartphone. Watch out for reverberations on the walls!




*light sensor*

# ABSORPTION



*optics*

## *MATERIAL*

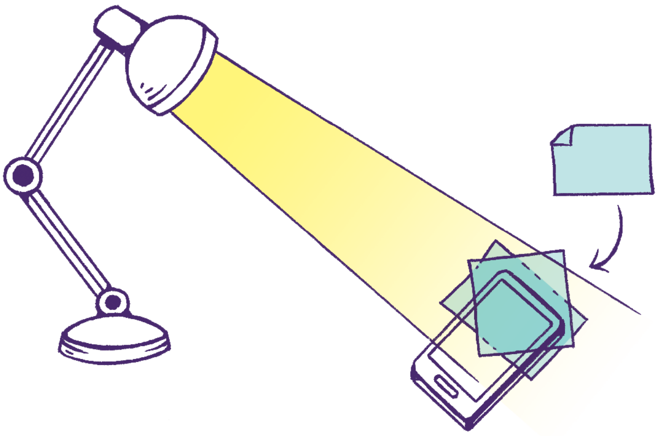
– a smartphone
– a lamp
– transparent plastic sheets (colored or not)

## *CHALLENGE*

Determine how light gets dimmer when going through thicker materials.

## *OVER TO YOU*

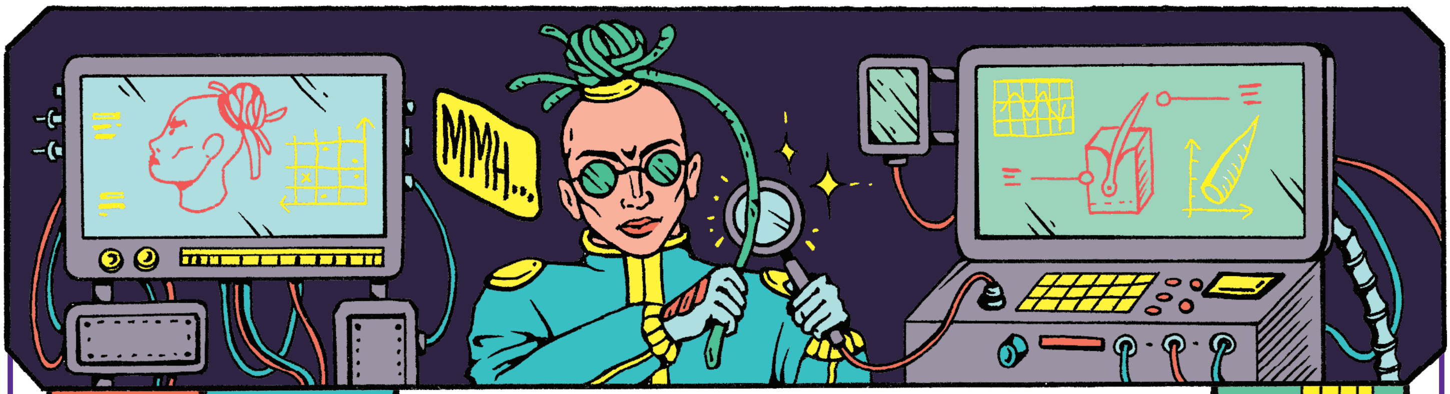
After having measured with your smartphone the illuminance in full lighting conditions, position on the smartphone's light sensor, 0, then 1 transparent sheet, then 2, etc. The transparent sheets will absorb a small amount of light, which will decrease the illuminance measured by the smartphone.
Determine how the illuminance varies with the number of sheets placed on the light sensor.

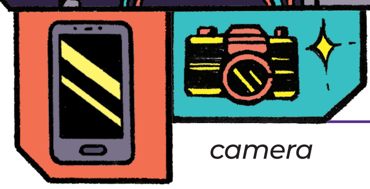


Plot the log of light intensity as a function of the number of sheets.
Look for "*Beer-Lambert law*" to understand why this plot is useful.

## *THE ULTIMATE CHALLENGE*

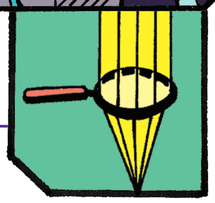
Analyze the variation of the illuminance when the absorbing medium is colored water (with ink for example) in function of its concentration or in function of the liquid thickness.



camera

# MICROSCOPE



optics

## MATERIAL

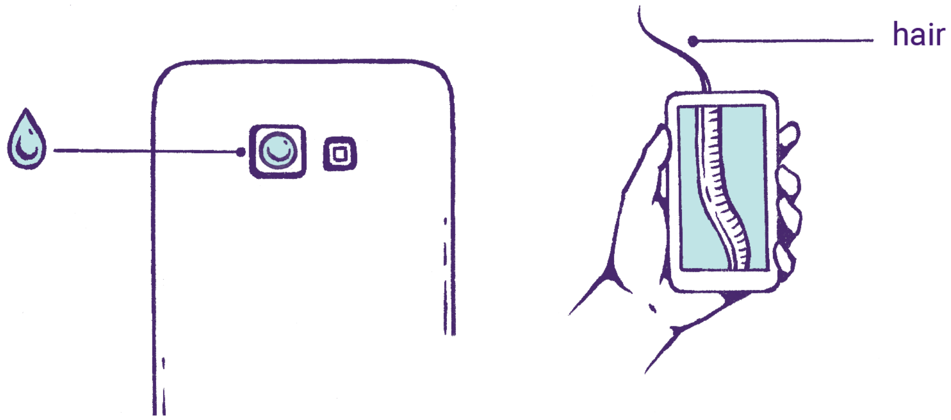
- a smartphone
- a small drop of water
- a hair

## CHALLENGE

By turning your smartphone into a microscope, measure the thickness of a hair.

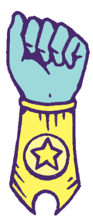
## OVER TO YOU

In using the tip of a pen or other suitable device, place a “very” small water drop on the lens of your smartphone camera. Tear off a hair from your neighbor’s head, and take a picture to measure its diameter. To see the real magnification of your camera, take a picture of a graduated ruler under the same conditions (with the same water drop).

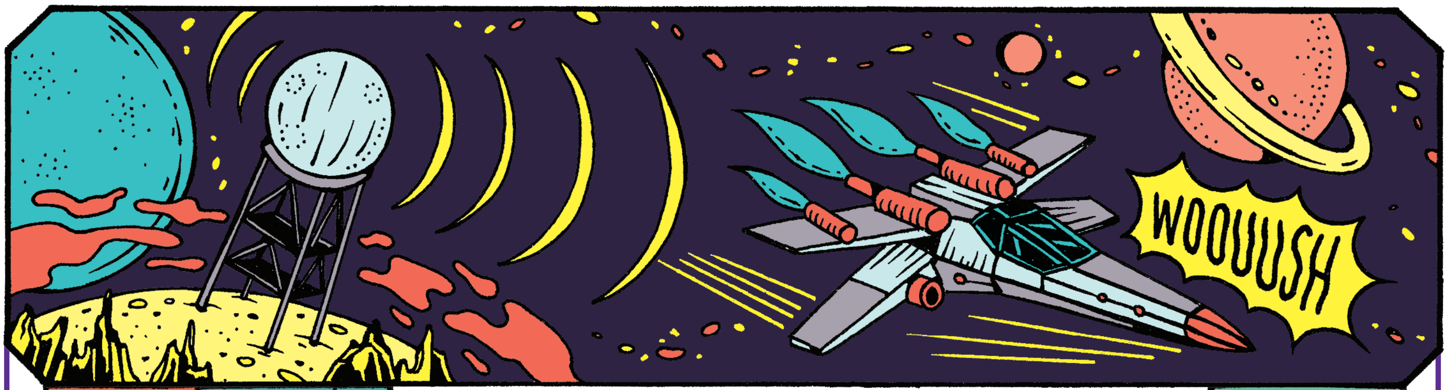


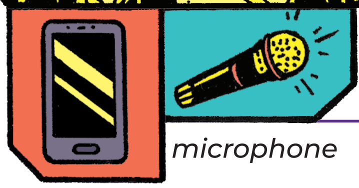

Determine how the magnification of your smartoscope depends on the size of the drop...

## THE ULTIMATE CHALLENGE

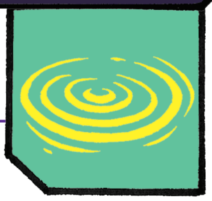


Fight forgers: Examine a bank note to discover the hidden symbols that will allow you to recognize the real stuff from a fake. For example, somewhere on euro banknotes it is written in very small letters *euro euro euro*...



microphone



wave physics

# DOPPLER EFFECT

## MATERIAL

- two smartphones
- a tape measure
- a sporty student
- a non-sporty student
- optional: Bluetooth speaker

## CHALLENGE

Like police radars or astronomers for galaxies, measure speed with a frequency shift.

## OVER TO YOU

The sporty student runs with his smartphone (or speaker) that emits a pure high-pitched note, above 5000 Hz –so that this note is well detached from the ambient sound. The second student remains motionless, and measures the frequency with his smartphone. The Doppler effect explains that the received frequency is different from the emitted frequency, depending on whether the runner approaches or moves away, and at what speed.

Determine the speed of the runner using the Doppler effect formula, and compare this result to a more traditional measure of the run speed, by timing the time taken to cover a known distance.

# DOPPLER EFFECT

The Doppler effect results in the following formula for speeds below Mach 1:

$$f = \frac{f_0}{1 \pm v/c}$$

$f_0$ is the emitted frequency
$v$ is the speed at which the athlete approaches (-) or moves away (+)
$c$ is the speed of sound (about 340 m/s)
$f$ is the frequency detected by the second student

## *THE ULTIMATE CHALLENGE*

Experimentally determine how the frequency changes when the non-sporty student starts to run as well.