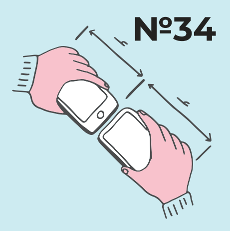
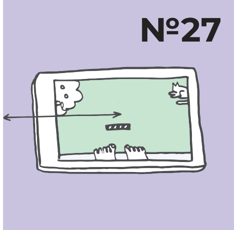
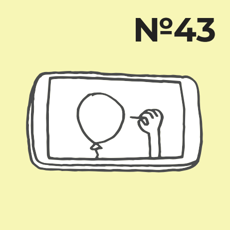
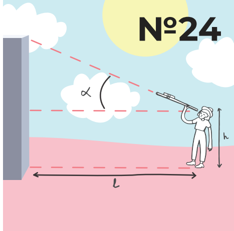
How many ways

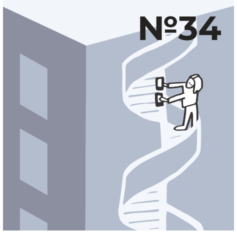


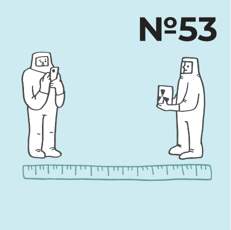


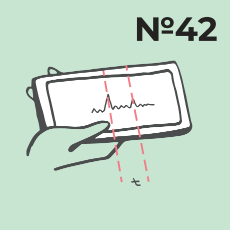




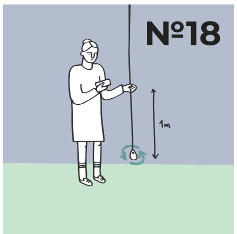
are there to measure



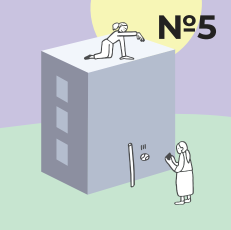




the height of a building



using a smartphone?



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

«Physics Reimagined» team (Paris-Saclay University)

Precision: high

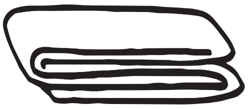
Difficulty: low

№1. Free Fall of the Smartpone

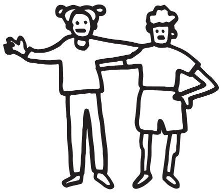
Formula

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

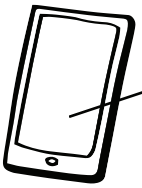
Material



1 sheet

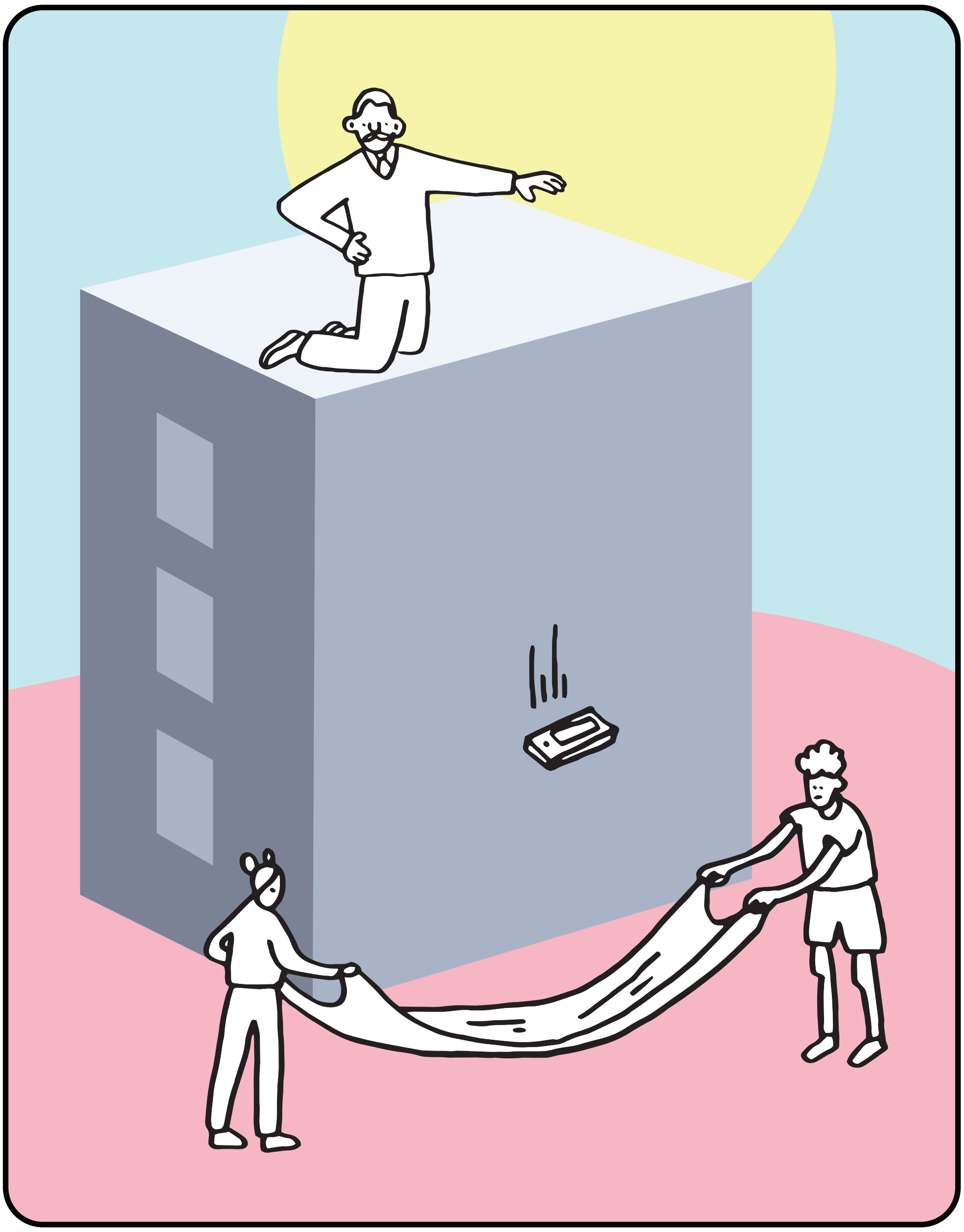


two friends

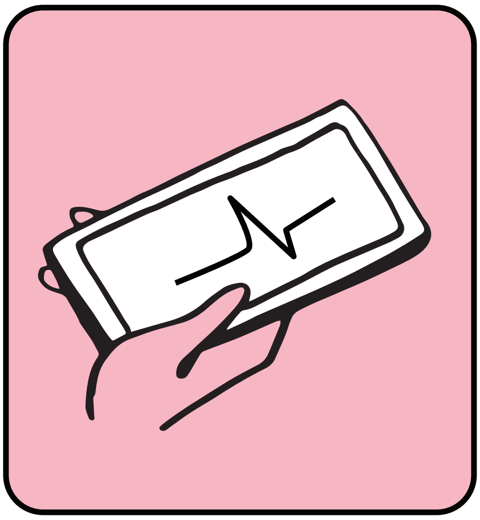


Sensor: **accelerometer**

1 smartphone



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,

$\dot{z}$ = smartphone's acceleration,

g = 9.8 ms^{-2}

Precision: intermediate

Difficulty: minimum

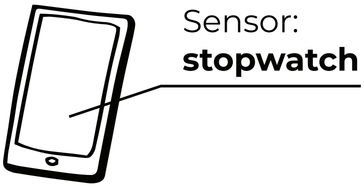
№2. Free Fall & Stopwatch

Formula

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

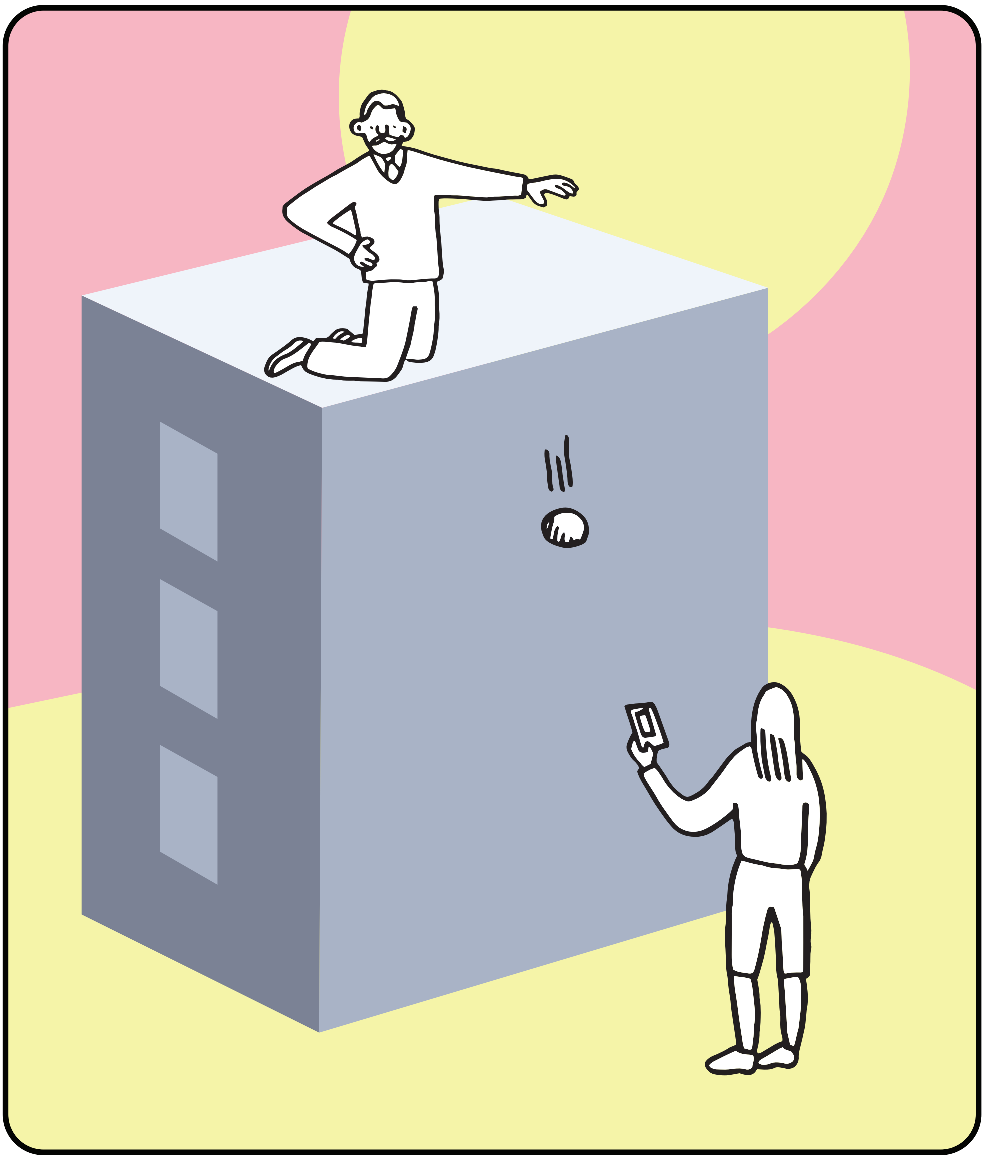
Material

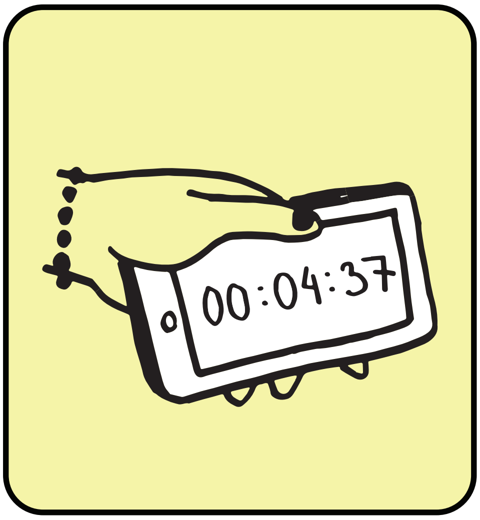
1 ball



Sensor: **stopwatch**

1 smartphone





Drop the ball from the top of the building. Time the fall.

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

The formula does not consider air drag.

Precision: high

Difficulty: minimum

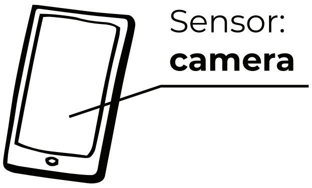
№3. Free Fall Filmed

Formula

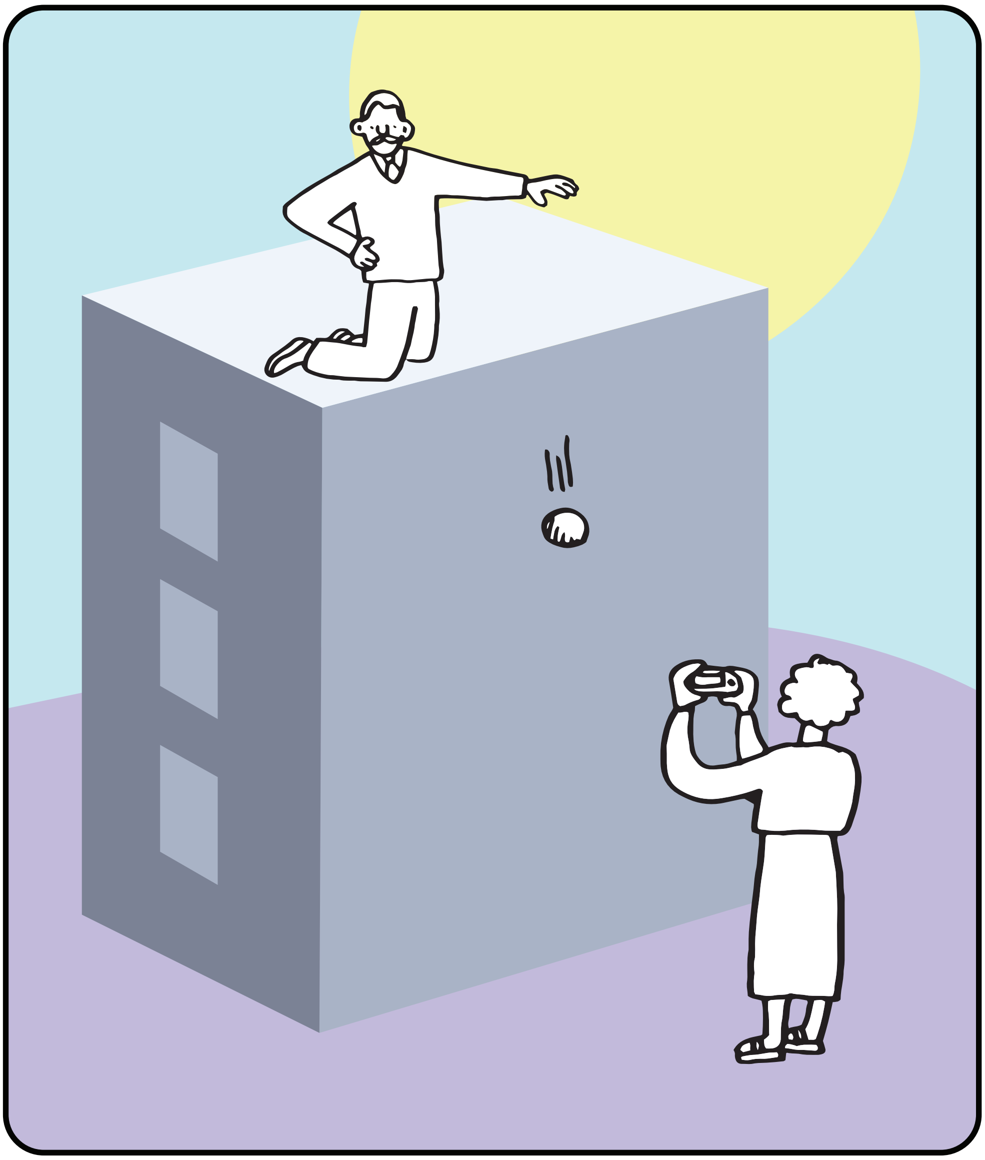
$$H = \frac{1}{2} g t^2$$

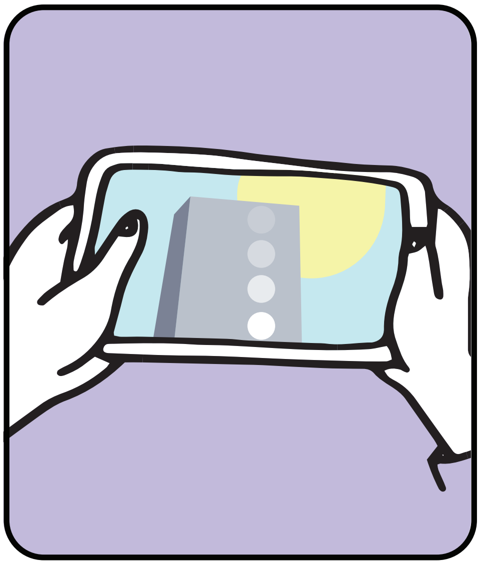
Material


1 ball


Sensor:
camera

1 smartphone





Drop the ball from the top of the building. Film the fall and determine its duration.

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

The formula does not consider air drag.

Precision: high

Difficulty: low

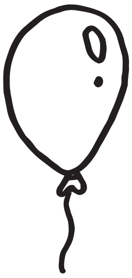
№4. Sound of a Free Fall

Formula

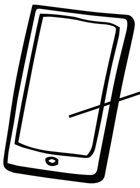
$$H = \frac{1}{2} g t^2$$

Material

1 ball

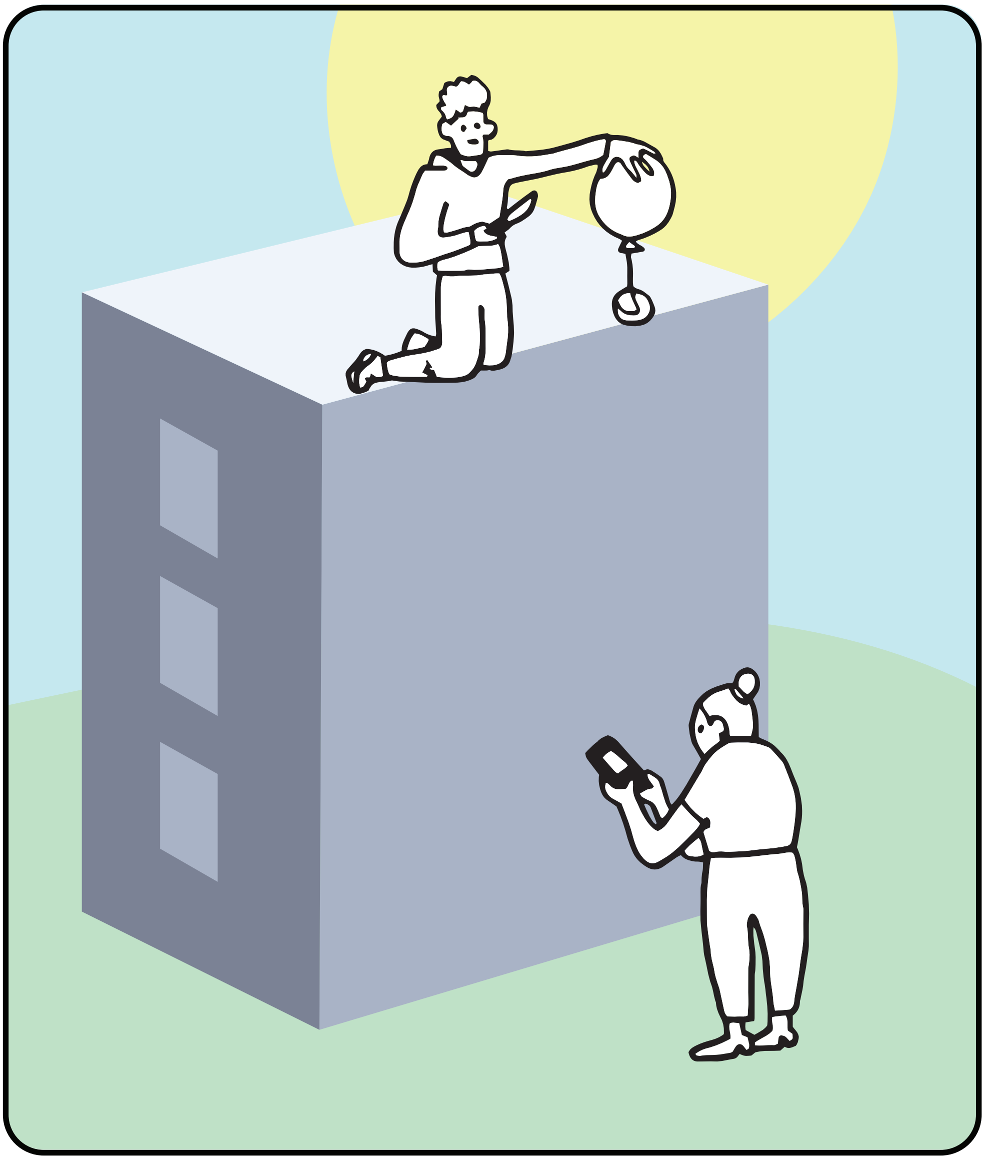


1 balloon



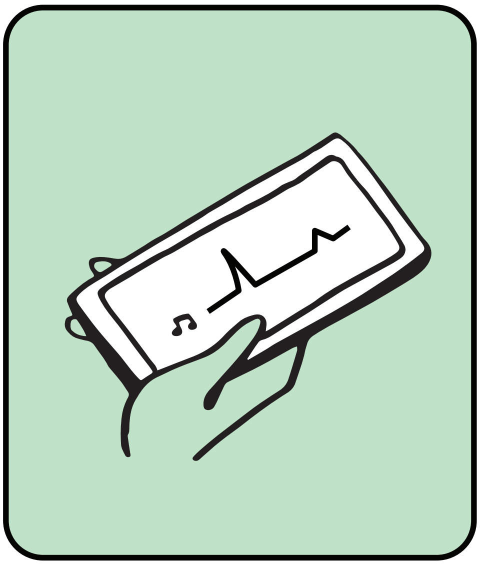
Sensor: **microphone**

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: intermediate

Difficulty: low

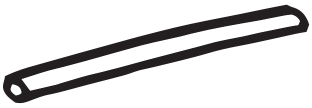
№5. End of the Fall Filmed

Formula

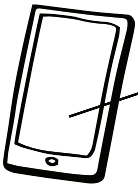
$$H = \frac{v^2}{2g}$$

Material

1 ball

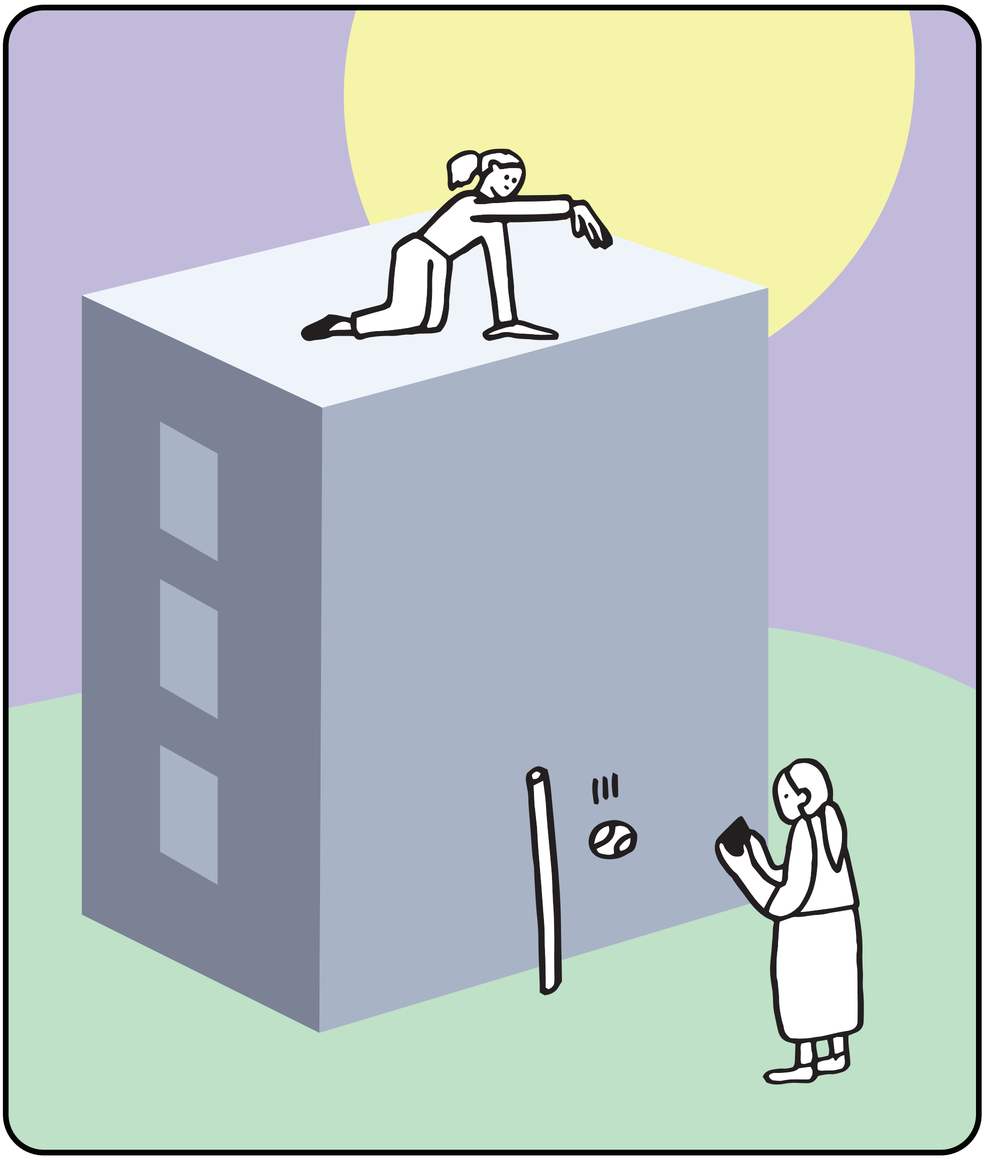


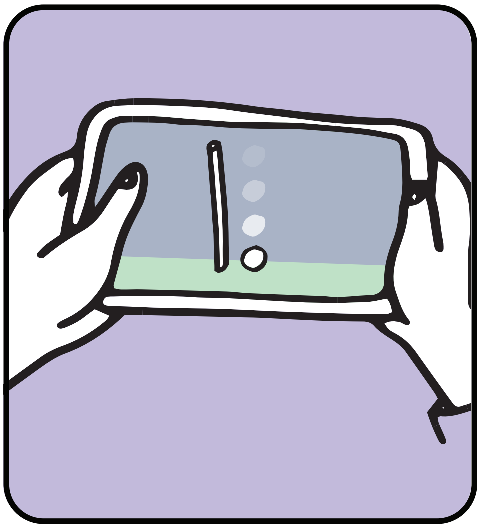
1 bar of known size



Sensor: **camera**

1 smartphone





Drop the ball from the top of the building. Film the last meters of the ball's fall, using the bar as a scale. Determine the final velocity of the ball.

v = ball’s final velocity,
g = 9.8 ms^{-2}

The formula does not consider air drag.

Precision: intermediate

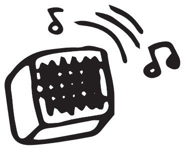
Difficulty: intermediate

№6. End of the Fall & Doppler

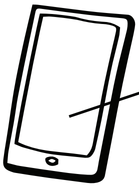
Formula

$$H = \frac{v^2}{2g}$$

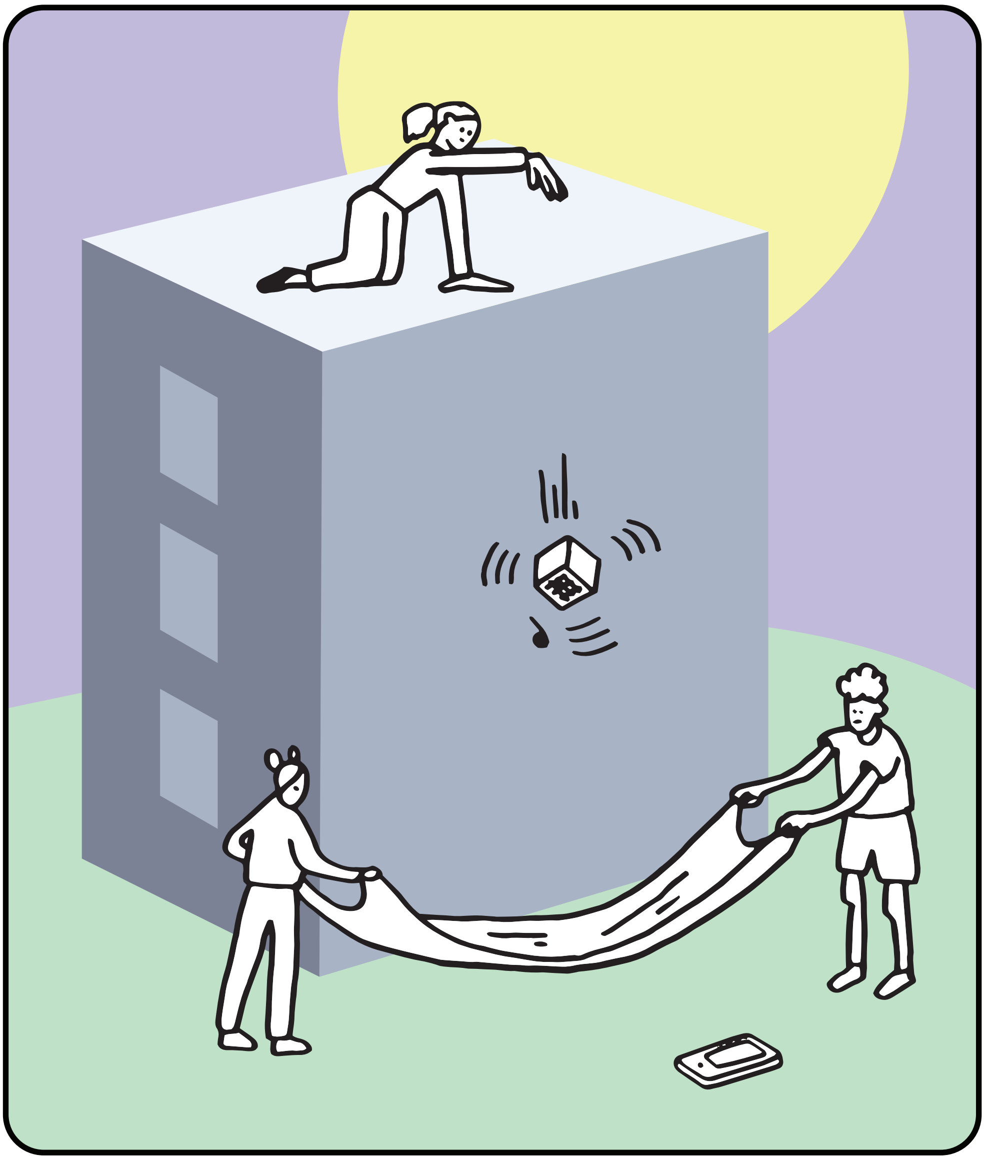
Material


1 bluetooth speaker


1 sheet

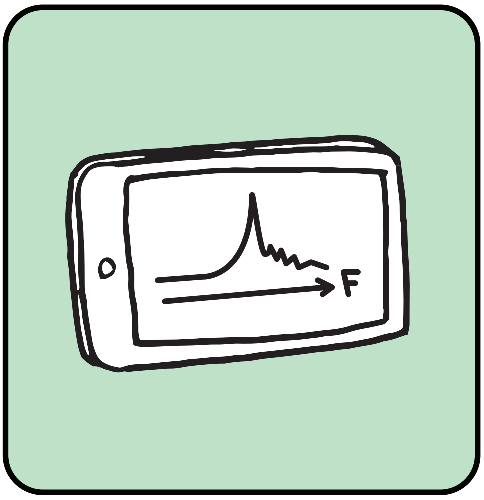

Sensor: **microphone**

1 smartphone



Let the loudspeaker fall from the top of the building, making it sound a continuous note. At the bottom, the smartphone records the sound to determine the speed of fall by Doppler effect. (Catch the speaker in a sheet stretched between two people.)

v = speaker's final velocity,
g = 9.8 ms^{-2}



The formula does not consider air drag.

Precision: intermediate

Difficulty: intermediate

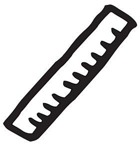
№7. Parabola

Formula

$$H = \frac{1}{2} g \left(\frac{l}{v_0}\right)^2$$

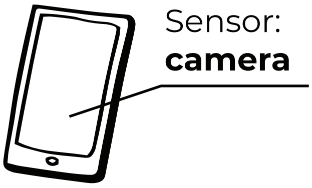
Material

1 tape measure



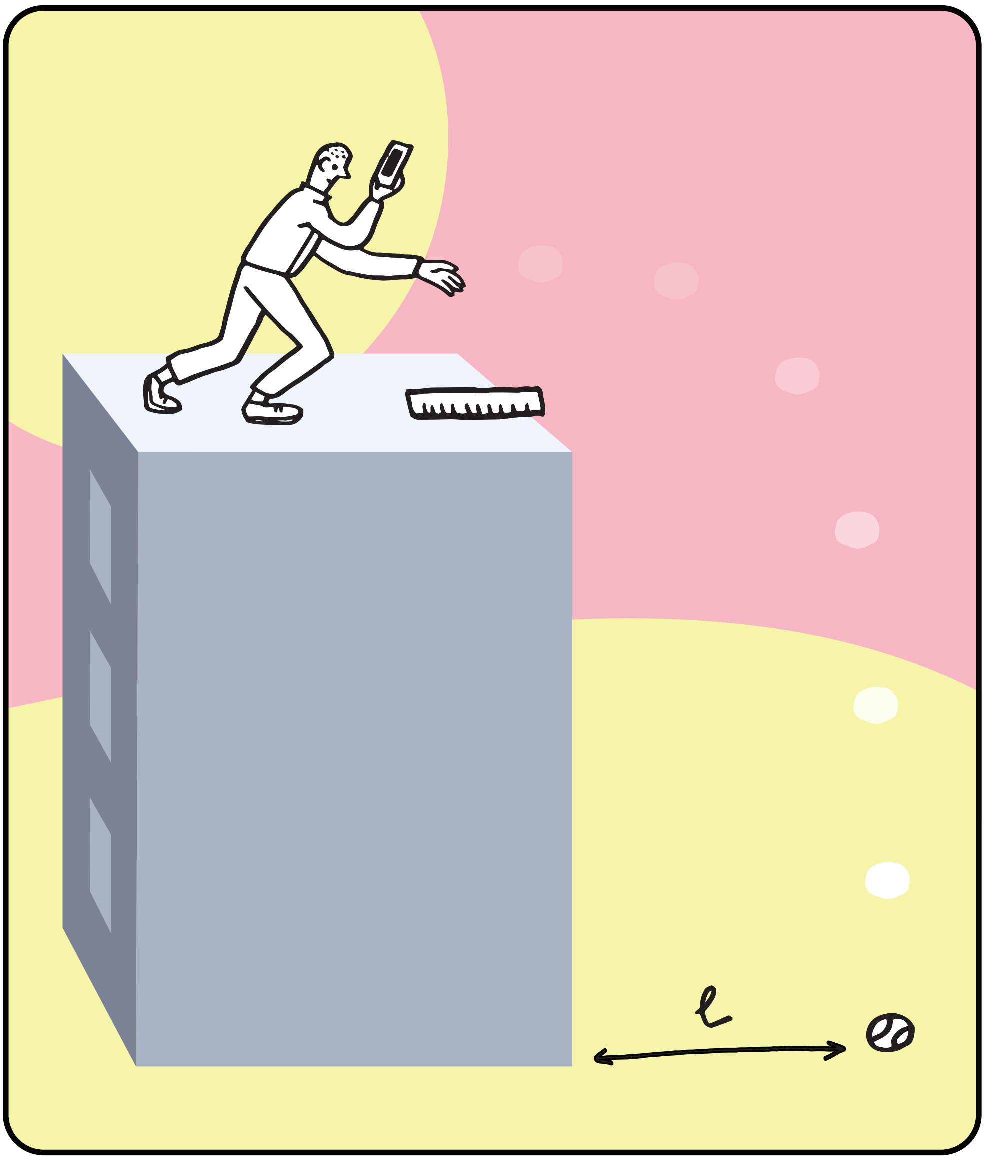
1 bar of known size

1 ball



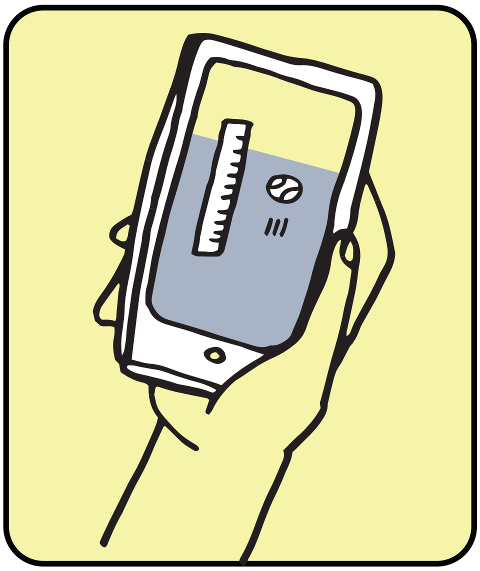
Sensor: **camera**

1 smartphone



From the top of the building, the ball is thrown horizontally. Film the throw to determine the initial velocity of the ball (the bar gives the scale). Measure the distance to the building where the ball is landing.

v_0 = horizontal velocity of the ball,
l = distance to the building where the ball touches the ground,
$g = 9.8\ ms^{-2}$



The formula does not consider air drag.

Precision: intermediate

Difficulty: low

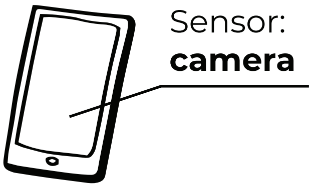
№8. Filmed Bounces

Formula

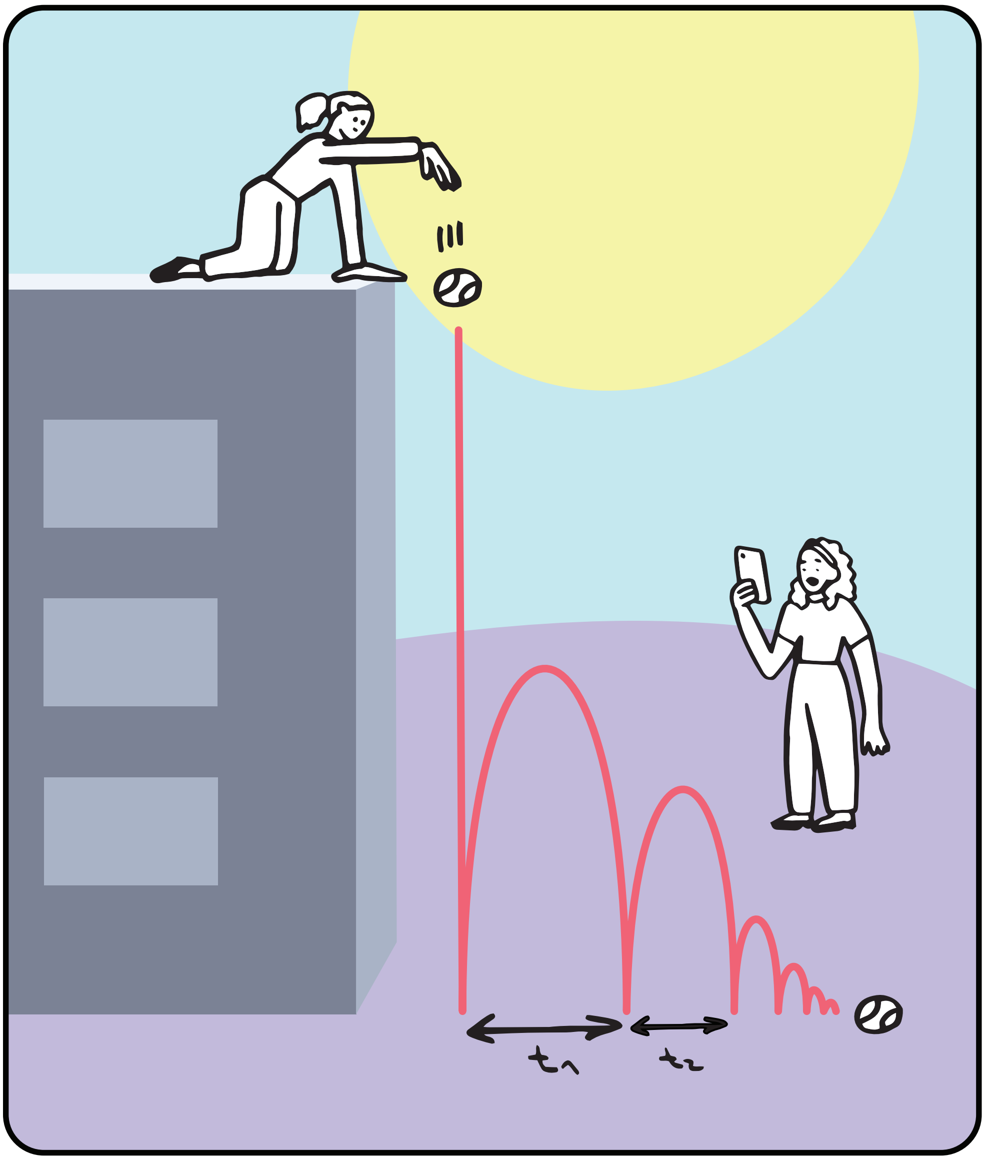
$$\begin{cases} t_n = 2e^n t_0 \\ H = \frac{1}{2} g t_0^2 \end{cases}$$

Material

1 ball



1 smartphone



Drop the ball from the top of the building. Shoot the successive rebounds of the ball to determine the coefficient of restitution (supposed constant) and the duration of rebounds.

t_n = duration of the nth rebound,
e = coefficient of restitution,
t_0 = duration of the fall from the top of the building, g = 9.8 ms^{-2}

The formula does not consider air drag.

Precision: intermediate

Difficulty: low

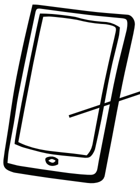
№9. Sound of Bounces

Formula

$$\begin{cases} t_n = 2e^n t_0 \\ H = \frac{1}{2} g t_0^2 \end{cases}$$

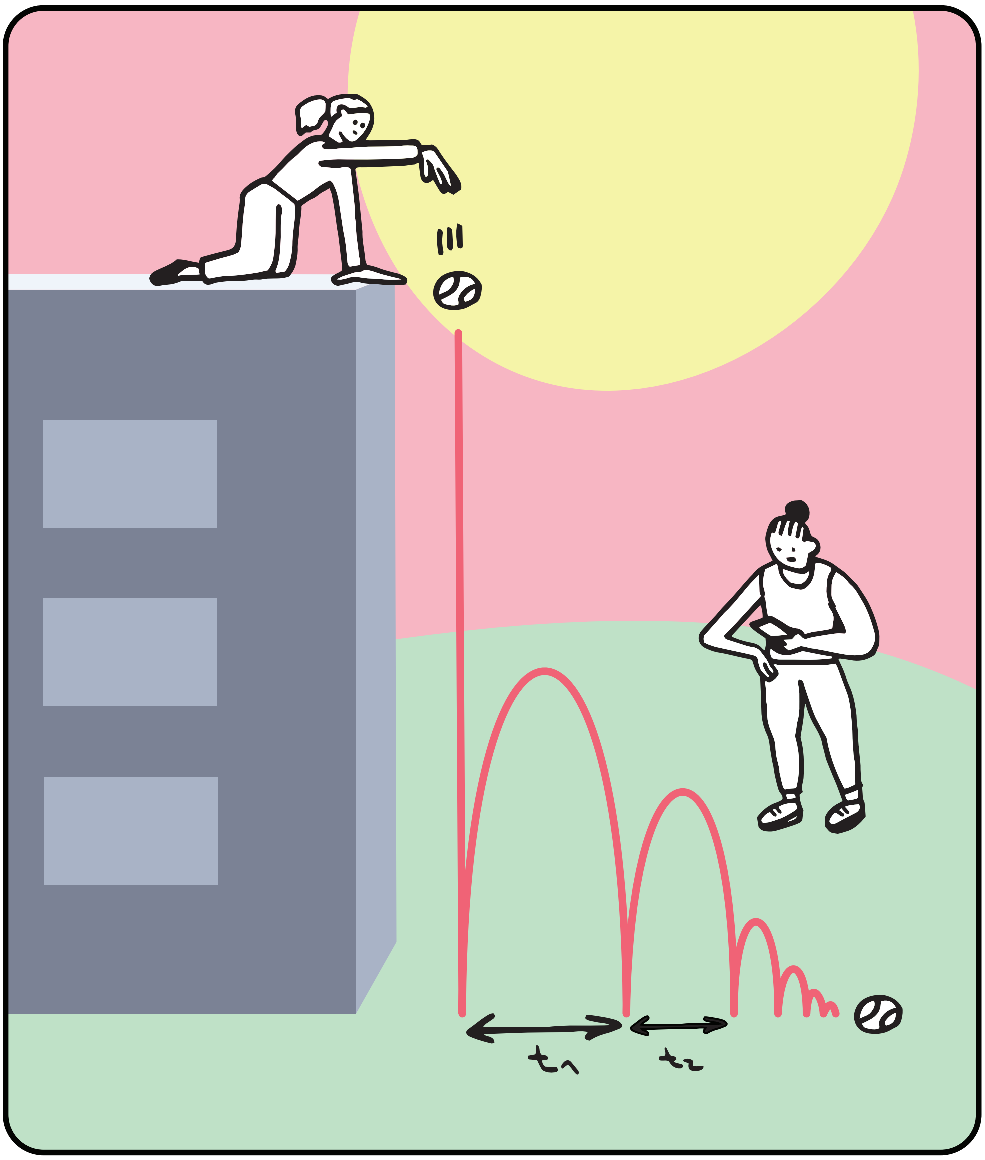
Material

1 ball



Sensor: **microphone**

1 smartphone



Drop the ball from the top of the building. Record the sound of the successive rebounds of the ball to determine their durations (the coefficient of restitution is assumed constant).

t_n = duration of the nth rebound,
e = coefficient of restitution,
t_0 = duration of the fall from the top of the building, g = 9.8 ms^{-2}

The formula does not consider air drag.

Precision: maximum

Difficulty: intermediate

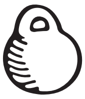
№10. Giant Pendulum Timed

Formula

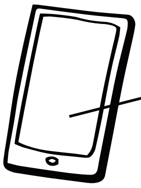
$$H = g\left(\frac{T}{2\pi}\right)^2$$

Material

1 long rope

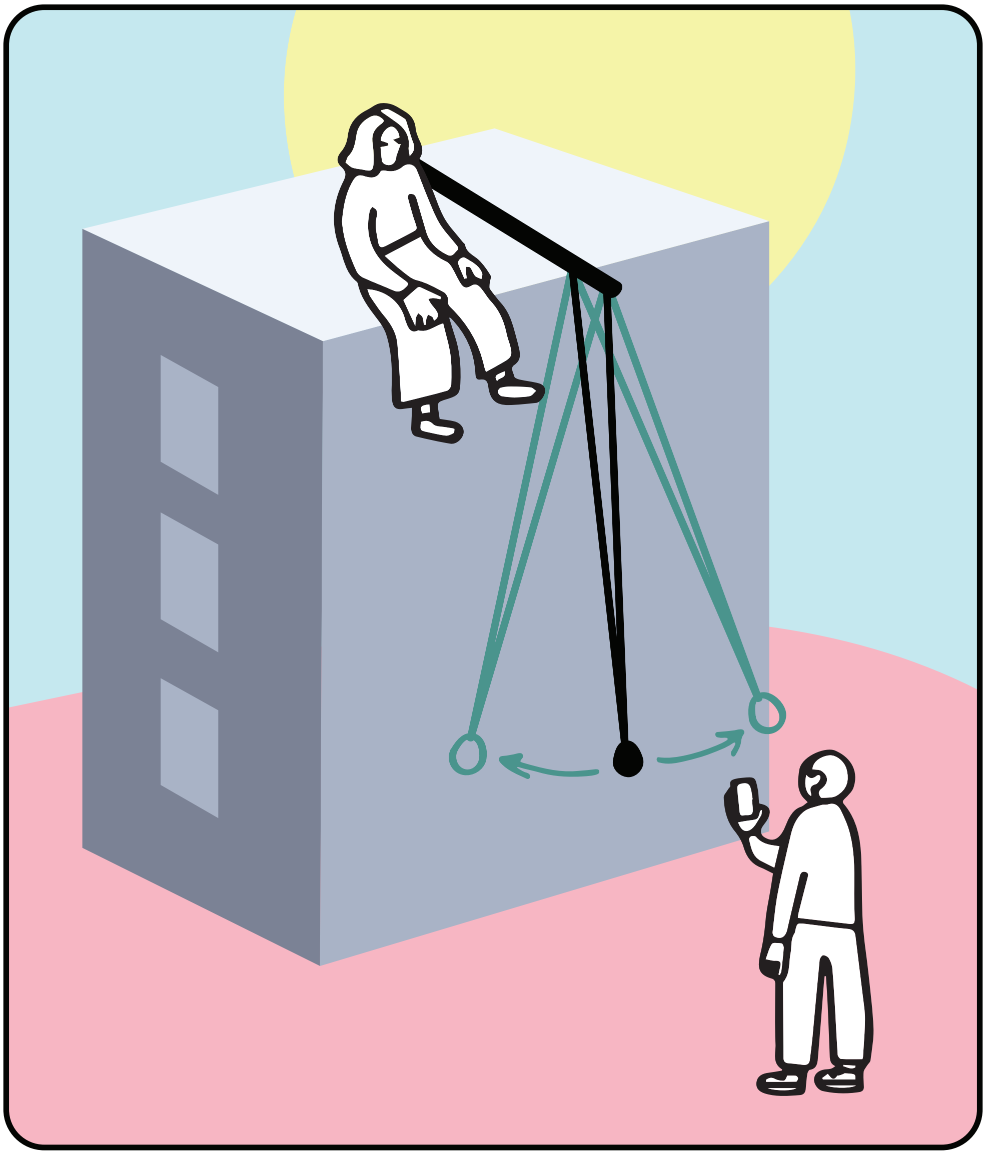


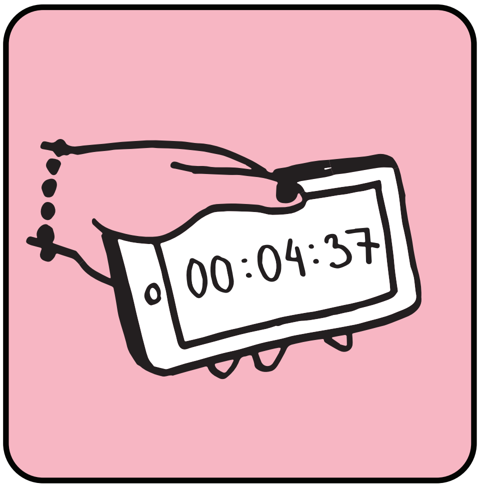
1 mass



Sensor: **stopwatch**

1 smartphone





Make a giant pendulum the size of the building. Use the smartphone timer to determine the period.

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

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

Precision: maximum

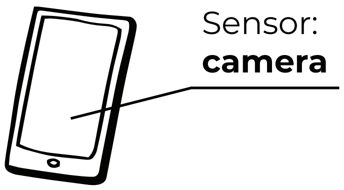
Difficulty: intermediate

№11. Giant Pendulum Filmed

Formula

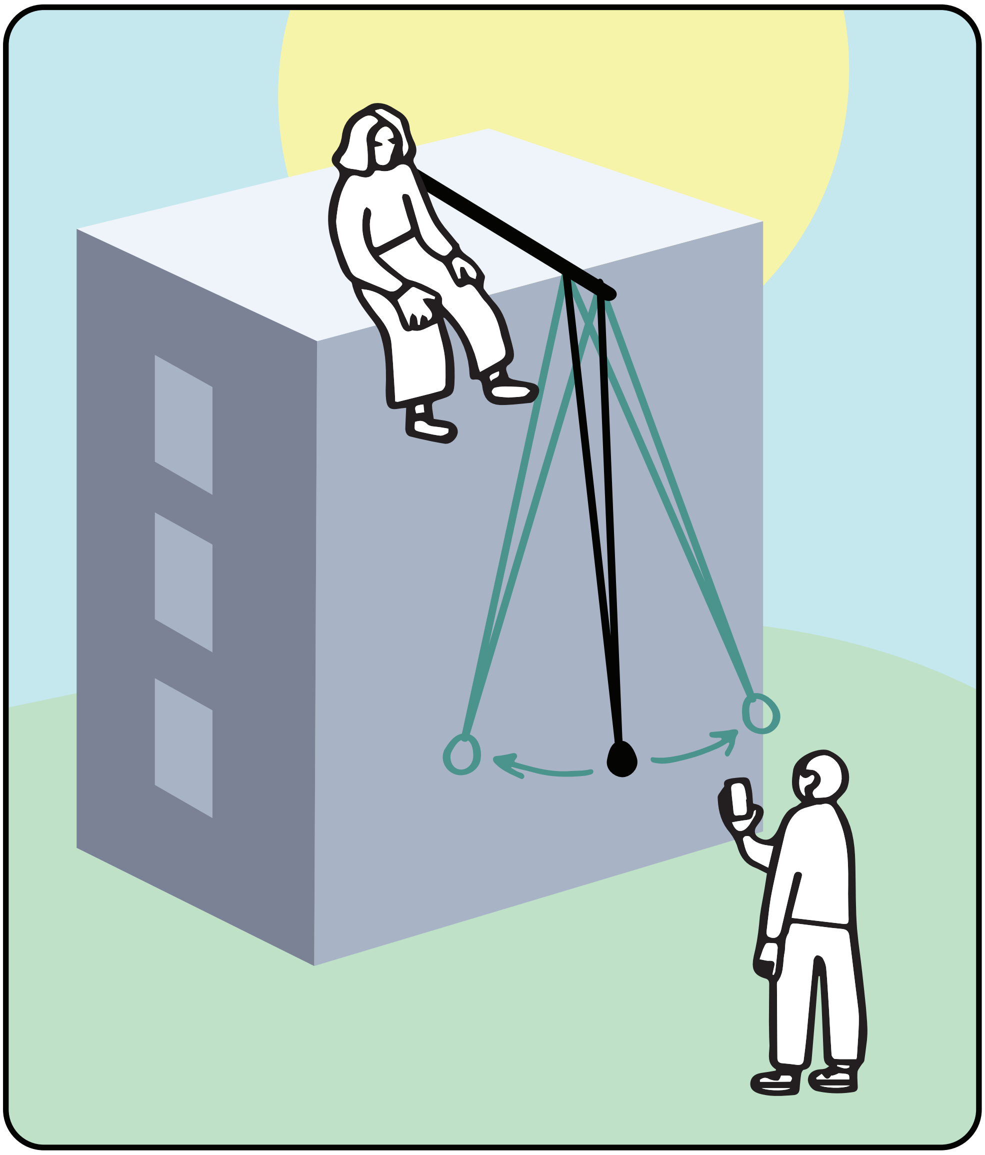
$$H = g\left(\frac{T}{2\pi}\right)^2$$

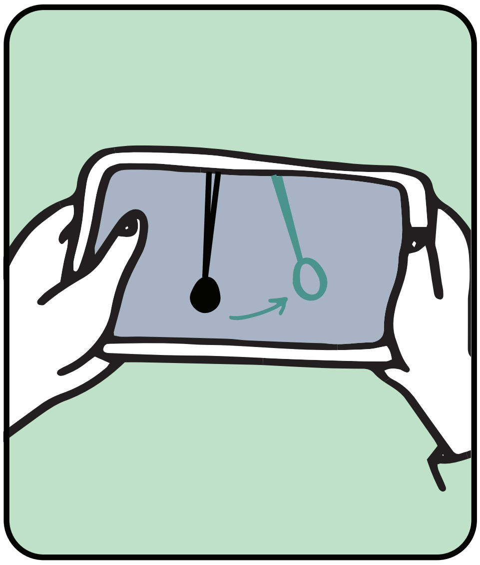
Material



Sensor: **camera**

1 smartphone





Make a giant pendulum the size of the building. Film the oscillations of the pendulum to determine the period.

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

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

Precision: low

Difficulty: intermediate

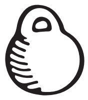
№12. Giant Pendulum & Accelerometer

Formula

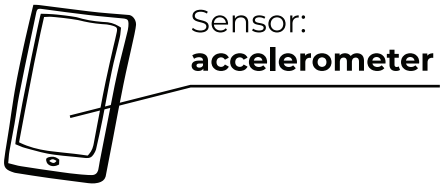
$$H = g\left(\frac{T}{2\pi}\right)^2$$

Material

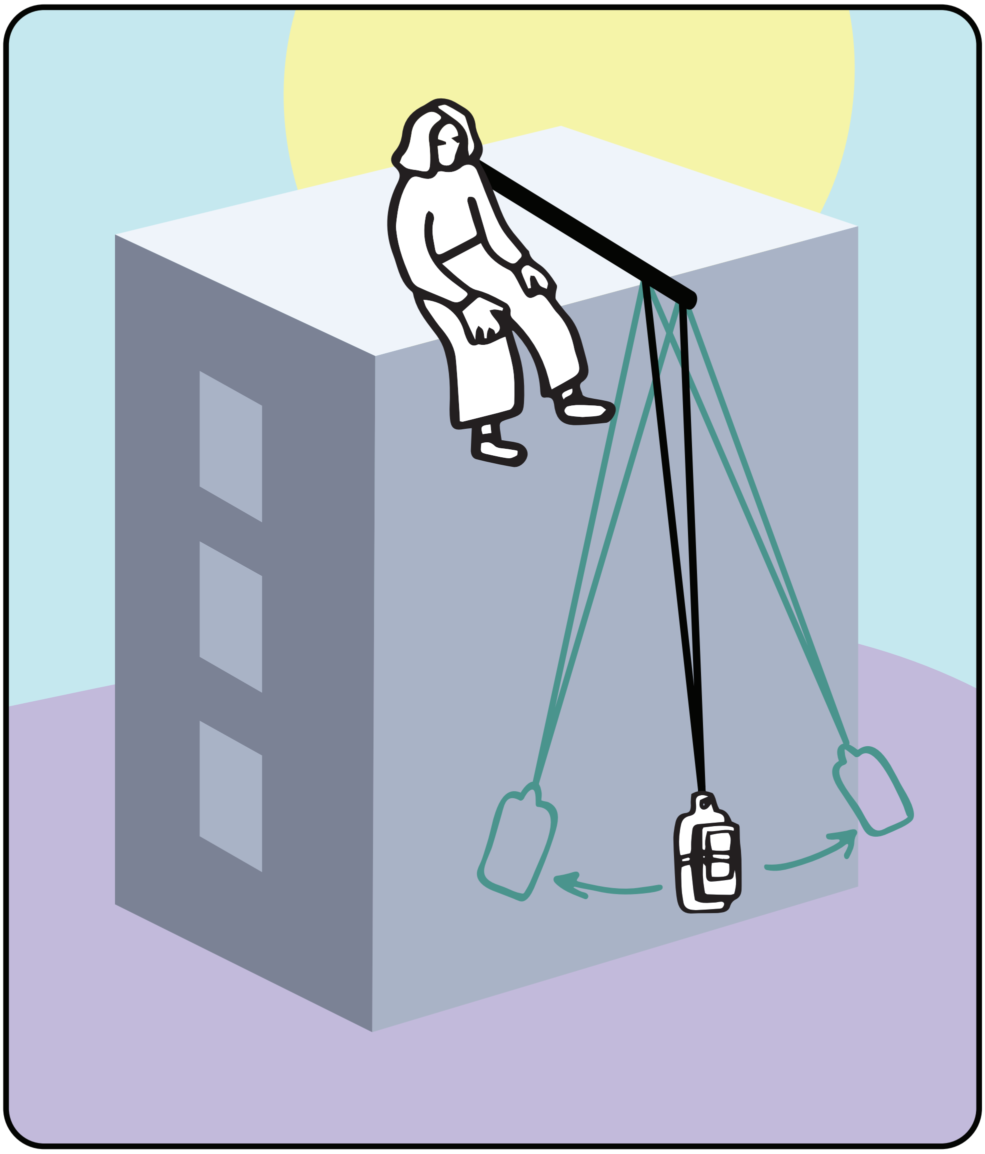
1 long rope



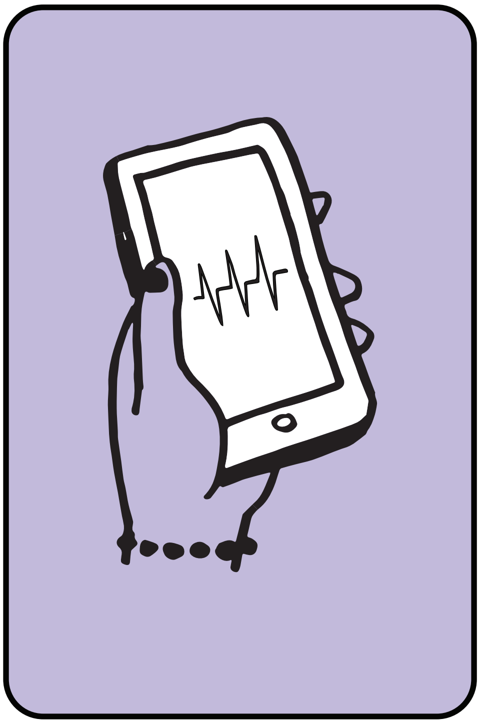
1 mass



1 smartphone



Make a giant pendulum the size of the building. Attach the smartphone to the pendulum, and use the accelerometer to determine the period.



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

The higher the building, the smaller the acceleration, and the harder the measure will be.

Precision: low

Difficulty: intermediate

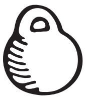
№13. Giant Pendulum & Gyroscope

Formula

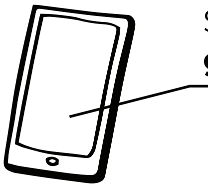
$$H = g\left(\frac{T}{2\pi}\right)^2$$

Material

1 long rope

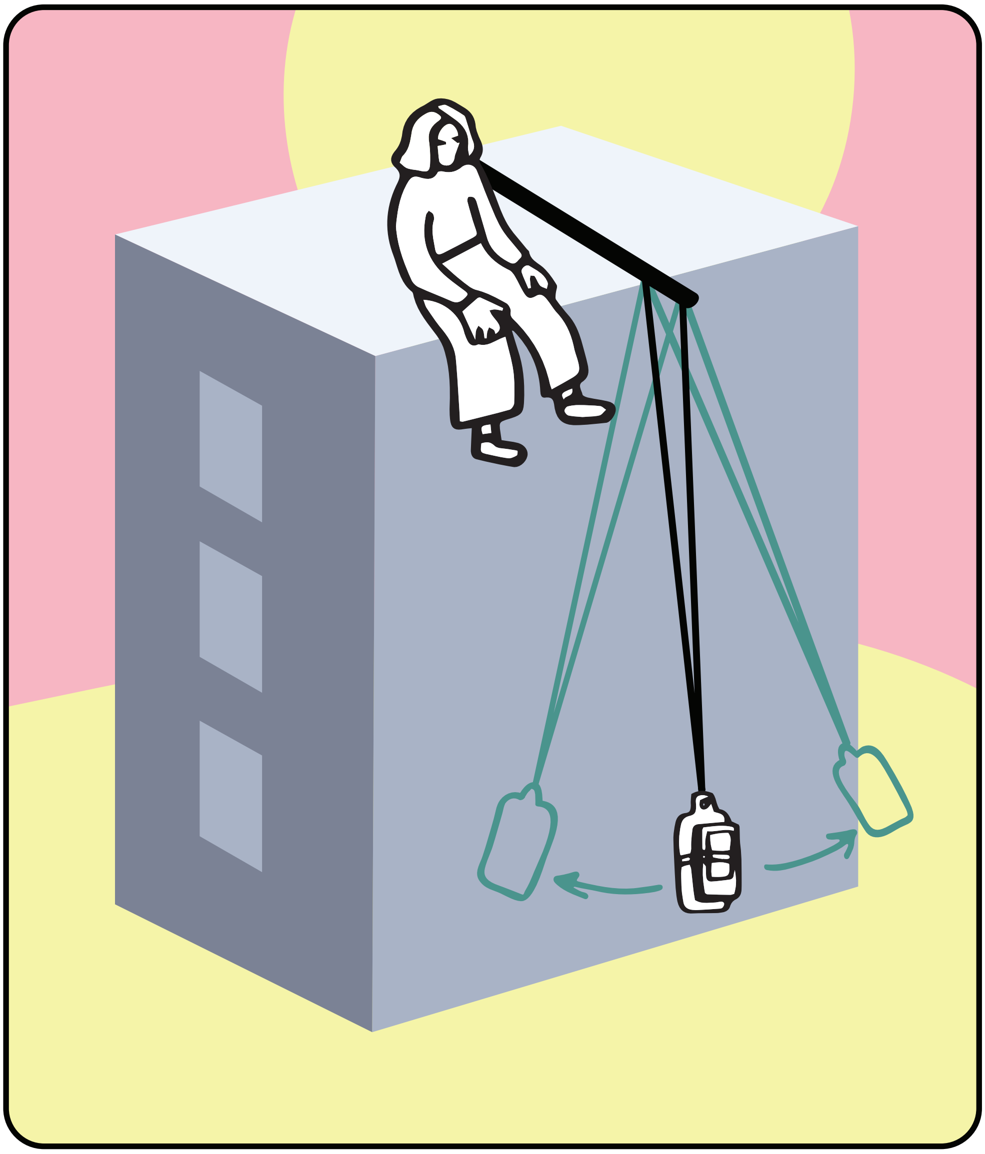


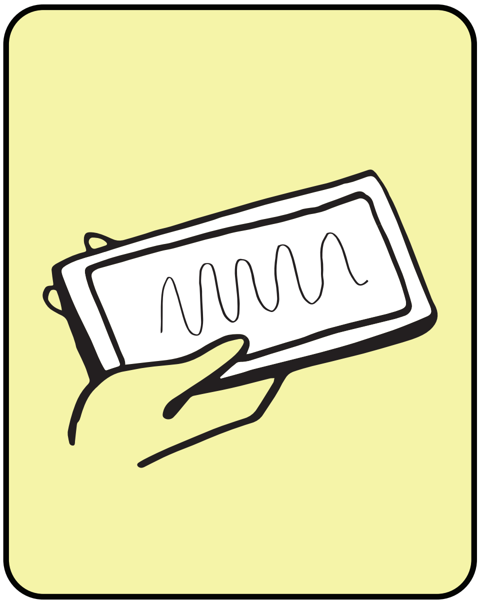
1 mass



Sensor: **gyroscope**

1 smartphone





Make a giant pendulum the size of the building. Attach the smartphone to the pendulum, and use the gyroscope to determine the period.

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

The higher the building, the smaller the acceleration, and the harder the measure will be.

Precision: high

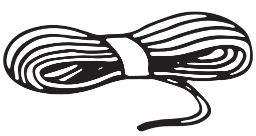
Difficulty: intermediate

№14. Giant Pendulum & Magnet

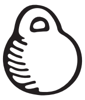
Formula

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

Material

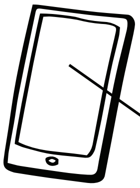


1 long rope



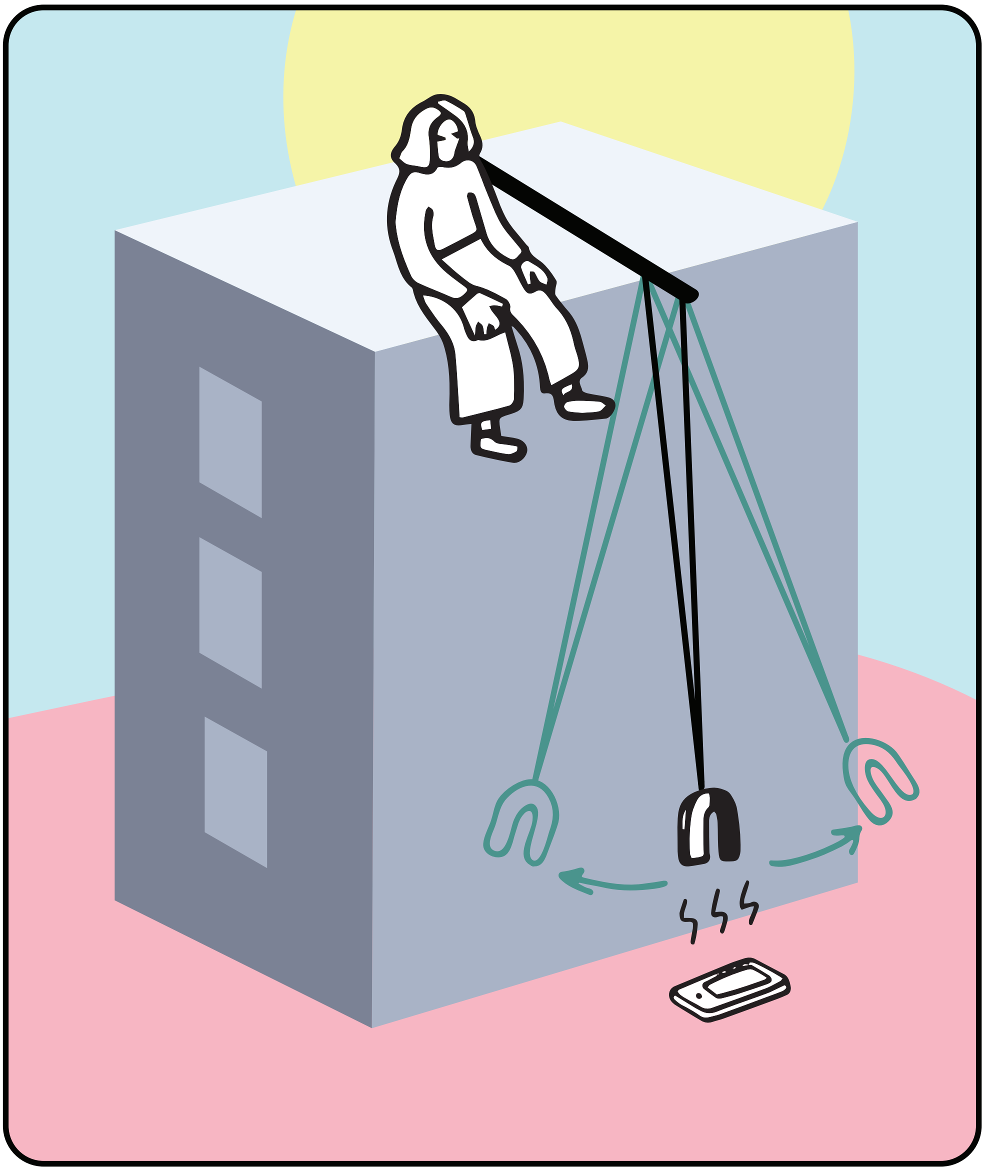
1 mass

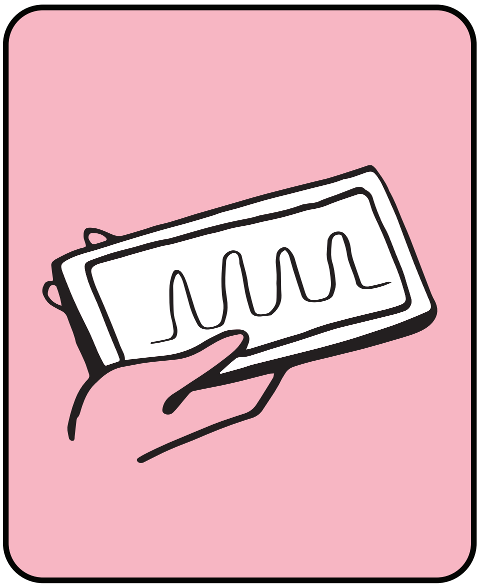
1 magnet



Sensor: **magnetometer**

1 smartphone





Make a giant pendulum the size of the building. Attach a magnet to the pendulum. Position the smartphone vertically to detect the passage of the magnet.

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

The Earth's magnetic field can be used in place of the magnet; the smartphone must then be fixed on the pendulum.

Precision: high

Difficulty: intermediate

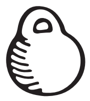
№15. Giant Pendulum & Light

Formula

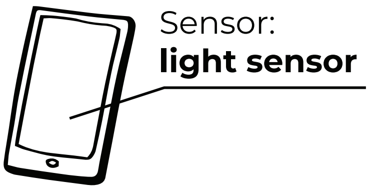
$$H = g\left(\frac{T}{2\pi}\right)^2$$

Material

1 long rope

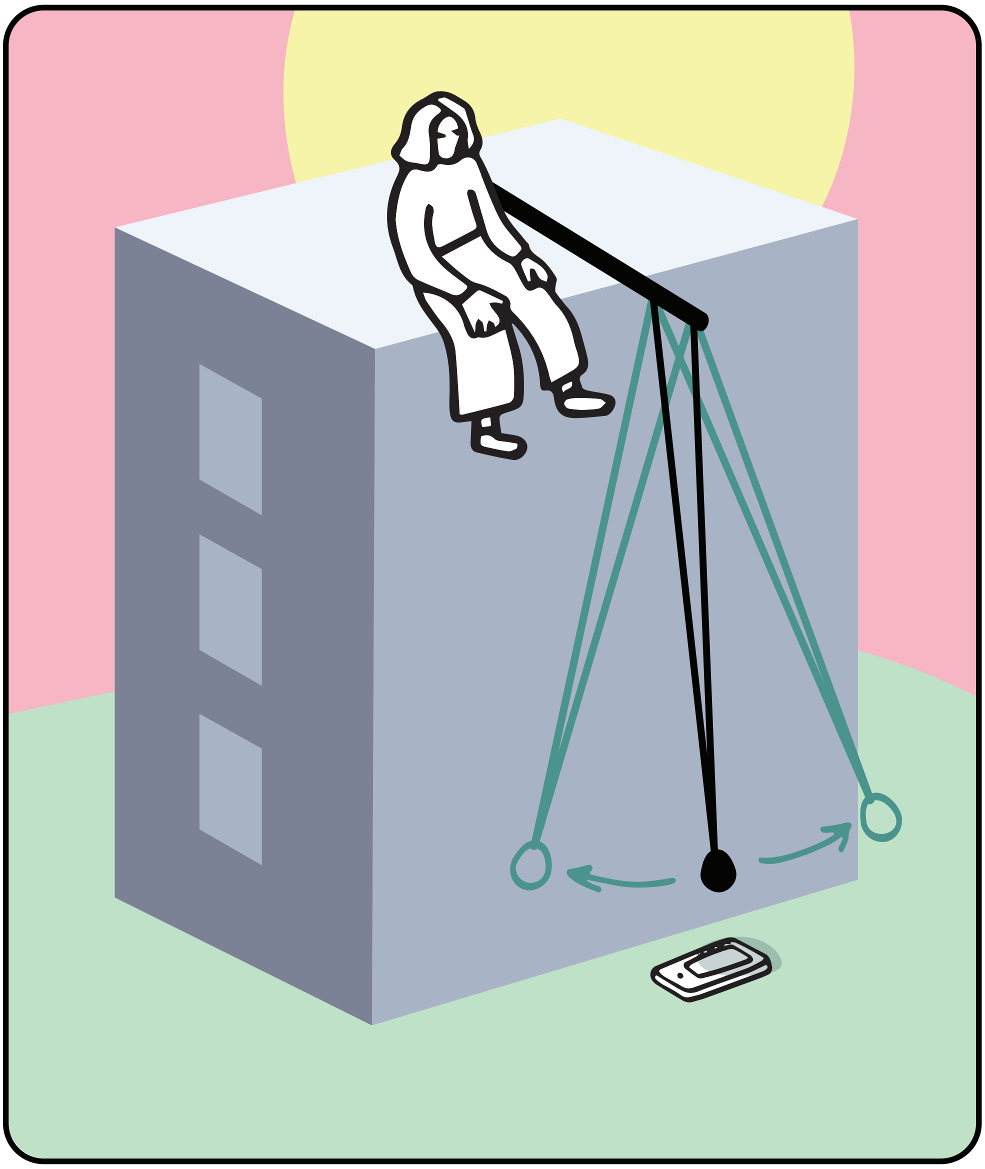


1 mass

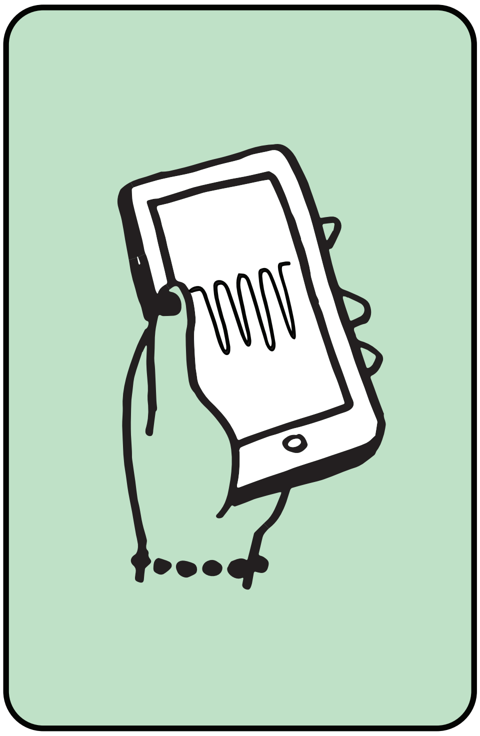


Sensor:
light sensor

1 smartphone



Make a giant pendulum the size of the building. Position the smartphone vertically to detect the shadow of the pendulum.



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

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

Precision: high

Difficulty: intermediate

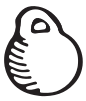
№16. Giant Pendulum by Proximity

Formula

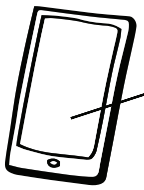
$$H = g\left(\frac{T}{2\pi}\right)^2$$

Material

1 long rope

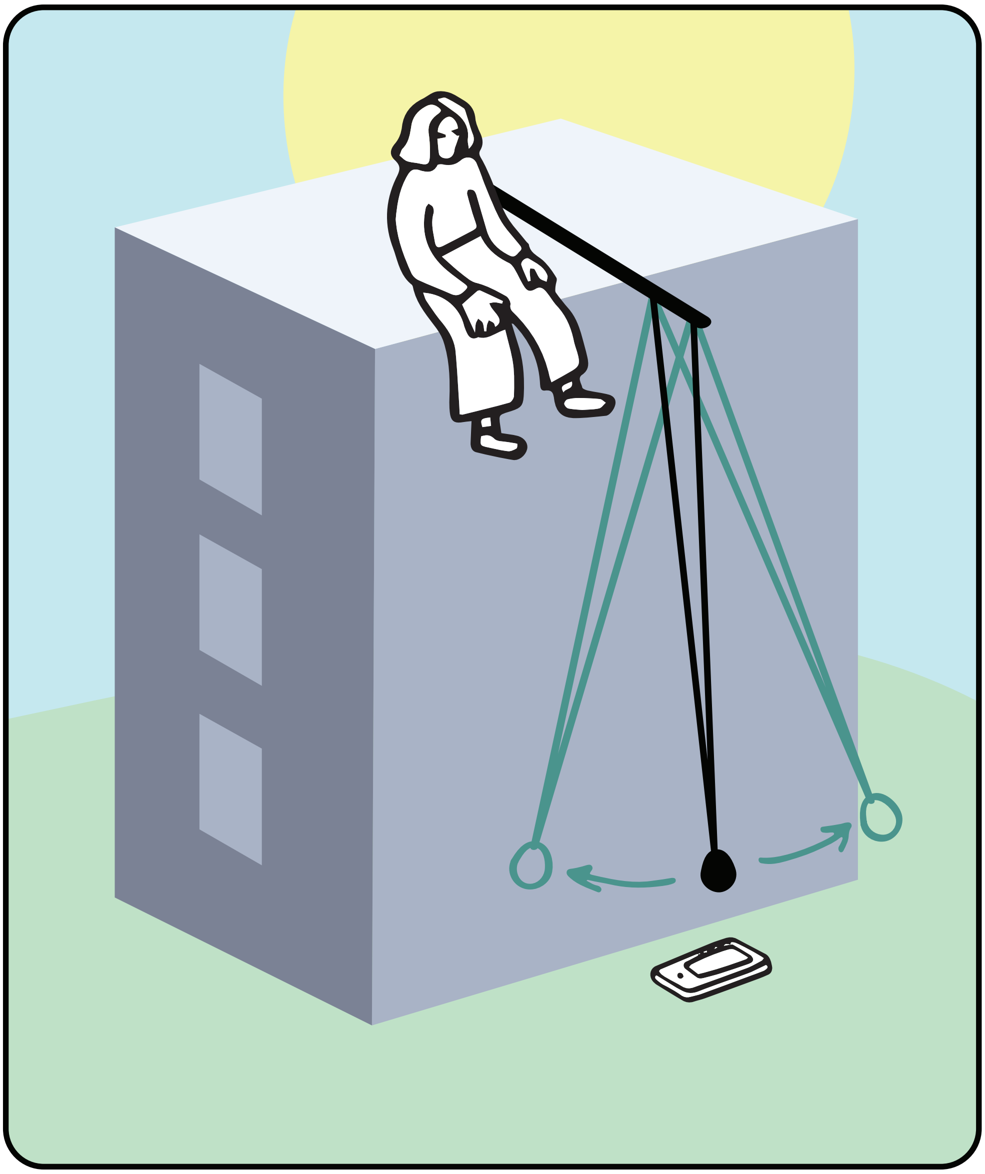


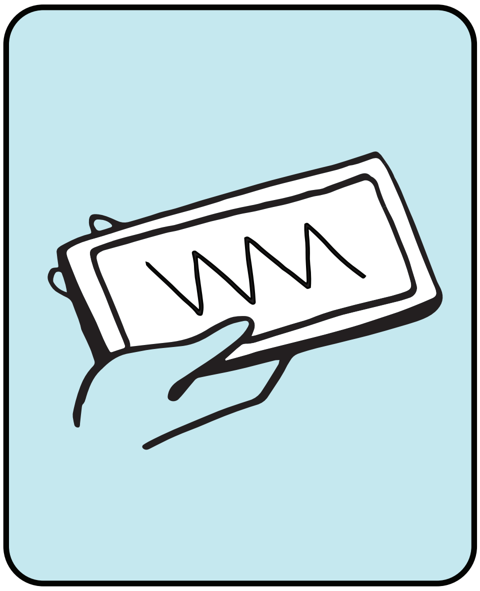
1 mass



1 smartphone

Sensor:
proximity sensor





Make a giant pendulum the size of the building. Position the smartphone vertically, very close to the pendulum to detect its passage.

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

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

Precision: high

Difficulty: intermediate

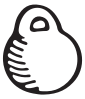
№17. Giant Pendulum with Sound

Formula

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

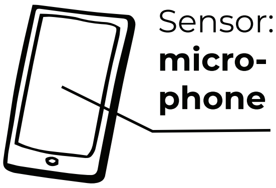
Material

1 long rope

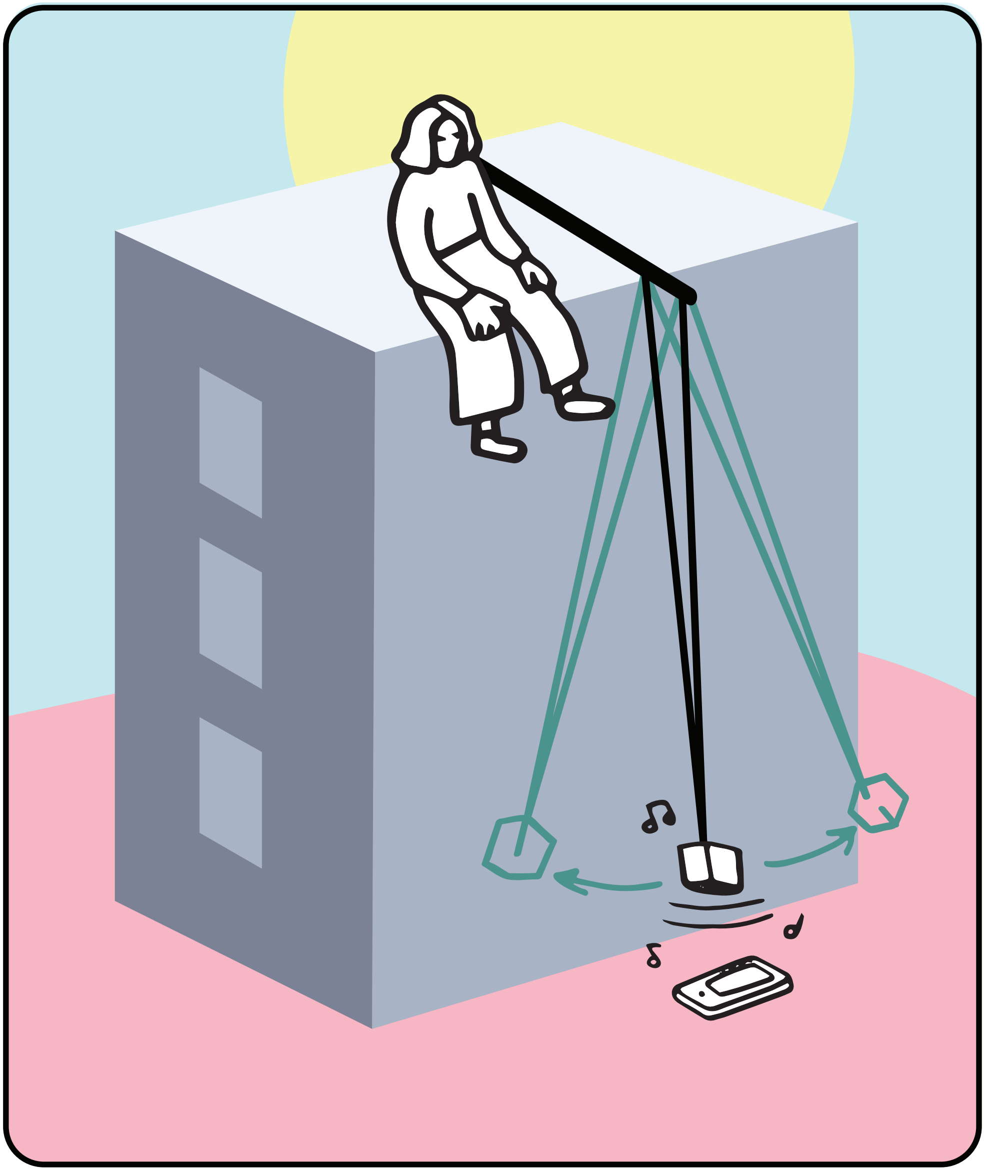


1 mass

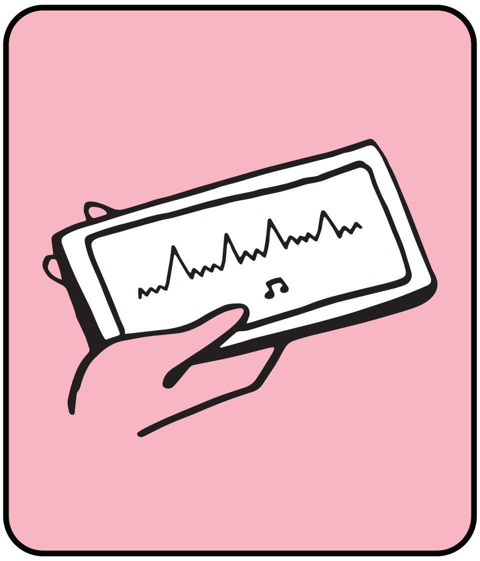
1 bluetooth speaker



1 smartphone



Make a giant pendulum the size of the building. Attach the speaker to the pendulum, and send a constant sound. Position the smartphone vertically, and use the variation in the amplitude of the recorded sound to determine the period.



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

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

Precision: low

Difficulty: intermediate

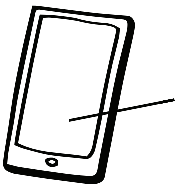
№18. Giant Torsional Pendulum

Formula

$$H \propto T^2$$

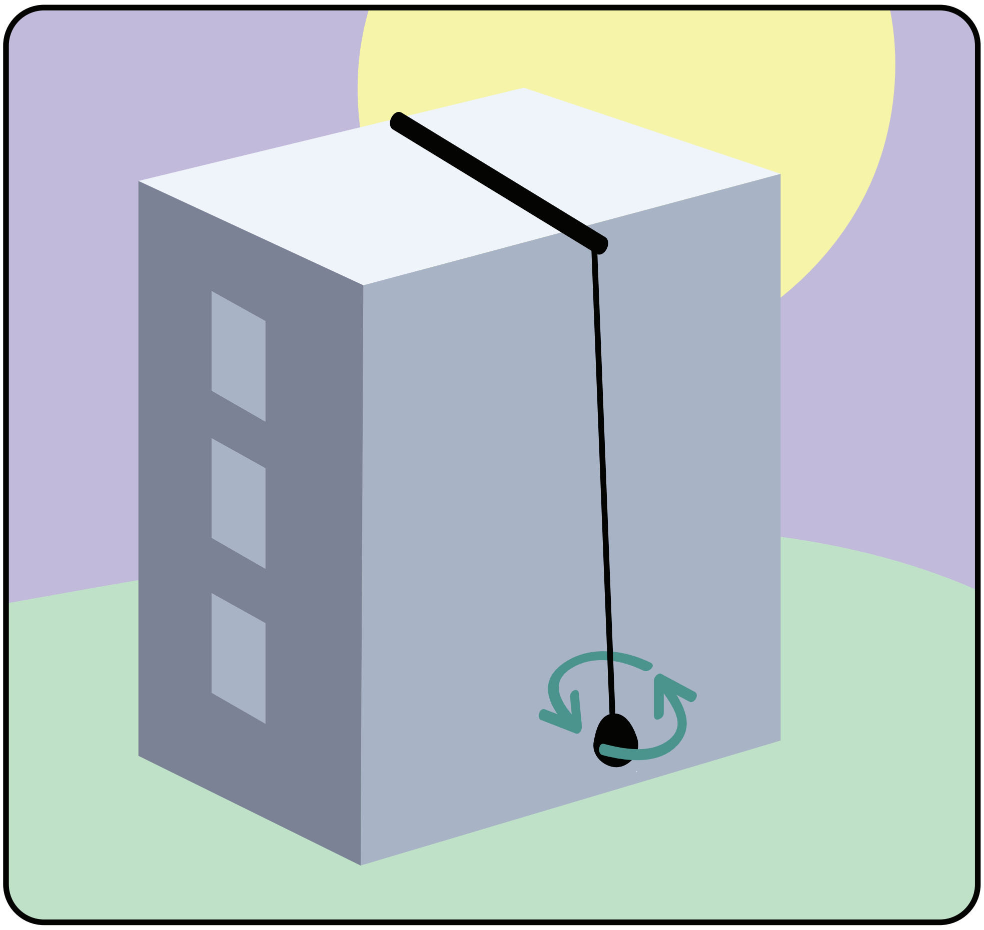
Material

1 long rope



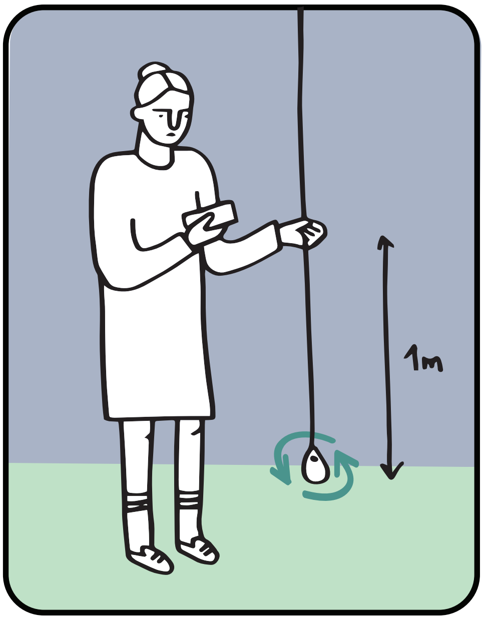
1 smartphone

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



Make a giant torsional pendulum the size of the building. Measure the period using one of the giant pendulum methods. Calibrate the torsion constant by measuring the period for a 1 m rope length.

T = pendulum period



Precision: low

Difficulty: high

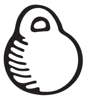
№19. Centripetal Acceleration

Formula

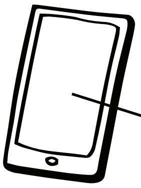
$$H = \frac{a_c}{\dot{\theta}^2}$$

Material

1 longue corde

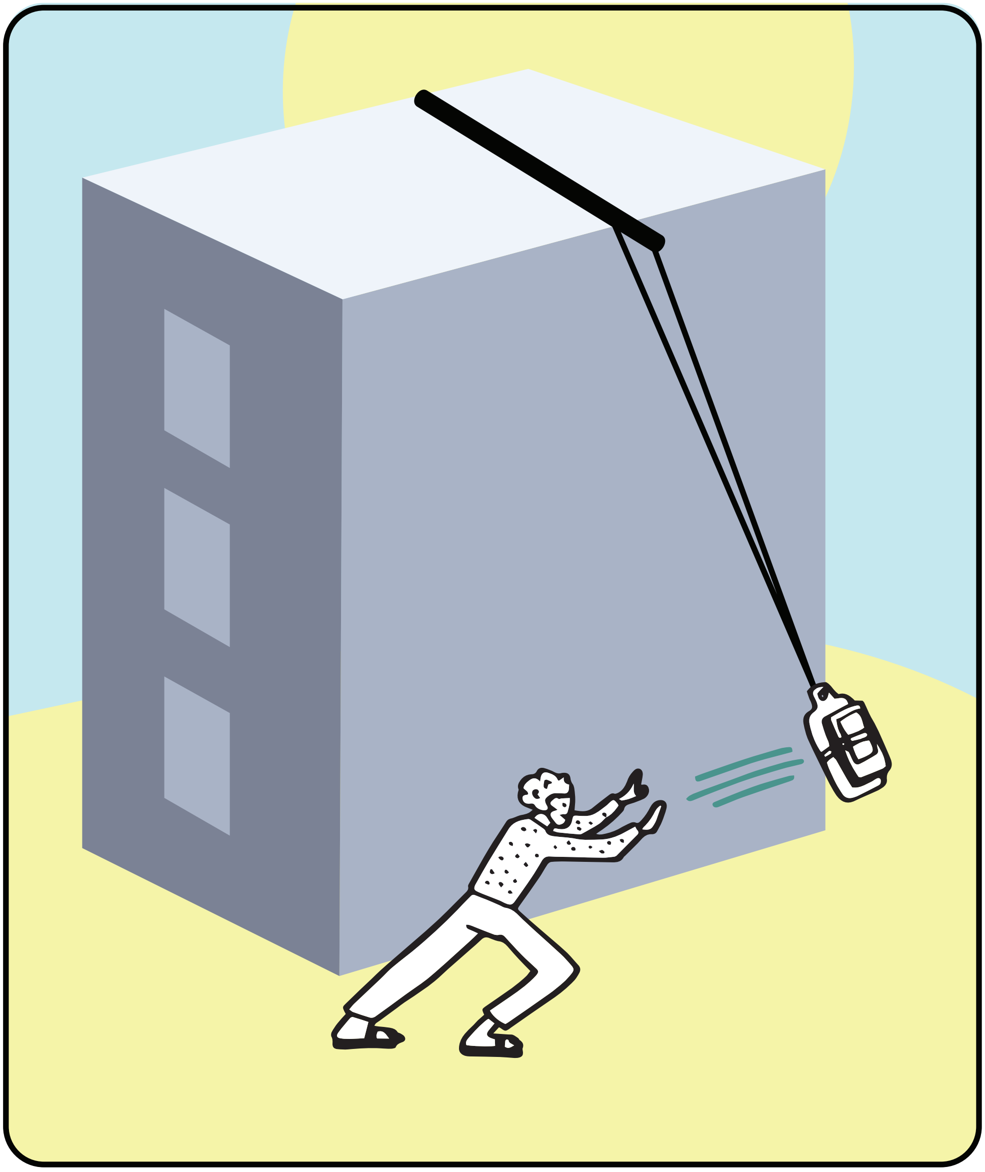


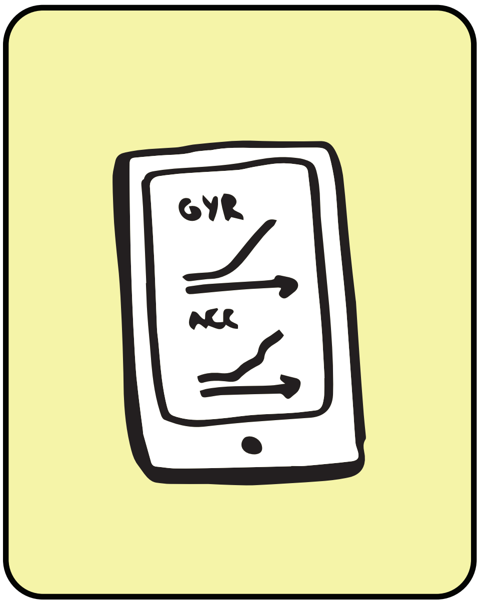
1 mass



Sensors: **accelerometer, gyroscope**

1 smartphone





Make a giant pendulum the size of the building. Attach the smartphone to the pendulum, and use the accelerometer to determine the centripetal acceleration and the gyroscope to determine the angular velocity.

a_c = centripetal acceleration,
$\dot{\theta}$ = angular velocity

The higher the building, the smaller the acceleration, and the harder the measure will be. Throw the pendulum as hard as you reasonably can.

Precision: low

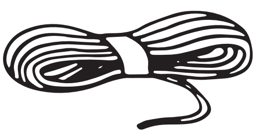
Difficulty: maximum

№20. Angular Velocity

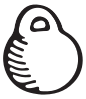
Formula

$$H = \frac{v}{\dot{\theta}}$$

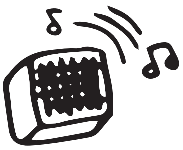
Material



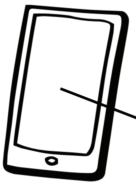
1 long rope



1 mass

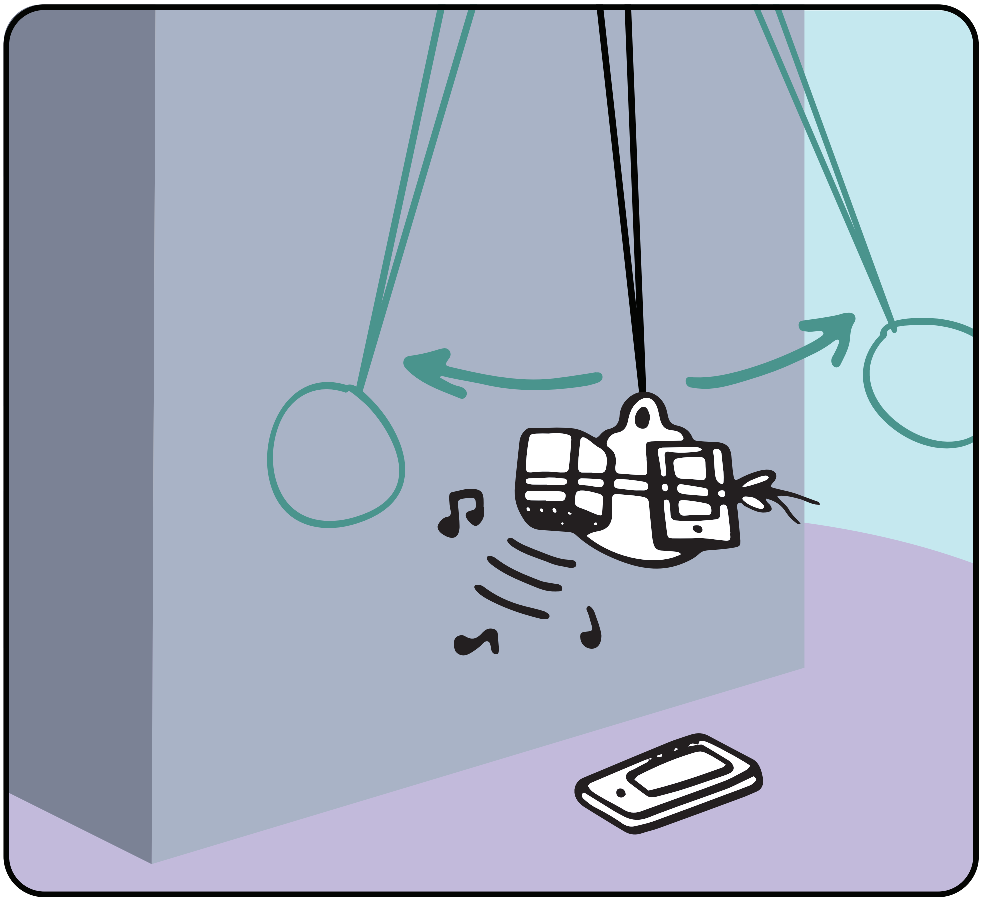


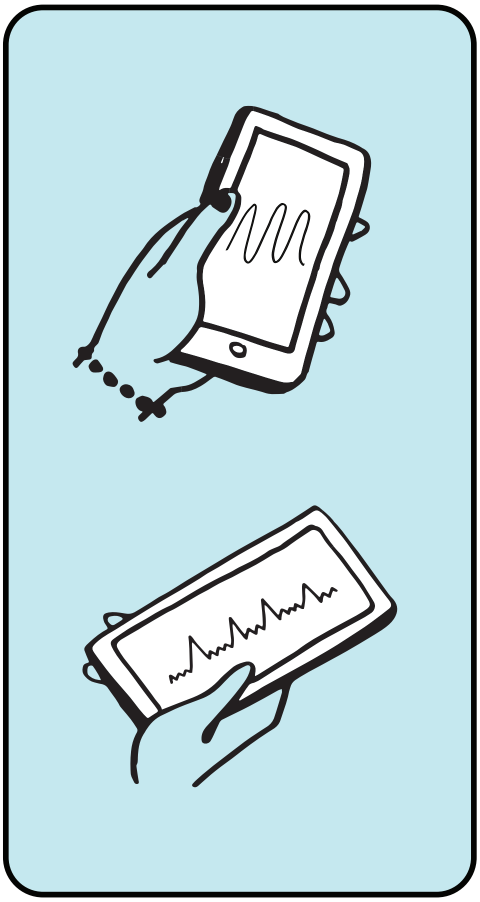
1 bluetooth speaker



Sensors:
microphone, gyroscope

2 smartphones





Make a giant pendulum the size of the building. Attach the smartphone to the pendulum, and use the gyroscope to determine the angular velocity. Attach the speaker to the pendulum, and send a single note. Position the second smartphone vertically, and use the recorded sound to determine the speed of the pendulum by Doppler effect.

v = speed, $\dot{\theta}$ = angular velocity

Precision: high

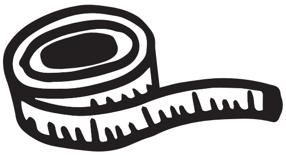
Difficulty: minimum

№21. Thales and the Shadows

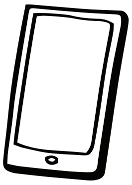
Formula

$$H = h\frac{l_2}{l_1}$$

Material

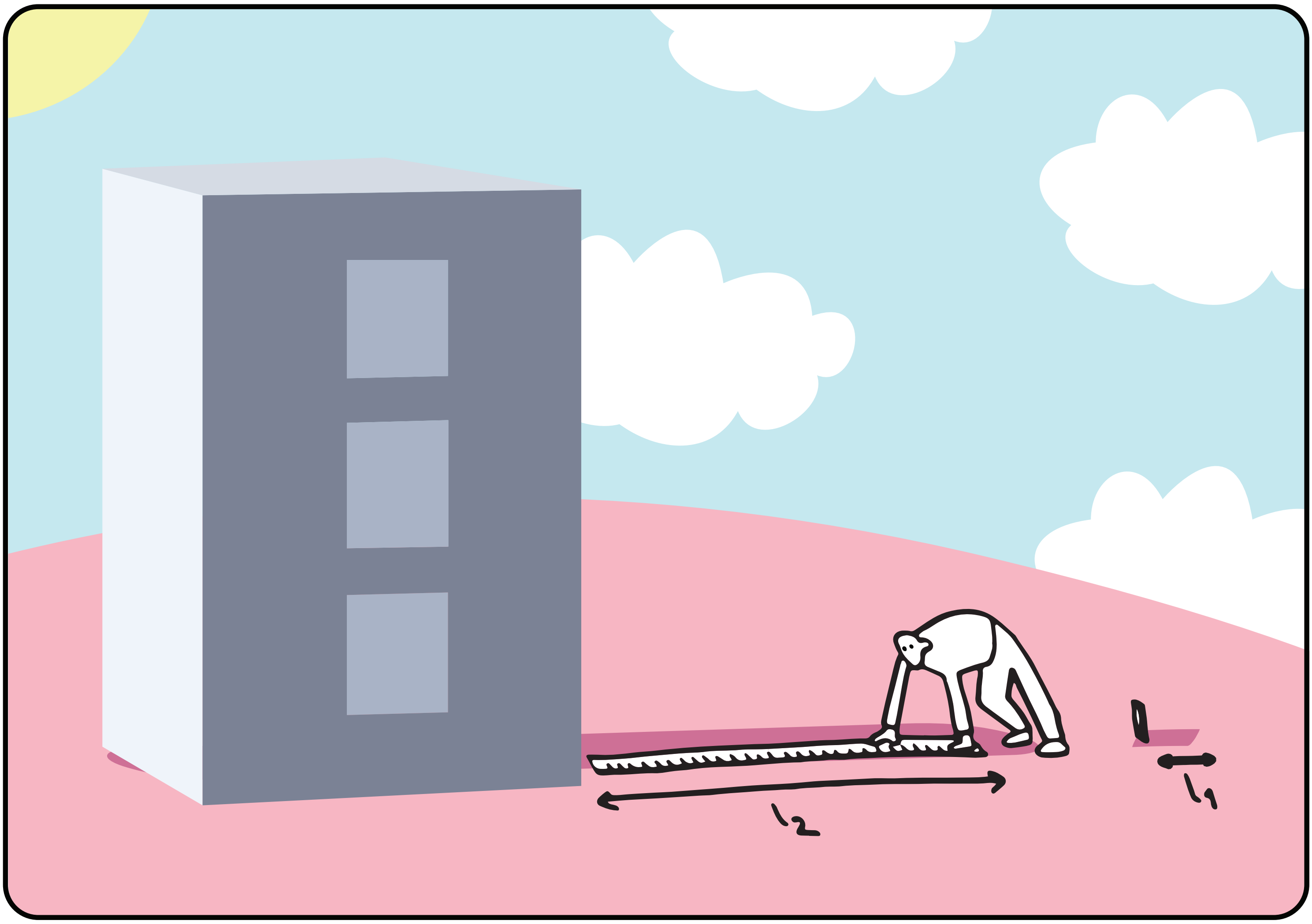


1 tape measure



1 smartphone

Measure the shadow of a smartphone and the shadow of the building. Use Thales' method to determine the height of the building from the height of the smartphone.



h = height of the smartphone l_2 = shadow of the building, l_1 = shadow of the smartphone.

Precision: maximum

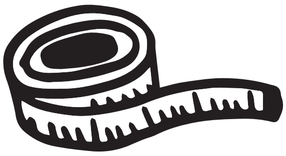
Difficulty: minimum

№22. Shadow and Position of the Sun

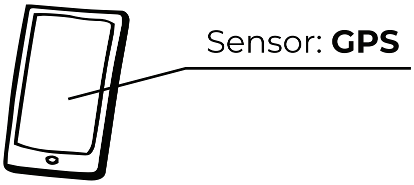
Formula

$$H = \ell \tan(\alpha)$$

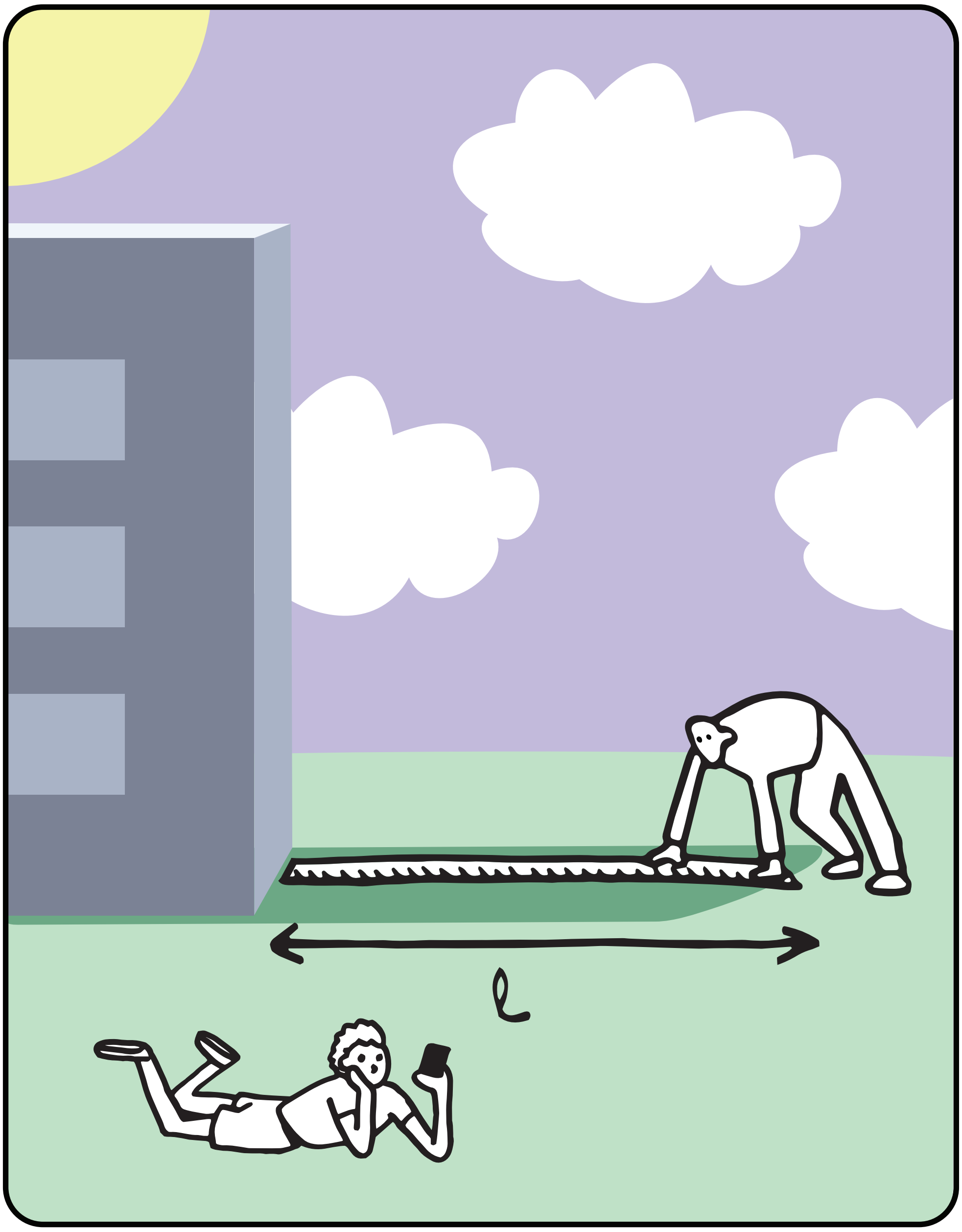
Material

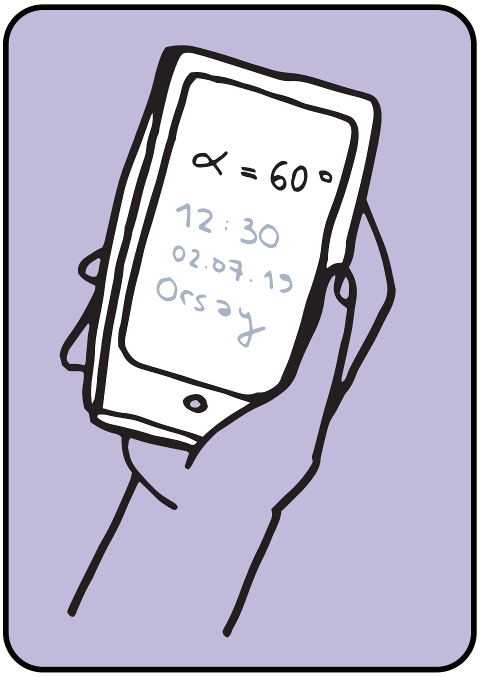


1 tape measure



1 smartphone





Measure the shadow of the building. Measure your latitude, longitude, and time with your smartphone. Find on the internet the elevation of the sun at that moment and place.

l = building shadow,
α = sun elevation

Precision: high

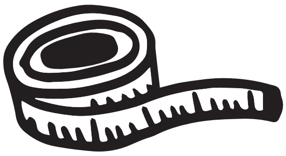
Difficulty: intermediate

№23. Shadow at the Equinox

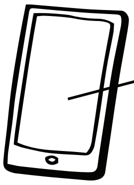
Formula

$$H = l \tan(\alpha)$$

Material

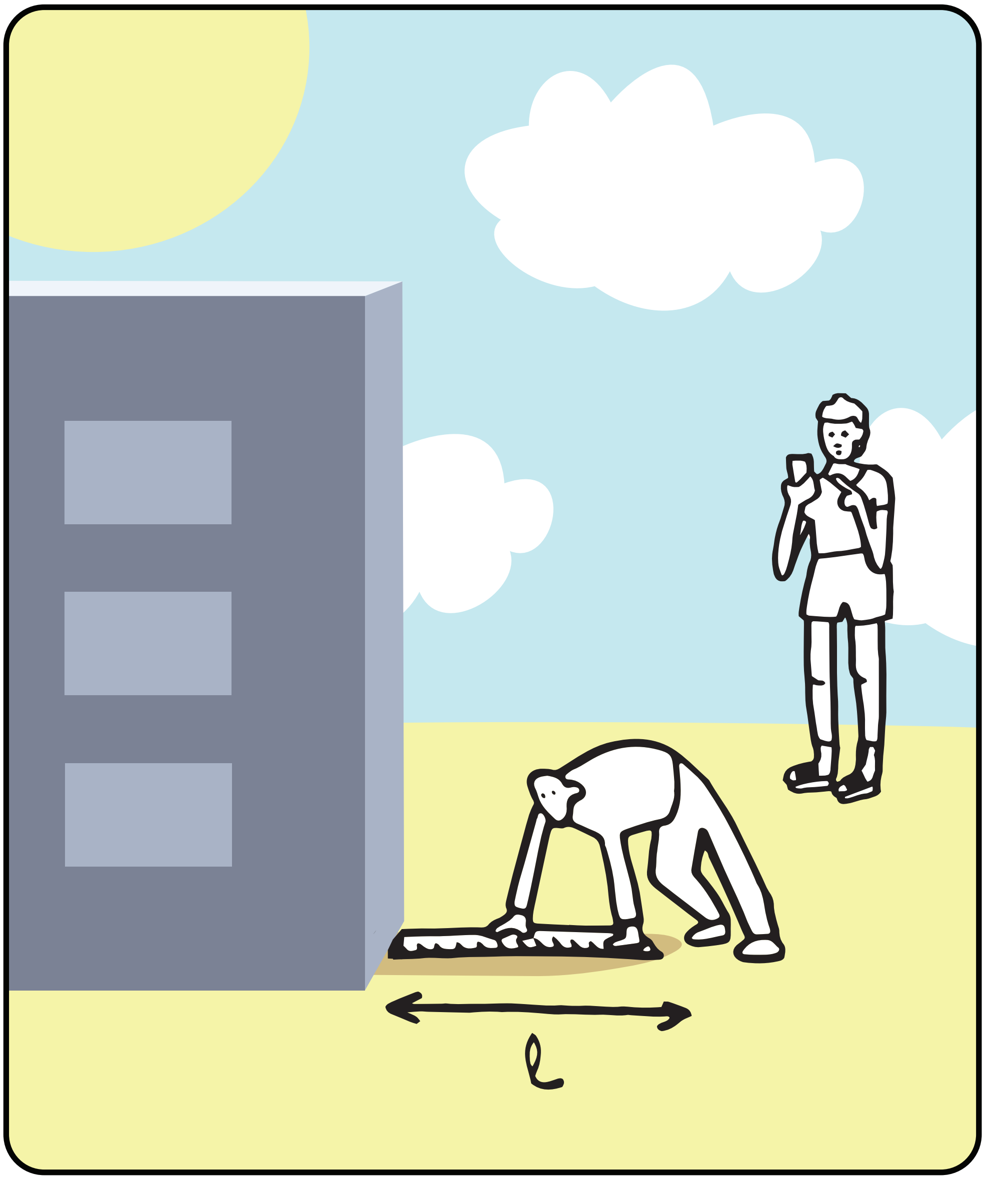


1 tape measure



Sensors:
GPS, camera

1 smartphone



Make a timelapse of the building shadow to determine the position of the shortest shade at noon. Measure the length of this shadow, as well as the latitude. At the equinox, the elevation of the sun corresponds to 90 ° - latitude.

l = building shadow,
α = sun elevation

This method can be used at soltices by adding or subtracting the latitude of the tropics.

Precision: maximum

Difficulty: low

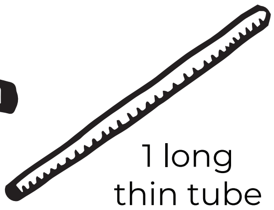
№24. Trigonometry Version 1

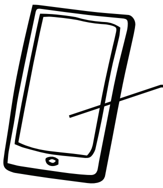
Formula

$H = h + l\tan\alpha$

Material


1 tape measure

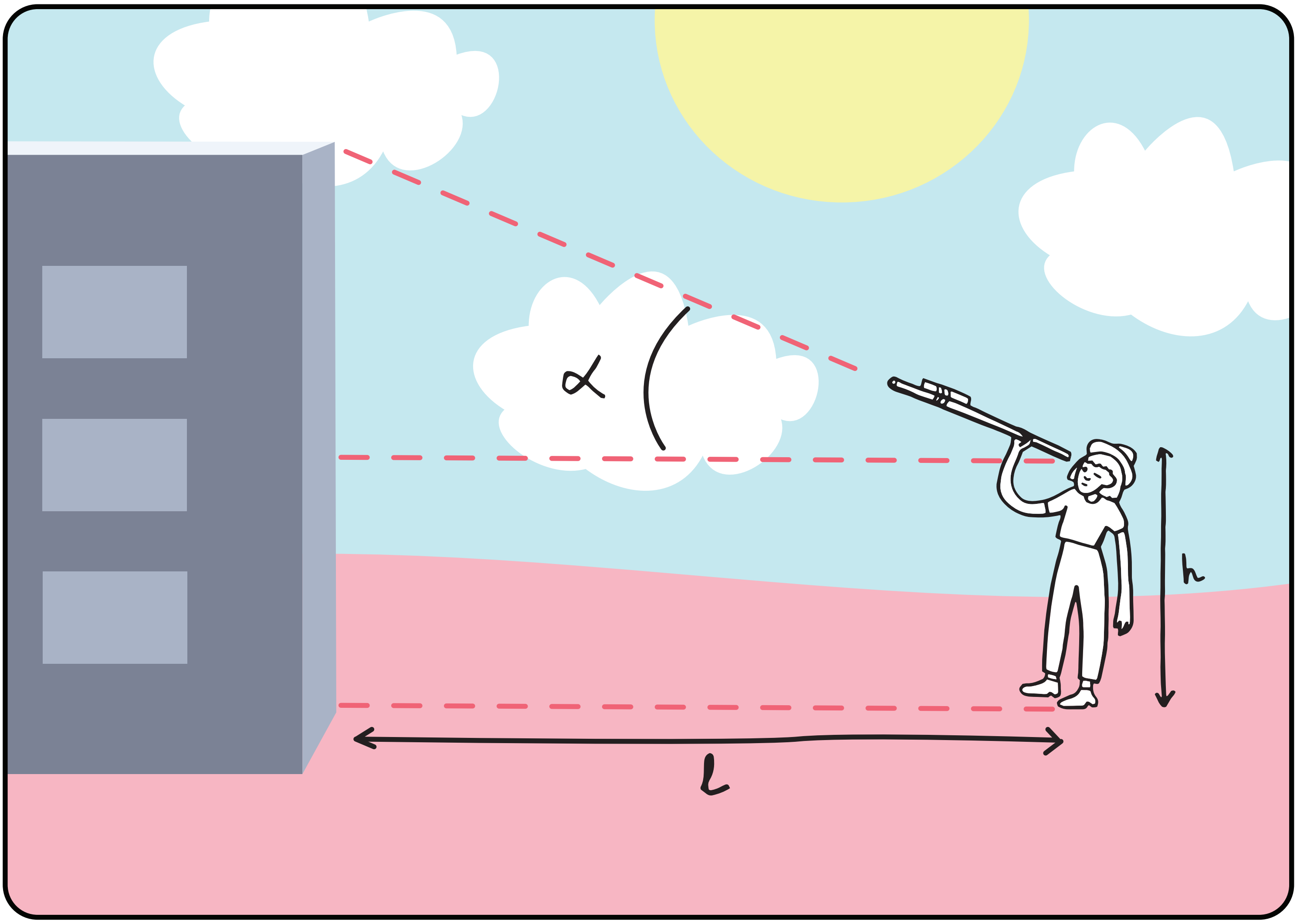

1 long thin tube


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: low

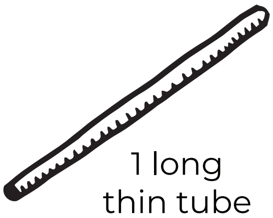
Difficulty: low

№25. Trigonometry Version 2

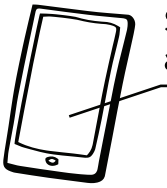
Formula

$$H = h + \frac{h}{\tan\alpha_2}\tan\alpha_1$$

Material



1 long thin tube

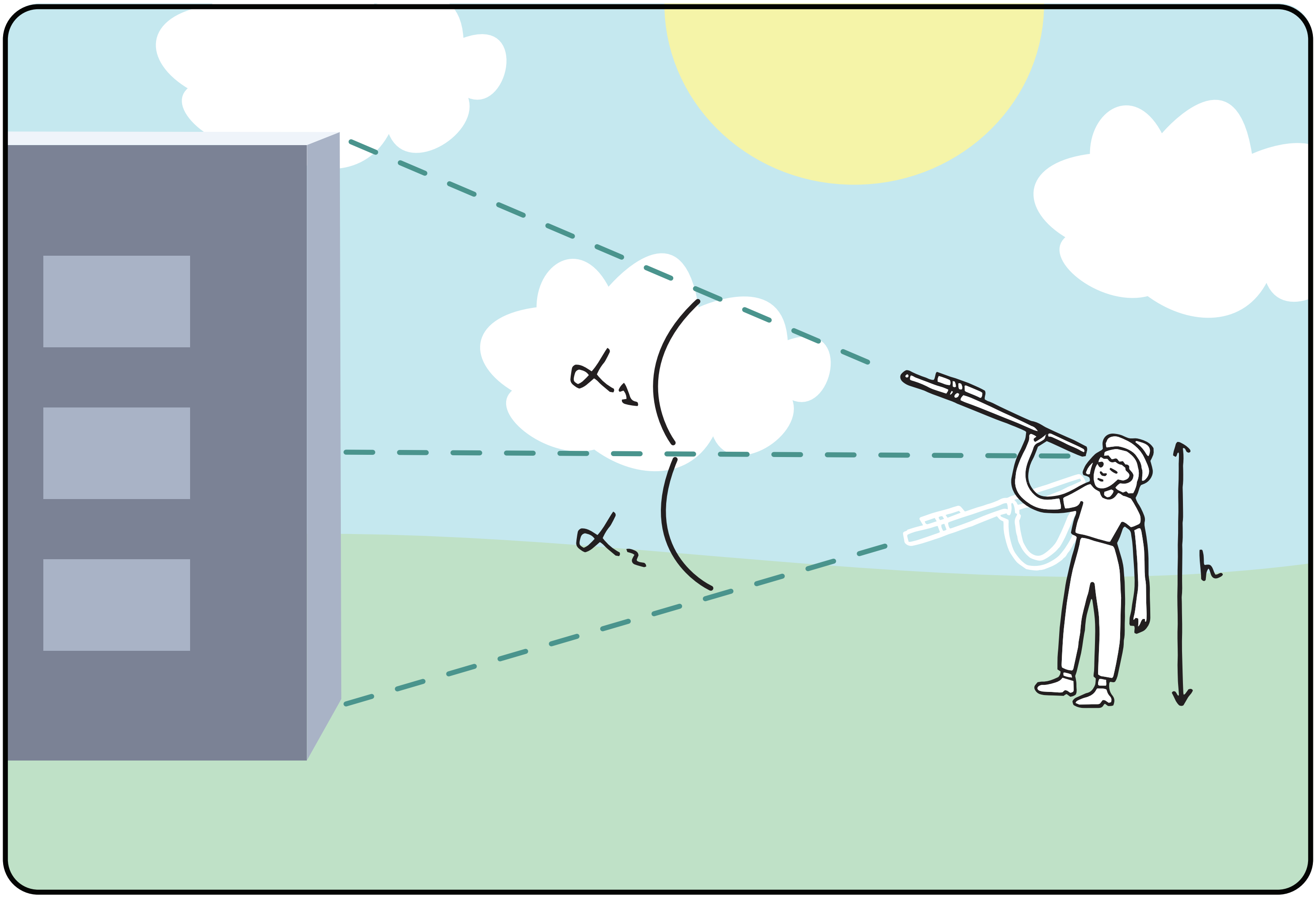


Sensor: **accelerometer**

1 smartphone

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

h = height of the eye of the investigator, α_1= angle of the top of building, α_2= angle of the bottom



Precision: intermediate

Difficulty: low

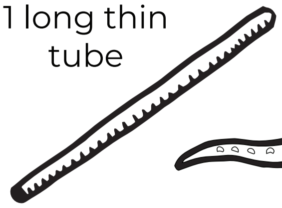
№26.
Trigonometry Version 3

Formula

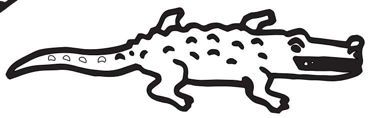
$$H = \frac{l}{2\tan(\alpha/2)}$$

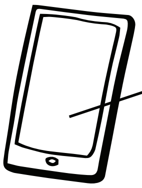
Material

1 long thin tube



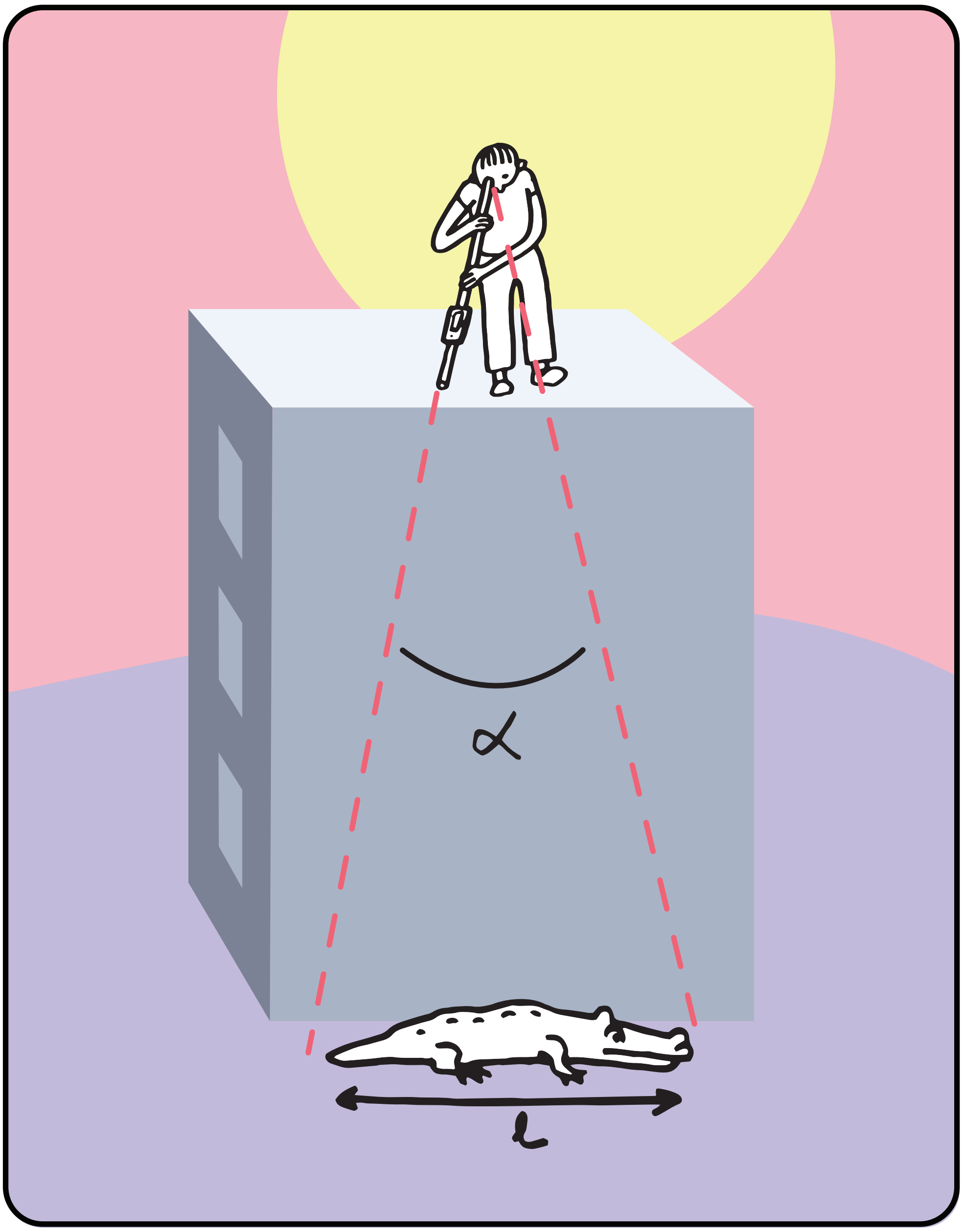
1 object of known size





Sensor: **accelerometer**

1 smartphone



Attach the smartphone to the tube, place the object of known size at the foot of the building, and go at the top, to the vertical of the object. Use the accelerometer to determine the angular size of the object.

l = size of the object, α = angular size of the object

Precision: high

Difficulty: minimum

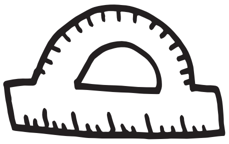
№27. Angle of View of a Picture

Formula

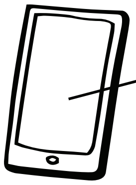
$$H = \frac{l}{2\tan(\alpha/2)}$$

Material

1 bar of
known size

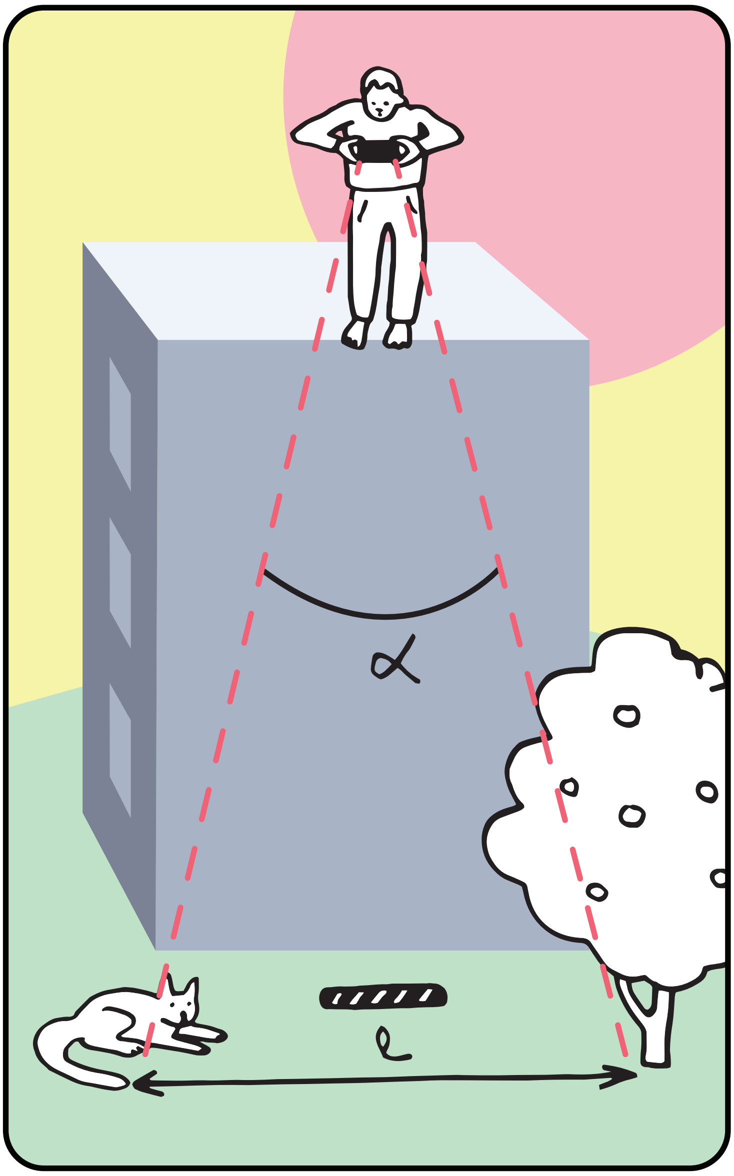


1 protractor



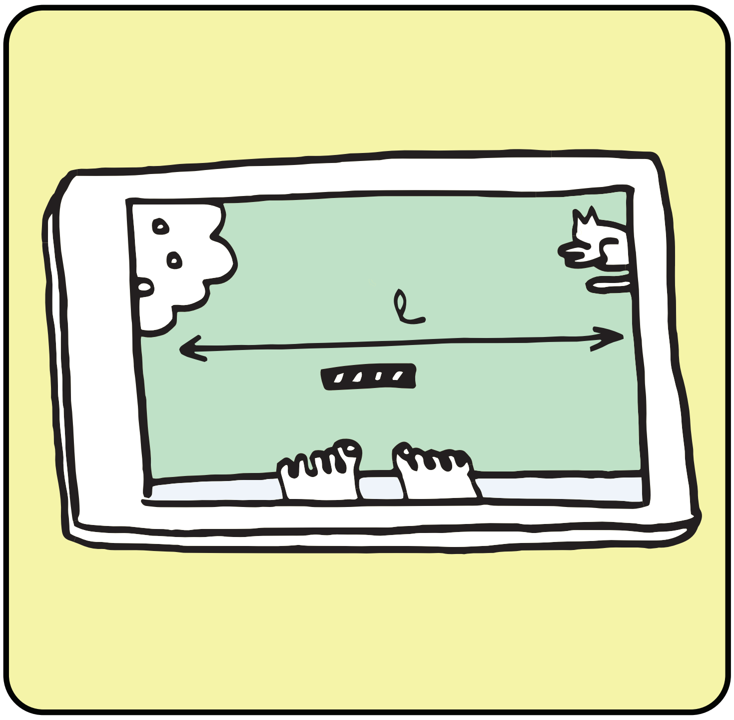
Sensor:
camera

1 smartphone



From the top of the building, take a picture of the ground, and determine the length of the ground photographed, the bar serving as a scale. Using the protractor, determine the angle of view of your smartphone.

l = length of ground visible in the picture,
α = smartphone angle of view



The angle of view can also be determined by taking a picture of the bar at a known distance.

Precision: maximum

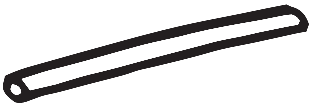
Difficulty: minimum

№28. Picture with Scale

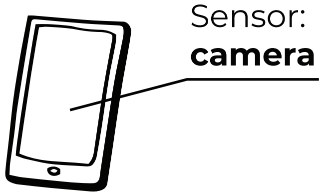
Formula

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

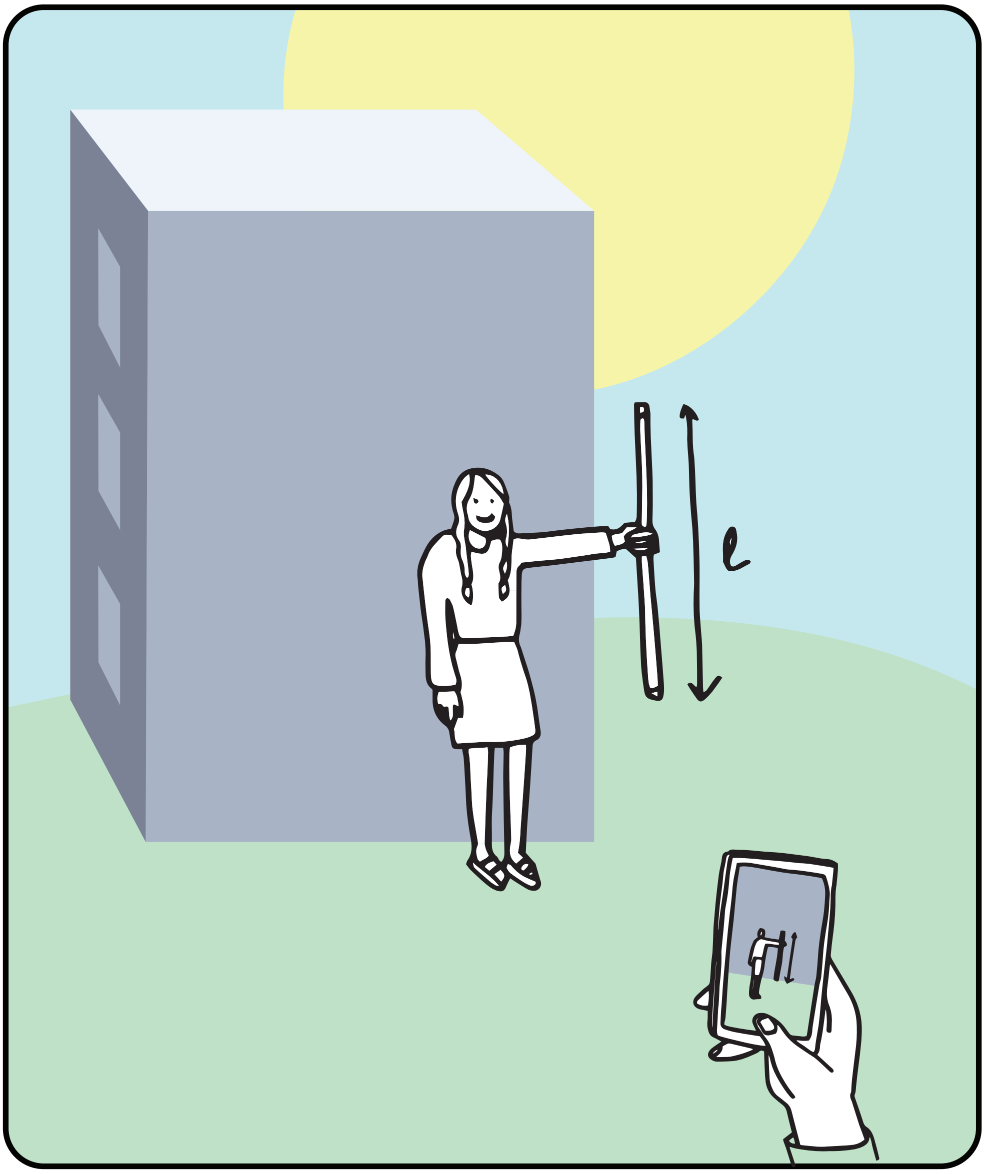
Material

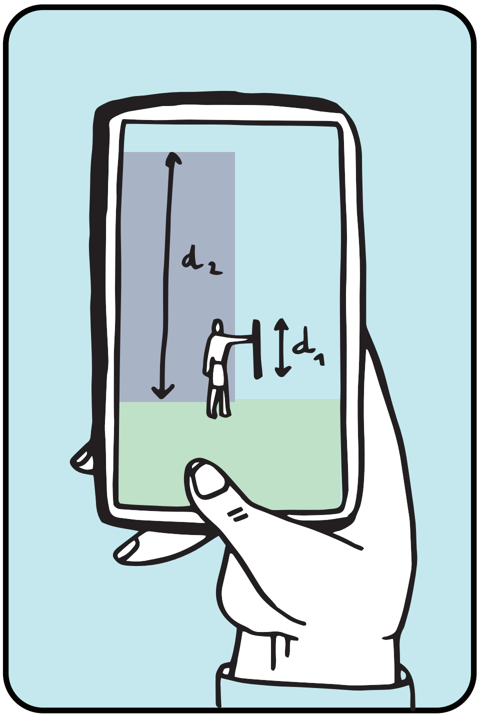


1 bar of known size



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

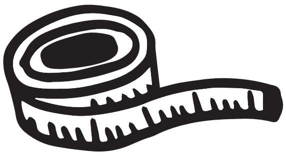
Difficulty: minimum

№29. Facade Picture

Formula

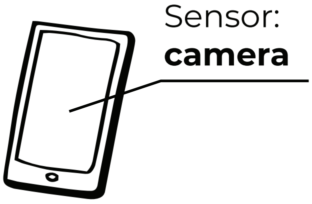
$$H = l \frac{d}{f}$$

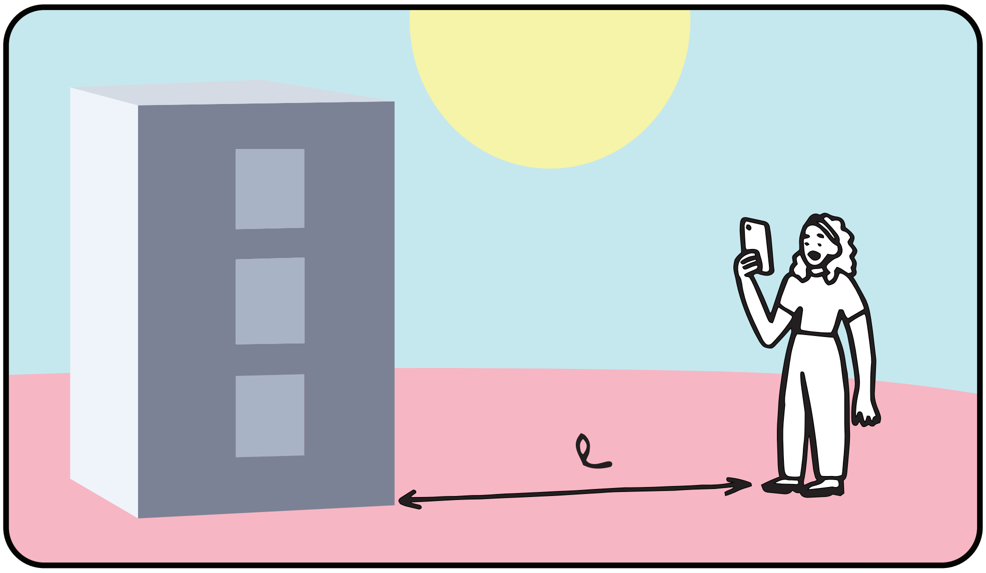
Material



1 tape measure

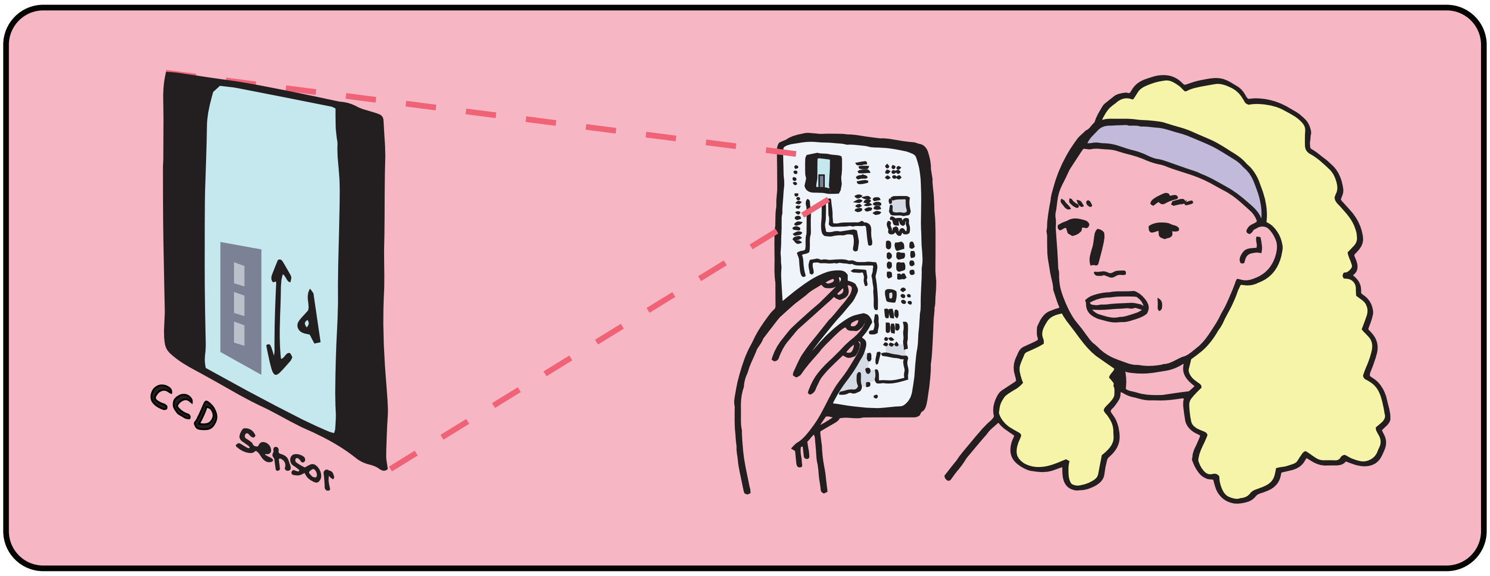
1 smartphone with known CCD sensor size and focal length





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: high

Difficulty: minimum

№30. Picture From the Top

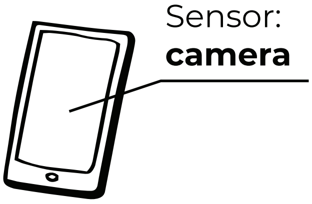
Formula

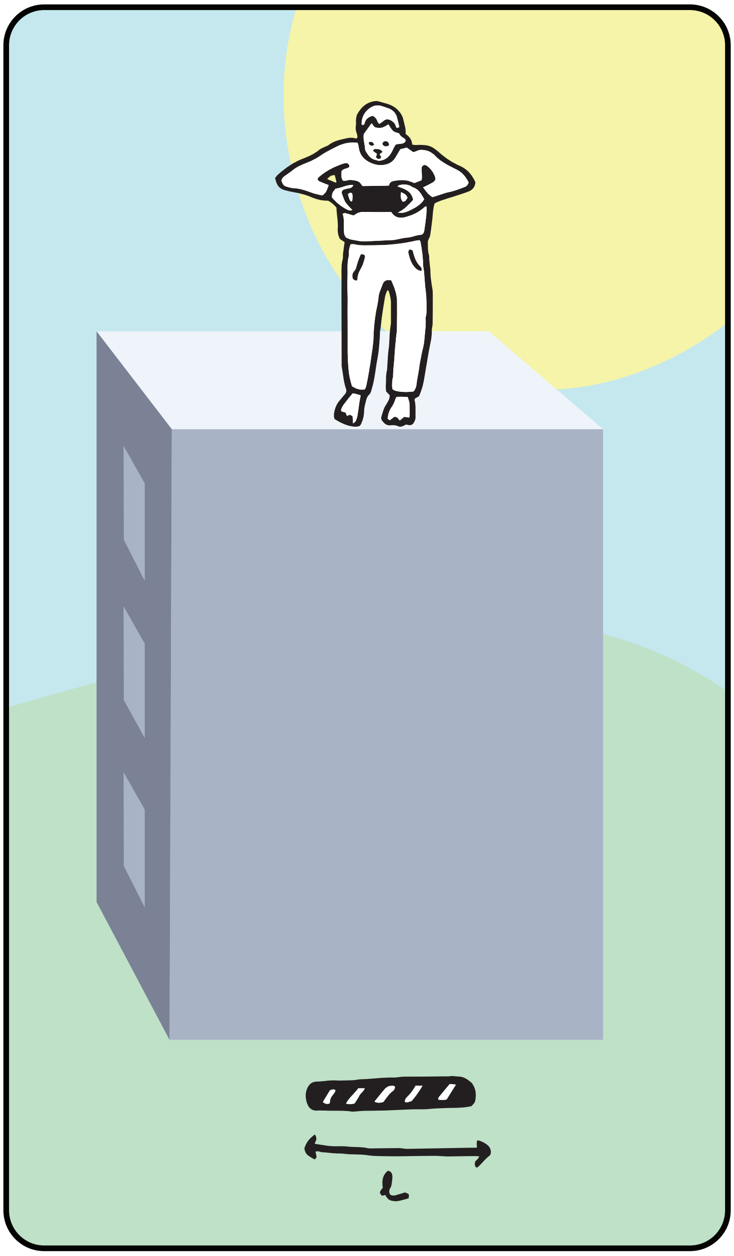
$$H = l\frac{f}{d}$$

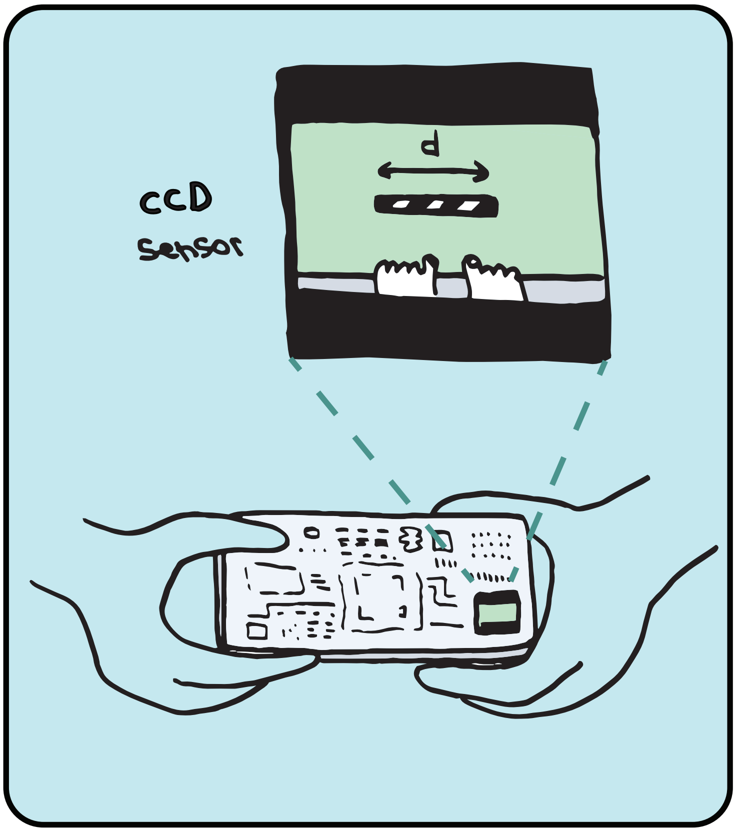
Material

1 bar of known size

1 smartphone with known CCD sensor size and focal length







From the top of the building, take a picture of the bar on the ground. Determine the actual size of the bar image on the CCD sensor by looking at the fraction of the picture width occupied by the bar.

l = size of the bar, f = focal length of the camera, d = size of the image of the bar on the CCD sensor

Precision: maximum

Difficulty: minimum

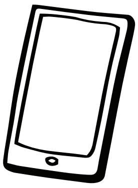
№31. Length of Rope

Formula

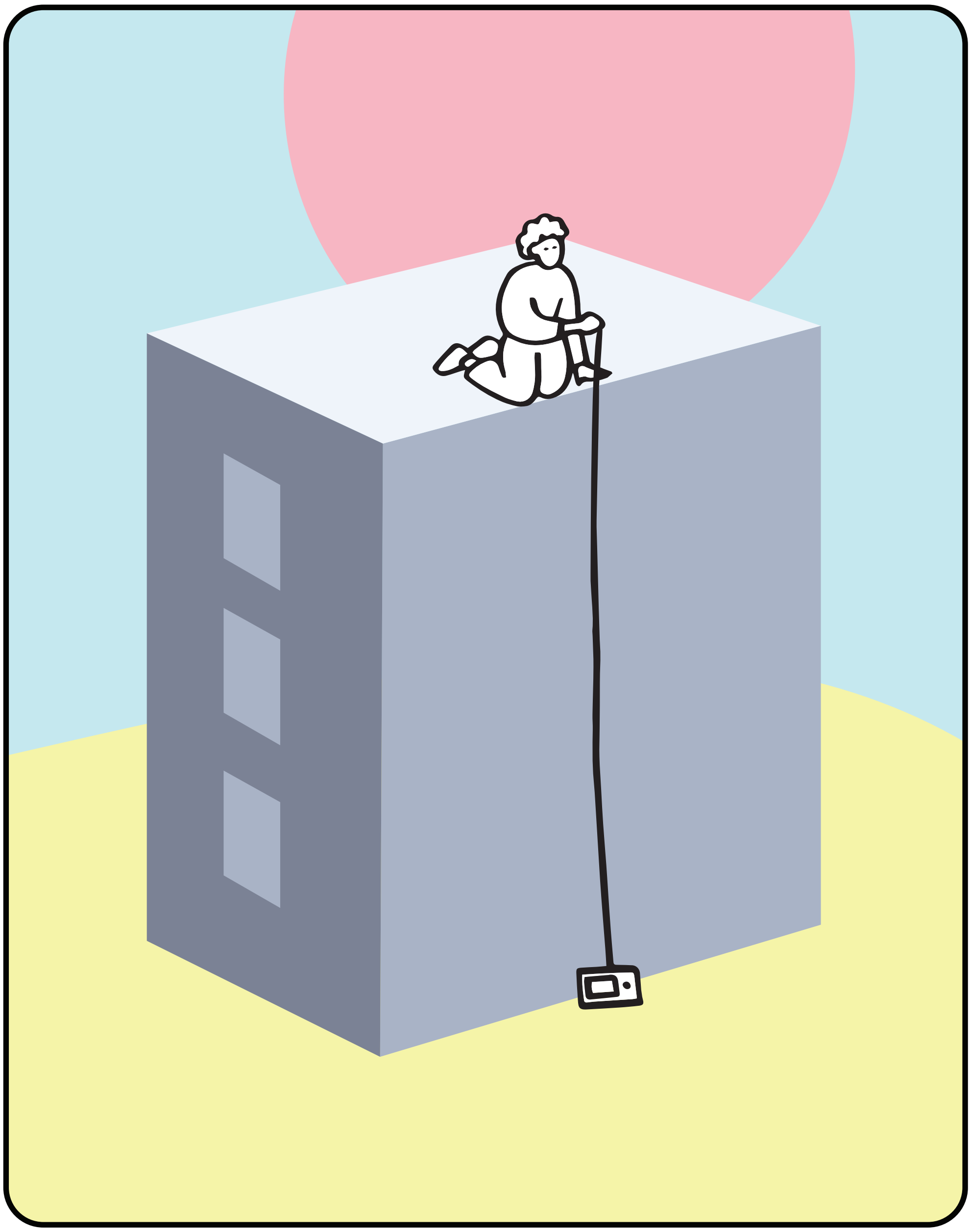
$$H = H$$

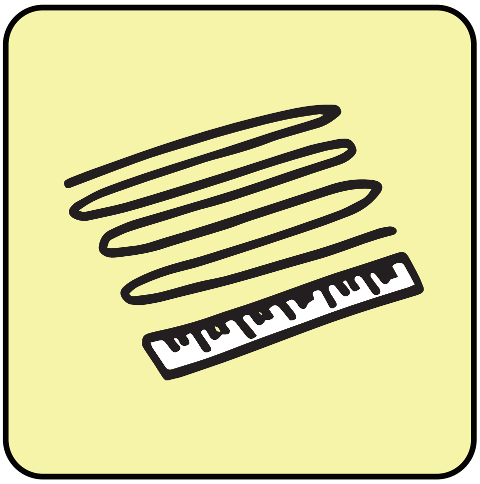
Material

1 long rope



1 smartphone





Weight the rope with your smartphone. Hang the rope from the top until the smartphone touches the floor. Then measure the length of rope with a meter.

H = length of the rope

Precision: intermediate

Difficulty: intermediate

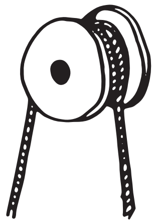
№32. Length of Rope & Gyroscope

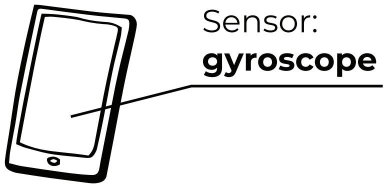
Formula

$$H = 2\pi R \int \dot{\theta}\, dt$$

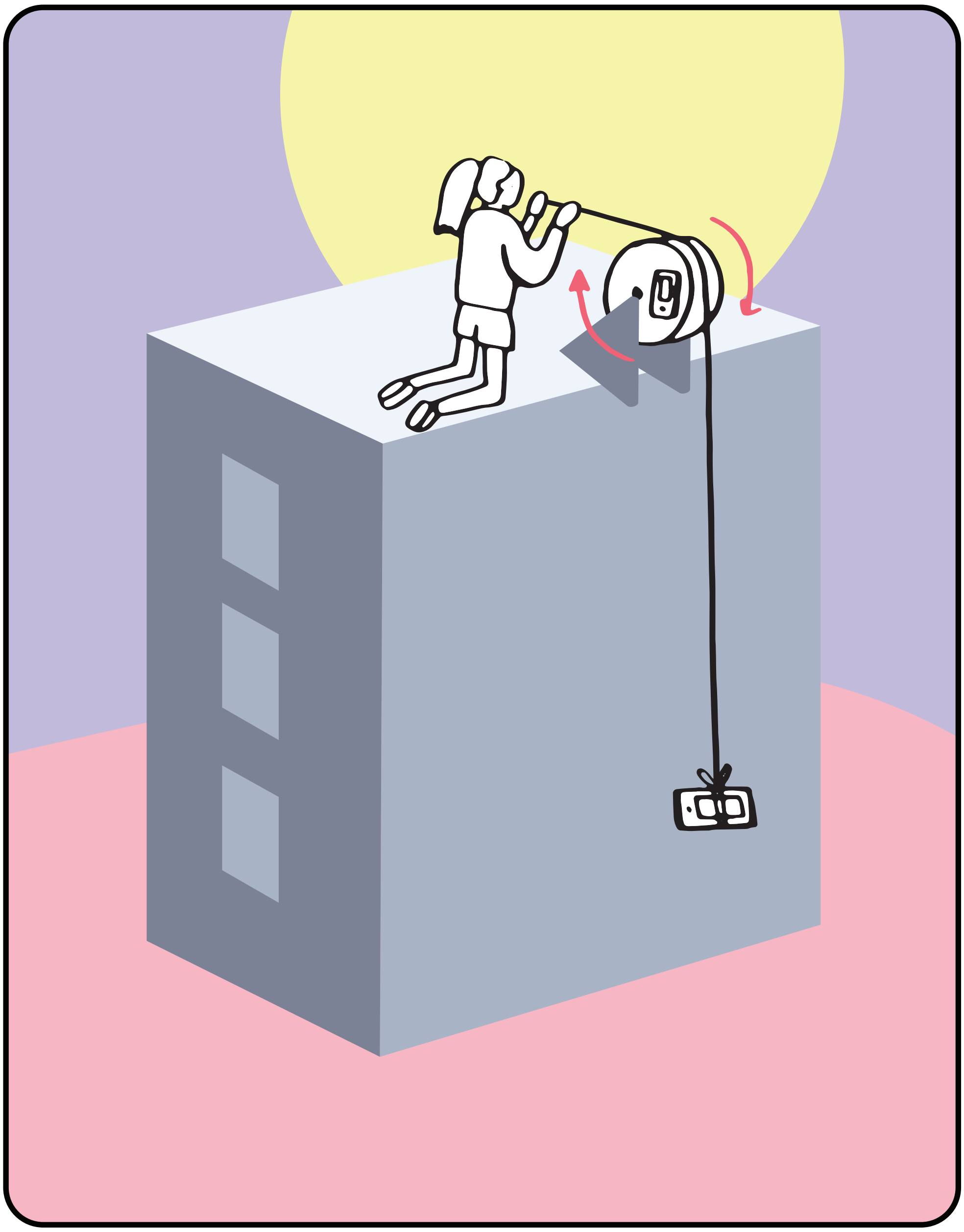
Material


1 long rope

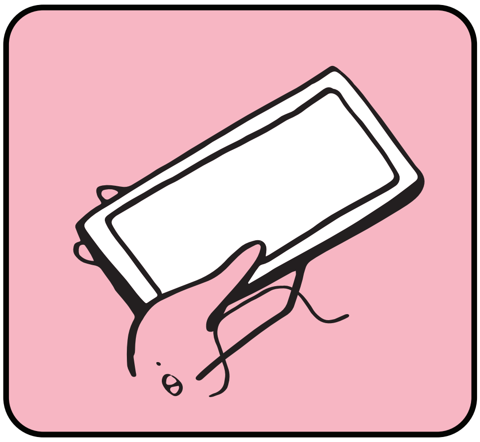

1 pulley



2 smartphones



Weight the rope with your smartphone. Install the pulley at the top of the building, and attach it a second smartphone. Pass the rope through the pulley and let it slide to the ground. Integrate the gyroscope signal to know the number of turns of the pulley, and thus the length of rope.



R = radius of the pulley, $\dot{\theta}$ = angular velocity

Precision: intermediate

Difficulty: intermediate

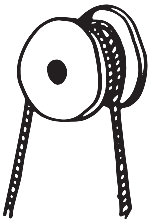
№33. Length of Rope & Accelerometer

Formula

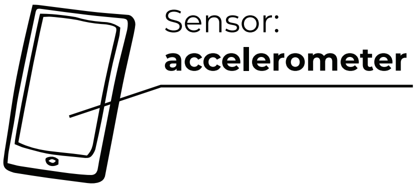
$$H = \iint \ddot{z}\, dt$$

Material

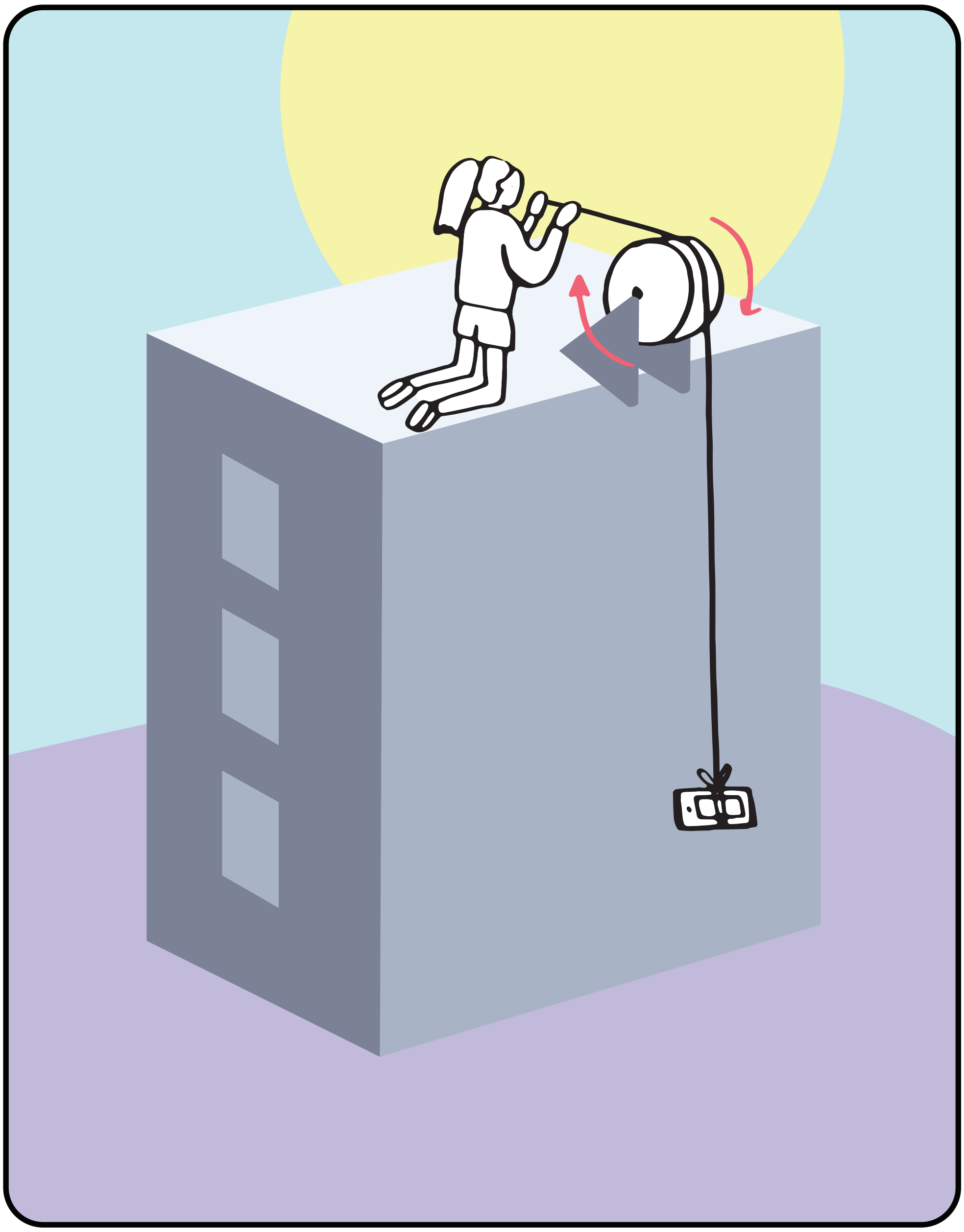
1 long rope

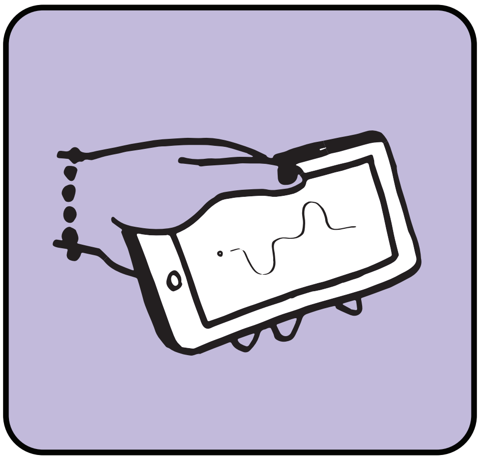


1 pulley



1 smartphone





Weight the rope with your smartphone. Install the pulley at the top of the building. Pass the rope through the pulley and let it slide to the ground. Integrate the accelerometer signal twice to obtain the height of the building.

$\ddot{z}$ = vertical acceleration

Precision: maximum

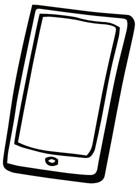
Difficulty: minimum

№34. Number of Smartphones

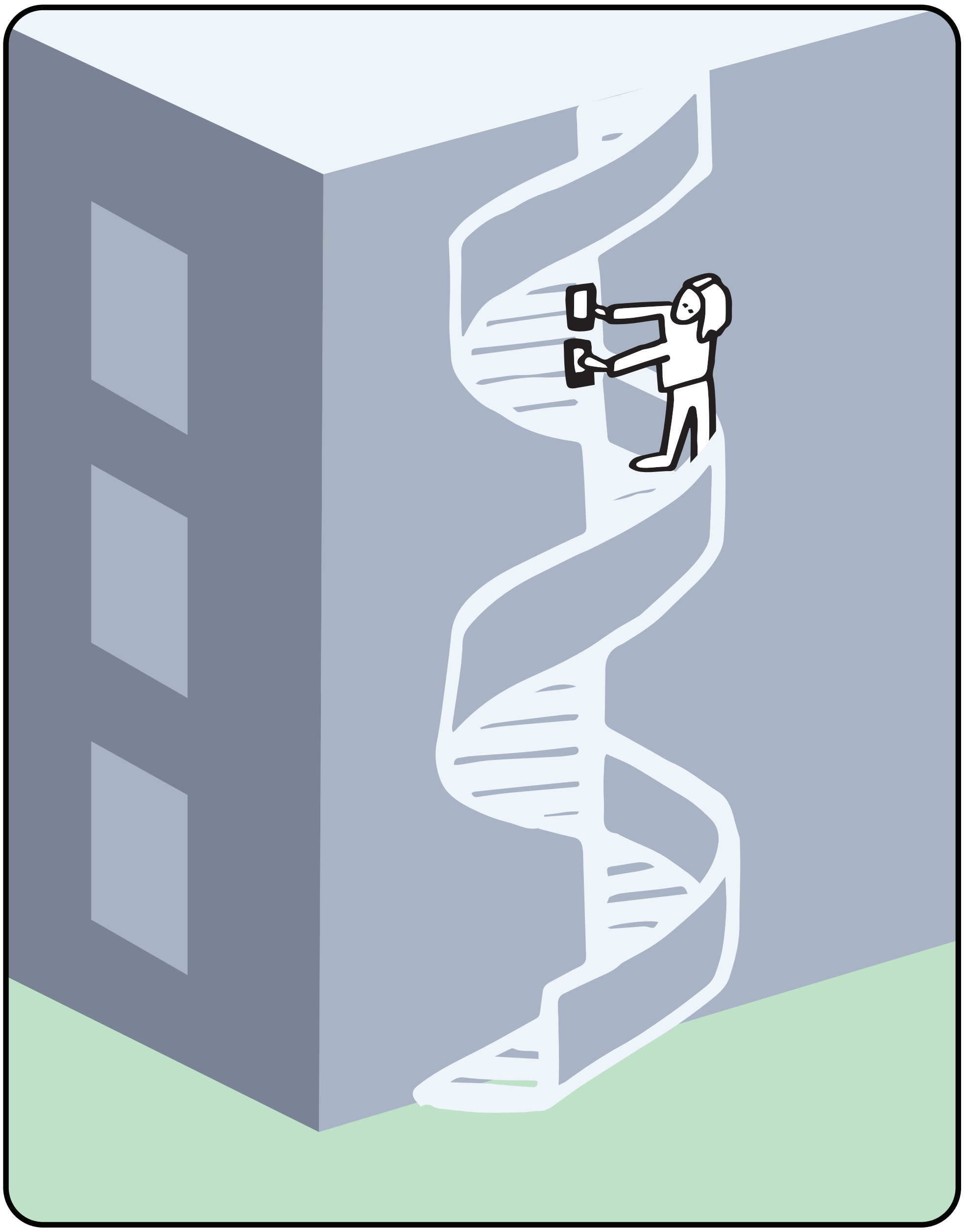
Formula

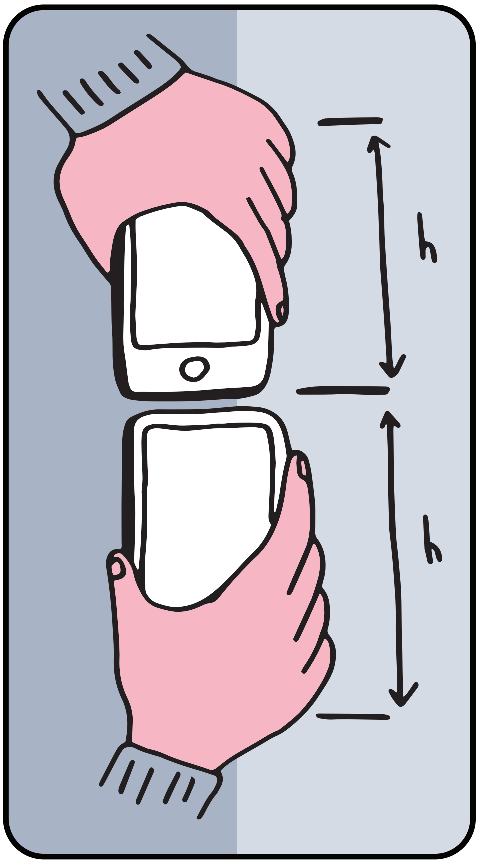
$H = Nh$

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: maximum

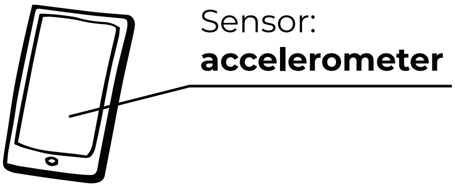
Difficulty: minimum

№35. Number of Steps

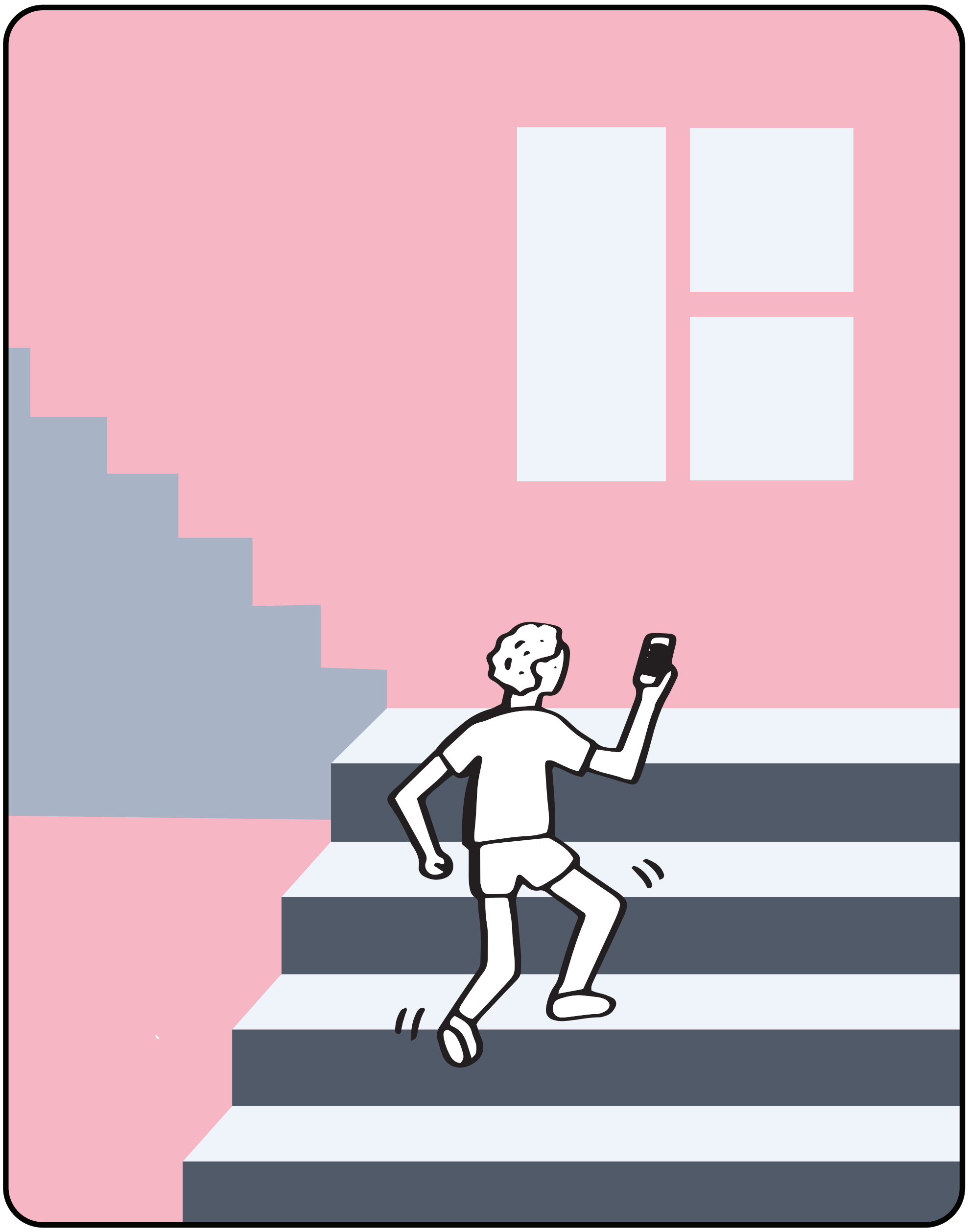
Formula

$$H = Nh$$

Material

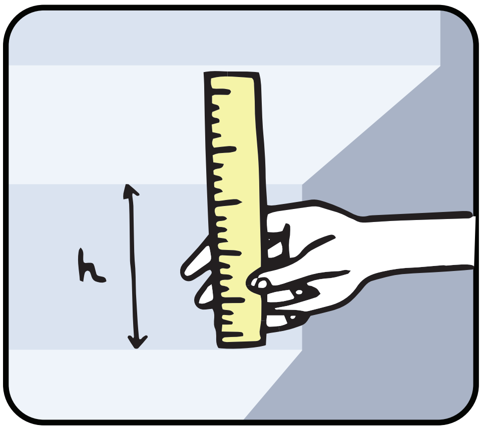


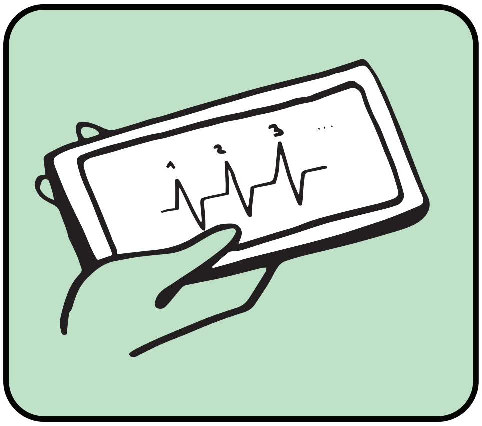
1 smartphone



Using the accelerometer, count the number of stair steps to the top of the building.

N = number of steps,
h = height of a step





Precision: high

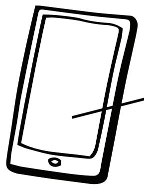
Difficulty: minimum

№36. Pressure Variation

Formula

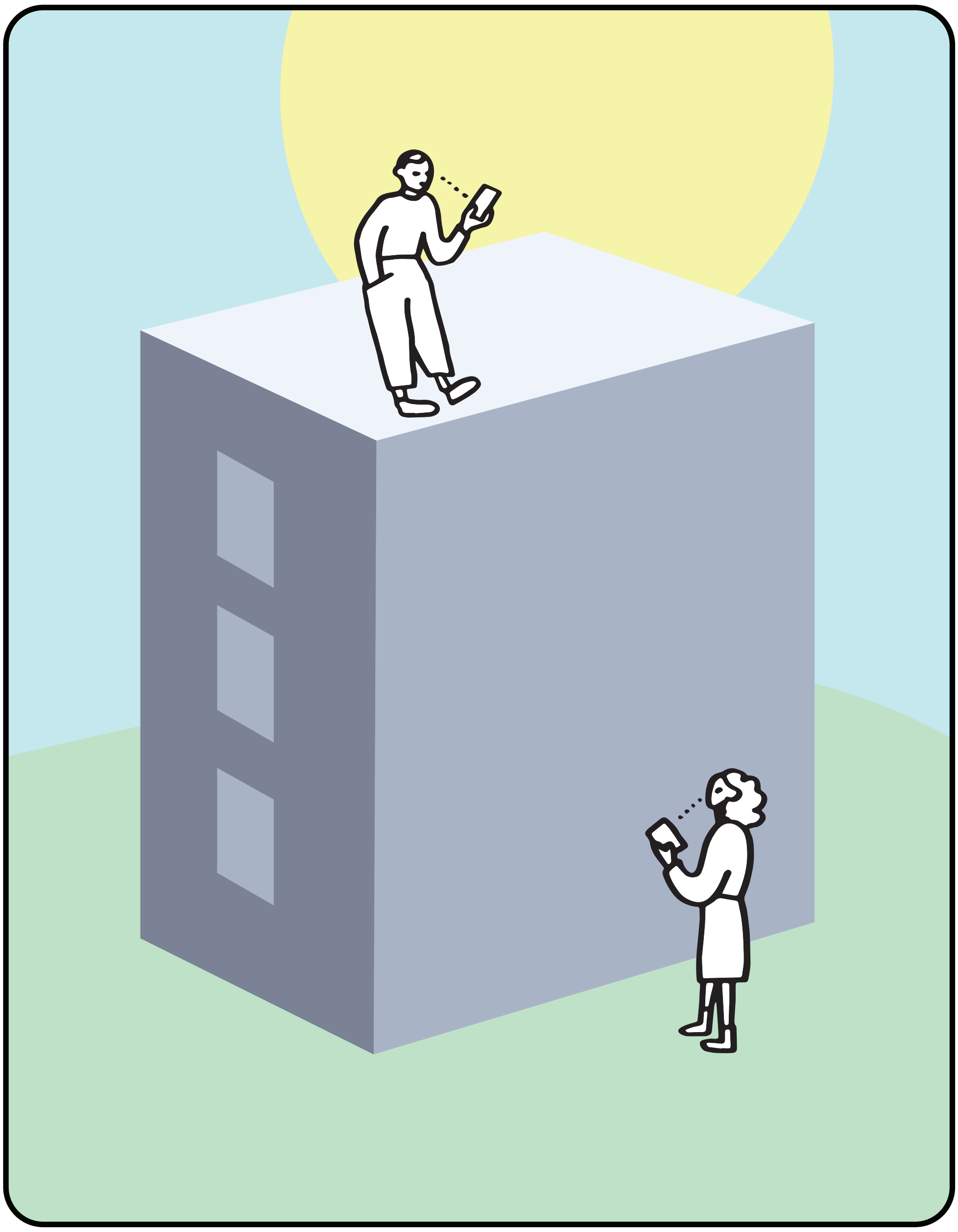
$$H = \frac{P_2 - P_1}{\rho g}$$

Material

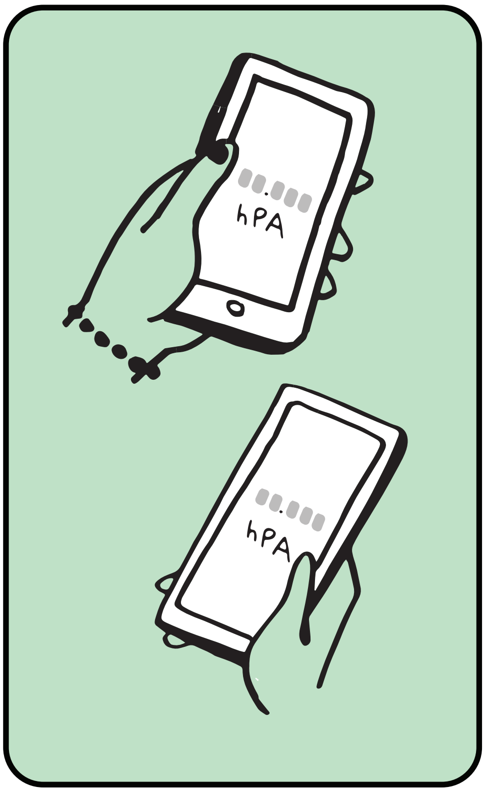


Sensor:
barometer

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, $g = 9.8\ ms^{-2}$

Precision: high

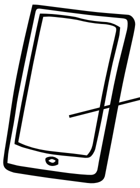
Difficulty: low

№37. Elevator

Formula

$$H = \iint \ddot{z} \, dt$$

Material



Sensor:
accelerometer

1 smartphone

Lay your smartphone flat in the elevator on the ground floor and then press the top floor button. Integrate the accelerometer measurements twice to obtain the height.

$\ddot{z}$ = vertical acceleration

№38. GPS

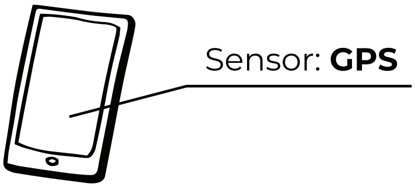
Precision: minimum

Difficulty: minimum

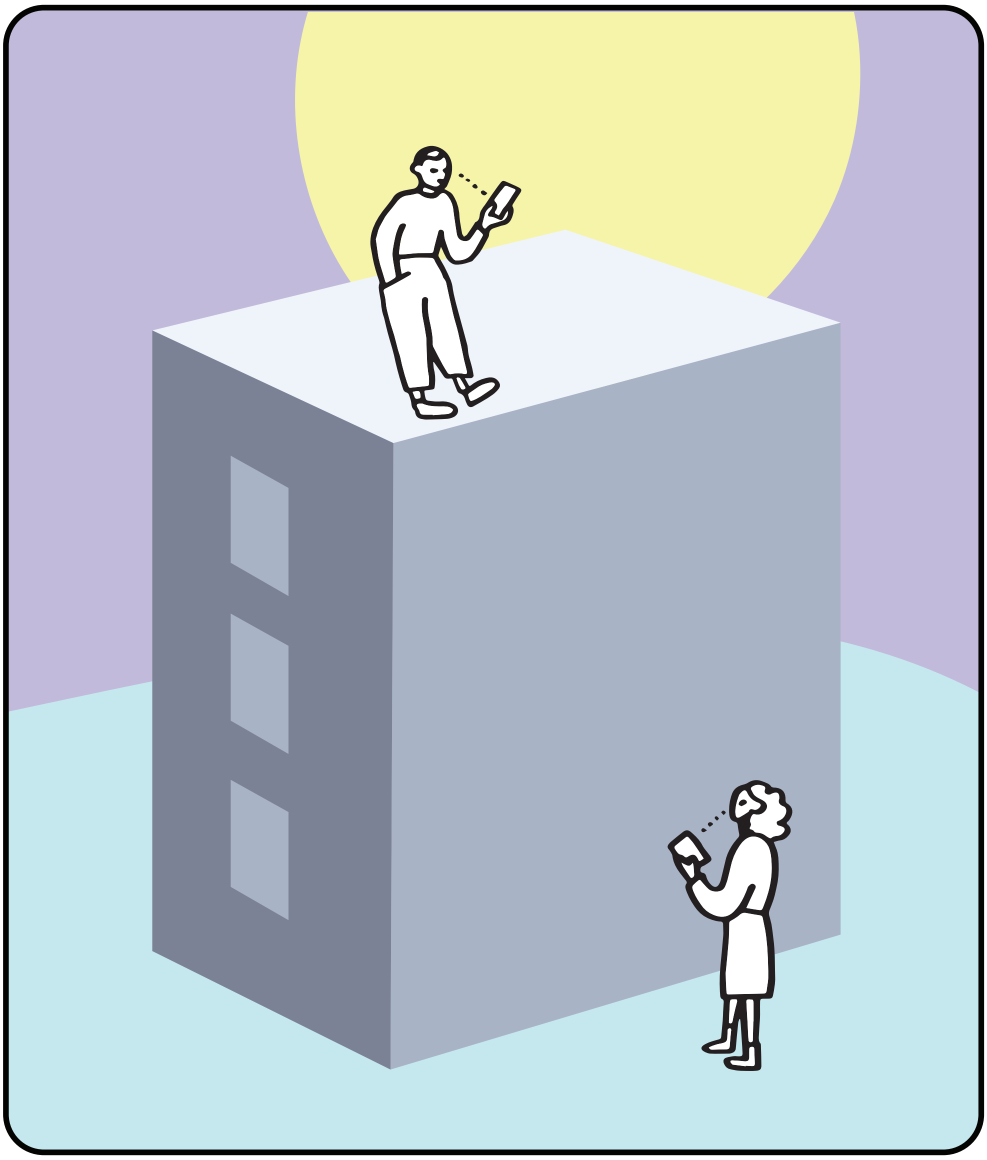
Formula

$$H = h_2 - h_1$$

Material

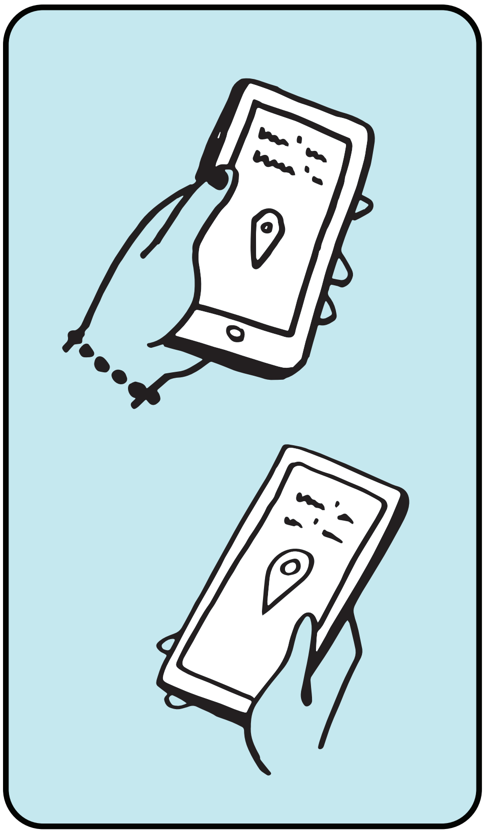


1 smartphone



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: intermediate

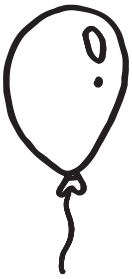
Difficulty: minimum

№39. Acoustic Stopwatch

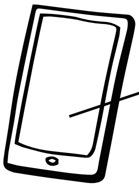
Formula

$$H = v\frac{\delta t}{2}$$

Material

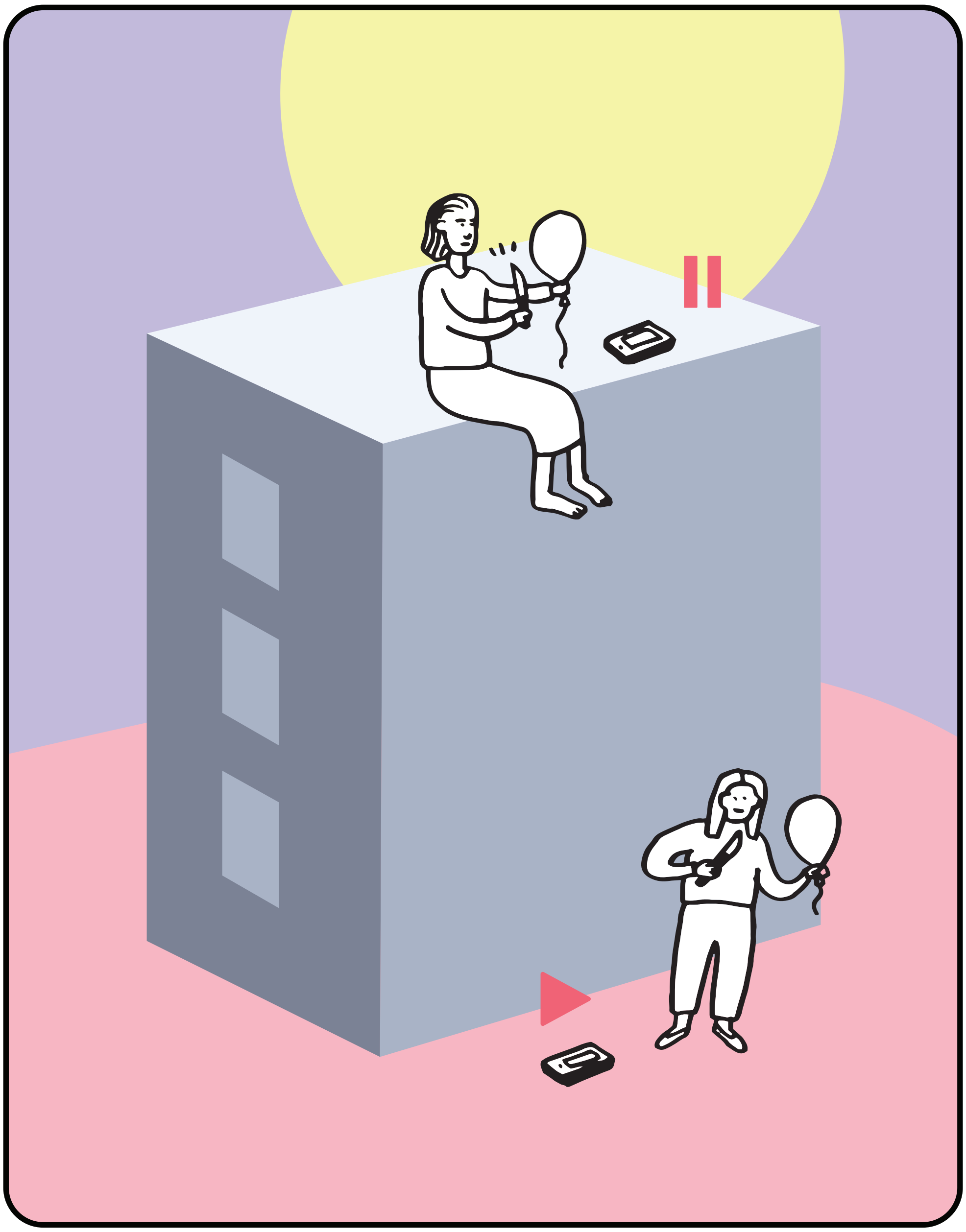


2 balloons

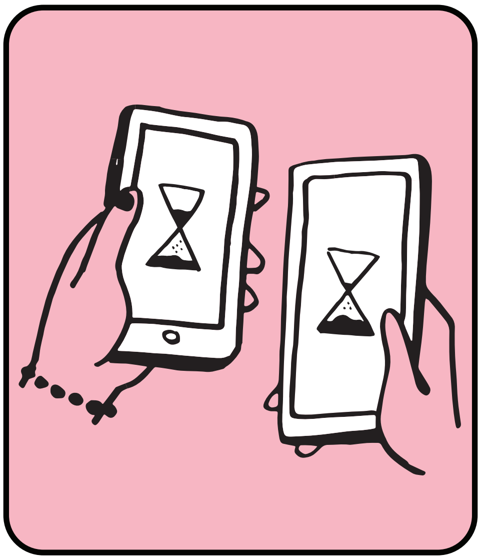


Sensor: **microphone**

2 smartphones



Install an acoustic stopwatch application on both smartphones (Phyphox for example). Launch the application, a smartphone at the bottom of the building, one at the top. Trigger the timers by popping a balloon at the bottom, then stop the timers by popping a balloon at the top.



v = speed of sound, δt = difference between the two chronometers

Precision: high

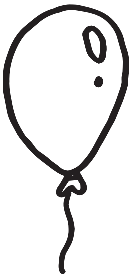
Difficulty: low

№40. Recording

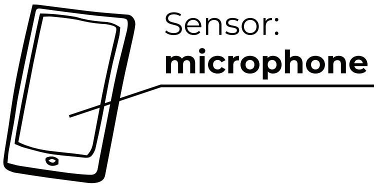
Formula

$H = vt$

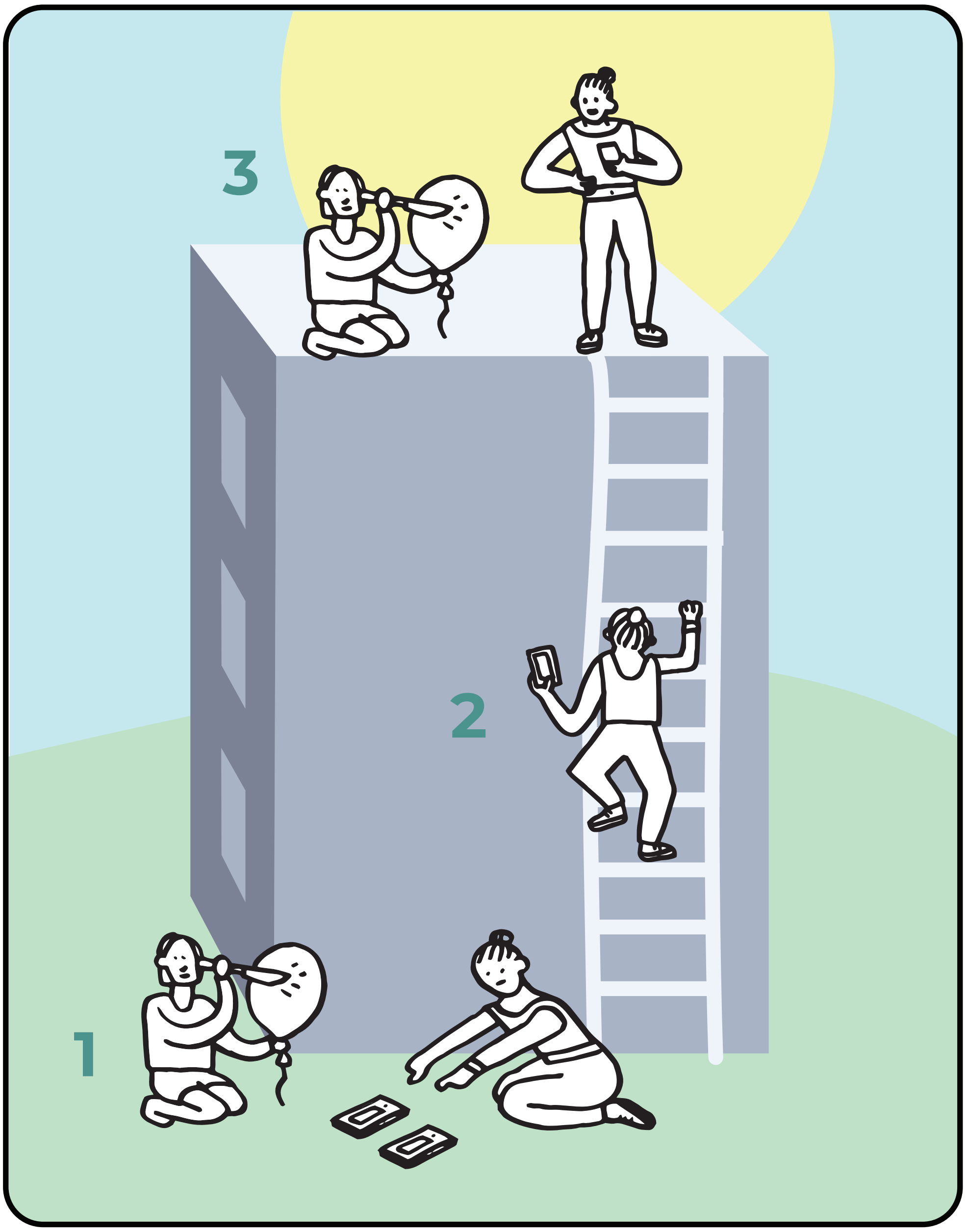
Material



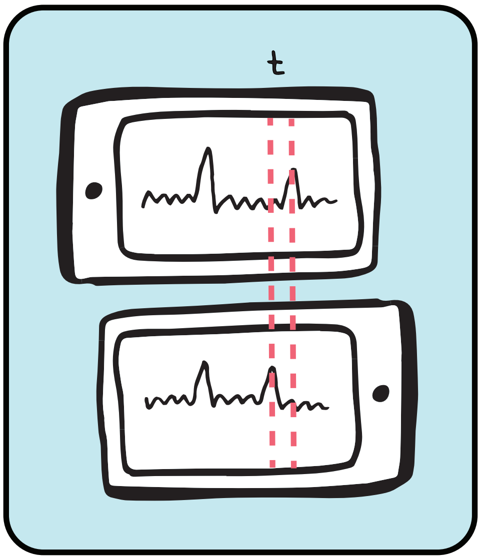
2 balloons



2 smartphones



Launch audio recording on both smartphones at the bottom of the building, and pop a balloon. Without stopping the recordings, bring one smartphone at the top of the building and pop a second balloon. The first pop synchronizes the two recordings, the second gives the height of the building.



v = speed of sound, t = time between the two second pops

Precision: minimum

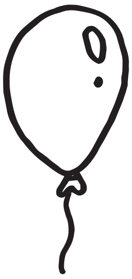
Difficulty: low

№41. Phone Call

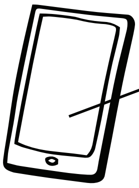
Formula

$$H = vt$$

Material

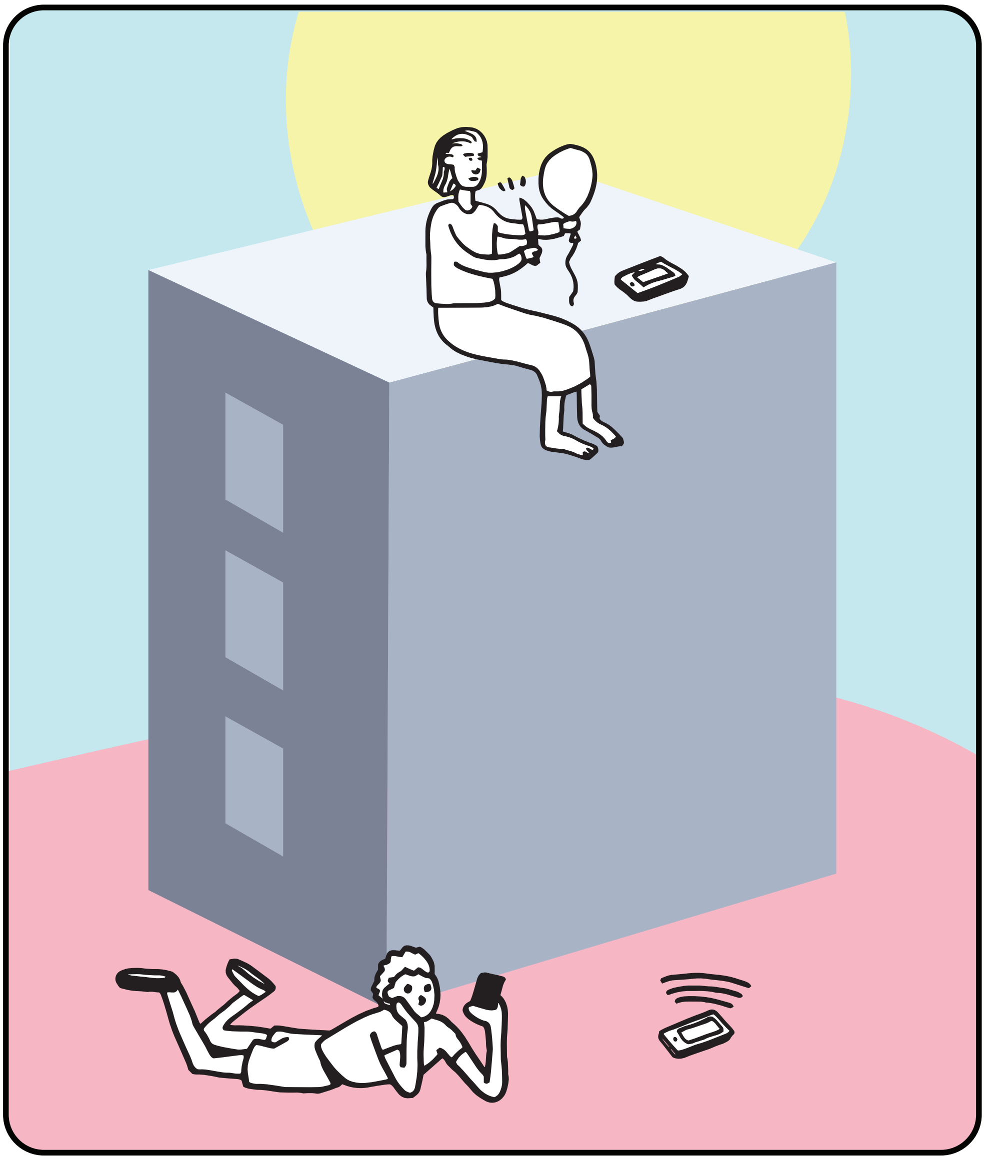


1 balloon



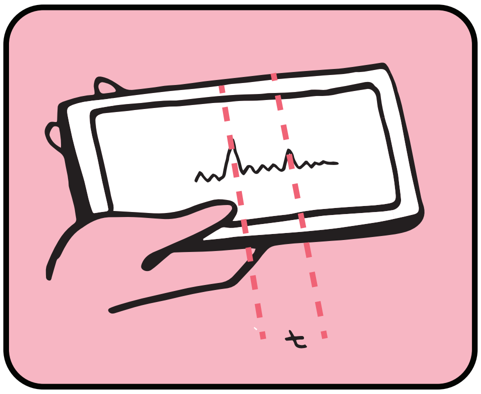
Sensors:
microphone, phone

3 smartphones



From the bottom of the building, call someone at the top. Put your smartphone on loudspeaker, and start an audio recording on the third smartphone. The person at the top pops a balloon. On the recording, measure the delay between the pop coming from the speaker and the pop coming from the balloon.

v = speed of sound, t = time between the two pops



This method assumes an instant connection between the two phones...

Precision: minimum

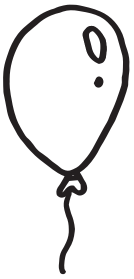
Difficulty: minimum

№42. Echo

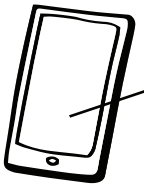
Formula

$$H = v\frac{t}{2}$$

Material

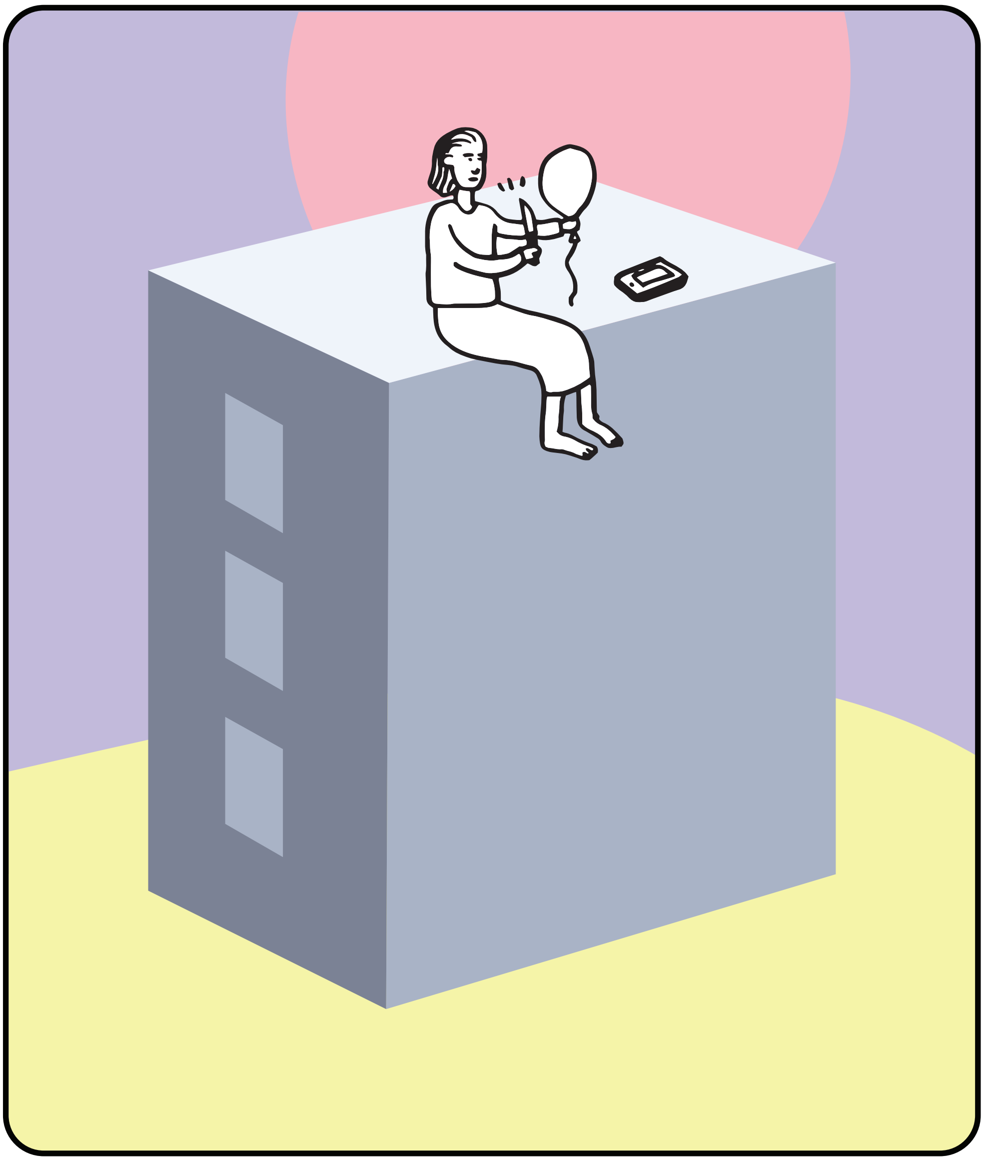


1 balloon



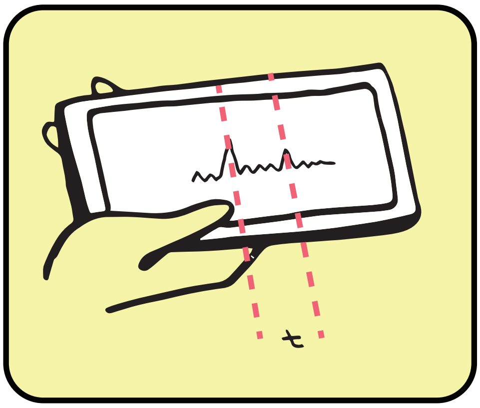
Sensor:
microphone

1 smartphone



Post yourself at the top of the building. Launch an audio recording on the smartphone, and pop a balloon. Measure the delay between the pop and its echo.

v = speed of sound, t = time between pop and echo



There must be an echo for this method to work…

Precision: high

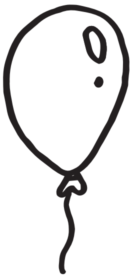
Difficulty: low

№43. Slow Motion

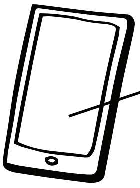
Formula

$$H = vt$$

Material

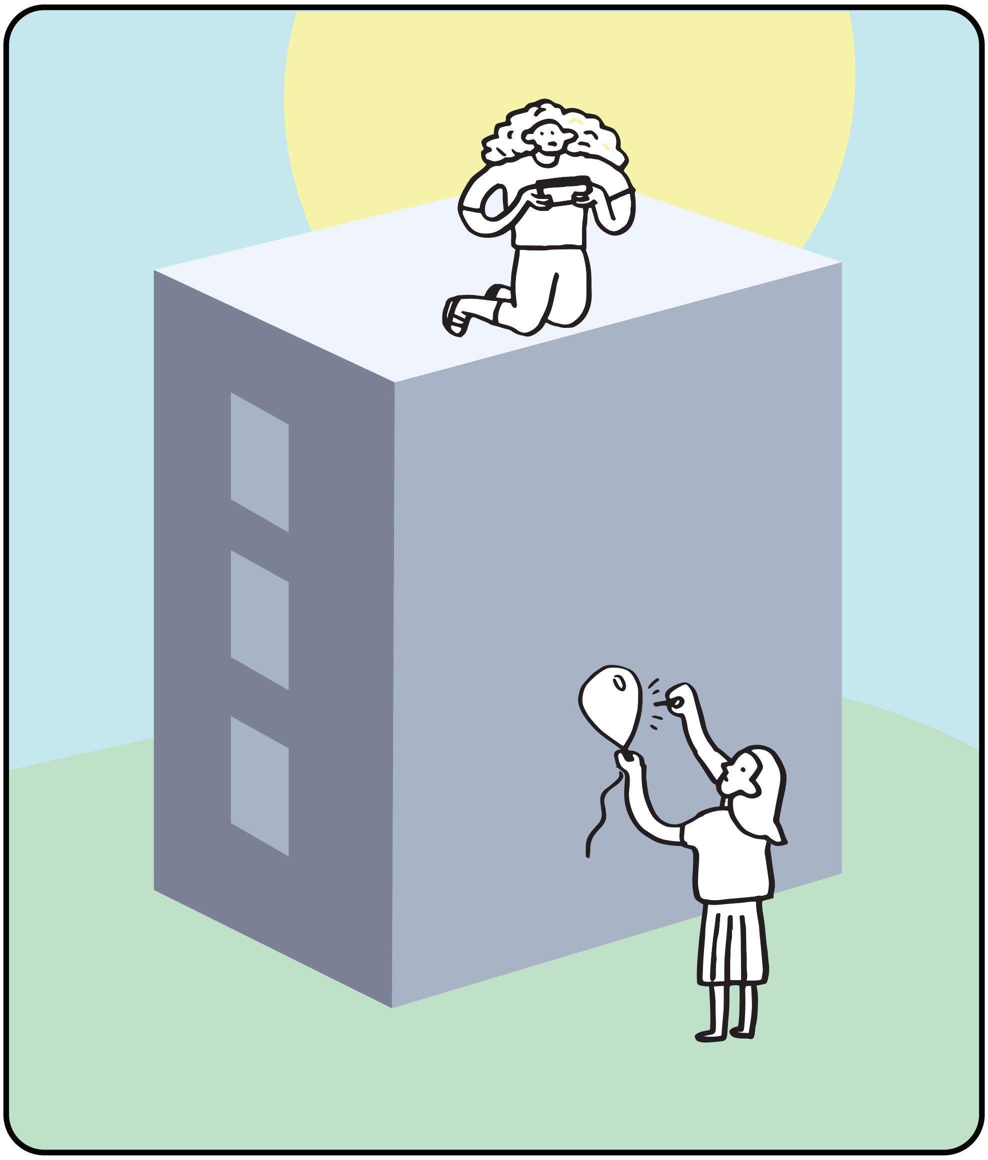


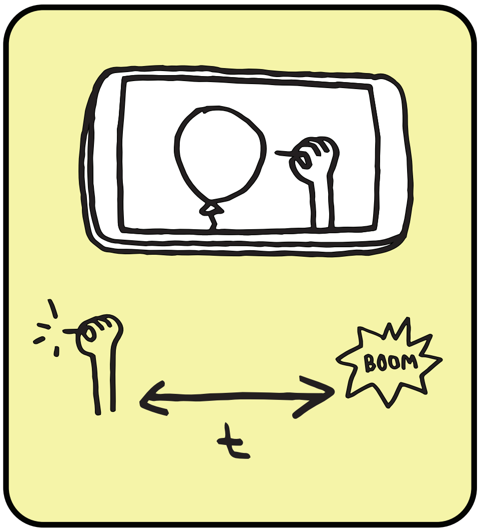
1 balloon



Sensors:
camera, microphone

1 smartphone with
slow motion





From the top of the building, film in "slow motion" the bursting of a balloon at the bottom of the building. Measure the time elapsed between the image and the sound of the exploding balloon.

v = speed of sound, t = delay between pop image and pop sound

Some smartphones do not record sound in slow motion.

Precision: high

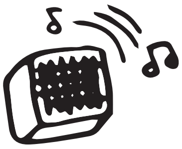
Difficulty: high

№44. Phase Shift of a Note

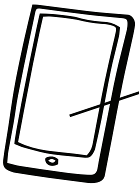
Formula

$$H = \Phi \frac{v}{2\pi f}$$

Material

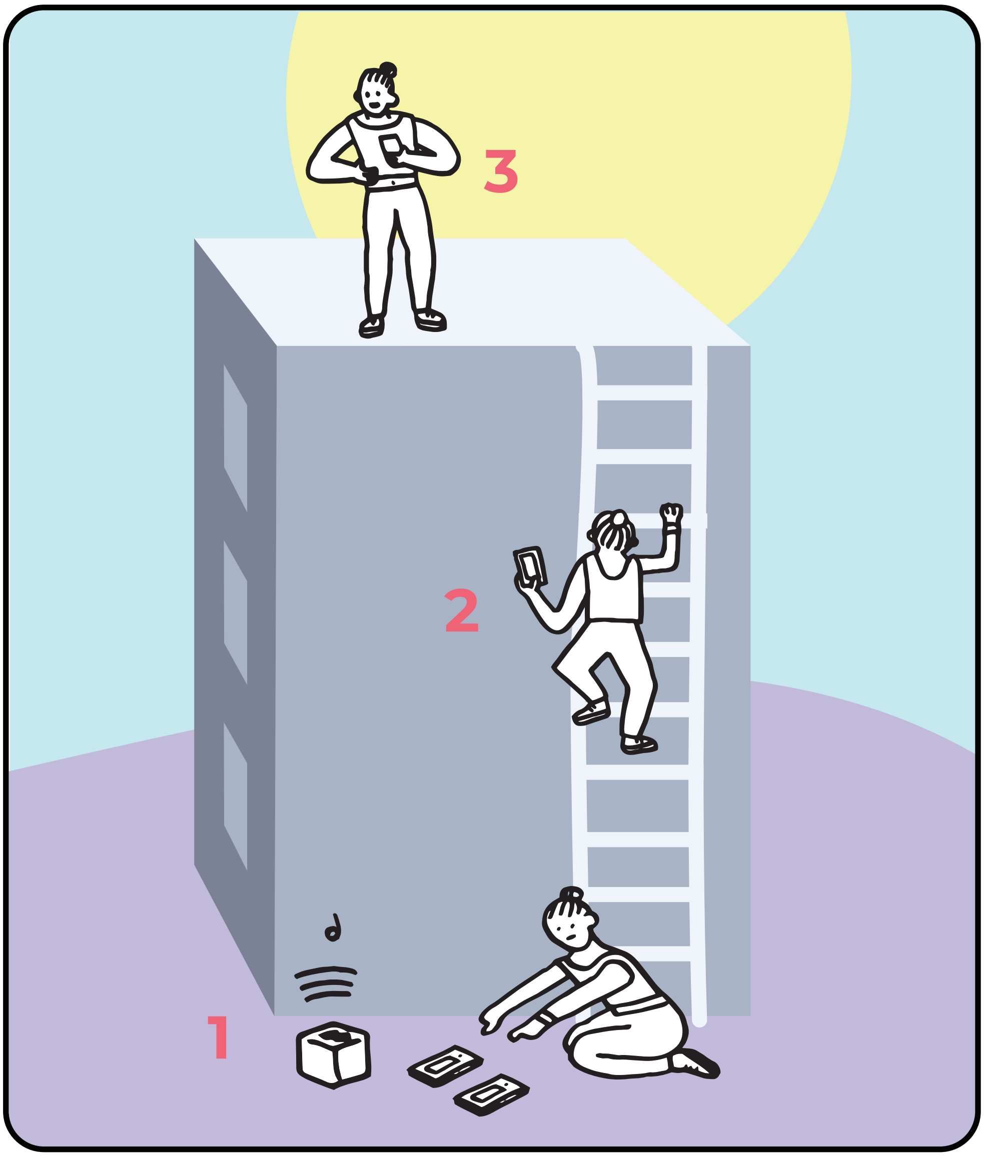


1 bluetooth speaker



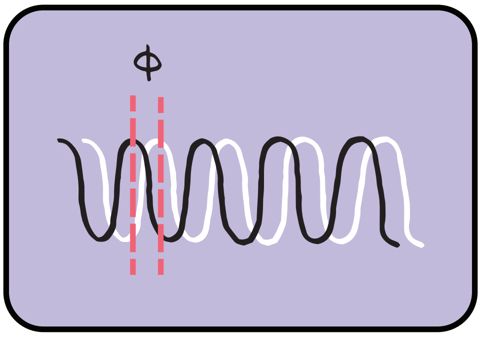
Sensor: **microphone**

2 smartphones



Place the loudspeaker at the bottom of the building, and let it sound a continuous note. Launch audio recordings on both smartphones. One stays at the bottom. Climb to the top by the fire escape with the second smartphone, still recording. Compare the records to determine the phase shift between the top and bottom of the building.

v = speed of sound, f = frequency,
Φ = phase difference in radian



Avoid high frequencies that have too short wavelengths.

Precision: high

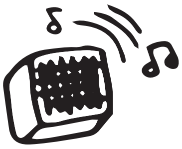
Difficulty: high

№45. Phase Shift

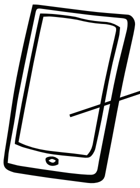
Formula

$$H = \frac{d\Phi}{df}\,\frac{v}{2\pi}$$

Material

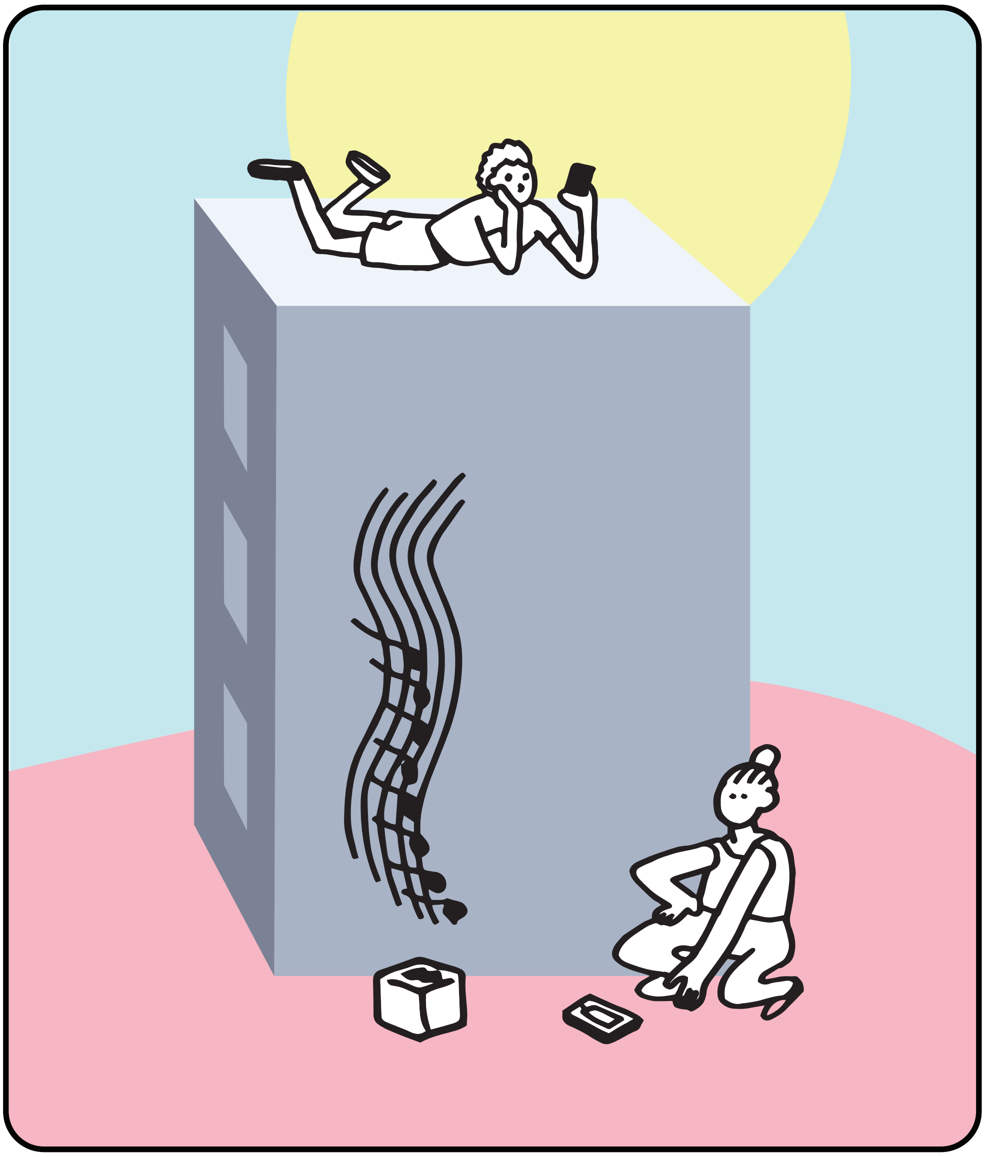


1 bluetooth speaker

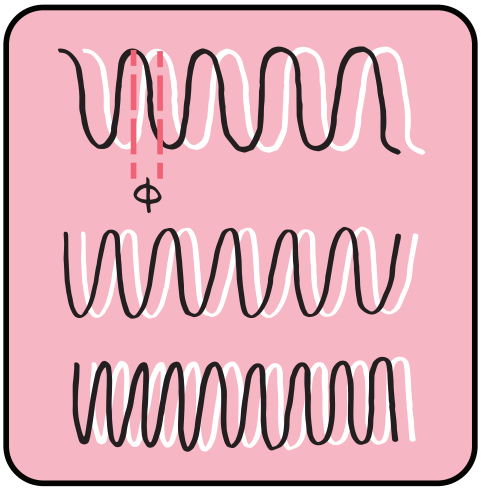


Sensor: **microphone**

2 smartphones



Place the loudspeaker at the bottom of the building, and let it sound a continuous note. Launch audio recordings on both smartphones, one at the top, the other at the bottom. Compare the records to determine how phase shift changes when the frequency of the note varies.



v = speed of sound, f = frequency,
Φ = phase difference in radian

The analysis of the data is not immediate and requires a certain technicality.

Precision: high

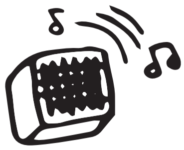
Difficulty: high

№46. Lateral Phase Shift

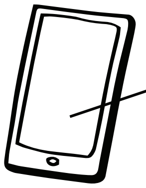
Formula

$$H = \frac{\pi f}{v} \cdot \frac{1}{\frac{d\Phi}{dd^2}}$$

Material

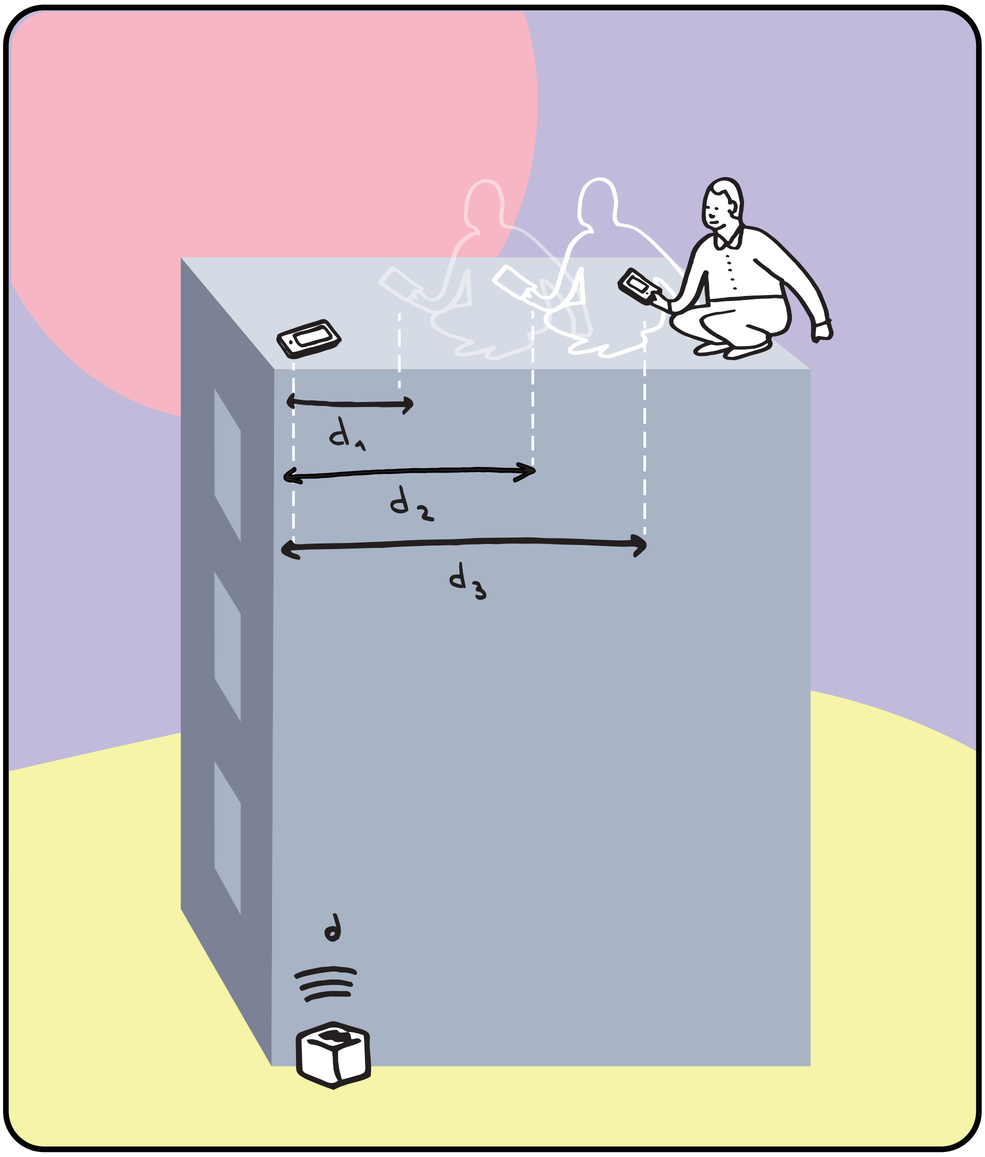


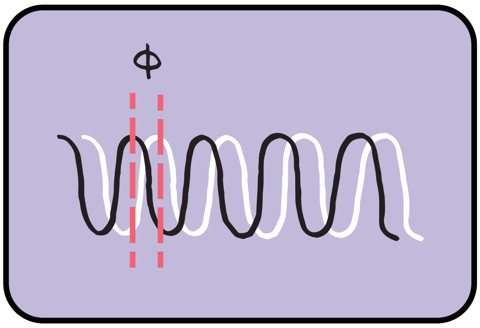
1 bluetooth speaker



Sensor: **microphone**

2 smartphones





Place the speaker at the bottom of the building, and let it sound a continuous note. Launch recordings on both smartphones, at the top of the building and at the vertical of the loudspeaker. Move one of the smartphones sideways. Compare the recordings to determine the phase shift between both smartphones.

v = speed of sound, f = frequency,
Φ =phase difference in radian,
d = distance between smartpones

The formula assumes that d << H.

Precision: intermediate

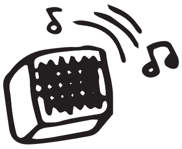
Difficulty: intermediate

№47. Acoustic Interference

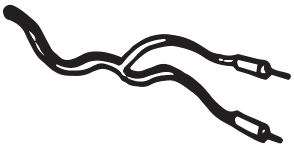
Formula

$$H = \frac{ldf}{v}$$

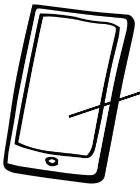
Material



2 bluetooth speakers

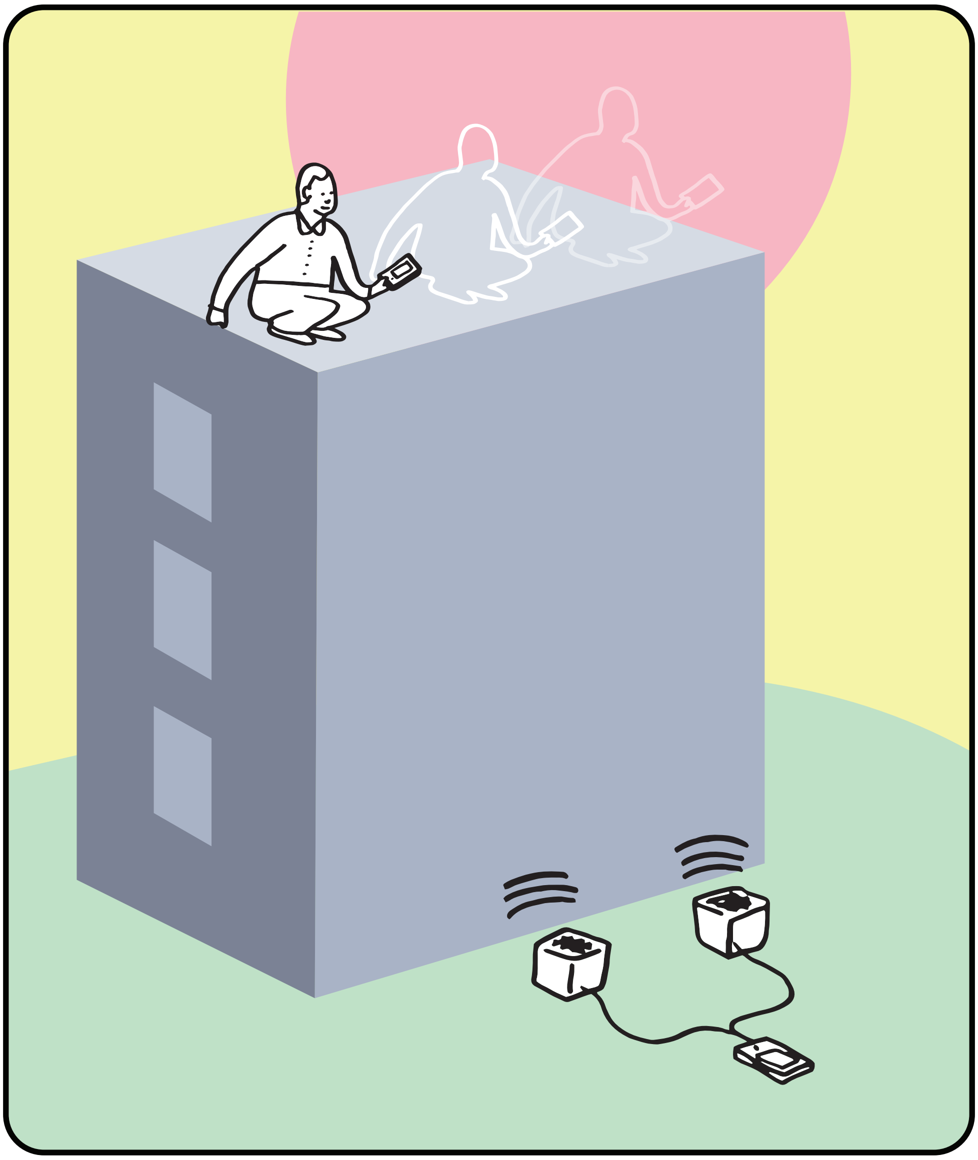


1 jack splitter

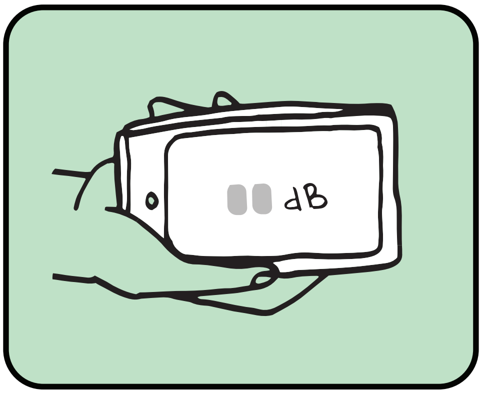


Sensor: **microphone**

2 smartphones



Place the two speakers on the ground separated by some distance. By connecting both of them to a smartphone with the jacksplitter, issue the same continuous note on both devices. On the top of the building, use a smartphone to determine the positions of minimum sound level.



v = speed of sound, f = frequency,
l = distance between loudspeakers,
d = distance between the two audio minimums

The formula assumes that d << H and l << H.

Precision: high

Difficulty: low

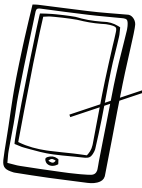
№48. Resonance of a Tube

Formula

$$H = \frac{v}{2f}$$

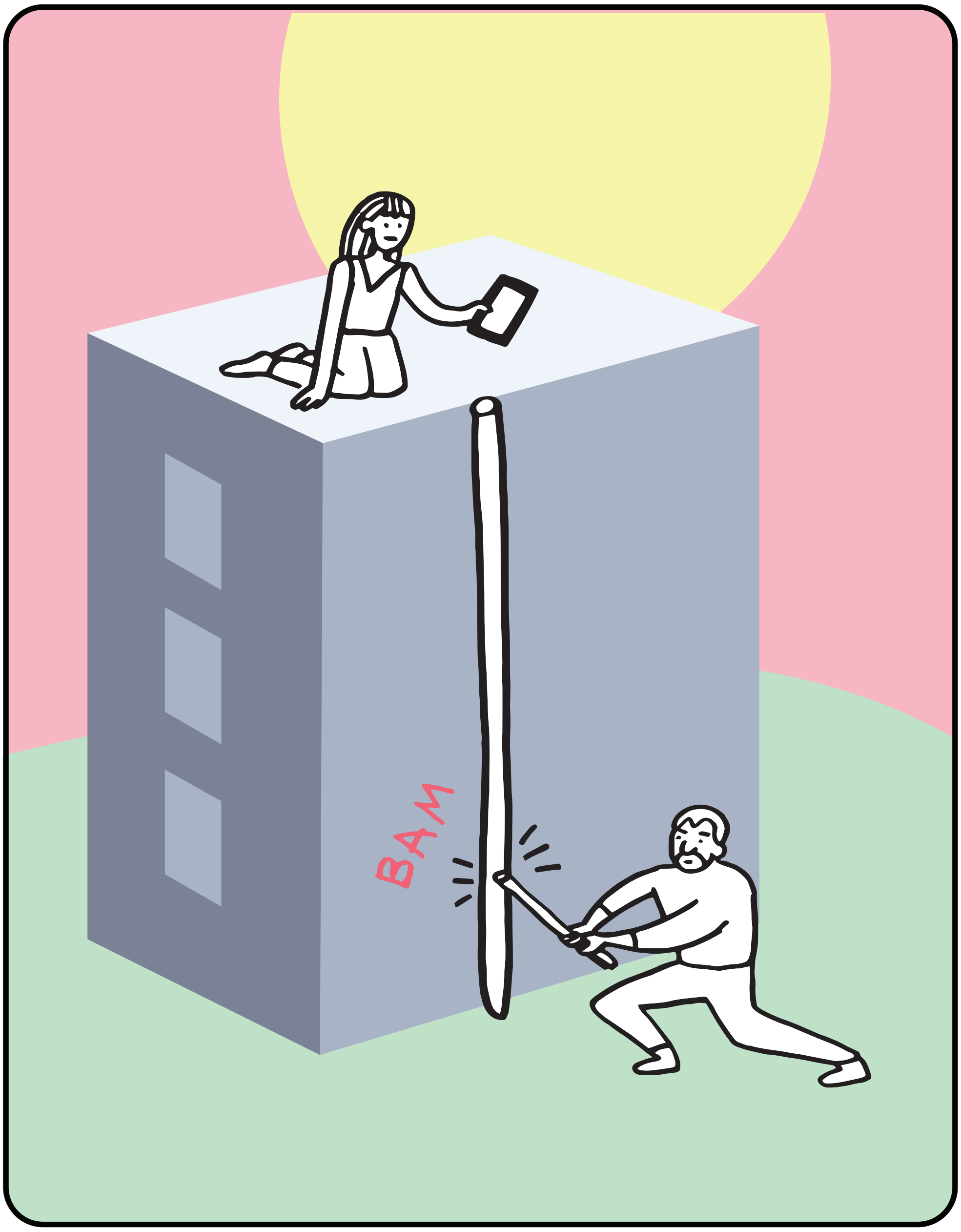
Material

1 long tube of the same length as the building height

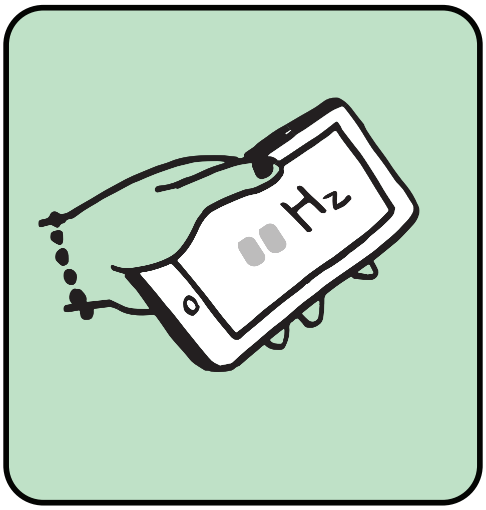


Sensor: **microphone**

1 smartphone



Find a rigid tube the same length as the height of the building. Determine the note that can propagate in the tube.



v = speed of sound, f = frequency

Precision: intermediate

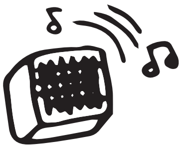
Difficulty: low

№49. Loudness

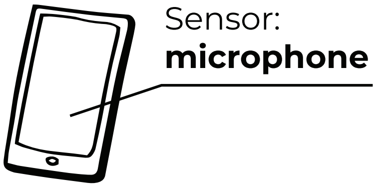
Formula

$$H \propto \frac{1}{\sqrt{I}}$$

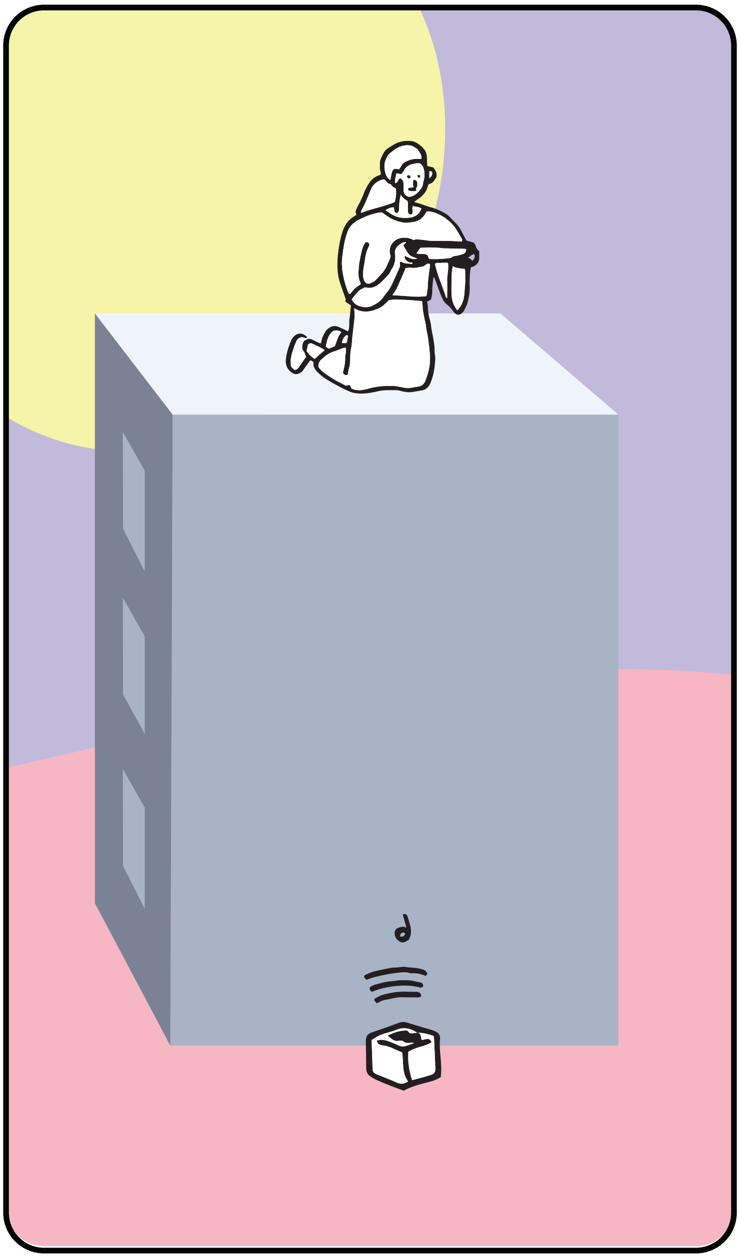
Material

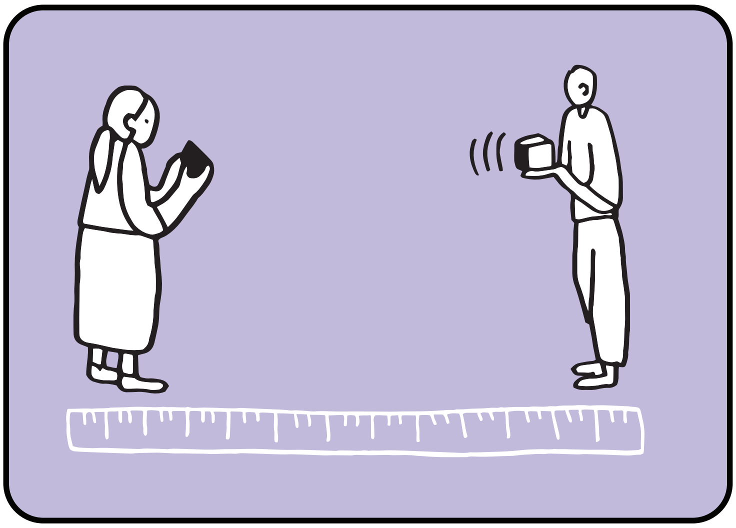


1 bluetooth speaker



1 smartphone





Install the speaker at the bottom of the building, and measure the sound intensity at the top. Turn off the sound to determine the ambient noise. The intensity varies in 1 / R^2, and must be calibrated before.

I = sound intensity

Precision: intermediate

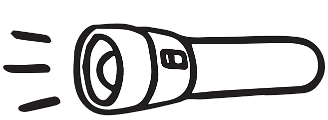
Difficulty: low

№50. Light Intensity

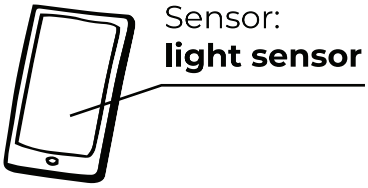
Formula

$$H \propto \frac{1}{\sqrt{I}}$$

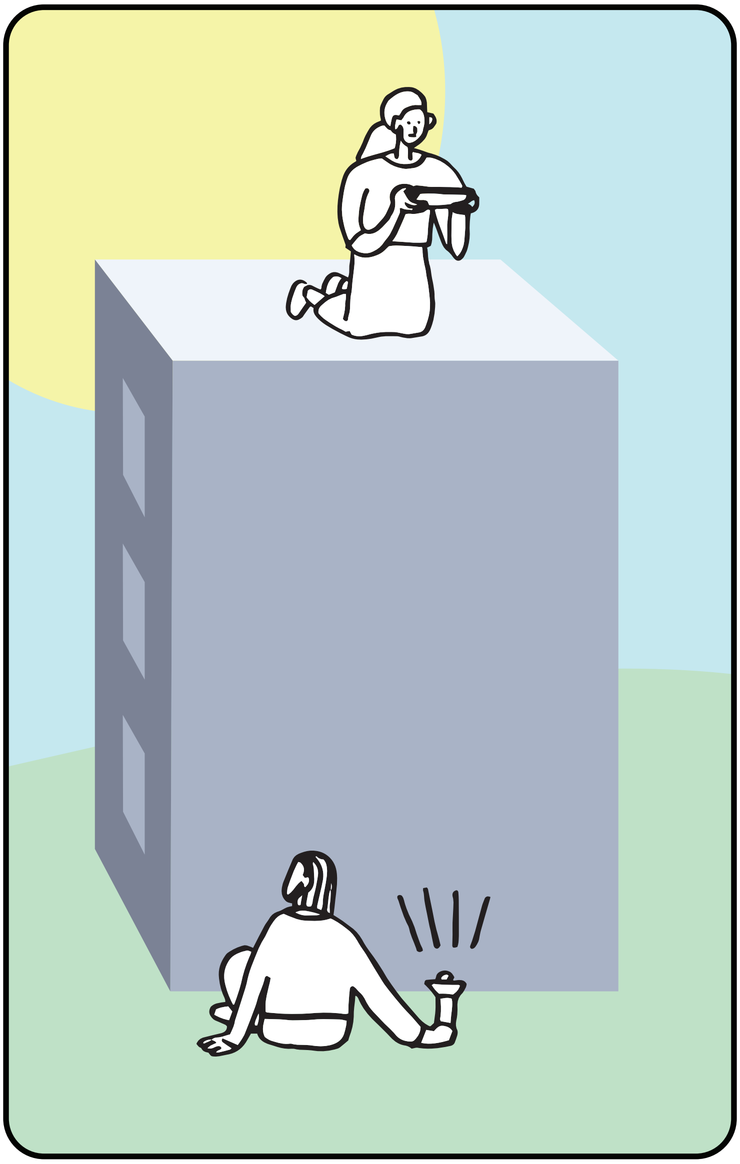
Material

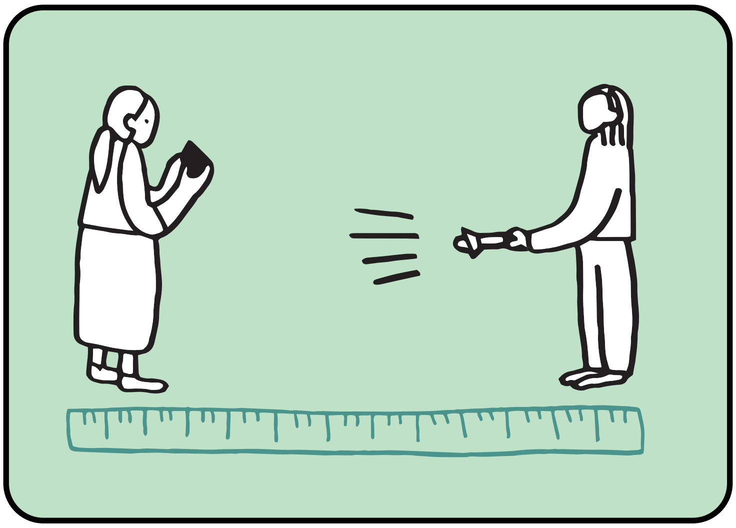


1 lamp



1 smartphone





Install the lamp at the bottom of the building, and measure the light intensity at the top. Turn off the light to determine the ambient light. The measured intensity varies in 1 / R^2, and must be calibrated before.

I = light intensity

Works best in the evening or at night.

Precision: minimum

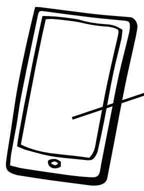
Difficulty: low

№51. Wifi Intensity

Formula

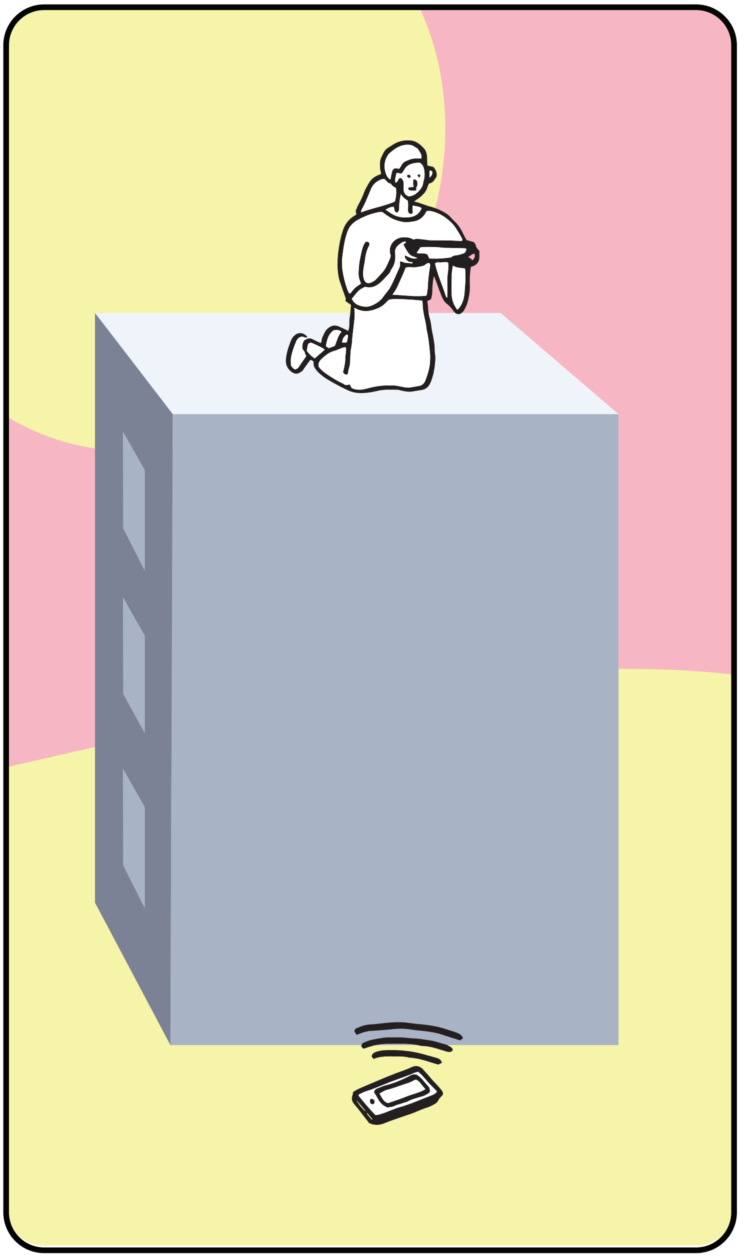
$$H \propto \frac{1}{\sqrt{I}}$$

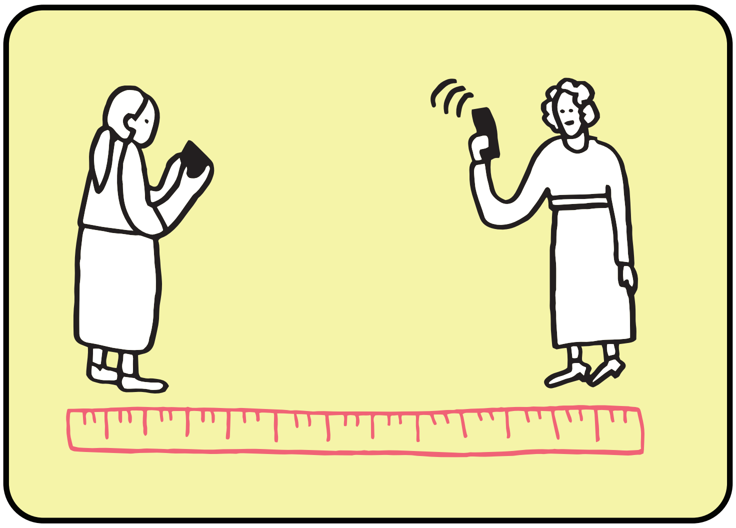
Material



Sensor:
wifi antenna

2 smartphones





Turn the hotspot on for the smartphone at the bottom of the building, and measure the wifi intensity at the top of the building. When no perturbation is present, the intensity of a propagating electromagnetic wave varies in $1 / R^2$, and must be calibrated before.

I = wifi intensity

Precision: minimum

Difficulty: low

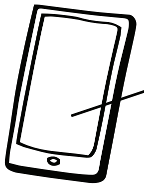
№52. Magnetic Field

Formula

$$H \propto \frac{1}{\sqrt[3]{B}}$$

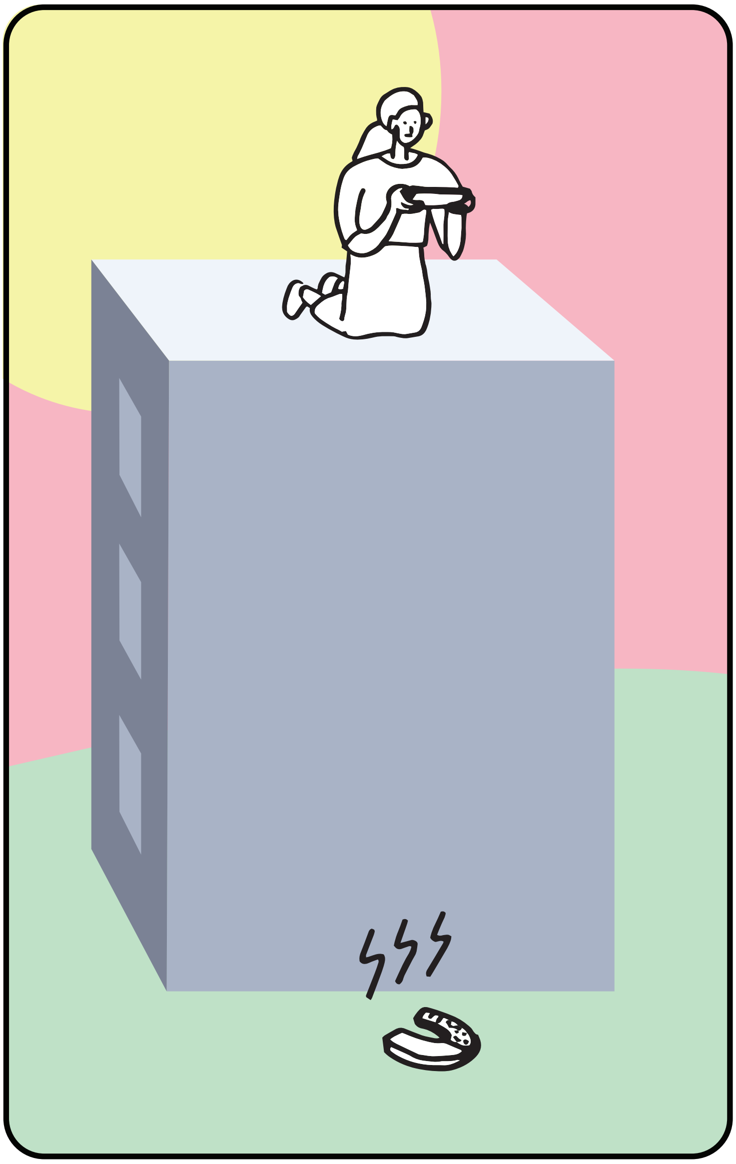
Material

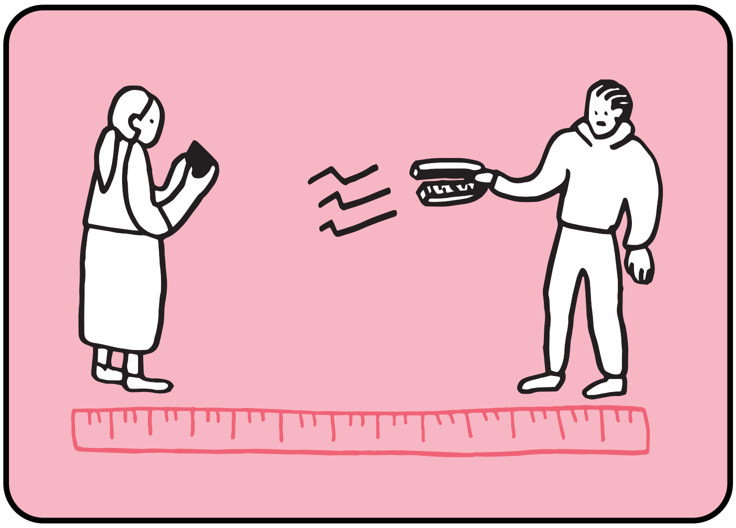
1 magnet



Sensor: **magnetometer**

1 smartphone





Install the magnet at the bottom of the building, and measure the magnetic field at the top. The intensity of the magnetic field varies in 1 / R^3, and must be calibrated before.

B = magnetic field

Warning: handling strong magnets is dangerous.

Precision: high

Difficulty: impossible

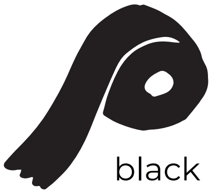
№53. Radioactivity

Formula

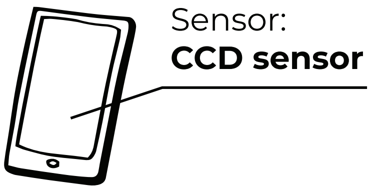
$$H \propto \frac{1}{\sqrt{I}}$$

Material

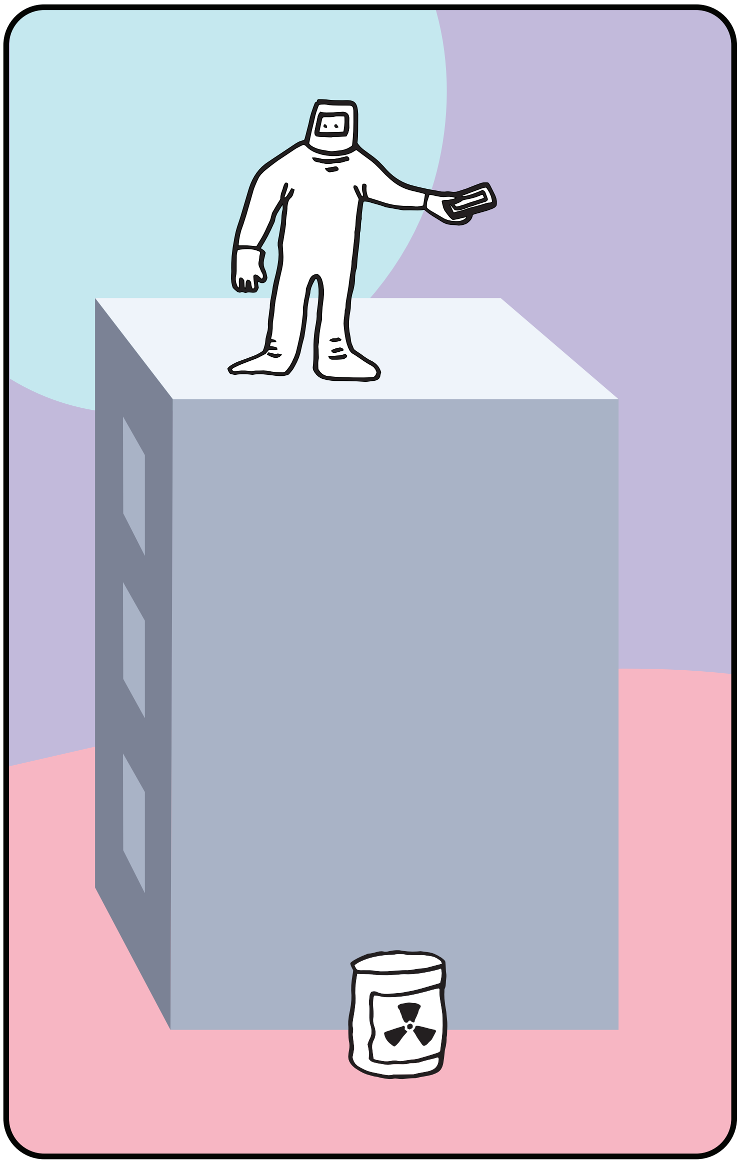
1kg of plutonium

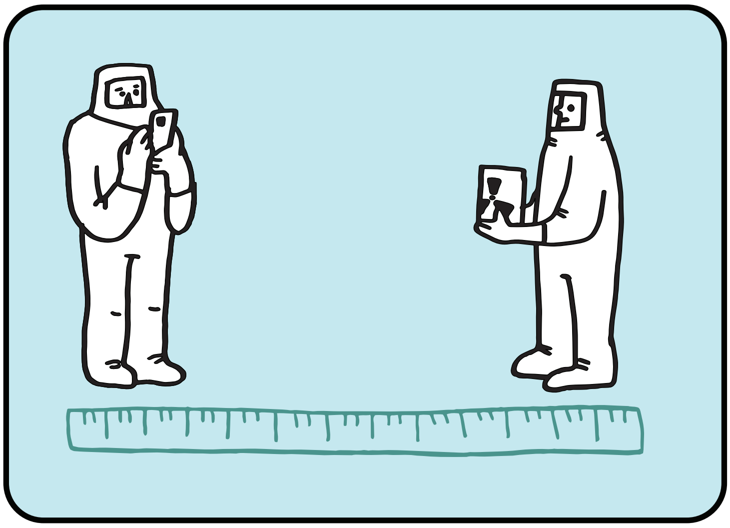


black tape

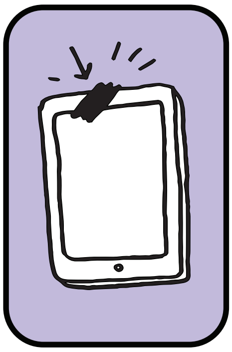


1 smartphone





Turn your smartphone into a Geiger counter with black tape. Install the plutonium at the bottom of the building, and measure the radioactivity at the top. The radioactive intensity varies in 1 / R^2, and must be calibrated before.



I = radioactive intensity

This method works in theory, but is too dangerous to be conducted for real.

Precision: high

Difficulty: low

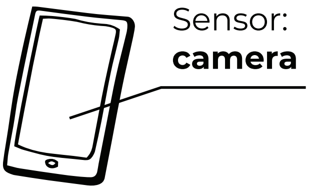
№54. Number of Pixels

Formula

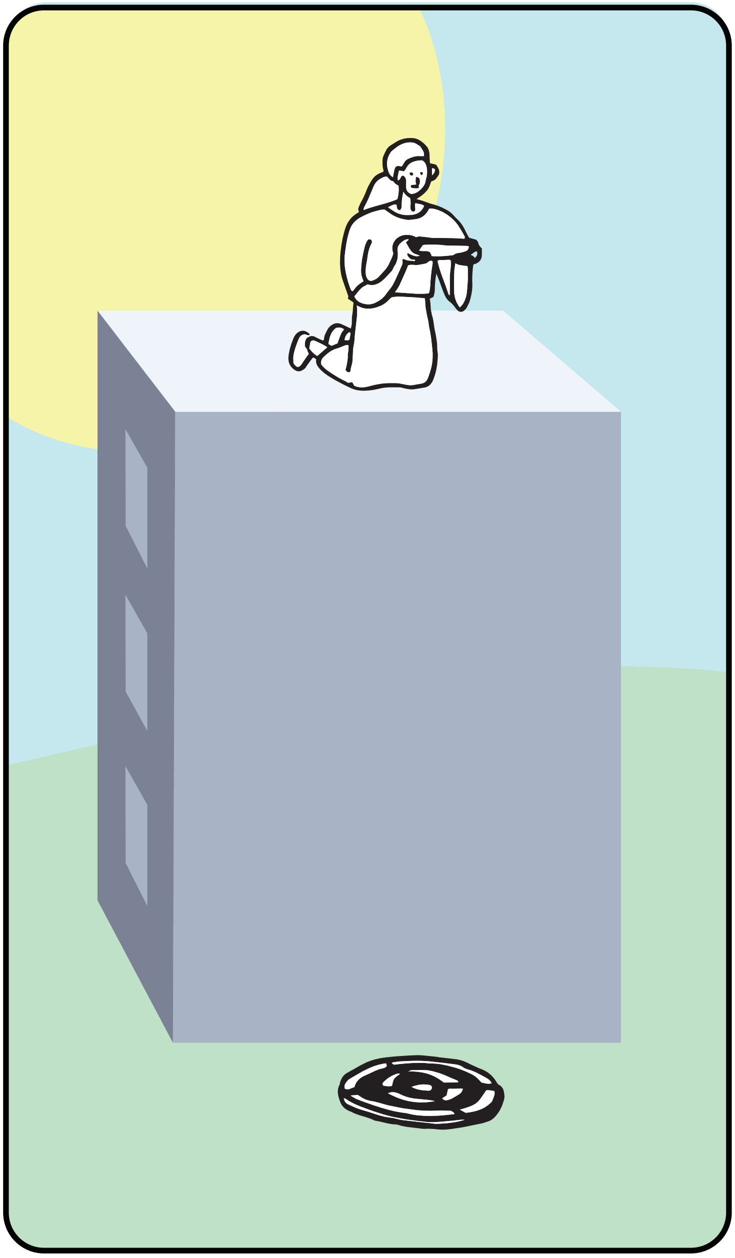
$$H \propto \frac{1}{\sqrt{N}}$$

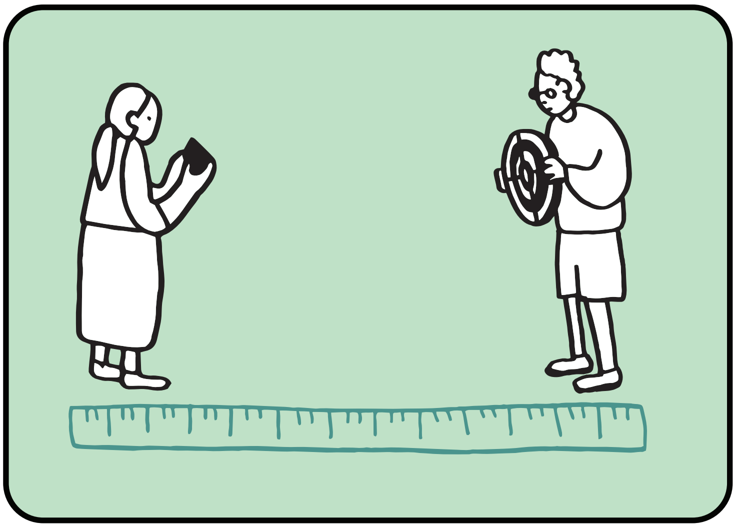
Material

1 target



1 smartphone





Install the target at the bottom of the building, and take a picture from the top of the building. The number of pixels representing the target in the picture varies in $1 / R^2$, and must be calibrated before.

N = number of pixels

Precision: high

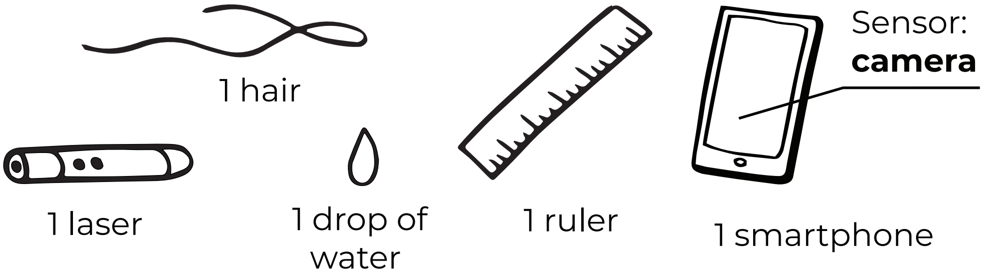
Difficulty: high

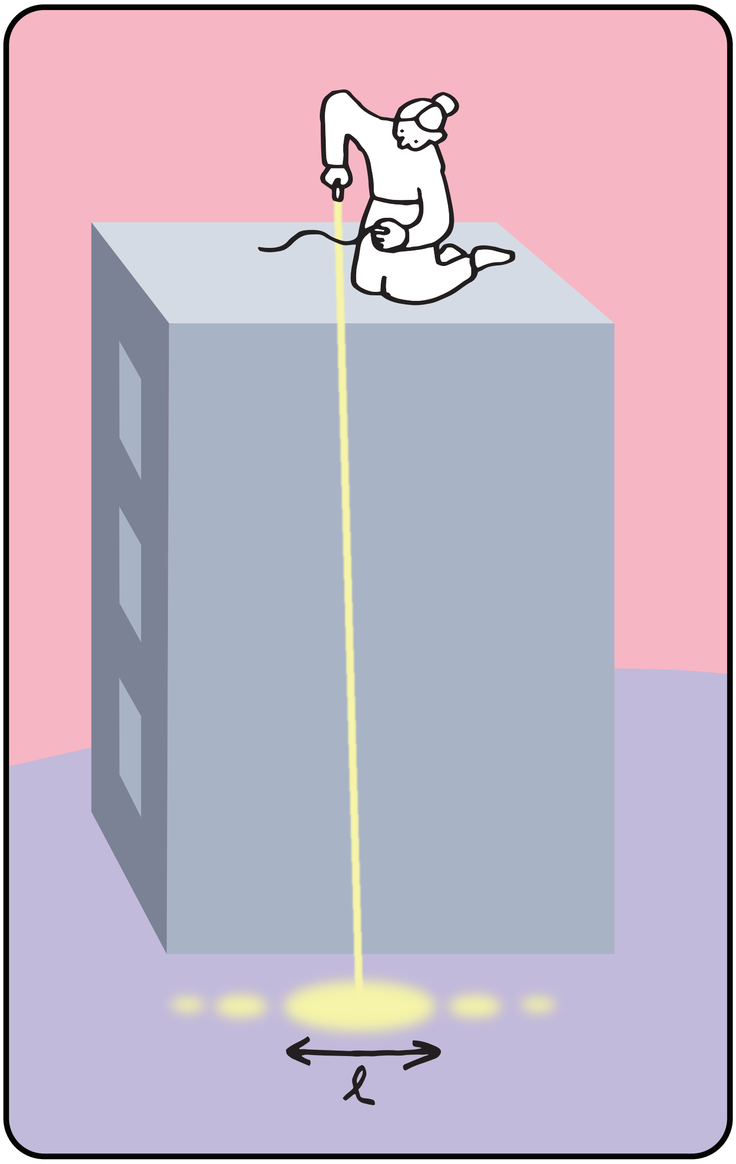
№55. Hair Diffraction

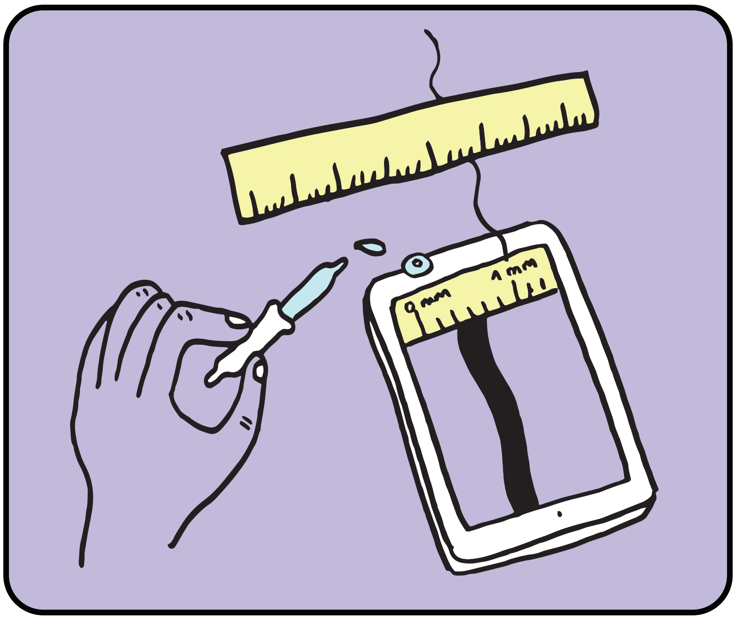
Formula

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

Material







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: high

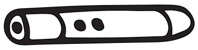
Difficulty: high

№56. LCD Screen Diffraction

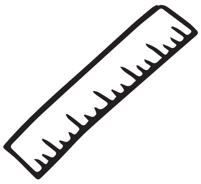
Formula

$$H = \frac{lp}{\lambda}$$

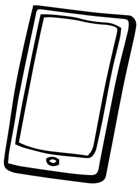
Material



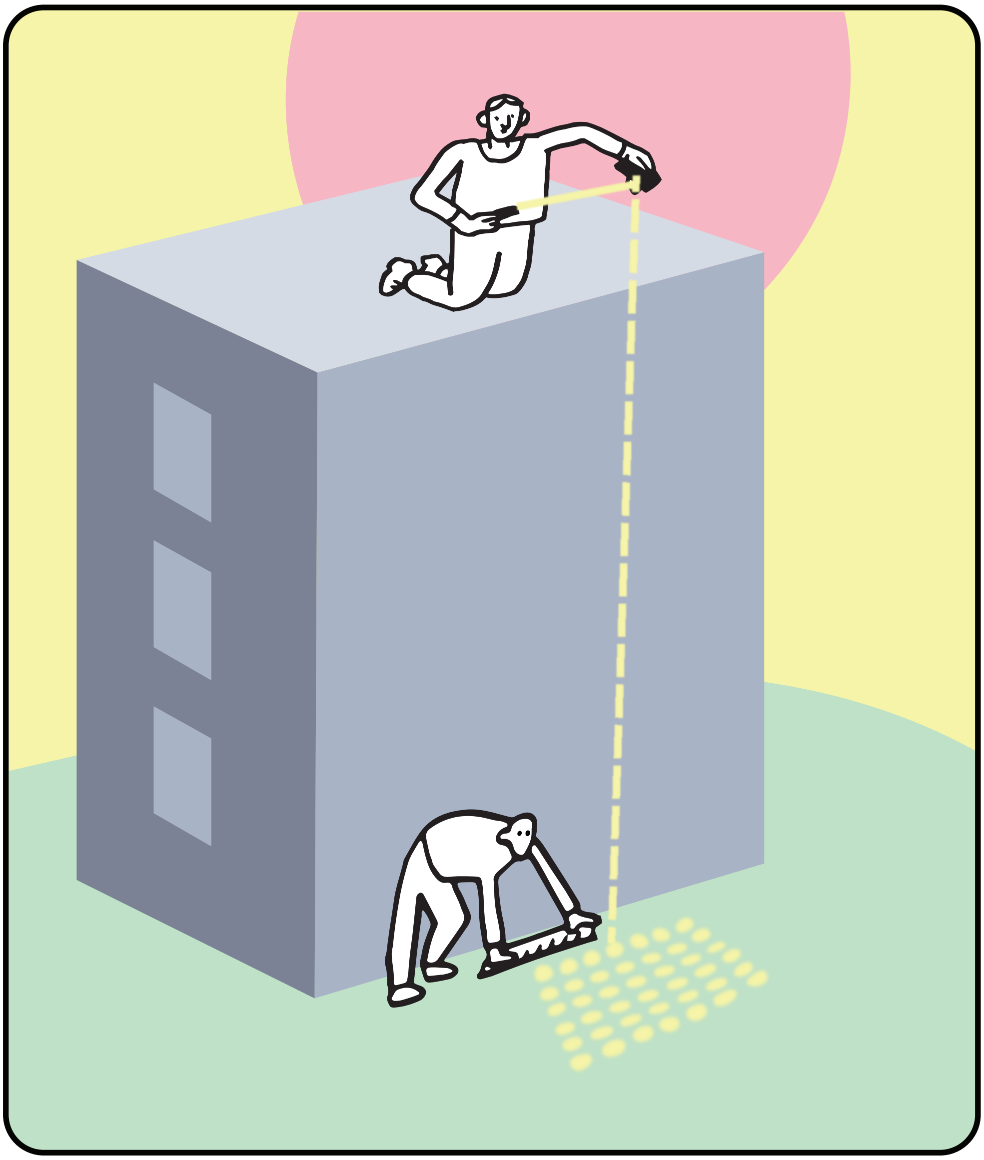
1 laser



1 ruler



1 smartphone



From the top of the building, illuminate the smartphone screen with the laser and project the diffraction pattern on the ground. Measure the characteristic distance of the pattern. Determine the size of the pixels by comparing their number and the size of the screen. (Some screens diffract better than others.)

l = distance between the diffraction spots, p = size of a pixel,
λ = wavelenght of the laser

Warning: handling a laser is dangerous.

Precision: awfully bad

Difficulty: low

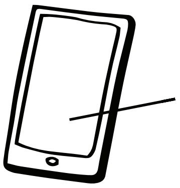
№57. Small Pendulum

Formula

$$H = \frac{T_2 - T_1}{2\pi}\sqrt{\frac{GM}{l}}$$

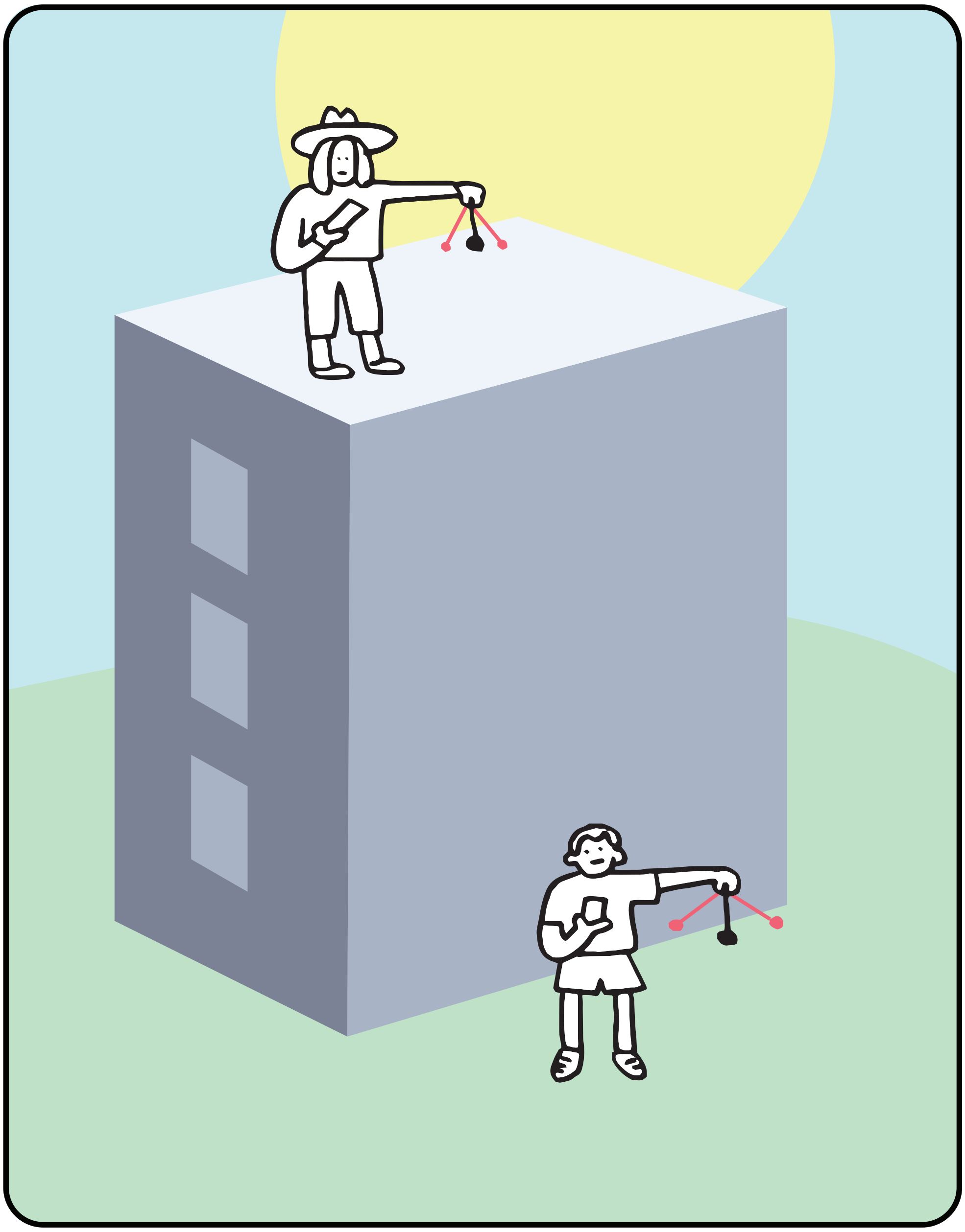
Material

1 rope



1 smartphone

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



Make a pendulum with your smartphone, and measure its period when it is at the bottom then at the top of the building, using the sensor of your choice. The difference of the periods makes it possible to determine the height if the measure is sufficiently precise.

T_2 and T_1 = periods of the pendulum at the bottom and at the top,
l = length of the pendulum,
G = universal constant of gravitation, M = mass of the Earth

Precision: awfully bad

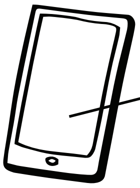
Difficulty: minimum

№58. Gravity Variation

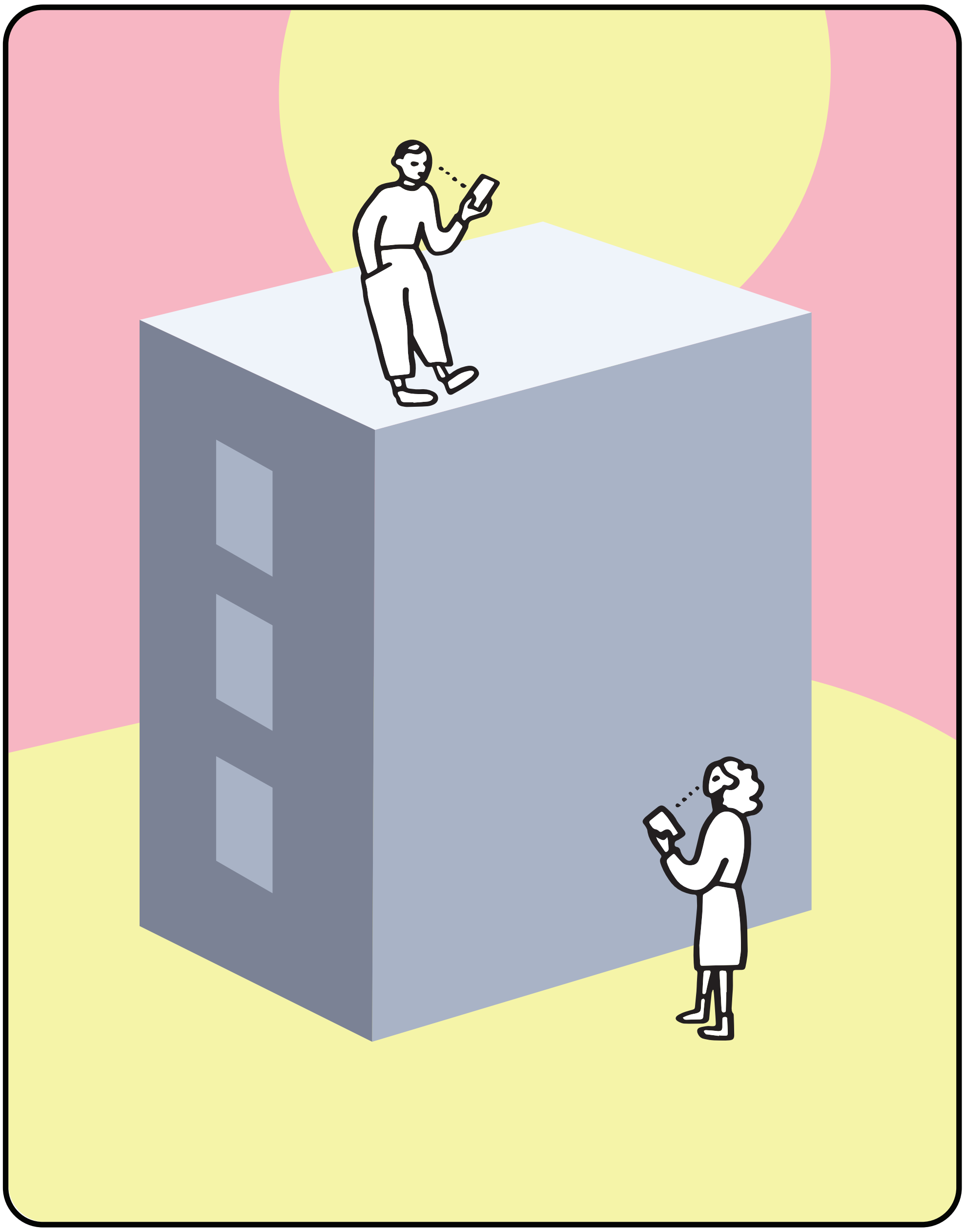
Formula

$$H=\frac{R}{2}\,\frac{g_2-g_1}{g_2}$$

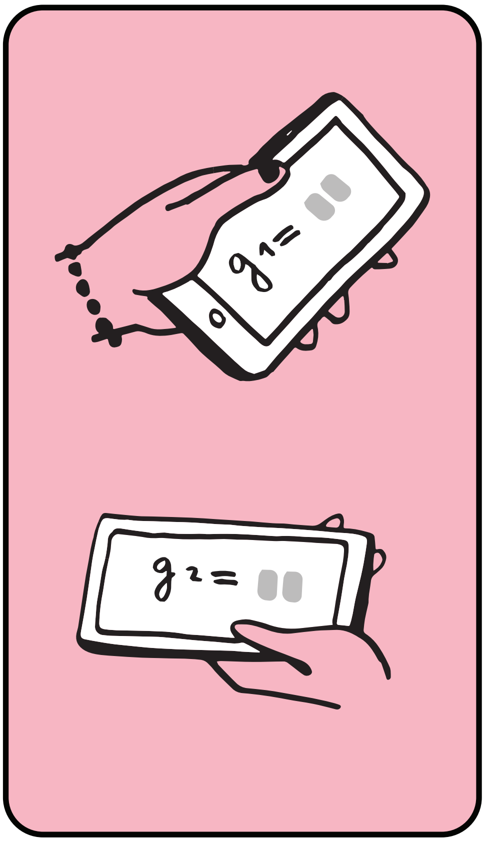
Material


Sensor: **accelerometer**

1 smartphone



Measure gravity at the top and at the bottom of the building with the accelerometer.



R = radius of the Earth, g_1 and g_2 = gravity at the top and bottom of the building

Precision: awfully bad

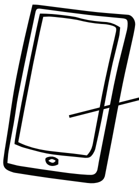
Difficulty: minimum

№59. Earth Magnetism

Formula

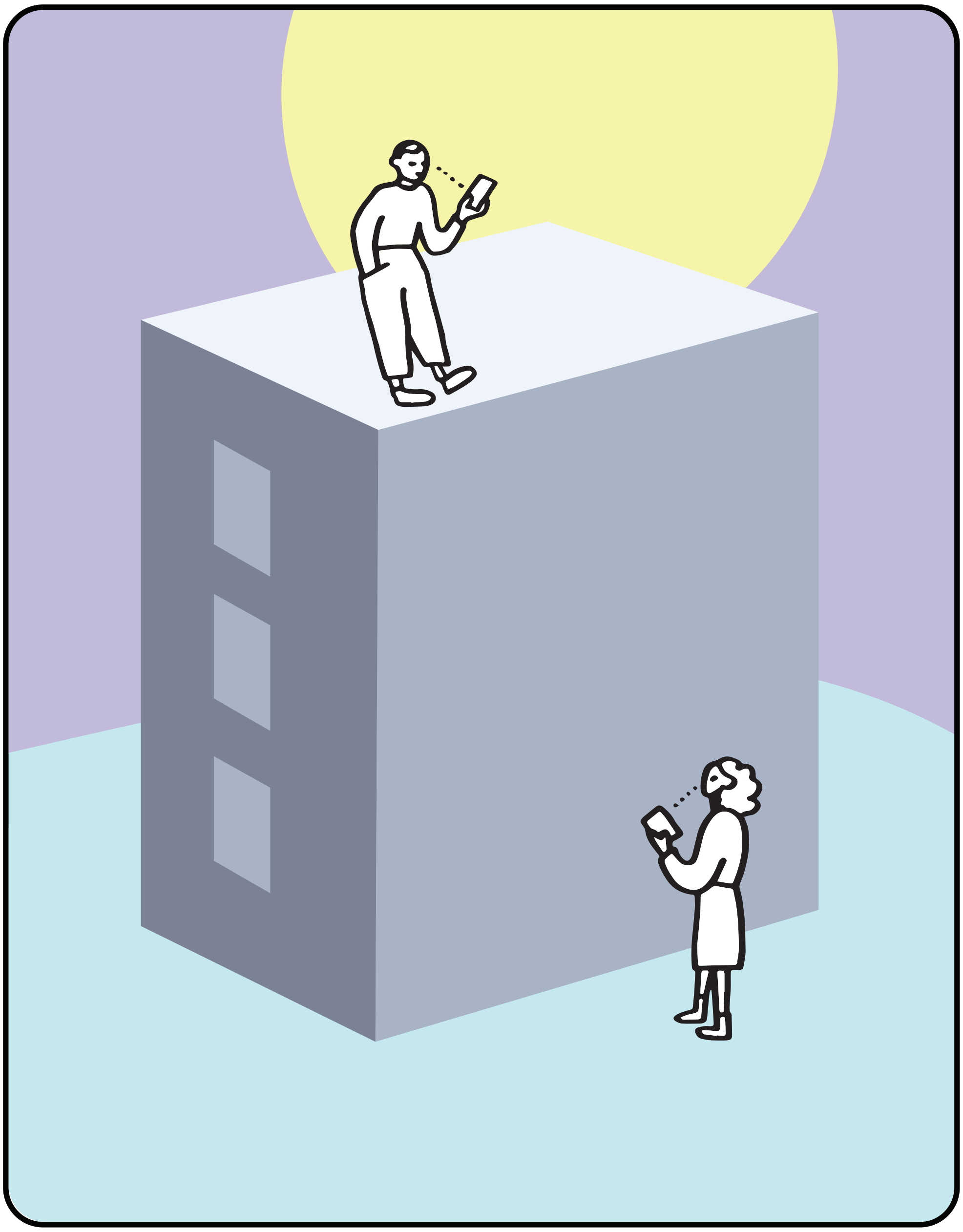
$$H = \frac{R}{3}\,\frac{B_2 - B_1}{B_2}$$

Material

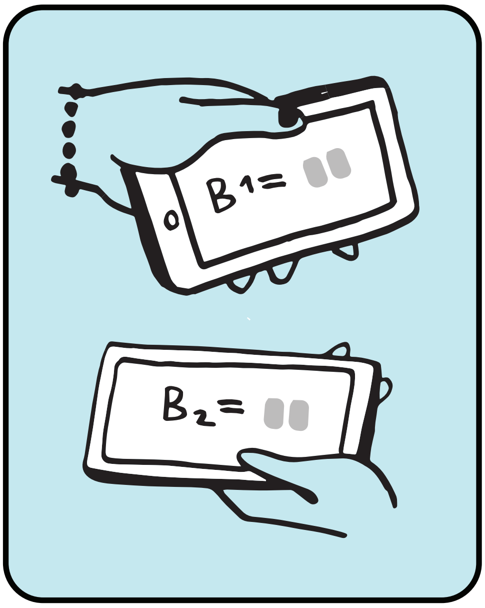


Sensor:
magnetometer

1 smartphone



Measure the magnetic field at the top and bottom of the building. Assuming that the magnetic field of the Earth is that of a dipole and that the building does not produce nor contain any magnetic field, the height can be determined.



R = Earth's radius, B_1 and B_2 = Earth's magnetic field at the bottom and top of the building.

Precision: awfully bad

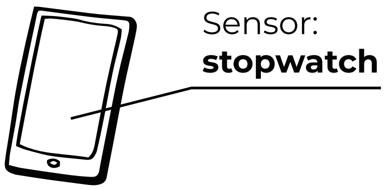
Difficulty: minimum

№60. General Relativity

Formula

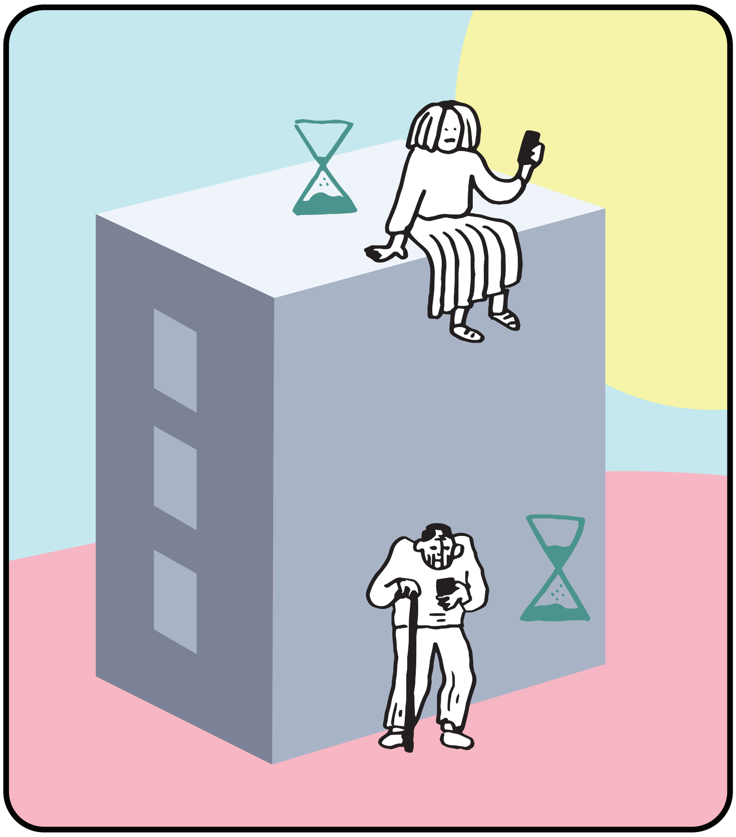
$$H = \frac{c^2}{g} \frac{\delta t}{t}$$

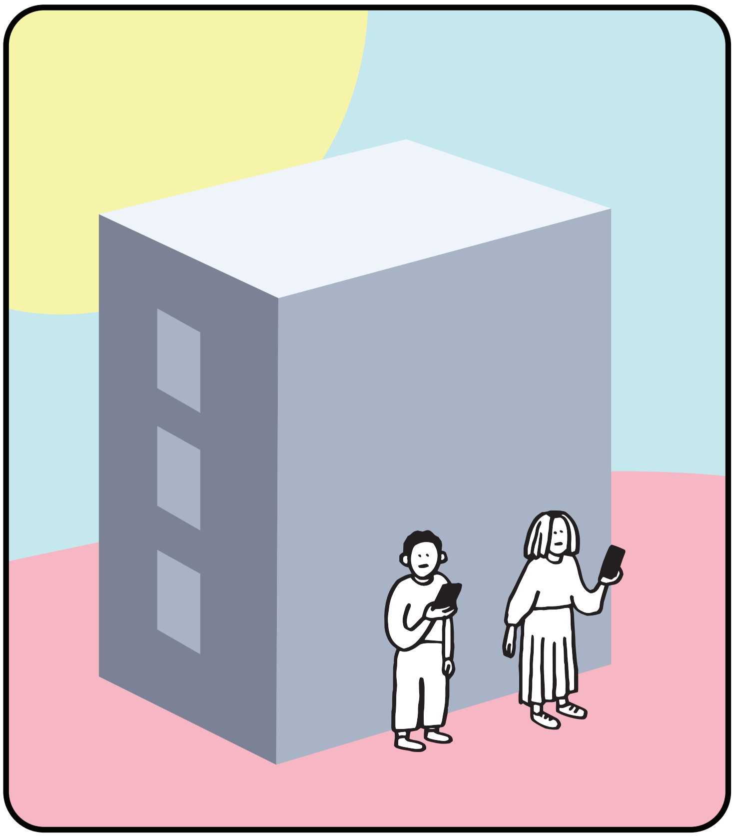
Material



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

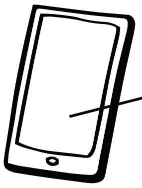
Difficulty: minimum

№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

This project is a production of «Physics Reimagined» from Paris-Saclay University and CNRS. It benefited from the support of the IDEX Paris-Saclay and of the «Physique Autrement» Chair, held by the Paris-Sud Foundation and supported by the Air Liquide Group.