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Viscardi Gymnasium

E L E C T R I C I T Y

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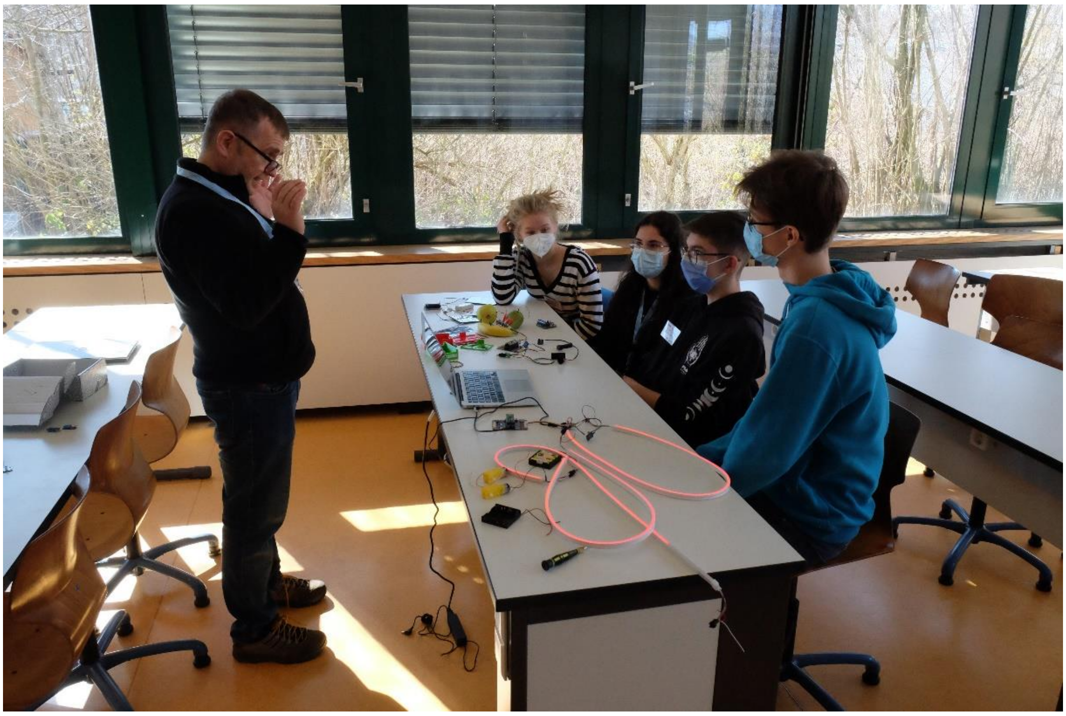
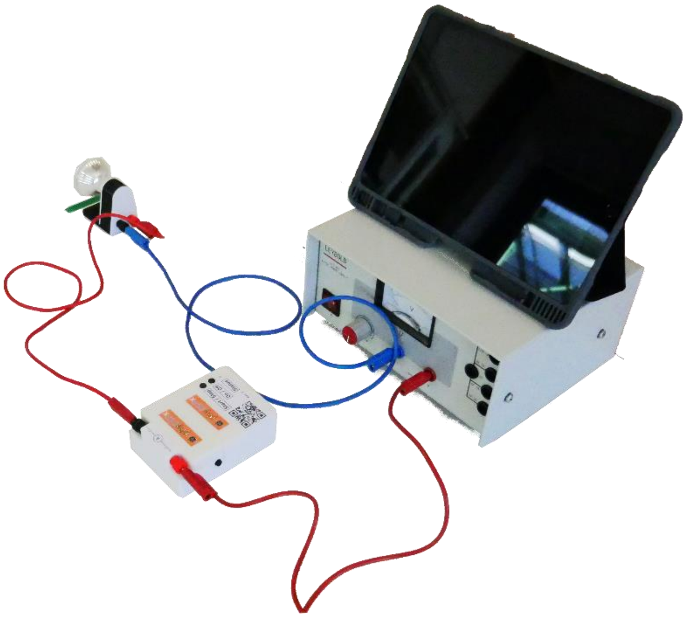


Topic	Age	Country	Date
Comparison of the efficiency of halogen and LED lights (using phyESPx)	>14	Germany	Mar 2022

Halogen vs. LED



Experimental setup materials:

1 Lab power supply

1 Halogen light bulb } equal beam angles

1 LED light bulb } (+ fitting socket)

2 PhyESPx server units

1 PhyEXPx illuminance sensor

1 PhyEXPx current sensor

1 iPad

Some banana wires to connect everything

Experimental setup and procedure:

Attach the **current sensor** to one of the **server**s and connect it to the power supply and the LED bulb **according to the circuit diagram.** Snap the **luminance hat** on the remaining **server unit**, and place it **directly in front of the LED** at around 0.5m distance (the sensor must point **directly towards the light source**). **Power up** the PhyESPx servers, **open** the web interface and put a cardboard box over the lamp and the sensor (in order to avoid light from other sources from being detected by the sensor). **Turn on the PSU** and **start the experiment** using the play button. Crank up the output voltage to **12 Volts** and note down the flowing current and the measured intensity.

Repeat the whole process with the **halogen bulb. Make sure** to keep the **distance** between the lamp and the illuminance sensor **remains the same**.

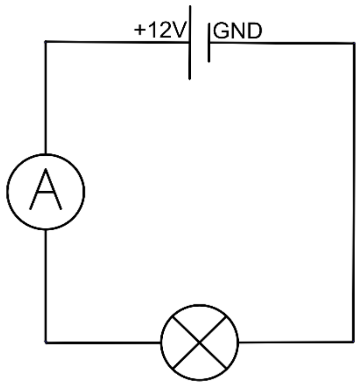
Experiment evaluation:

1) Try to find out which of the lights is more efficient!

2) Calculate by how much the LED is more efficient than the halogen lamp.

3) Verify your results with the help of the internet

Circuit diagram:



Useful formula:

$$P_{EL} = U \times I$$

$$E_v = \frac{\Phi_v}{A}$$

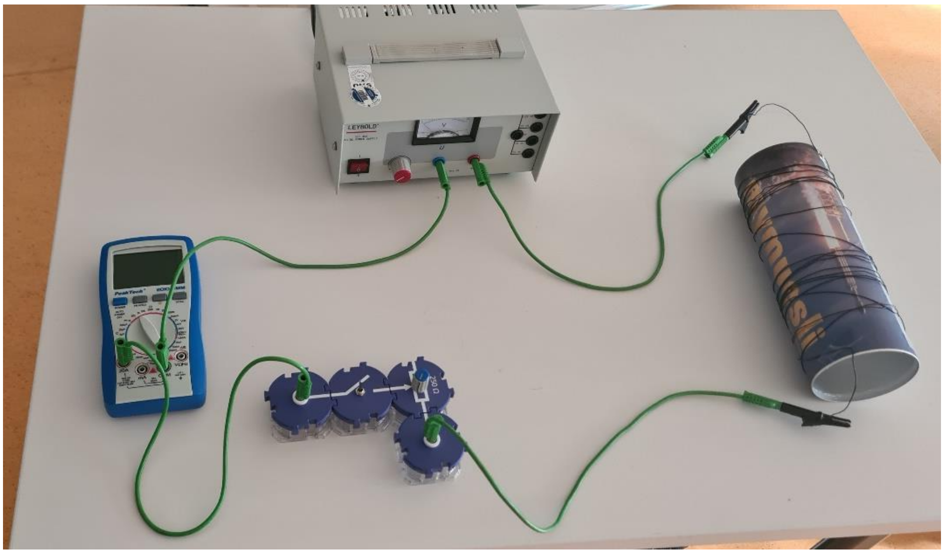
Experiment results:

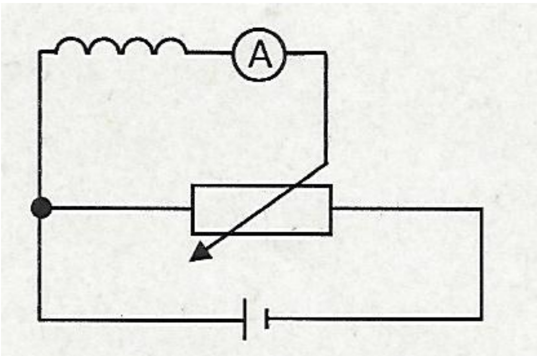
	LED BULB	HALOGEN BULB
CURRENT (IN AMPS)		
VOLTAGE (IN VOLTS)		
POWER (IN WATTS)		
ILLUMINANCE (IN LUX)		
EFFICIENCY (IN LUX PER WATT)		

Evaluation:

Topic	Age	Country	Date
Magnetic field coil	>14	Germany	Mar 2022

- Power Supply (0 - 5V)
- Cylindrical box (e.g. for crisps)
- Ampmeter (0 – 3A)
- Flexible resistance (250 Ohm)
- 2 banana plugs
- Flex (A= 0,14mm²; length 2 m)
- Cables



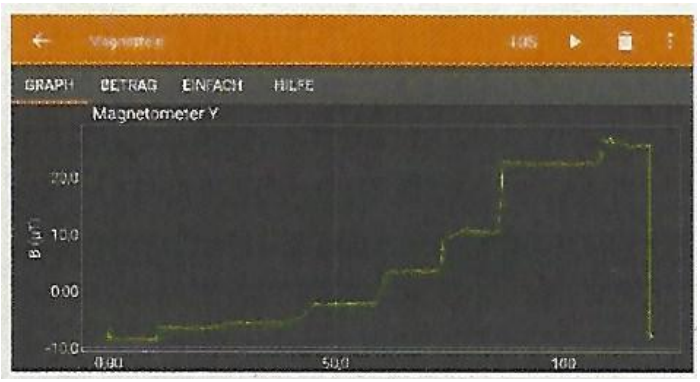


1. The bottom and the top of the box have to be removed. Then you can regularly wrap the cable around the box and fix it at the end (by holes or with a tape).
2. Choose the function “Magnetometer” from “Phyphox”. It is advisable to use the possibility of a timed run (fix start delay and duration – e.g. 120s). Even better is to allow the remote access and to use another smartphone or a tablet PC.

A) <u>Variation of current</u>

After the start of the measure you choose 0 mA for the first 15s to get the value of the magnetic field of the earth in y-direction. Then you can increase the electric current in steps of e.g. 500mA each 15 s.

Perhaps you have to deactivate the recalibration of magnetic sensor and calculate the real values.



I (A)						
B(µT)						

B) <u>Variation of length</u>

Now you can cut the cable in half and keep the current at a fixed value.

C) <u>Conclusion</u>

Topic	Age	Country	Date
Study of RC circuit	>14	Italy	March 2021

Study of RC circuit

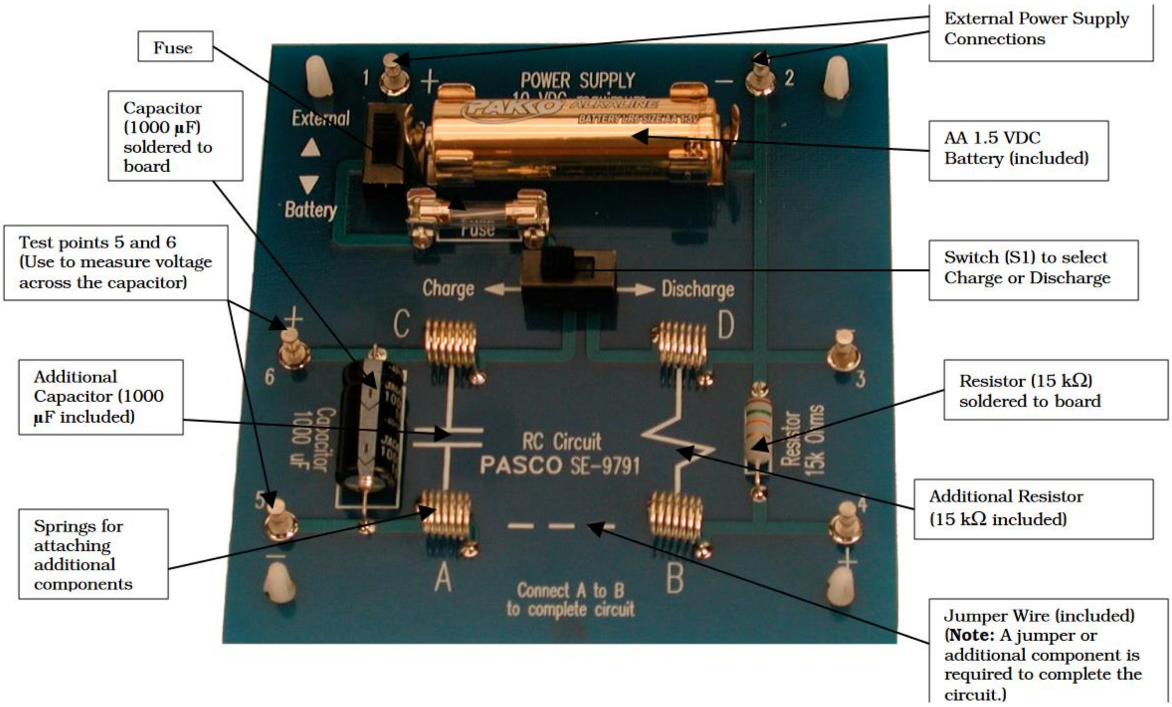
Experimental setup materials:

1 smartphone with SPARKvue APP

1 RC circuit

1 voltmeter

1 Chronometer



Experimental setup and procedure:

When a capacitor is placed in series with a battery and a resistor, the capacitor charges up to the voltage of the battery.

This kind of circuit is called a RC Circuit because the only two components besides a power supply are a resistor and a capacitor.

The resistor limits the electrical current so that the charging takes place over an extended time.

This allows students time to think about what must be happening as the circuit charges up to the applied voltage of the battery. After the simple voltage-time data for the charging is collected, fundamental electrical quantities of charge, current, and capacitance can be calculated via a spreadsheet.

At the end of the experiment, you will be able to understand how the charge, voltage, and current change as the capacitor charges

How long does it take for the capacitor to charge?

The charging time depends on the capacitance and resistance values of the capacitor.

RC product is called time constant.

When a fully charged capacitor discharges through a resistor, the amount of charge which flows in the first instant is large. However, as more and more charge is transferred, coulombic repulsion starts to slow down the flow.

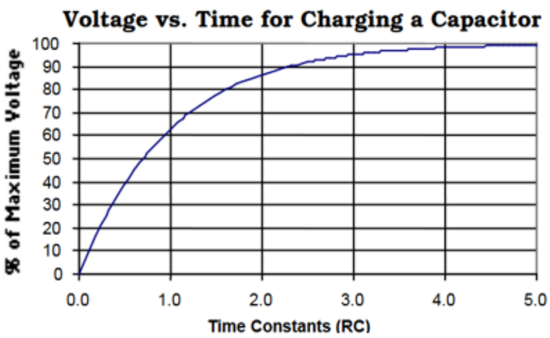
Finally, when the capacitor is fully discharged, each plate of the capacitor is electrically neutral.

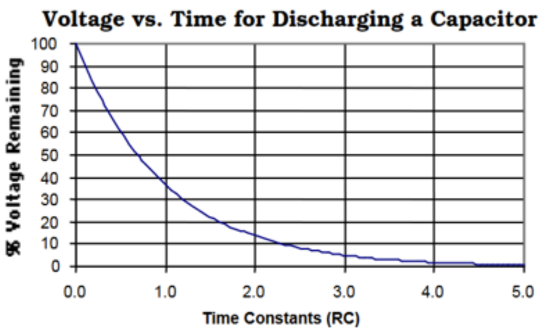
The shape of the graph for this discharge is a classical definition for exponential decay.

The time constant for exponential growth or decay, (the Greek letter tau), is the time in seconds for the capacitor to charge or discharge to a certain percent of its final voltage.

For the charging cycle, when the voltage across the capacitor gets to 63.2 % of its maximum value, one time constant, t seconds, has passed.

For the discharge cycle, when the voltage across the capacitor gets to 36.8 % of its starting maximum value, one time constant, t seconds, has passed.



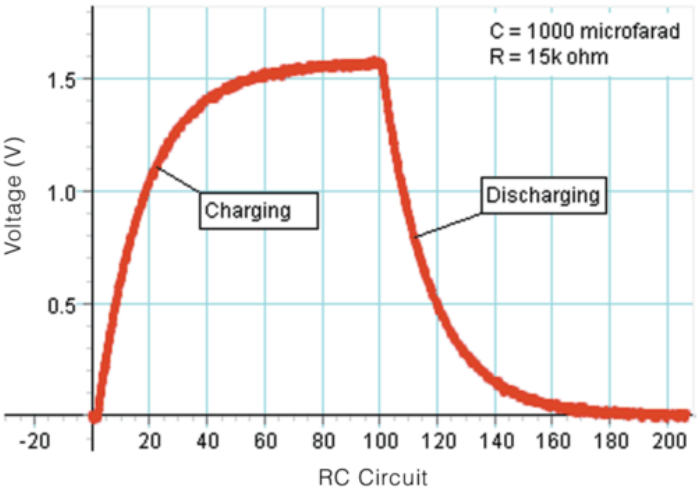


Experiment evaluation:

1) build an RC circuit,

2) find the time constant,

3) Build the charge and discharge curve by recording voltage value every 5 s with MS-EXCEL



Topic: Electricity Electric conductivity- Keyboard of fruits and vegetables	Age >12	Country Poland	Date March 2022

Function, realisation

This project will allow students to understand the phenomenon of electrical conductivity in an attractive way. It is also an opportunity to understand how a conditional statement "IF" works in Python. Conductive material responds when contacted by another electrical conductor, like finger. Students will experimentally confirm that vegetables and fruits, and even the human finger, are electrical conductors. They can also come to the conclusion that the reason for the good operation of the created keyboard is a high water content in fruits and vegetables. They can also replace vegetables with, for example, aluminum foil packaging. Students will learn that the same phenomenon is used in touch screens

Hardware required

- Microcontroller Raspberry Pi Pico with Micropython 1.18 or above
- Cytron Maker Pico docking station for Pico (or different docking station for Pico: Waveshare, Seeedstudio)
- Grove - 12 Key Capacitive I2C Touch Sensor V3(MPR121) from Seeedstudio
- PC or Mac computer

Materials required

- 12 Key Capacitive I2C Touch Sensor V3 (MPR121) from Seeedstudio

- 1xGrove wire for connection between MPR121 sensor and Raspberry Pi Pico
- Crocodile --> male DuPont wire (maximum 12)
- up to 12 fruits, wegetables
- micro usb 2.0 high speed (15cm or 30 cm)
- paper for note

Software required

-Thonny App (thonny.org)

-library: https://github.com/mcauser/micropython-mpr121/blob/master/mpr121.py

Setup Hardware

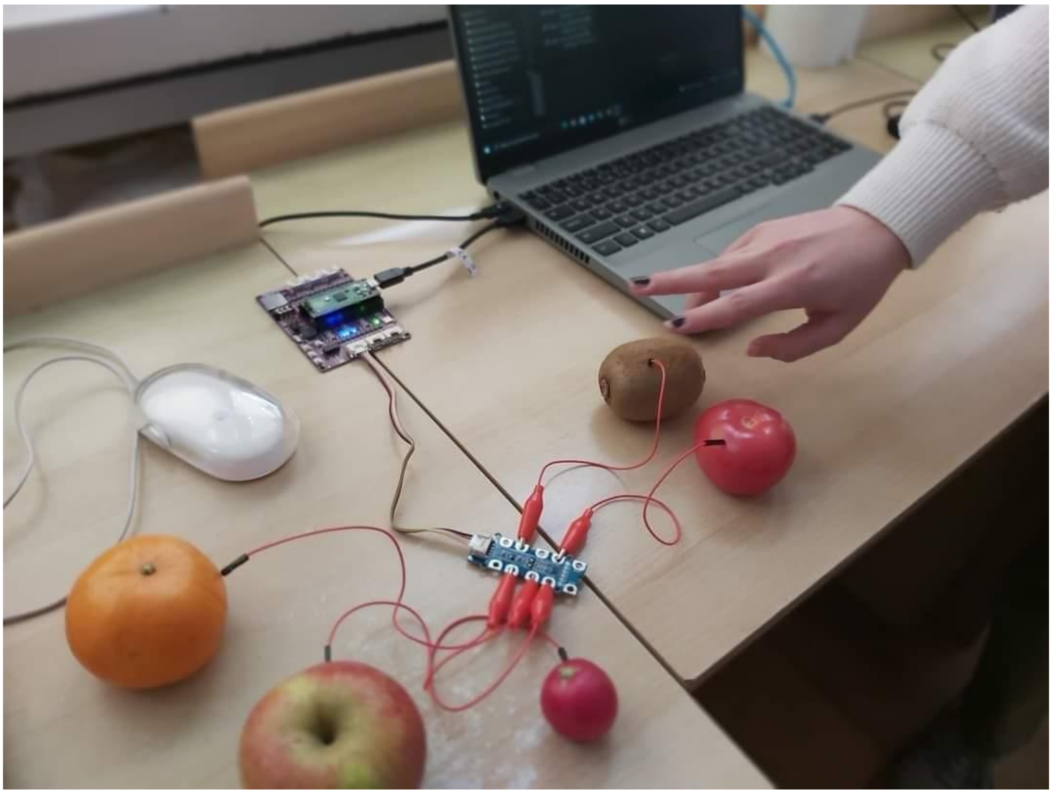
Connect MPR121 sensor with socket GP6, GP7 on docking station for Raspberry Pi Pico using standard Grove Wire.

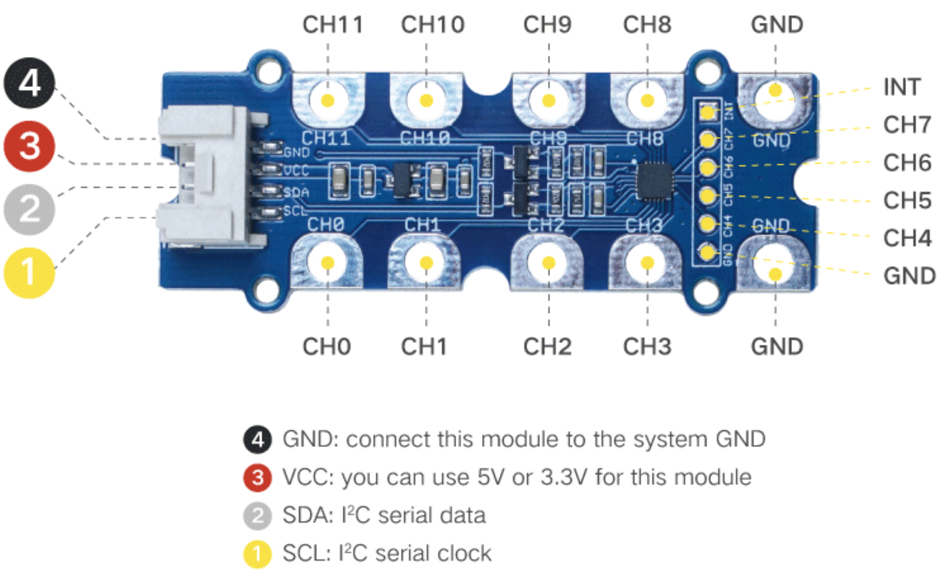
Detailed information about this connection

MPR121 Grove socket	Raspberry Pi Pico pins	Grove wire
SCL	GP7	yellow
SDA	GP6	white
VCC	3V3	red
GND	GND	black

Connections between fruits, vegetables and MPR121 sensor is very easy.

Use crocodile wires like on the photo below (Ch0-Ch11 pads)





Setup software

Library for MPR121 must be saved inside folder "lib" on Raspberry Pi Pico.

We must modify the script according to connection made and to the name of fruits/ wegetables.

```
import mpr121
from machine import Pin, I2C
import utime
i2c = I2C(1,scl=Pin(7), sda=Pin(6), freq=400000)
utime.sleep_ms(100)
#It is worth checking if your sensor also has the address 0x5B
mpr = mpr121.MPR121(i2c,0x5B)
# check keys one by one
while True:

    if mpr.is_touched(0):
            print("banana")
    if mpr.is_touched(1):
            print("mango")
    if mpr.is_touched(2):
            print("kiwi")
    if mpr.is_touched(3):
            print("orange")
    if mpr.is_touched(8):
            print("beetroot")
    if mpr.is_touched(9):
            print("apple")
    if mpr.is_touched(10):
            print("potato")
    if mpr.is_touched(11):
            print("pear")

    utime.sleep_ms(100)
```

MPR121 sensor- main features

- I2C interfaceHardware configurable I2C address

- 12 electrodes/capacitance sensing inputs in which 8 are multifunctional for LED driving and GPIO

Applications

- PC Peripherals
- MP3 Players
- Remote Controls
- Lighting Controls

Experiment testing, evaluation and application ideas.
Go further.

- comparison of the operation of the keyboard depending on the percentage of water in the fruit
- Replacing fruit with aluminum foil packaging
- building a system that generates different sounds depending on the choice of fruit
- Multiple **Grove - 12 Key Capacitive I2C Touch Sensor V3 (MPR121)** to be used together for channel expansions in a single system, you can build a touch system that contains max. 36 electrodes.

Topic: Electricity Skin resistance measurement-GSR	Age >14	Country Poland	Date March 2022

Function, realisation

Grove - GSR Sensor stands for galvanic skin response and it is a method of measuring the electrical conductance of the skin. It can be used to reflect human emotional activity. When we are emotionally stressed or have strong expressions on the face, sympathetic activity increases and promotes the secretion of sweat glands, which increases the skin's electrical conductivity.

Grove - GSR allows you to spot such strong emotions by simply attaching two electrodes to two fingers on one hand. It is an interesting gear to create emotion related projects like sleep quality monitor. In some galvanic skin response devices such as lie detectors, this scientific principle is also applied.

In the experiment, we inserted our fingers from the same hand into the two electrode fingertips of the sensor

Hardware required

- Microcontroller Raspberry Pi Pico with Micropython 1.18 or above

- Cytron Maker Pico docking station for Pico (or different docking station for Pico: Waveshare, Seeedstudio)
- PC or Mac computer

Materials required

- Grove male wire
- micro usb 2.0 high speed (15cm or 30 cm)

Software required

-Thonny (thonny.org)

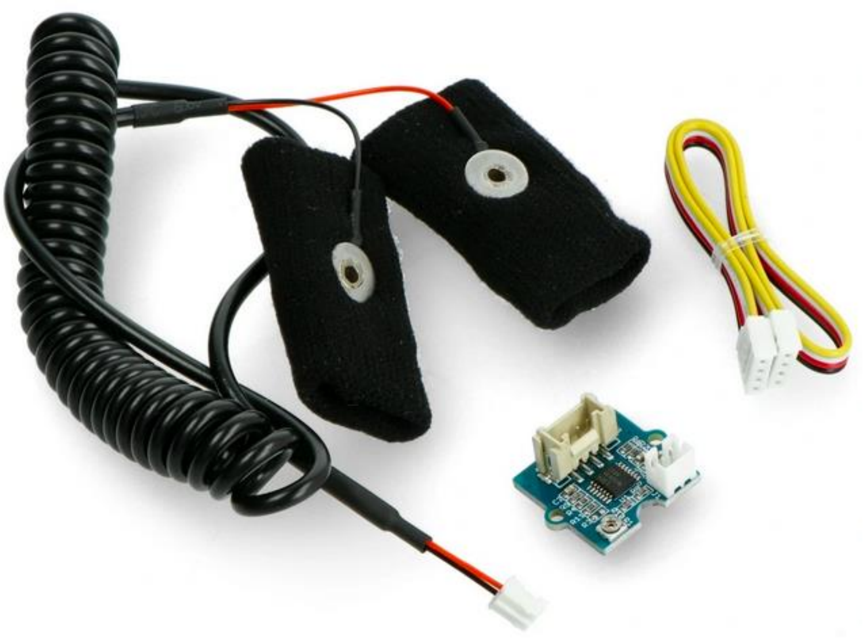
Custom micropyhon library is not required, because it is analog sensor.

We read raw data in the form of voltage on the pin

Setup Hardware

```
import utime
import machine
#GSR connected to pin28- ADC2
analog_value = machine.ADC(27)
#conversion_factor = 3.3/ 65535
while True:
    gsr_raw = analog_value.read_u16()
    print("raw:", gsr_raw)
    skin_resistance=(65535+2*gsr_raw)*10000/(32768-gsr_raw)
    print("Skin resistance", skin_resistance)
    utime.sleep(2)
```

In our Python script, we assume that the analog sensor GSR will use two signal pins: GP26, GP27



Sensor	Raspberry Pi Pico pins	Grove
analog signal	GP27	yellow
not connected	GP26	white
power (+)	3V3	red
ground (-)	GND	black

The Pico use 3.3V power (not 5!!!). Usually we connect red wire to pin 3V3 and black wire to the ground (GND)

GSR sensor can show us how person who wore electrodes feels. On the graph, on the top of the page, we can see the moment when someone takes a deep breath.

Experiment Evaluation

System testing:

-electrical conductance of the skin

-influence of changing feelings on skin resistance

Write down Your results:

....

....

....

....

....

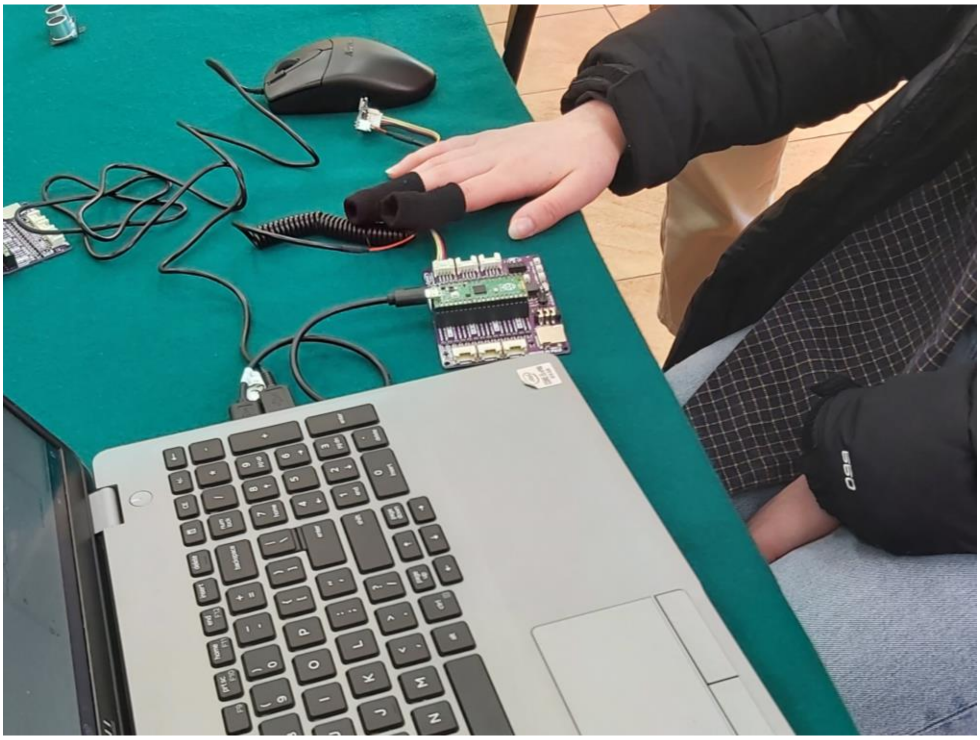
Go further

-Supplementing the code with the operation of the LCD display

-Building a mobile version (with UPS) adding results logging to the microcontroller memory

-script modification to provide results in Ohm

-logging results during a sleep, math test in classroom



-truthfulness test

Topic: Electricity Measurement electric power consumption, current measurement	Age >14	Country Poland	Date March 2022

Function, realisation

In this experiment we propose energy consumption testing using Gravity Wattmeter module with INA219 Texas with Raspberry Pi Pico. This experiment describes how to measure the energy consumption of the motor, LEDs and sensors. Measurement precision very high: 1%. INA219 is present inside many professional measuring devices.

Hardware required

- Microcontroller Raspberry Pi Pico with Micropython 1.18 or above
- Cytron Maker Pico docking station for Pico (or different docking station for Pico from Waveshare, Seeedstudio),
- Dfrobot Gravity Wattmeter module with INA219 chip (analog 3.3V for Pico, 5V for Arduino),
  - 3V3 LCD 1602 I2C display Seeedstudio with Grove socket,
  - DHT11 sensor (temperature and humidity) or different 3V3 sensor,
  - 5 led modules with different colour led (red, green, blue, yellow, white),
  - 3V DC motor or different (compatible with additional power source, e. g. 9V battery),
- PC or Mac computer

Materials required

- Grove male wire (or 3x Dupont male-male wire)
- 1 Grove standard Wire and 1 Grove-Female wire
- Dupont wires (male-female, male-male)
- micro usb 2.0 high speed (15cm, 30 cm or longer)
- paper for note
- optional 9V battery

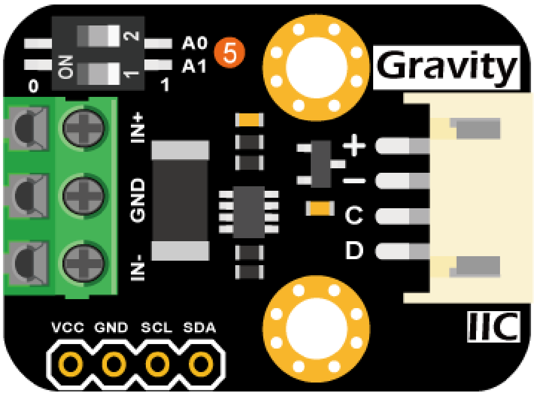
Software required

-Thonny App (thonny.org)
-library for INA219 sensor:
https://github.com/chrisb2/pyb_ina219/blob/master/ina219.py

-library for LCD1602:
https://files.seeedstudio.com/wiki/Grove_Shield_for_Pi_Pico_V1.0/Libraries.rar

Setup Hardware

The Pico uses 3.3V power (not 5!!!). Usually we connect red wire to pin 3V3 and black wire to the ground (GND)



Specification of Gravity Wattmeter module with INA21

- Version: 2.0
- Supply voltage: from 3.3 V to 5 V
- Voltage measurement range: 0 V to 26 V
- Resolution voltage: 4 mV
- Error of voltage measurement: up to 0,2% (typical)
- Measuring range of the current: from 0 to 8 A (bi-directional)
- Resolution of the current: 1 mA
- Error of current measurement: up to 2% (typical, it requires manual calibration)
- The range of power measurement: from 0 to 206 W
- Resolution power: 20 mW (hardware) / 4 MW (software)
- Quiescent current: 07 mA
- Interface: I2C Gravity
- I2C address: 0x40, 0x41, 0x44, 0x45
- Dimensions: 30 x 22 mm

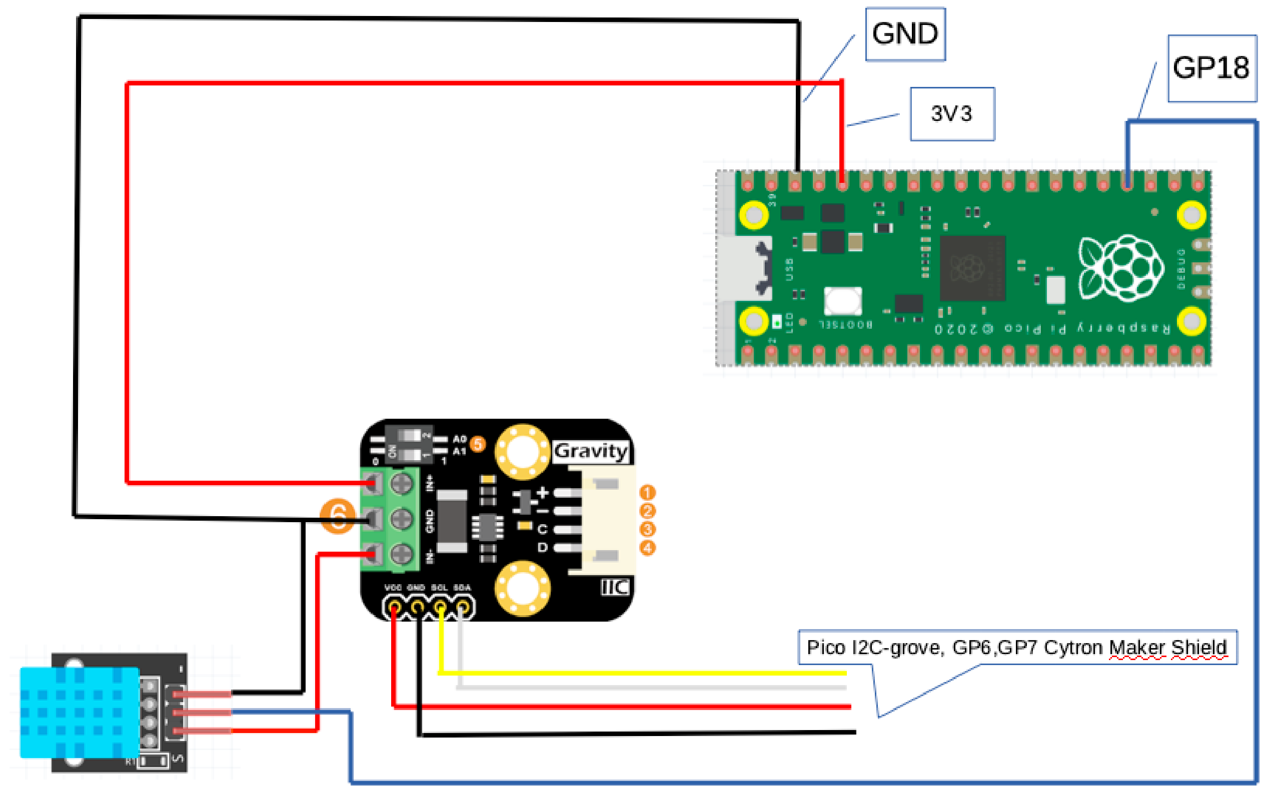
Power Pins

The sensor on the breakout requires between a 2.7V and 5.5V, and can be easily used with most microcontrollers

- **Vin+** is the positive input pin.
Connect to supply for high side current sensing or to load ground for low side sensing.
- **Vin-** is the negative input pin. Connect to load for high side current sensing or to board ground for low side sensing

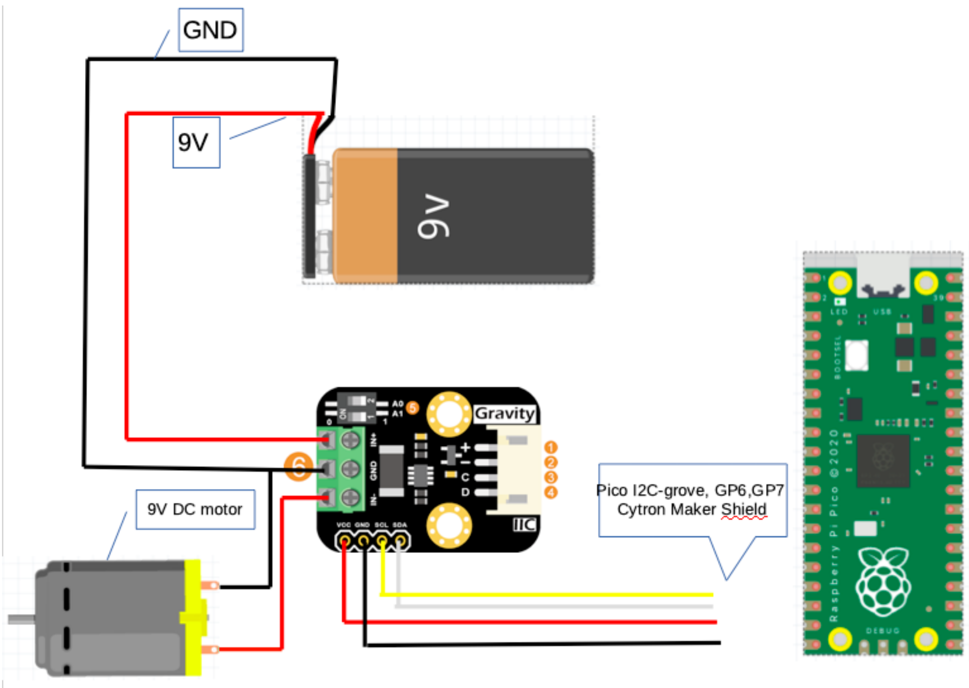
GND - This is common ground for power and logic.

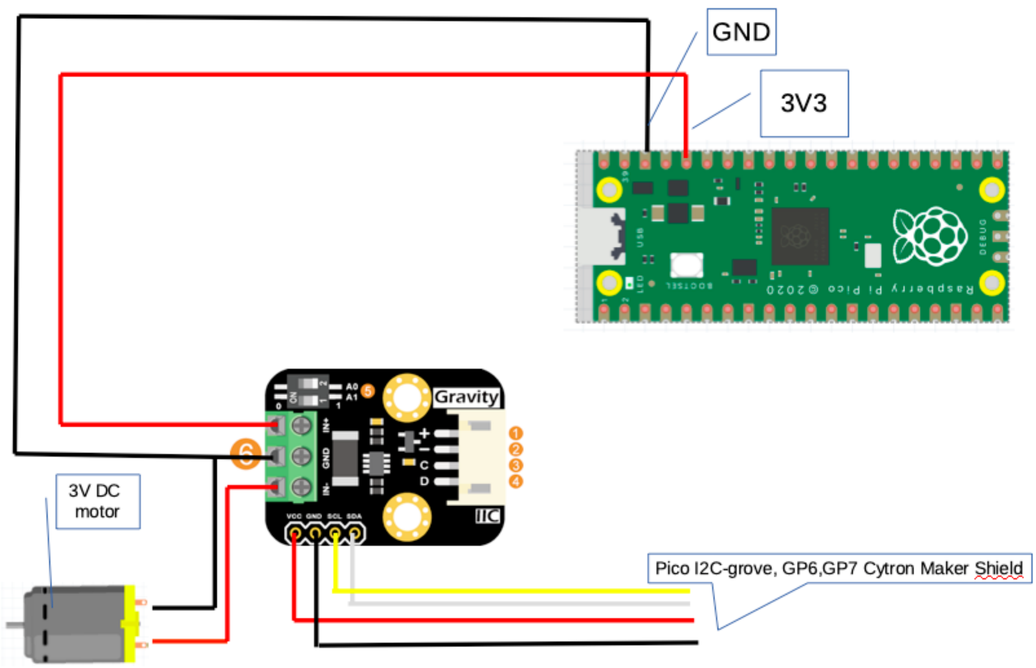
This script requires an LCD screen with GROVE socket which is really



easy to connect.

A0 and **A1 solder jumpers** -You can use it, if you want change the I2C address (in the case of many Wattmeters used at the same I2C bus).



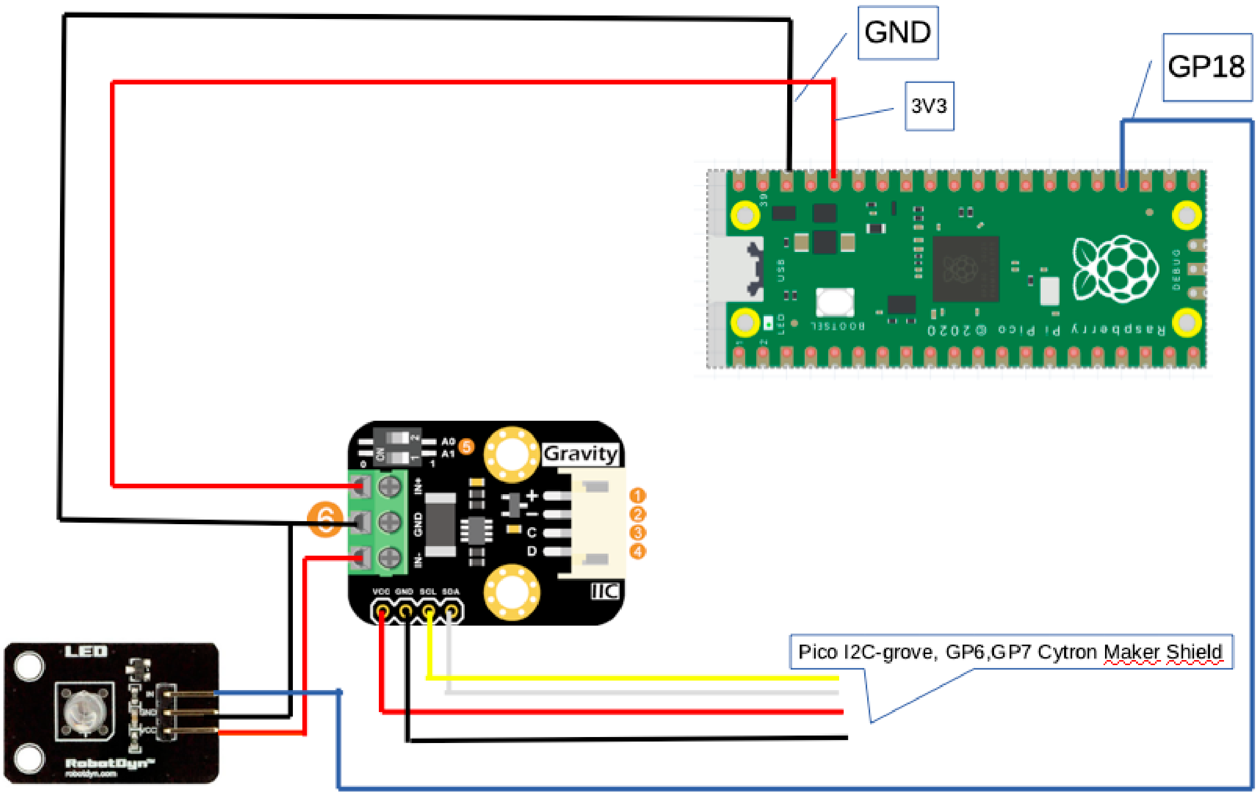


LCD 1602 pins	Raspberry Pi Pico pins	Grove wire
GND	GND	black
VCC	3V3	red

SDA	GP8	white
SCL	GP9	yellow

Wattmeter-Pins

- **Vin+** is the positive input pin. Connect to supply for high side current sensing or to load ground for low side sensing.
- **Vin-** is the negative input pin. Connect to load for high side current sensing or to board ground for low side sensing
- according to the list below.



Setup software

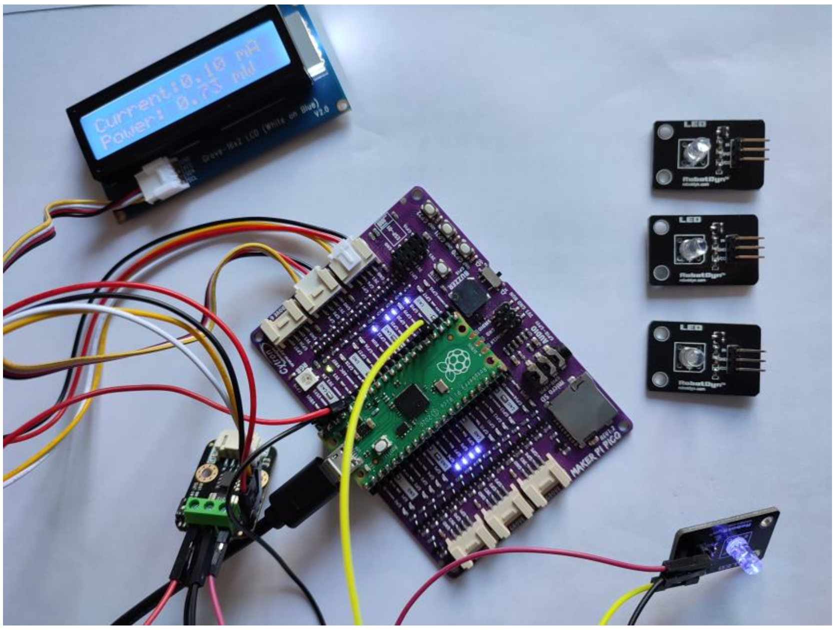
Libraries installation

In Thonny Application we can open Python file with library downloaded from github: and save in the lib folder on the Pico

```python
from lcd1602 import LCD1602
from machine import Pin, I2C
from ina219 import INA219
from logging import INFO
from utime import sleep
from dht11 import DHT
LEDtest = machine.Pin(15,machine.Pin.OUT)
LED = machine.Pin(25,machine.Pin.OUT)
LED.value(0)
LEDtest.value(1)
SHUNT_OHMS = 0.1
i2cbis = I2C(0, scl=Pin(9), sda=Pin(8), freq=400_000)
i2c = I2C(1,scl=Pin(7), sda=Pin(6), freq=400000)

d = LCD1602(i2cbis, 2, 16)
d.display()

dht = DHT(18)

ina = INA219(SHUNT_OHMS, i2c, log_level=INFO)
ina.configure()

for i in range(60):
    LED.value(1)
```

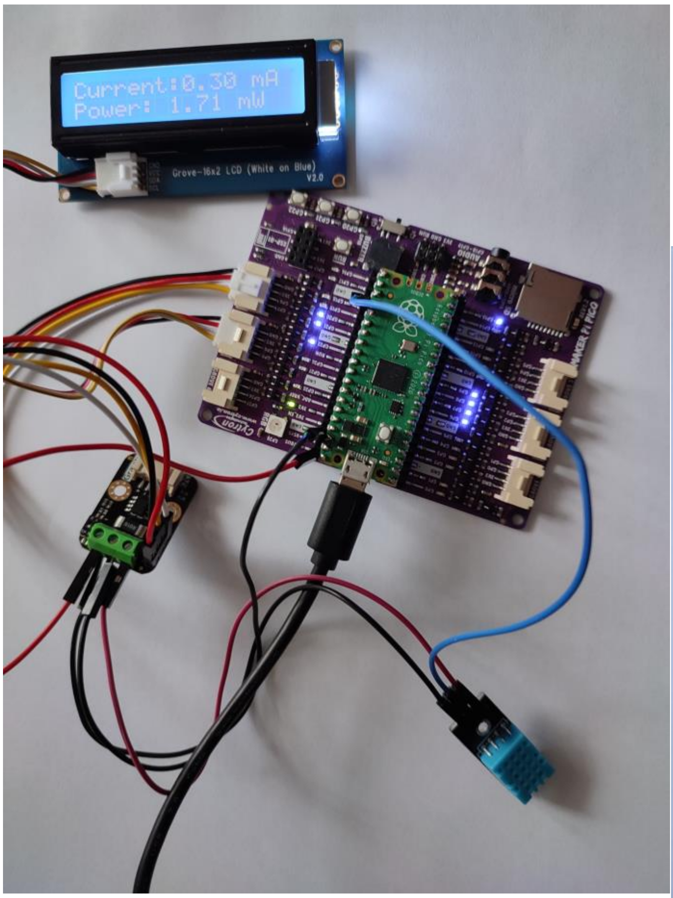
```
    sleep(1)
    d.clear()
    LED.value(0)
    d.setCursor(0,0)
    #print("Bus Voltage: %.2f V" % ina.voltage())
    #d.print("B:%.3f V" % ina.voltage())
    #d.setCursor(8,0)
    print("Current: %.3f mA" % ina.current())
    temp,humid = dht.readTempHumid()
    d.print("Current:%.2f mA" % ina.current())
    print("Power: %.3f mW" % ina.power())
    d.setCursor(0,1)
    d.print("Power: %.2f mW" % ina.power())
    sleep(1)
```

Demonstration of the system operation:

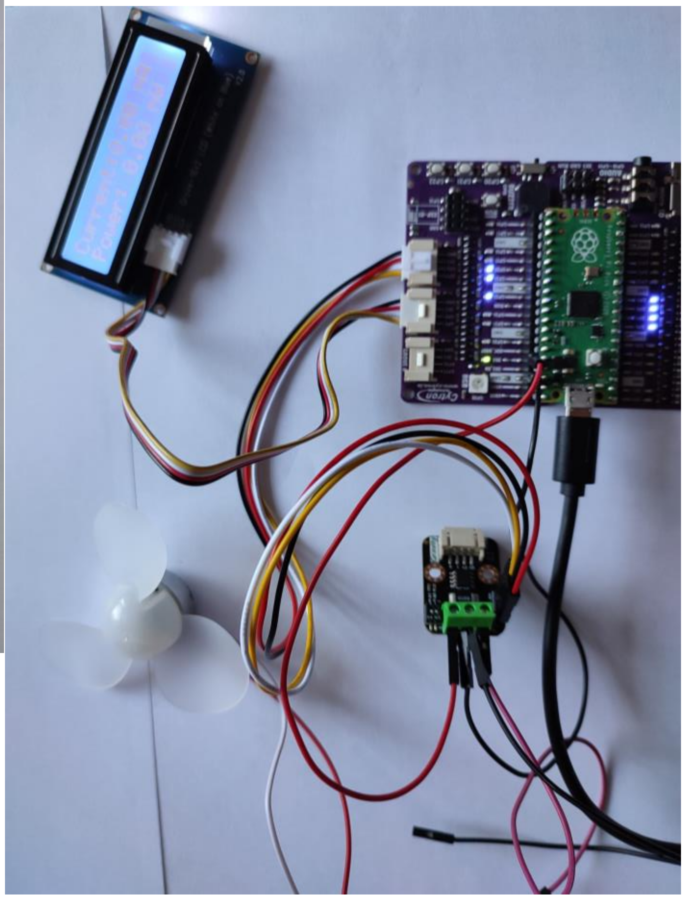


Testing power led's consumption depend of the colour

Testing DHT11 power consumption and DC motor power consumption:



Experiment testing, evaluation and application ideas:



System testing:

- measurement the power consumptions of various sensors connected to microcontroller,
- measurement power consumptions by leds depending of the colour of the led (the same size of the led from the same manufacturer),
- measurement the power consumption of DC motors,
- measurement power generated by mini solar panels,
- measure discharge of battery,
- find dependencies between power consumption of DC motor under the weight and the mass,

-change the Python script to plot graph based on results (using internal ploter from Thonny App).

The code for testing Led's power consumption:

```python
from lcd1602 import LCD1602
from machine import Pin, I2C
from ina219 import INA219
from logging import INFO
from utime import sleep
#external LED
LED_EX = machine.Pin(18,machine.Pin.OUT)
LED_EX.value(0)
SHUNT_OHMS = 0.1
#I2C bus intialisation
i2cbis = I2C(0, scl=Pin(9), sda=Pin(8), freq=400_000)
i2c = I2C(1,scl=Pin(7), sda=Pin(6), freq=400000)
d = LCD1602(i2cbis, 2, 16)
d.display()

ina = INA219(SHUNT_OHMS, i2c, log_level=INFO)
ina.configure()

for i in range(60):
    d.clear()
    LED_EX.value(1)
    d.setCursor(0,0)
    print("Current: %.3f mA" % ina.current())
    d.print("Current:%.2f mA" % ina.current())
    print("Power: %.3f mW" % ina.power())
    print("Bus Voltage: %.2f V" % ina.voltage())
    d.setCursor(0,1)
    d.print("Power: %.2f mW" % ina.power())
    sleep(2)
```

Write down your results

Sensor/led/motor	power consumption	min	max
red led			
green led			
blue led			
yellow led			
white led			
DC motor 3V			
DHT11			
DC motor under mass			

Co-funded by the Erasmus+ Programme of the European Union

Topic	Age	Country	Date
Earth magnetic field	≥14	Portugal	March 2022

Earth magnetic field - Basic information

(from https://ngdc.noaa.gov/geomag/declination.shtml)

The Earth acts like a large spherical magnet: it is surrounded by a magnetic field that changes with time and location. The field is generated by a dipole magnet (i.e., a straight magnet with a north and south pole) located at the centre of the Earth.

The axis of the dipole is offset from the axis of the Earth's rotation by approximately 9 degrees. This means that the north and south geographic poles and the north and south magnetic poles are not located in the same place.

At any point and time, the Earth's magnetic field is characterized by a direction and intensity which can be measured.

Often the parameters measured are the magnetic declination, D, the horizontal intensity, H, and the vertical intensity, Z. From these elements, all other parameters of the magnetic field can be calculated.

The Earth's magnetic field intensity is roughly between 25 – 65 μT

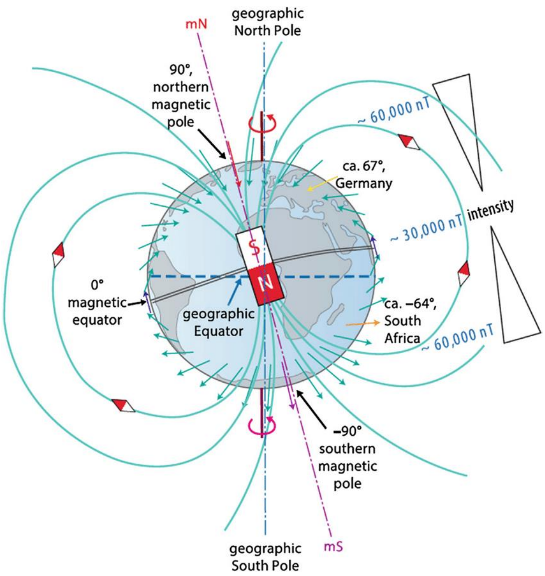
Magnetic declination is the angle between magnetic north and true north. D is considered positive when the angle measured is east of true north and negative when west.

Magnetic inclination is the angle between the horizontal plane and the total field vector, measured positive into Earth.

The magnetic field is different in different places. In fact, the magnetic field changes with both location and time

The magnetic poles are defined as the area where declination is vertical. Based on the NOAA models, the geomagnetic north pole is at 72.68°W longitude and 80.65°N latitude. The axis of the dipole is currently inclined at 9.41° to the Earth's rotation axis.

The Earth's magnetic field is slowly changing and appears to have been changing throughout its existence.



Does the compass needle point toward the magnetic pole?

No. *The compass points in the directions of the horizontal component of the magnetic field* where the compass is located, and not to any single point.

What influences the magnetic field measured by my compass?

The Earth's magnetic field is actually a composite of several magnetic fields generated by a variety of sources. These fields are superimposed on each other and through inductive processes interact with each other. The most important of these geomagnetic sources are:

a. the Earth's conducting, fluid outer core (~90%)

b. magnetized rocks in Earth's crust

c. fields generated outside Earth by electric currents flowing in the ionosphere and magnetosphere

d. electric currents flowing in the Earth's crust (usually induced by varying external magnetic fields)

e. ocean current effects

Determination of the $\vec{B}_{earth}$

Horizontal direction off the field.

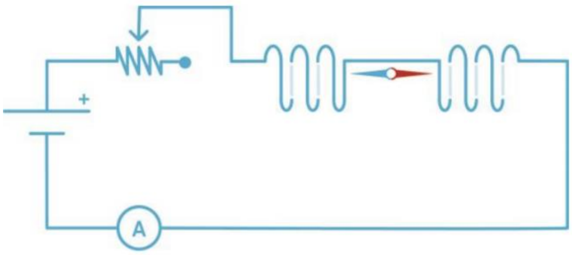
Fix a paper sheet in a plane surface, like a table, use a compass to get the horizontal direction of the field. Certify that the measurement is done far from other magnetic fields or ferromagnetic materials and in a horizontal surface.

Trace the horizontal direction of the magnetic field component off the field in the paper.

Horizontal magnitude off the field

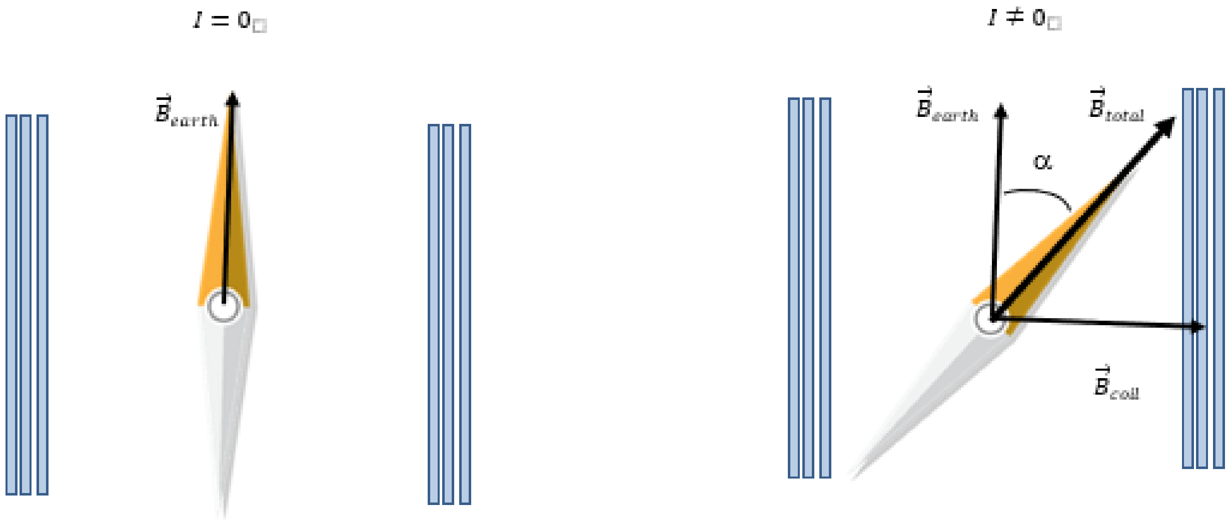
Building a simple apparatus based on electromagnetic phenomena

The experiment requires the construction of a Helmholtz coil and the determination of an angle displaced by the needle of a compass placed inside it, due to an electrical current.



Material:
0.5 l empty plastic water bottle with parallel grooves;
1 ammeter (0-200mA);
Insulated copper wire with varnish;
Support 1.5V batteries
Compass
Rheostat from 100Ω to 1kΩ
Electric wire qb
Caliper
connectors

When an electric current *I* is flowing through the coil, a uniform magnetic field B_{coil} is created in the region between the coils of radius *R* and *n* spires; if the distance between the coil equal to their radius, this filed is determined by $B = (4/5)^{\frac{3}{2}} \frac{\mu_0 n I}{R}$, where is the permeability of free space ($\mu_0 = 4\pi \times 10^{-7}\ (SI)$)



Setting the angle α=45° $\rightarrow |B_{\text{earth}}| = |B_{\text{coil}}|$

Setting the coil in order to be simple to measure B_{coil}.

A- Measure the diameter of the bottle;

B- Determine the n spires needed on each coil in order to get B_{coil}= 1 μT when a I =1 mA; this will depend on the radius of the bottle.

$$n = \left(\frac{4}{5}\right)^{-3/2} \frac{r}{\mu_0} \frac{B}{I} \cong 26$$

(17, no nosso caso)

C- A value of a few dozen off turns is expected (i.e., 15 to 30)

Place the compass inside the bottle and between the coils according to their medium plane, align the bottle so that the coils are parallel to the compass needle. In this way we ensure that when the electric current begins, the created field will be orthogonal to the earth field;

The circuit is connected and the resistance of the rheostat is reduced in order to increase the current circuit, which is easily observed when measuring the mA value in the ammeter. **Because we choose the number of turns properly, this measure indicates the value of the field magnetic directly in micro-tesla.**

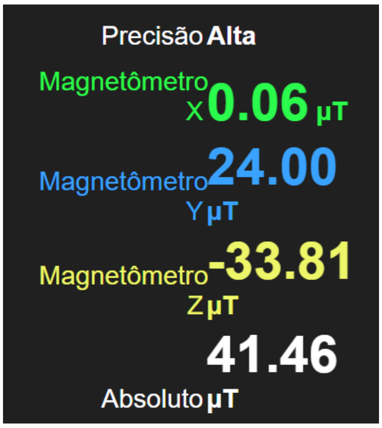
When the compass needle deviates 45° the field created is of equal value to the local field that in the beginning is only that of the Earth. It is advisable to verify that there are no objects with significant masses of ferromagnetic material nearby.

Due to the sensitivity of the compass, it is also advisable to perform the experiment a dozend times *either approaching by excess or by default* the 45° measurement. In this way, the systematic errors due to internal friction within the needle are minimized.

B_{earth} /µT (=Bcoil= “miliamperimeter”)	B_{earth} /µT (mean value)	

Vertical magnitude off the field

Using high technologies – your mobile phone!



Open the “magnetometer” on the Phyphox.

Place the telephone in a horizontal plane, far from objects with significant masses of material ferromagnetic nearby.

Aline the phone in order to have the *xx* axis with zero field and the *zz* axis vertically.

Compare the B_y value off the field with the horizontal component obtain previously with the electromagnetic experiment. Comment on the results.

Get the missing B_z component of earth magnetic field in the day and location where the experiment took place! Thanks to Viscardi-Gymnasium Fürstenfeldbruck for this opportunity!

Final results:

GPS coordinates		*B*/ µT			
Latitude/°	Longitude/°	B_x	B_y	B_z	B_{value}

You can compare the results with the ones derived from the American Model from NOAA (National Oceanic and Atmospheric Administration) in: https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#igrfwmm

Topic	Age	Country	Date
Eddy currents	≥14	Portugal	March 2022

Experiments with neodymium magnets #1

1- Introduction: How electromagnetic brakes work?

Over their lifetime running, they can cost half as much as traditional friction brakes. What are they and how do they work? Let's take a closer look!

2-Information on neodymium magnets (from Wikipedia[i])

"A neodymium magnet (also known as NdFeB, NIB or Neo magnet) is the most widely used type of rare-earth magnet. It is a permanent magnet made from an alloy of neodymium, iron, and boron to form the $Nd_2Fe_{14}B$ tetragonal crystalline structure. Developed independently in 1984 by *General Motors* and *Sumitomo Special Metals*, neodymium magnets are the strongest type of permanent magnet available commercially."[1]

3- Experiment:

A- Test the material available with the magnet. Divide them in *1- metals that are attracted* to the magnet (ferromagnetic), *2- metals that are NOT attracted to the magnet* (diamagnetic) and *3- non-metals* (diamagnetic)

B- Let the neodymium magnet slip from a non-metal surface of an inclining plate. Observe and pay attention to the time the magnet takes to slip across the plane.

What to expect if we do a similar experiment with a ferromagnetic plate (e.g. iron)?

What to expect if we do a similar experiment with a non-ferromagnetic plate (like aluminium or copper)?

[1] https://en.wikipedia.org/wiki/Neodymium_magnet

C- Let the neodymium magnet slip from a non-ferromagnetic plate (like aluminium or copper).

Now use the similar plate but make the magnet slip above the cut.
Compare it with the uncut nom(?)-metal experiment.

How to understand these results?

Topic	Age	Country	Date
Gauss cannon	≥14	Portugal	March 2022

Experiments with neodymium magnets #2

The magnetic accelerator

Start with a simple neodymium magnet. If you roll a steel ball toward the magnet, the magnet induces a magnetic dipole within the ball. A strong force of attraction pulls the two objects together.

If you roll a second steel ball toward the first ball, an attraction occurs again, but this time it's weaker. The third ball feels a weaker attraction still.

Remove one ball at a time, noting the increasing force that you need to apply as you remove each one.

Attach the three balls again and place the system in the groove of the track.

Take a fourth ball and place it in the groove on the opposite side of the magnet, but do not allow it to get pulled in by the magnet.

Give the ball a small push, just enough that it rolls slowly toward the magnet-ball system. The incoming ball should strike the magnet and knock loose a ball on the opposite side. Repeat this scenario a few times. [Feel free to try out different scenarios – e.g., 4 balls on one side, 2 on the other, etc. – to familiarize yourself with the basic interaction.]

An exact model of the magnetic accelerator it´s not basic physics … but we can make a first approach from some basic laws of physics, like Energy Conservation, and maybe get to know interactions better.

Co-funded by the Erasmus+ Programme of the European Union

Experiments with neodymium magnets #2

The magnetic accelerator

initial – 1 ○ □○○○

final -2 ○□○○ ○

1. Would you say that the spheres and the magnet are more strongly attached in the initial system 1 (□○○○) or in the final system 2 (○□○○)?

(It may be helpful to actually feel the magnet and the balls in both configurations to get a tactile sense of how tightly they are held together.)

2. Think in a more familiar situation, for example, the gravitational force. When a body approximates the earth, does the force during the interaction increase or decrease? And the potential energy between them, does it increase or decrease?

3. Based on your previous two answers, would you say that the magnet-ball system has a lower potential energy in the final (2) or in the initial (1) configuration? (When it is 'weakly bonded' or 'strongly bonded')?

4. Diagram this scenario with an energy diagram you like (energy pies, energy bars, etc). Consider four moments:

1) the incoming ball rolling very slowly toward the magnet-ball system,

2) the moment before the incoming ball strikes the magnet,

3) the moment the outgoing ball releases from the right side, and

4) the outgoing ball farther away.

5. If a magnet and ball are far apart, then no discernible attraction is felt. We say that the magnet-ball system has zero magnetic potential energy. When the ball and magnet come together, does the magnet-ball system have positive, zero, or negative energy? Explain your reasoning.

7. In this demonstration, it seems as though "we get something for nothing." The incoming ball is given a small push and the outgoing ball exits with a large amount of kinetic energy. To explore what is going on in more detail, take a glass marble and roll it slowly toward the initial setup. What happens? What do you need to do in order to actually remove the outgoing ball?

8. Based on the above example, which phrase is more appropriate: "making a bond releases energy" or "making a bond requires energy"?

Appendix 1 - Magnetic properties of matter

(from https://www.britannica.com/science/magnetism/Induced-and-permanent-atomic-magnetic-dipoles)

All matter exhibits magnetic properties when placed in an external magnetic field. Even substances like copper and aluminium that are not normally thought of as having magnetic properties are affected by the presence of a magnetic field such as that produced by either pole of a bar magnet. Depending on whether there is an attraction or repulsion by the pole of a magnet, matter is classified as being either paramagnetic or diamagnetic, respectively. A few materials, notably iron, show a very large attraction toward the pole of a permanent bar magnet; materials of this kind are called ferromagnetic.

In 1845 Faraday became the first to classify substances as either diamagnetic or paramagnetic. He based this classification on his observation of the force exerted on substances in an inhomogeneous magnetic field. At moderate field strengths, the magnetization M of a substance is linearly proportional to the strength of the applied field H. The magnetization is specified by the magnetic susceptibility χ, defined by the relation $M = \chi H$.

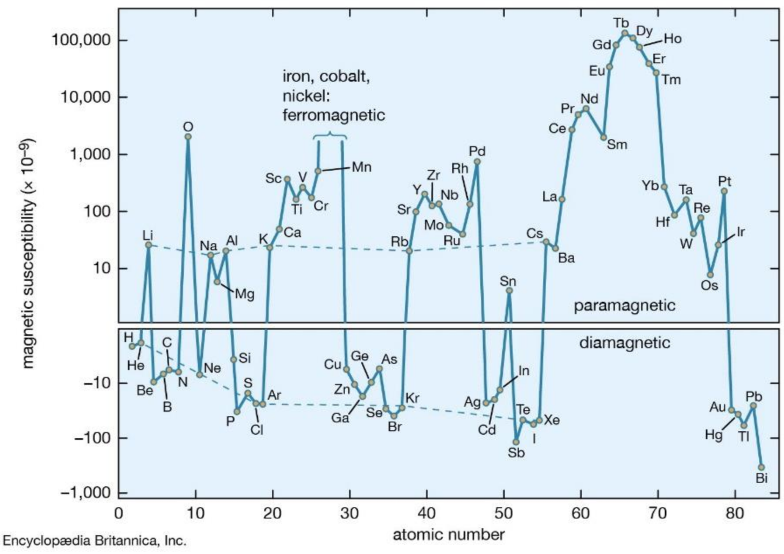
Substances for which the magnetic susceptibility is negative (e.g., copper and silver) are classified as diamagnetic.

Substances for which the magnetic susceptibility is positive are classed as paramagnetic.

Induced and permanent atomic magnetic dipoles

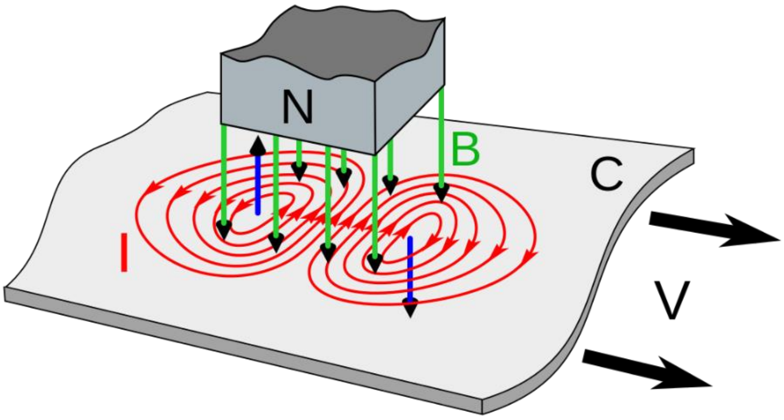
Whether a substance is paramagnetic or diamagnetic is determined primarily by the presence or absence of free magnetic dipole moments (i.e., those free to rotate) in its constituent atoms. When there are no free moments, the magnetization is produced by currents of the electrons in their atomic orbits. The substance is then diamagnetic, with a negative susceptibility independent of both field strength and temperature.

In matter with free magnetic dipole moments, the orientation of the moments is normally random and, as a result, the substance has no net magnetization. When a magnetic field is applied, the dipoles are no longer completely randomly oriented; more dipoles point with the field than against the field. When this results in a net positive magnetization in the direction of the field, the substance has a positive susceptibility and is classified as paramagnetic.

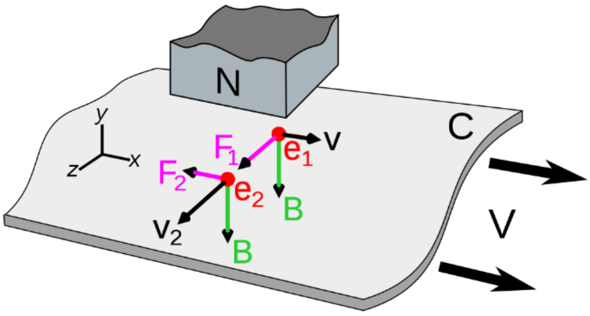


Appendix 2 – Eddy currents

Eddy currents (also called Foucault's currents) are loops of electrical current induced within conductors by a changing magnetic field in the conductor according to Faraday's law of induction. Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field. They can be induced within nearby stationary conductors by a time-varying magnetic field created relative motion between a magnet and a nearby conductor. The magnitude of the current in a given loop is proportional to the strength of the magnetic field, the area of the loop, and the rate of change of flux, and inversely proportional to the resistivity of the material. When graphed, these circular currents within a piece of metal look vaguely like eddies or whirlpools in a liquid.



Eddy currents (I, red) induced in a conductive metal plate (C) as it moves to the right under a magnet (N). The magnetic field (B, green) is directed down through the plate. The Lorentz force of the magnetic field on the electrons in the metal induces a sideways current under the magnet. The magnetic field, acting on the sideways moving electrons, creates a Lorentz force opposite to the velocity of the sheet, which acts as a drag force on the sheet. The (blue arrows) are counter magnetic fields generated by the circular motion of the charges.



Forces on an electron in the metal sheet under the magnet, explaining where the drag force on the sheet comes from. The red dot shows a conduction electron in the sheet right after it has undergone a collision with an atom, and shows the same electron after it has been accelerated by the magnetic field. On average at the electron has the same velocity as the sheet (black arrow) in the direction. The magnetic field (green arrow) of the magnet's North pole N is directed down in the direction. The magnetic field exerts a Lorentz force on the electron (pink arrow) of , where e is the electron's charge. Since the electron has a negative charge, from the right-hand rule this is directed in the direction. At this force gives the electron a component of velocity in the sideways direction (black arrow) The magnetic field acting on this sideways velocity, then exerts a Lorentz force on the particle of . From the right-hand rule, this is directed in the direction, opposite to the velocity of the metal sheet. This force accelerates the electron giving it a component of velocity opposite to the sheet. Collisions of these electrons with the atoms of the sheet exert a drag force on the sheet.