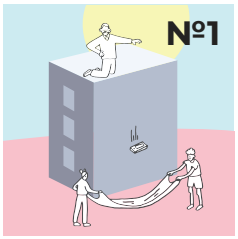
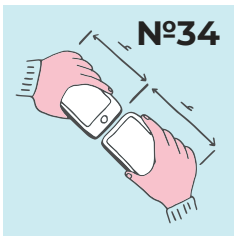
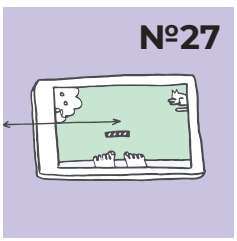
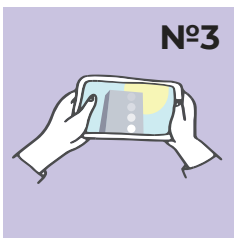
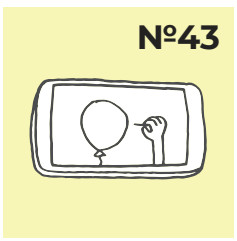
How many ways are there to measure the height of a building using a smartphone?

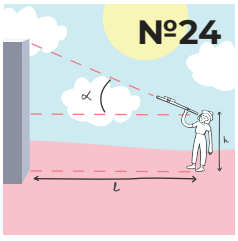


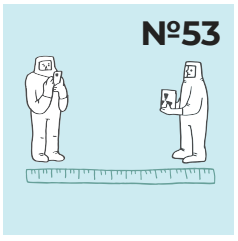


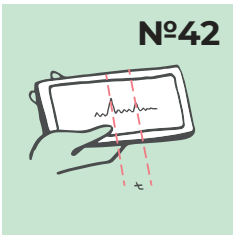


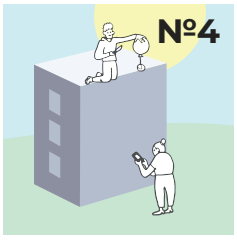


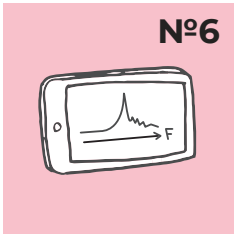


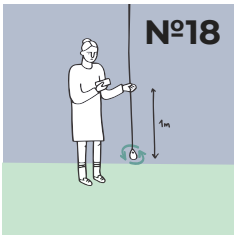


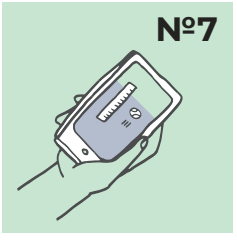


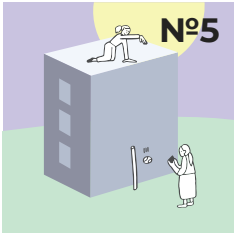












Discover **The Smartphone Physics Challenge** at **VULGARISATION.FR**

«Physics Reimagined» team (Paris-Saclay University)

Precision: high

Difficulty: low

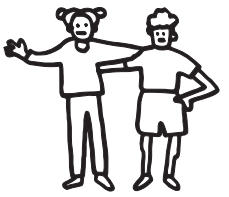
№1. Free Fall of the Smartpone

Formula

$$\begin{cases} H = \frac{1}{2} g t^2 \\ \text{or} \\ H = \iint \ddot{z}\, dt \end{cases}$$

Material

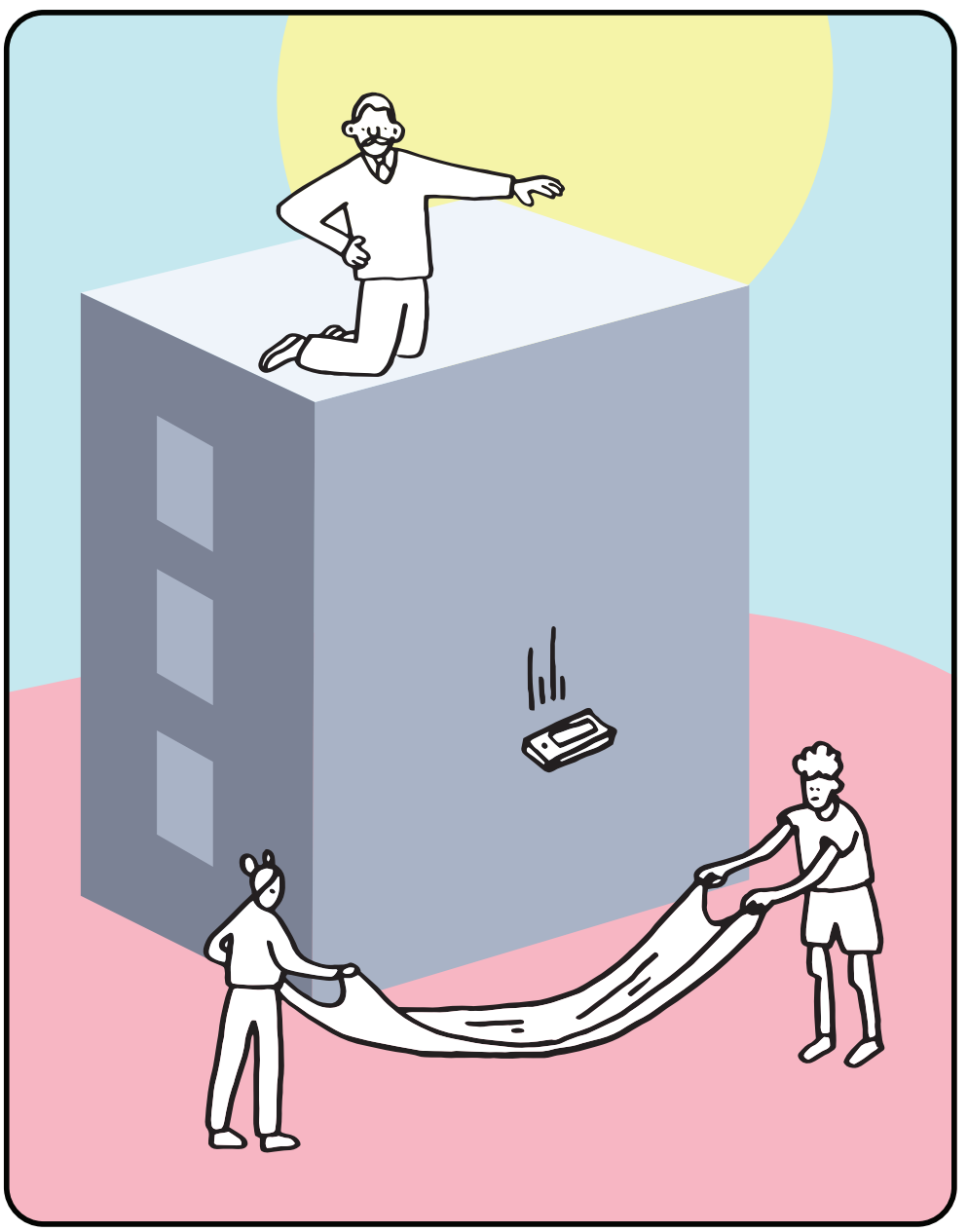
1 sheet



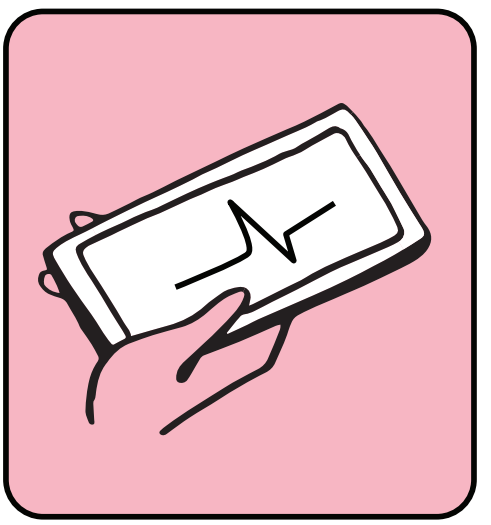
two friends

1 smartphone

Sensor: **accelerometer**



Drop your smartphone from the top of the building, your friends receiving it down in a sheet, like firefighters. The recording of the accelerometer data makes it possible to determine the time of fall, and if needed the value of the acceleration can be used to take air drag into account.



t = fall time of the smartphone,
$\ddot{z}$ = smartphone's acceleration,
g = 9.8 ms^{-2}

Precision: high

Difficulty: low

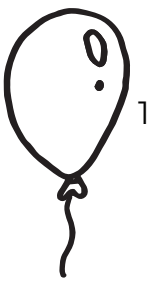
№4. Sound of a Free Fall

Formula

$$H = \frac{1}{2} g t^2$$

Material

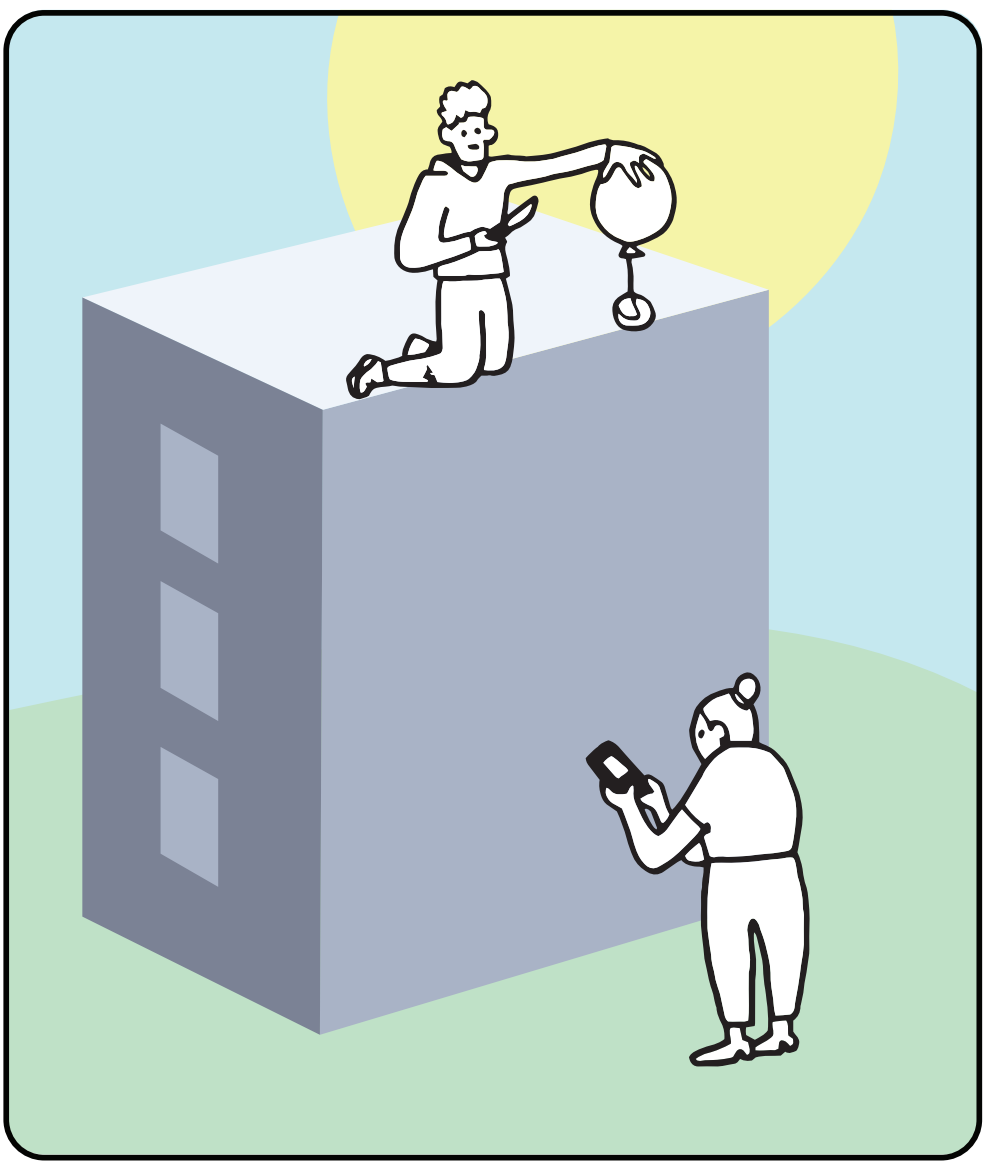
1 ball



1 balloon

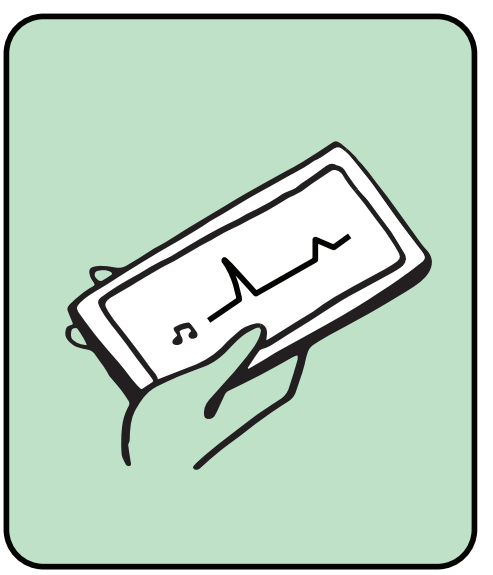
Sensor: **microphone**

1 smartphone



Attach the ball to the balloon. Go to the top of the building, and let the ball fall by popping the balloon. The smartphone is at the bottom of the building and records the sound to determine the time of fall.

t = fall time of the ball,
g = 9.8 ms^{-2}



The formula does not consider air drag.

Precision: high

Difficulty: intermediate

№10 to 17 Giant Pendulum

Formula

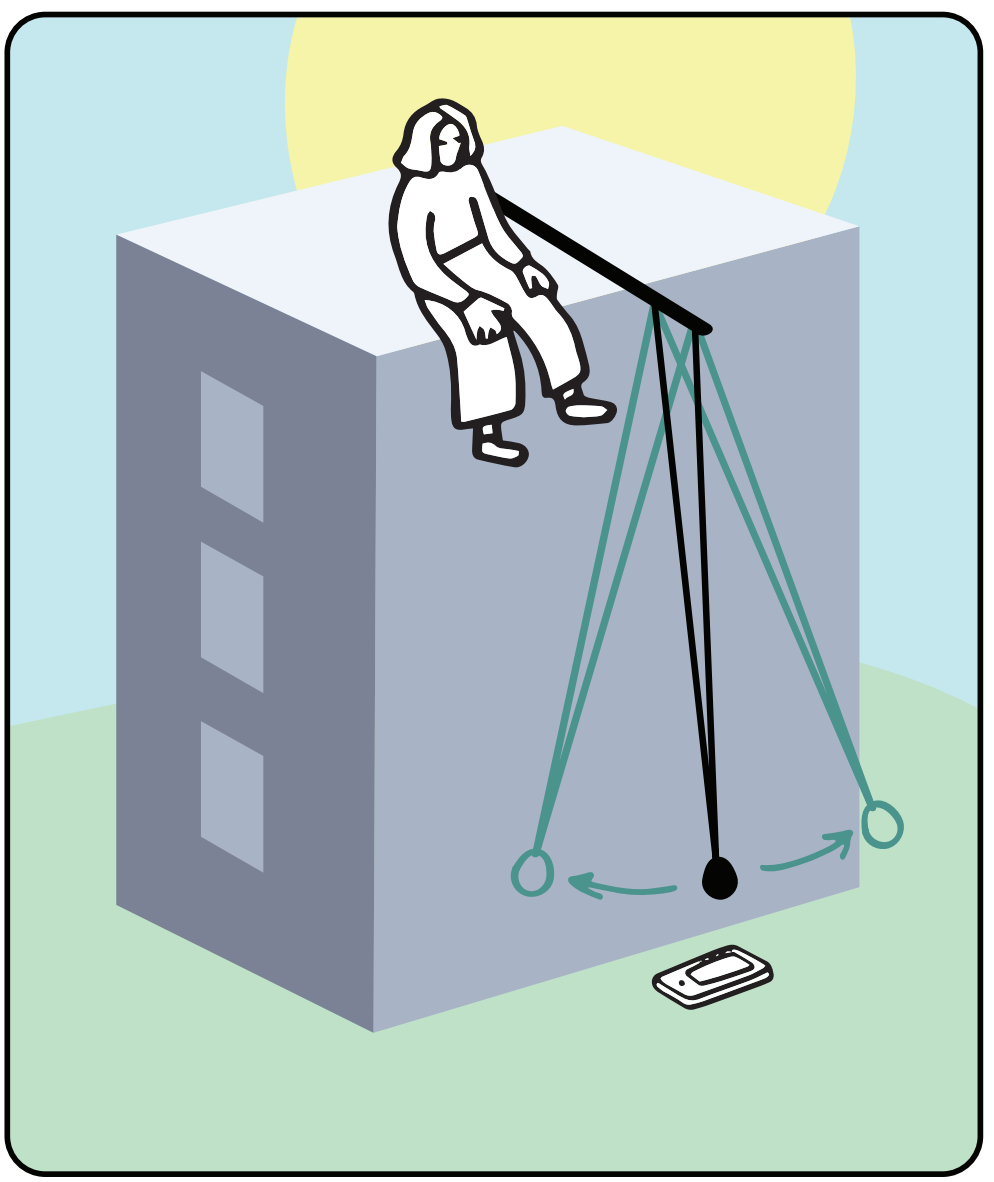
$$H = g\left(\frac{T}{2\pi}\right)^2$$

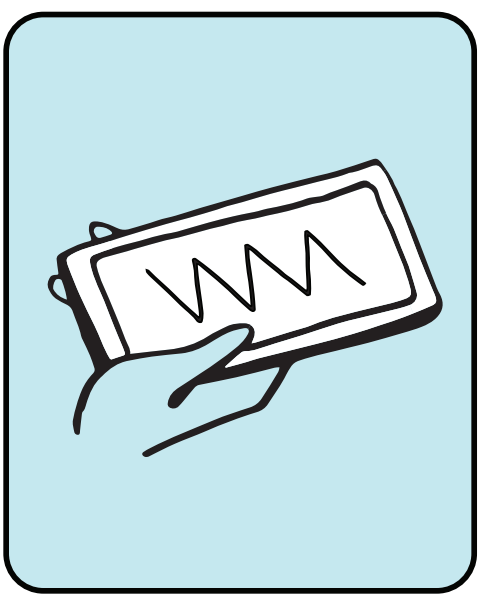
Material

1 long rope

1 smartphone

Sensors:
stopwatch, camera, accelerometer, gyroscope, magnetometer, light sensor, proximity sensor, microphone





Make a giant pendulum the size of the building. Use one of the sensors to measure its period.

T = pendulum period,
g = 9.8 ms^{-2}

The pendulum must not rotate in all directions, it must only swing.

Precision: maximum

Difficulty: low

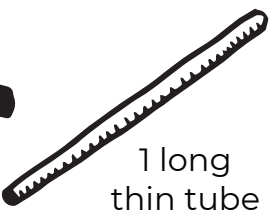
№24. Trigonometry Version 1

Formula

$H = h + l \tan \alpha$

Material

1 tape measure



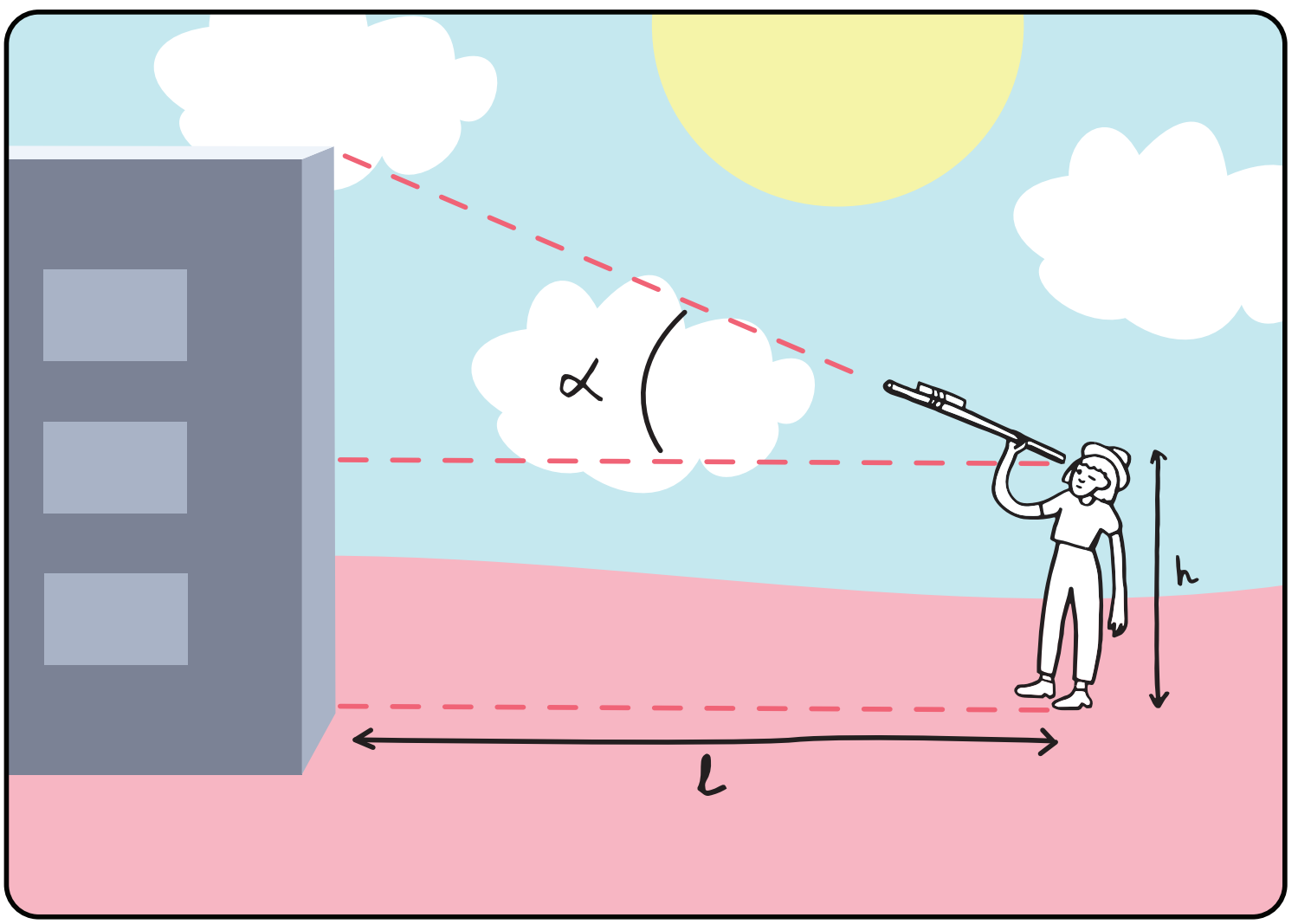
1 long thin tube

Sensor: **accelerometer**

1 smartphone

Attach the smartphone to the tube, and go at a known distance from the building. With the accelerometer, measure the inclination from the horizontal when you aim at the top of the building.

h = height of eye of the investigator, l = distance to the building, α = angle of the top of the building



Precision: maximum

Difficulty: minimum

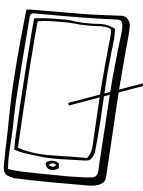
№28. Picture with Scale

Formula

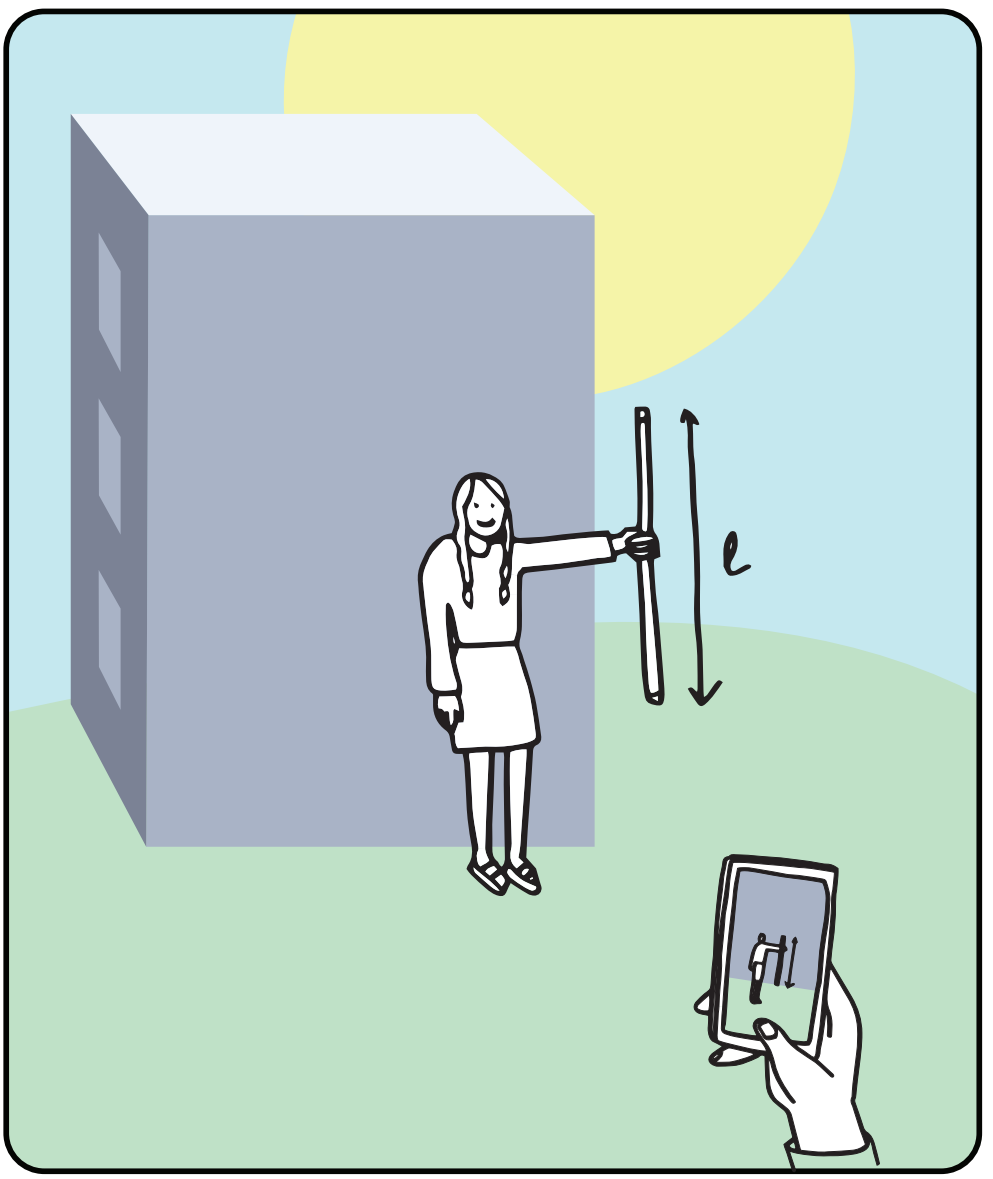
$$H = \frac{d_2}{d_1} l$$

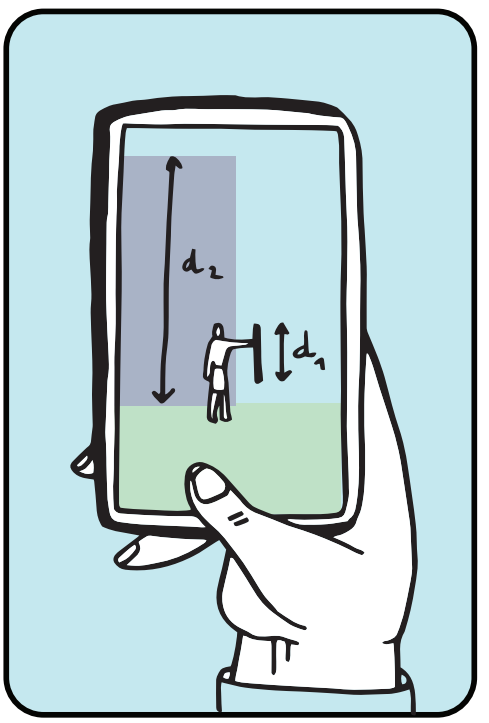
Material

1 bar of known size



1 smartphone





Take a picture of the facade of the building, with the bar serving as a scale. Measure the sizes of the building and the bar on the picture.

d_2 = size of the building on the photo, d_1 = size of the bar on the photo, l = actual size of the bar

Minimize perspective distortion while taking the picture!

Precision: high

Difficulty: minimum

№29. Facade Picture

Formula

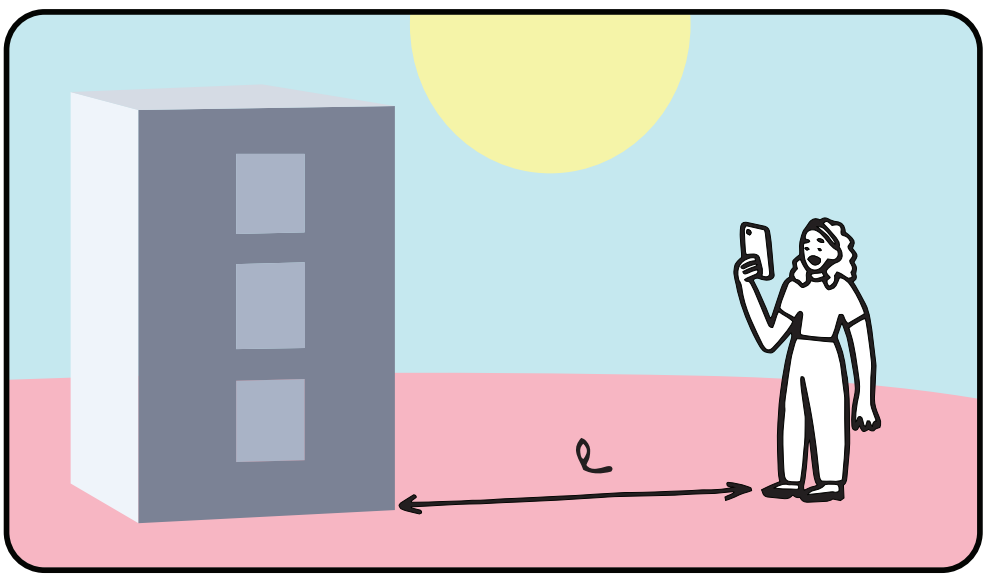
$$H = l \frac{d}{f}$$

Material

1 tape measure

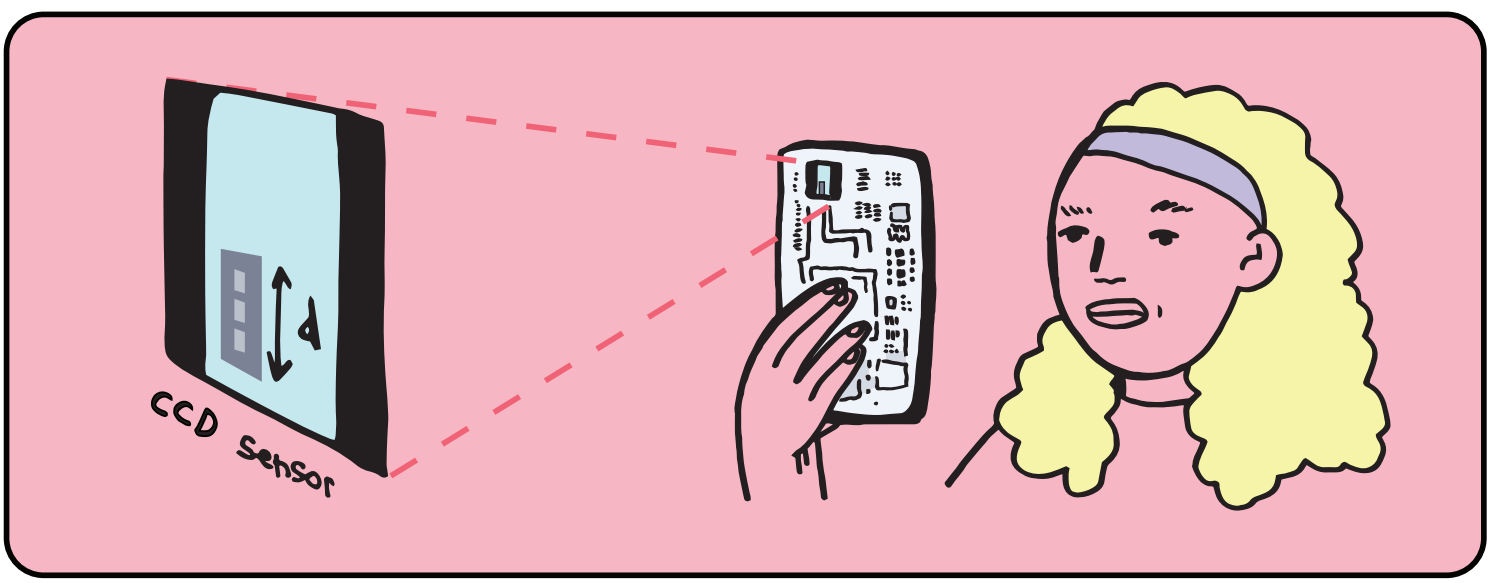
1 smartphone with known CCD sensor size and focal length

Sensor: **camera**



Take a picture of the building facade, at a known distance. Determine the actual size of the building image on the CCD sensor by looking at the fraction of the picture height occupied by the building.

l = distance to the building, d = size of the building image on the CCD sensor, f = focal length of the camera



Minimize perspective distortion while taking the picture!

Precision: maximum

Difficulty: minimum

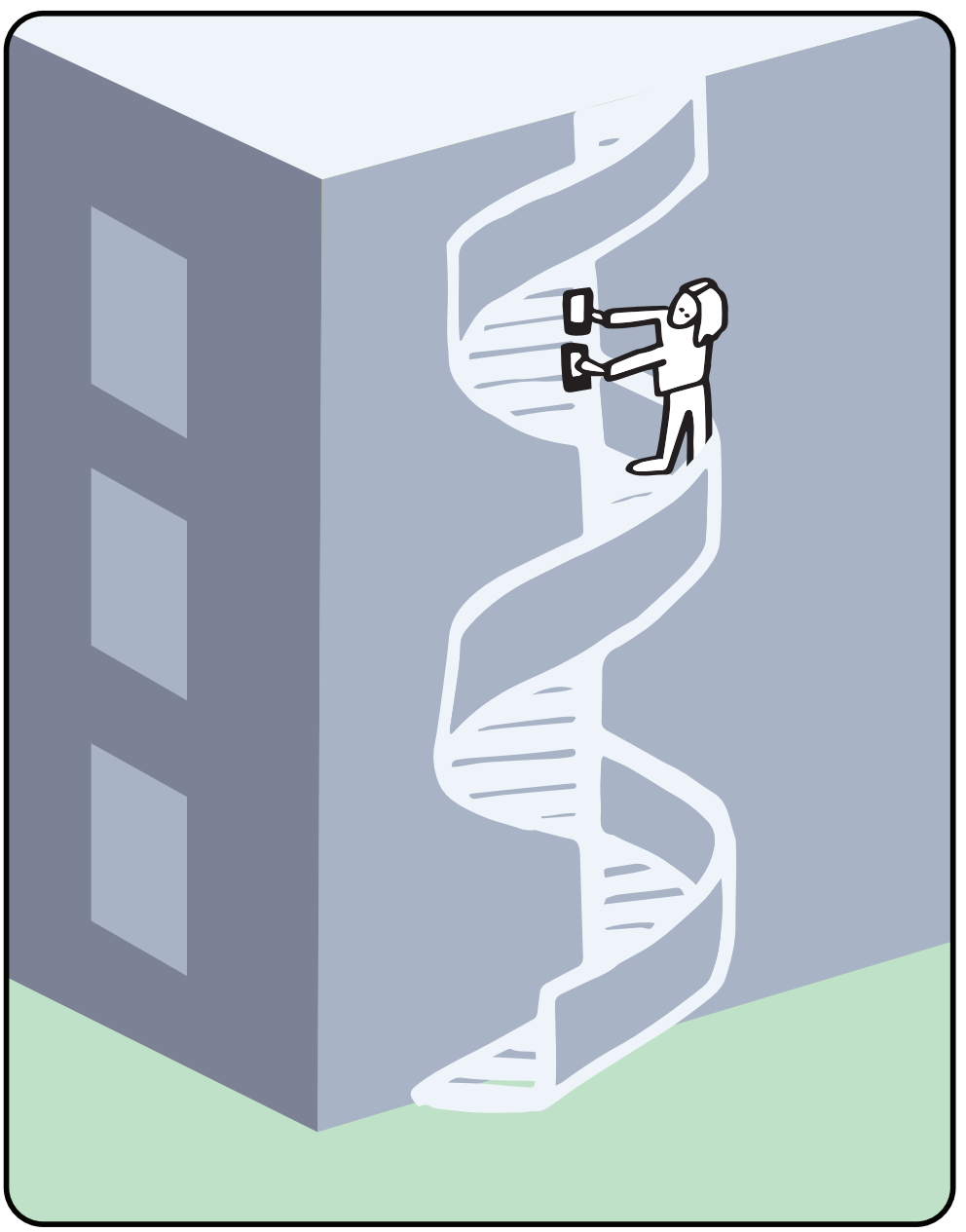
№34. Number of Smartphones

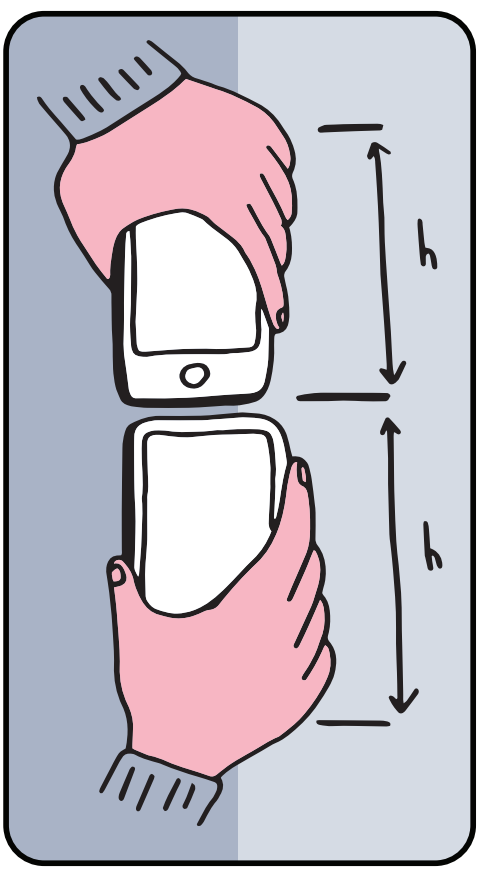
Formula

$H = Nh$

Material

2 identical smartphones





Using the outside emergency staircase, count the number of smartphones that must be stacked to reach the top of the building.

N = number of smartphones,
h = height of a smartphone

Precision: high

Difficulty: minimum

№36. Pressure Variation

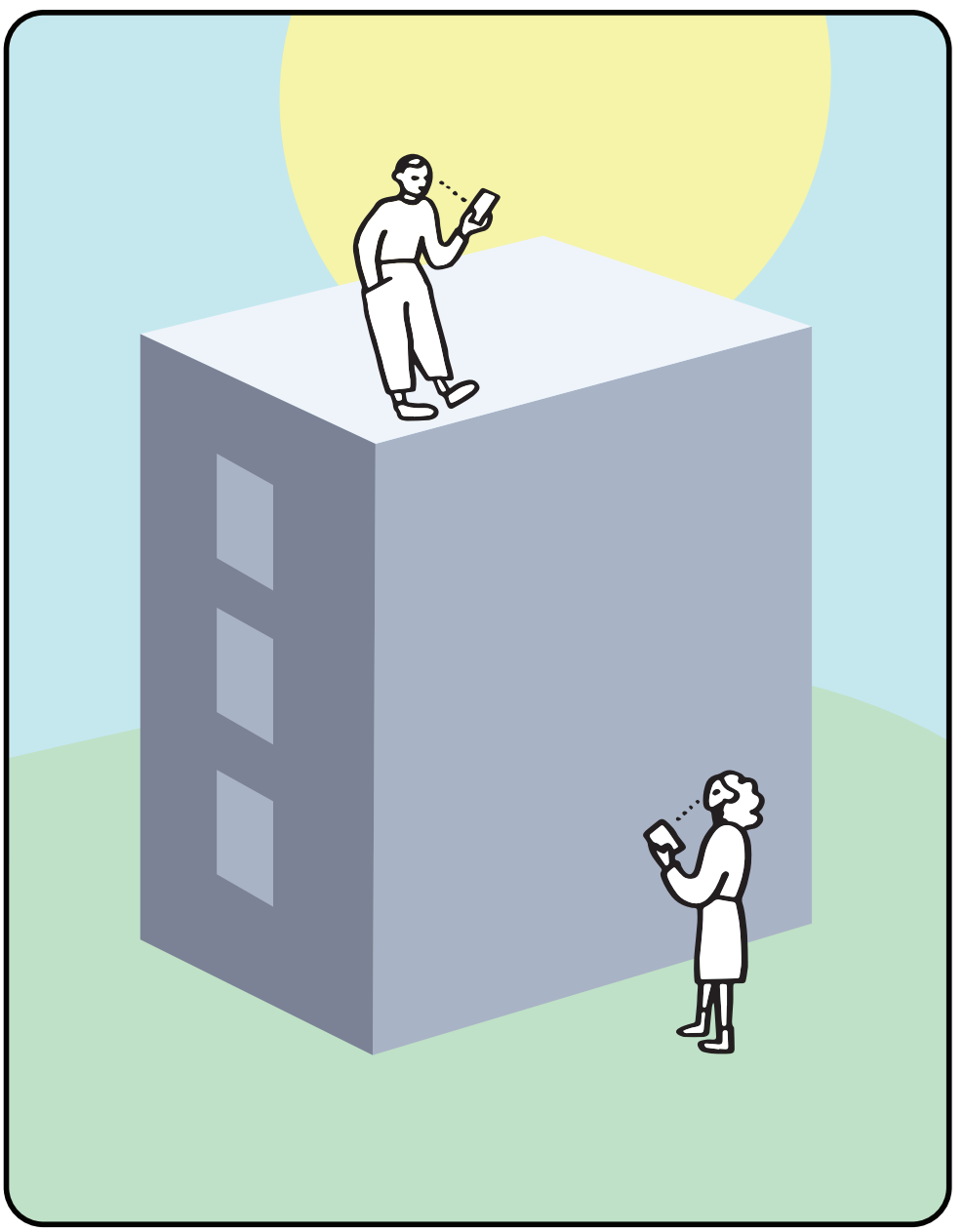
Formula

$$H = \frac{P_2 - P_1}{\rho g}$$

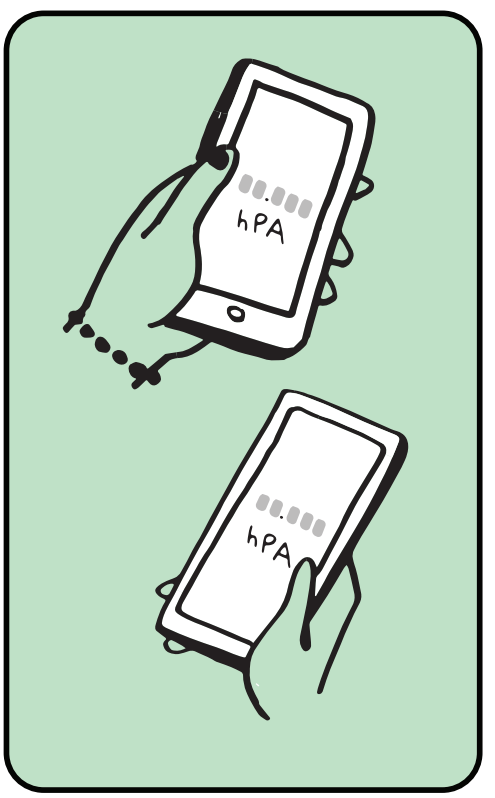
Material

Sensor:
barometer

1 smartphone



Measure the atmospheric pressure at the top and bottom of the building. The pressure variation depends directly on the height and density of air.



P_1 = pressure at the top,
P_2 = pressure at the bottom,
ρ = density of air, g = 9.8 ms^{-2}

№38. GPS

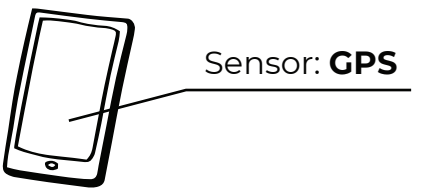
Precision: minimum

Difficulty: minimum

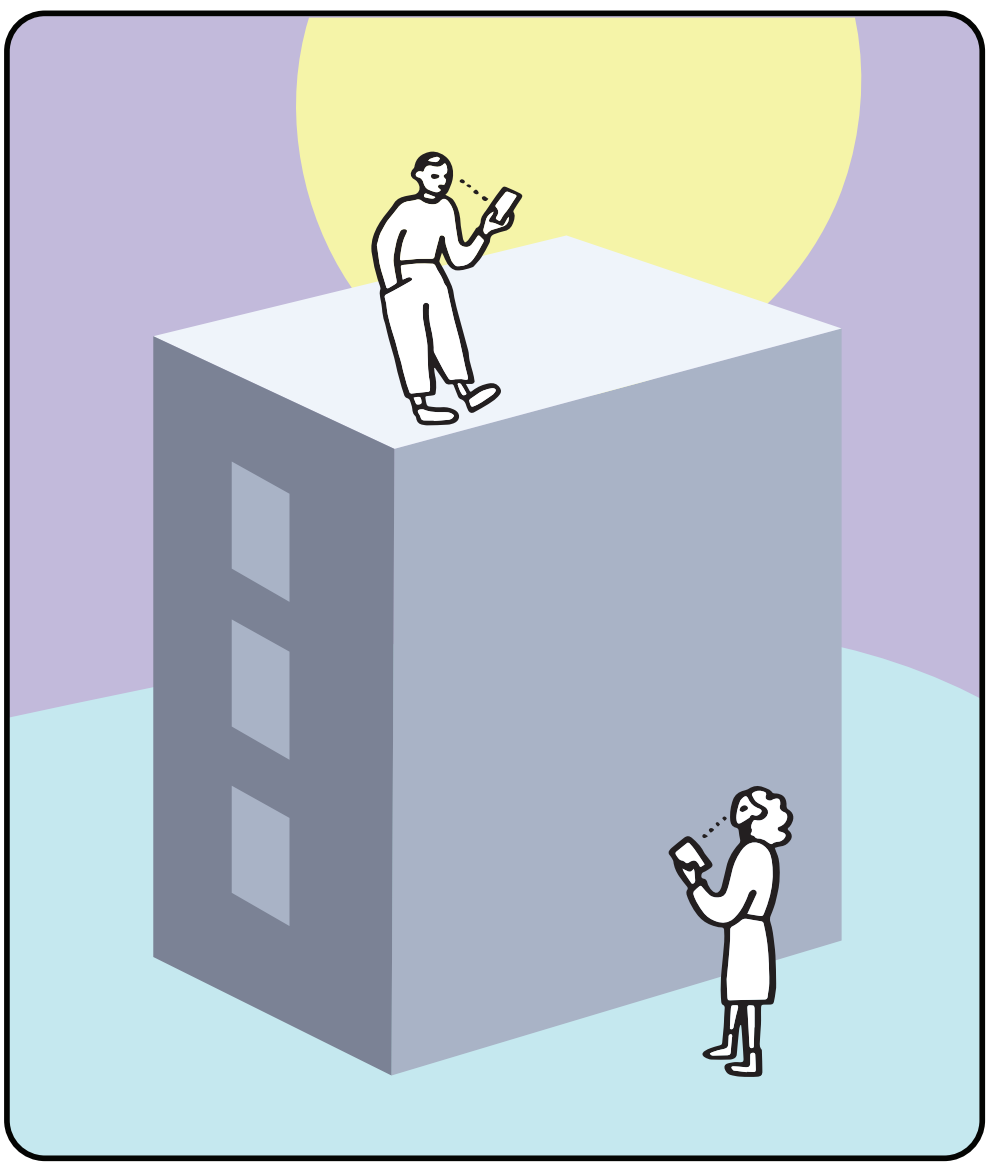
Formula

$$H = h_2 - h_1$$

Material

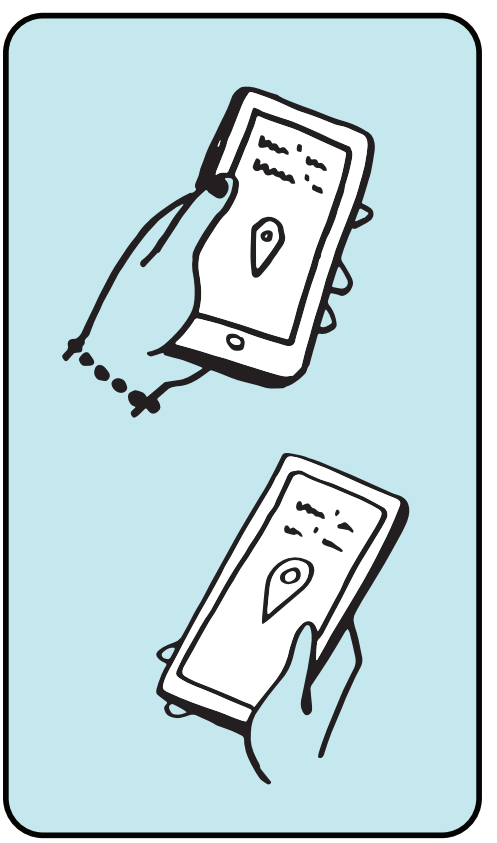


1 smartphone



Use the GPS data to determine the altitude at the bottom and at the top of the building.

h_2 = altitude at the top of the building, h_1 = altitude at the bottom



The altitude function of the GPS is really not accurate.

Precision: high

Difficulty: high

№55. Hair Diffraction

Formula

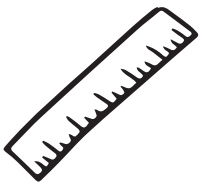
$$H = \frac{ld}{2\lambda}$$

Material

1 hair

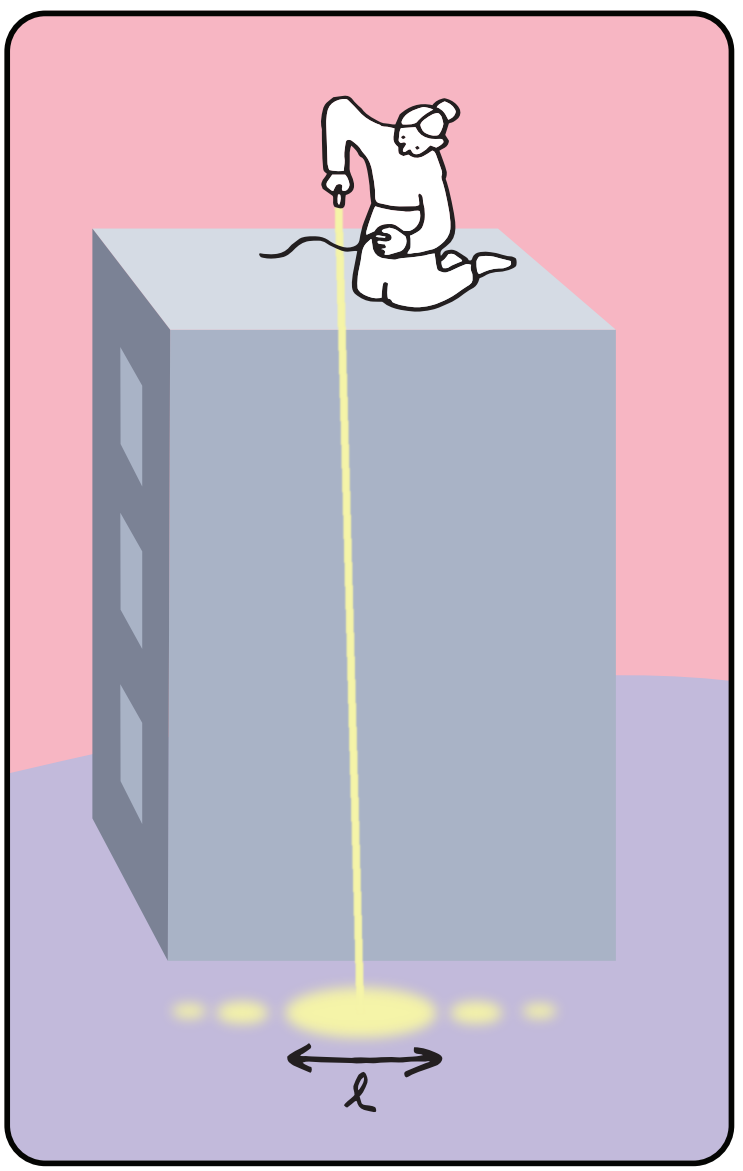
1 laser

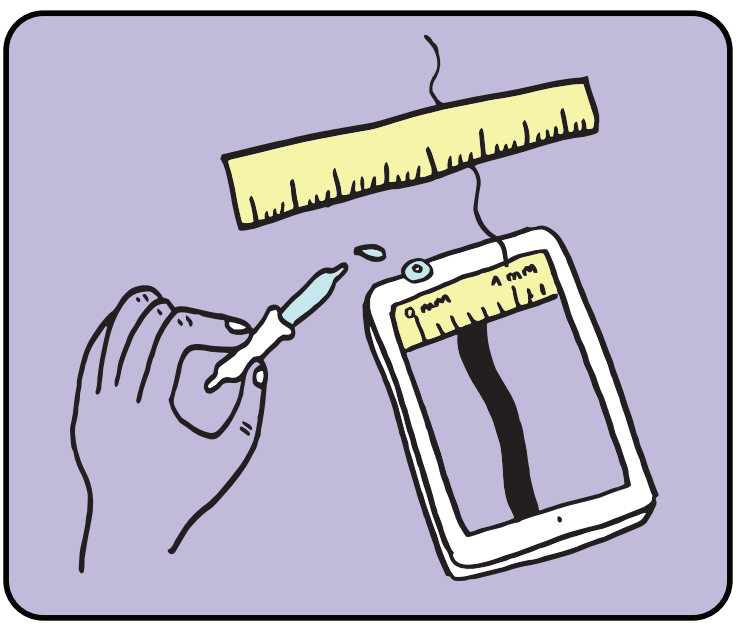
1 drop of water



1 ruler

1 smartphone





From the top of the building, illuminate the hair with a laser down. Measure the diffraction spot at the bottom of the building. Then, using a drop of water placed on the camera lense, turn your smartphone into a microscope, and measure the diameter of the hair.

l = size of the diffraction spot, d = hair diameter, λ = wavelenght of the laser

Warning: handling a laser is dangerous.

Precision: awfully bad

Difficulty: minimum

№60. General Relativity

Formula

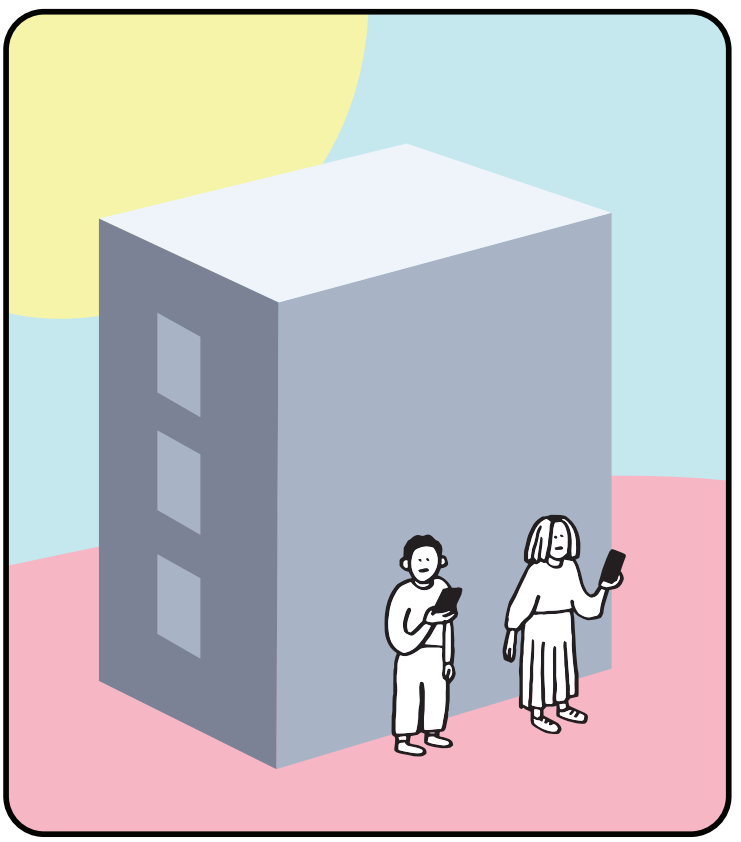
$$H = \frac{c^2}{g}\,\frac{\delta t}{t}$$

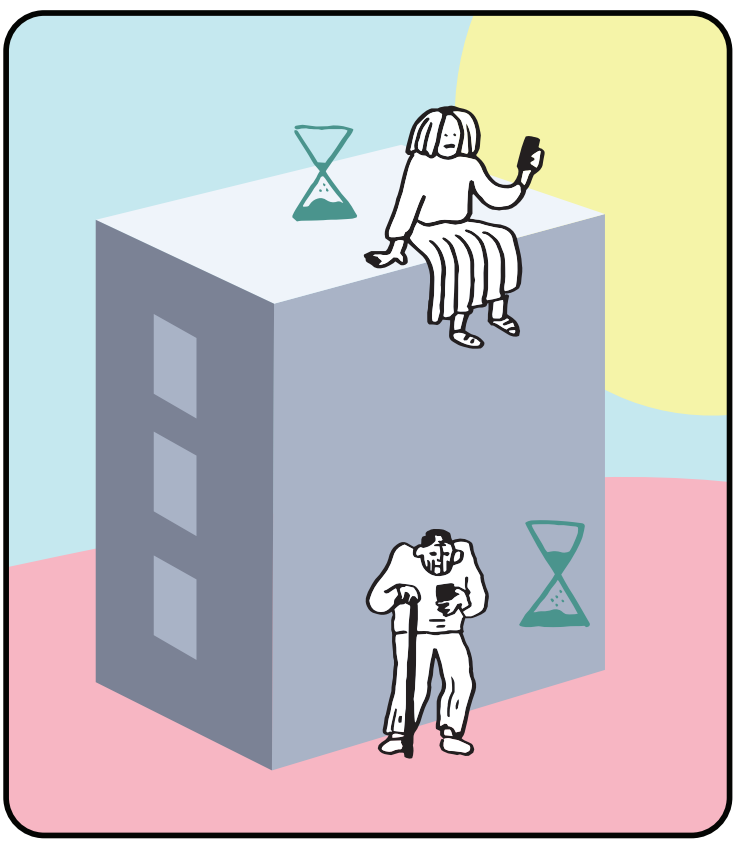
Material

Sensor: **stopwatch**

2 smartphones

At the bottom of the building, start both chronometers, then go to the top of the building with one of the smartphones. Wait for a while, then go down again. Measure the delay (due to general relativity) between the two chronometers.





c = speed of light, g = gravity, δt = difference between the two chronometers, t = duration of the experiment

The effect of velocity (twin paradox) is negligible in front of the effect of altitude in this situation.

Precision: maximum

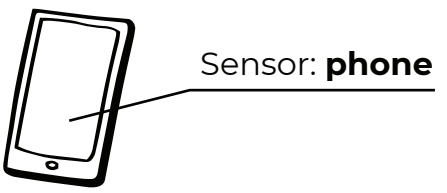
Difficulty: minimum

№61. The Architect

Formula

$$H=H$$

Material



1 smartphone

Call the building architect, and ask him.

This project was imagined by Frédéric Bouquet (Paris-Saclay University) and Giovanni Organtini (Sapienza Università di Roma, Italy).

Physics: Frédéric Bouquet, Giovanni Organtini, Julien Bobroff

Videos, photos, gifs: Amel Kolli

Graphic design and illustrations: Anna Khazina

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