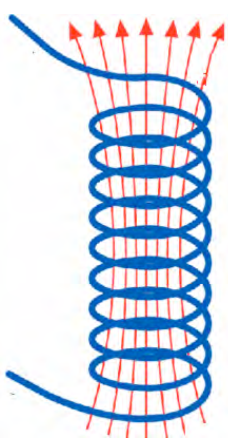
centre de développement pédagogique
pour la formation générale en science et technologie

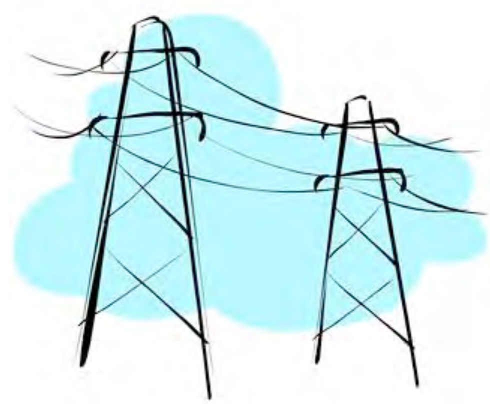
Working document

GAUSSBUSTERS



STUDENT BOOKLET

March 2011



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Here is your mandate

NOTE: This activity was designed within the framework of teacher training sessions. It may require adaptation before being used with students.

Many devices that surround us use alternating current. These devices are apt to emit electromagnetic fields. What is the intensity and configuration of these fields?

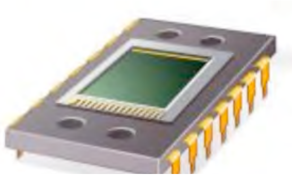
In the last several years, many studies have questioned the effects these fields may have on humans. The authors, protocols and conclusions are tremendously varied, depending on which study you look at. It is interesting to educate yourself in order to develop critical judgement. We must, however, be sure to validate and multiply the sources of information in order to cross reference the data and the conclusions gathered.

Electrical installations from electricity suppliers such as Hydro Quebec most often operate on alternating current. What is the intensity of the electromagnetic fields around these high tension lines? It would also be interesting to study these fields. One way to become familiar with this topic is to carry out your own detection of potential electromagnetic fields.

Your challenge:
Familiarise yourself with the basics of electronics in order to make a device for detecting electromagnetic fields. To succeed, you will have to use your scientific and technological knowledge paired with your qualities as a designer, to ensure easy data collection.

Computers and the Internet occupy a more and more significant place in our lives. We write, count, present, compose music, all using computers. We *chat*, *surf*, *tweet* and *blog* on the net. Using this technology, we can make it faster, nicer and more captivating. This virtual world seems nearly magical. We almost forget what is inside these little marvels that are our smart phones, tablets, GPSs and computers.

For most people, the electronics in these circuits is unintelligible. It goes without saying that miniaturisation makes them extremely complex. On this topic, here is a video that shows you how **integrated**



circuits can be made on a silicon wafer. The sites where these are made are extremely clean. This is the reason they are sometimes called white rooms. The engineers who work there are dressed as they are not to protect themselves, but rather to protect the circuits from any contamination.

Making an integrated circuit in a white room, on a silicon wafer
http://www.youtube.com/watch?v=6zh4lIQtNCI

We can not hope to do such an extreme job. We must be content to make a **printed circuit**, which is much simpler. The device you will build is called a Gaussmeter. It is used to detect electromagnetic fields.

Essentially, here is what we propose to do in the course of this LES to help you meet the challenge:

- Learn to recognise the basic components in a printed circuit.
- Study each of these components in order to understand its basic operation.
- Make a printed circuit using a resin photosensitive to UV rays.
- Solder the components onto the circuit board and connect the external components.
- Design the Gaussmeter housing keeping in mind the circuit board and its external components.
- Control the state of operation of the Gaussmeter.

Now, let's get to work!

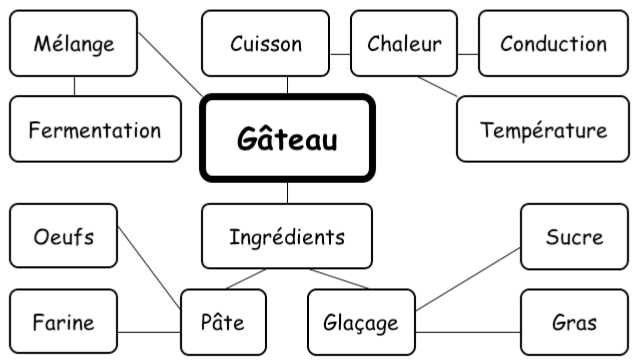
Let's warm up a bit

In the past year, you have had the occasion to study several concepts related to electricity. This section will allow you to refresh your memory.

Now build a network of concepts previously studied. This will allow you to check to see if you clearly grasp the basic notions required to understand electronic components. Building this network will allow you to organise your knowledge visually, in card form.

Word bank: wire, switch, supply function, plastic, battery, conduction function, casing, electrical current, push-button switch, glass, metal, battery, source of current, fuse, contact (terminal), toggle switch, insulation function, copper, protection function, command function, electron

Example of a network of concepts



Network of concepts

Electrical engineering

It's time to learn a little more!

At this point it's time to demystify electronics. Now we'll present various activities which will allow you to better understand how the targeted components work. Afterwards, we can approach the fabrication of a printed circuit on which these components will interact.

Learning activities to be broached

1. **Electronic components**
   - Description of electronic components
   - Recognition exercise: components and their symbols

2. **Resistor**
   - Characteristics of the fixed resistor
   - Variable resistor

3. **Capacitor**
   - Ceramic capacitor
   - Electrolytic capacitor

4. **Diode**
   - Light emitting diode (LED)
   - Ordinary diode

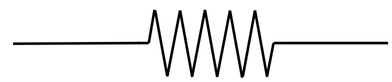
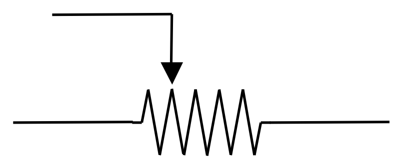
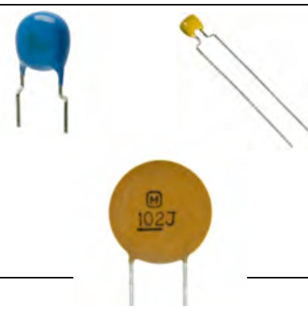
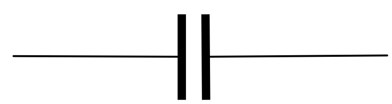
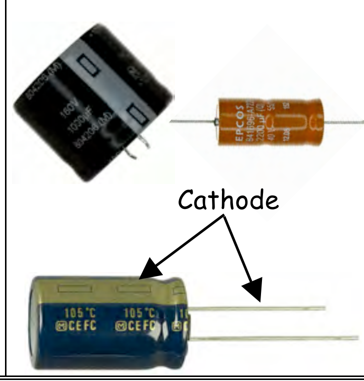
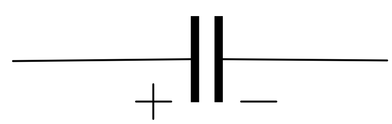
5. **Solenoid**
   - Electromagnet
   - Relay
   - Single bobbin (inductance) ⇒ Electromagnetic induction

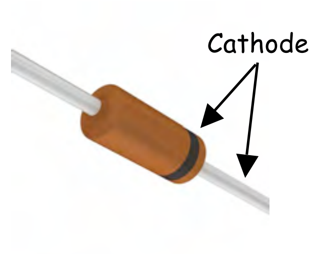
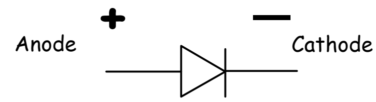
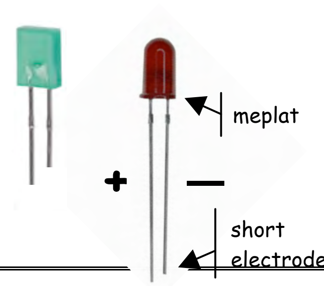
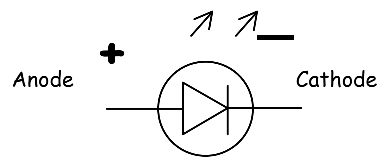
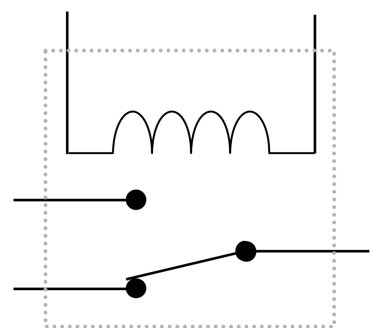
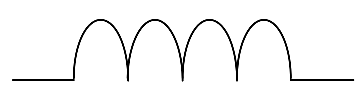
6. **Transistor**

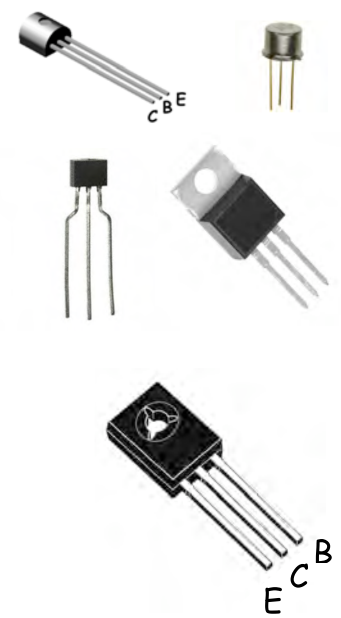
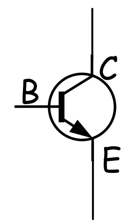
7. **Theory regarding printed circuits**
   - Making the plate
   - Controlling the state of its operation
   - Tin soldering

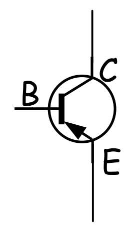
Electronic components

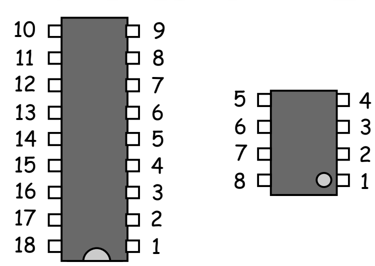
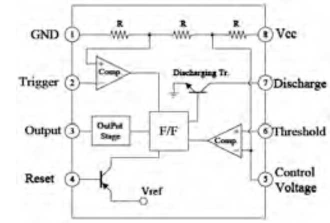
Here now is the description of the components targeted in the fourth year high school AST program. Identify each of the components among those distributed.

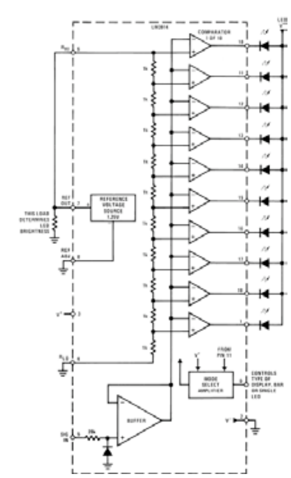
Name and description	Photo	Symbol
RESISTOR		
Fixed resistor A resistor has a fixed resistance (R) which is measured in ohms (Ω). A code made up of coloured strips indicates its value.		
Variable resistor The resistance of a variable resistor can be adjusted from 0 Ω to a predetermined value indicated on its back.		
CAPACITOR		
Ceramic capacitor A capacitor has a capacity (C) that is measured in farad (F). This value is usually written on its side.		
Electrolytic capacitor This type of capacitor has a greater capacity. It is polarised and its cathode (-) is usually indicated by minus signs. Its capacity and maximum voltage (not to be surpassed) are indicated.		

Name and description	Photo	Symbol
DIODE		
Ordinary diode A diode is a polarised component. The cathode (-) is indicated by a line at one of its ends.		
Light emitting diode An LED can emit several colours and is polarised. The cathode (-) is usually indicated by the shorter electrode and by its meplat (flat side).		
SOLENOID		
Relay The relay is always made up of an electromagnet and contact strips. The operating voltage of the solenoid as well as the maximum voltage of its strips are indicated on its housing.		
Solenoid A solenoid has an inductance (L) measured in Henry (H).		

<table>
<tr><th>Name and description</th><th>Photo</th><th>Symbol</th></tr>
<tr><td colspan="3">BIPOLAR TRANSISTOR</td></tr>
<tr><td>There are many types of transistors. We will concentrate only on the bipolar transistor. This transistor is made up of 3 electrodes: the emitter (E), the base (B), and the collector (C). The position of each one varies depending upon which model is used. The number of the transistor is written on its side. There are 2 major types of bipolar transistors: PNP and NPN types.</td><td>
</td><td>

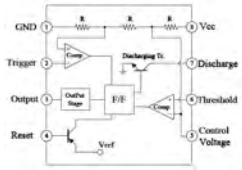
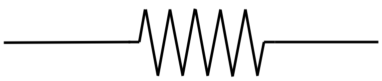
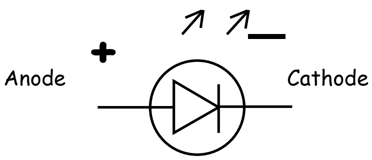
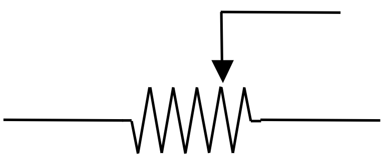
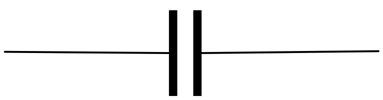
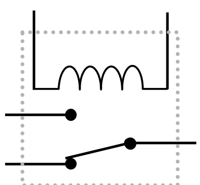
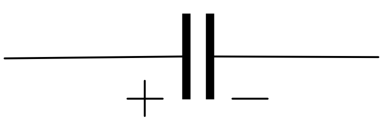
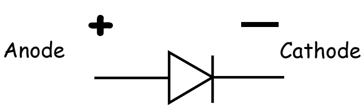
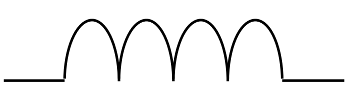
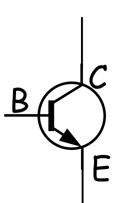
NPN type


PNP type</td></tr>
<tr><td colspan="3">INTEGRATED CIRCUIT</td></tr>
<tr><td>There are a multitude of different integrated circuits (chips). Every year that goes by sees the birth of new ones. They are composed of a great number of basic components. They may therefore include resistors, transistors, diodes etc. Its number is written on the top. Its terminals are usually numbered like those pictured at right. The circular mark indicates terminal number 1. The notch indicates the extremity where the numbering starts and ends.</td><td>

</td><td>

</td></tr>
</table>

Can you recognise these components?

Using its letter, associate the name (in the center), to the symbol at left and to the photo at right.

Symbol		Name		Photo
	( )	(A) Fixed resistor	( )	
	( )	(B) Variable resistor	( )	
	( )	(C) Ceramic capacitor	( )	
	( )	(D) Electrolytic capacitor	( )	
	( )	(E) Ordinary diode	( )	
	( )	(F) Light emitting diode	( )	
	( )	(G) Relay	( )	
	( )	(H) Solenoid	( )	
	( )	(I) Bipolar transistor	( )	
	( )	(J) Integrated circuit	( )	

Characteristics of the fixed resistor

A fixed resistor is characterised by its resistance and its capacity for power dissipation. The Gaussmeter that we will build is made up of several of these resistors. To identify them, you will have to use the colour codes shown below.

Power of the resistor

When we speak of power, we specifically refer to the maximum amount of power that a resistor can dissipate per joule effect (in the form of heat, while current flows through it). In this context, it is possible to have two 500 Ω resistors in hand of very different size and fabrication. You can almost swear that the bigger one is sturdier and that it could, in any given circuit, dissipate more heat without breaking. For the fabrication of our gaussmeter, $\frac{1}{2}$ or $\frac{1}{4}$ watt resistors will do, since the current used in the circuit will be very weak.

Resistance of the resistor

The resistance of a resistor indicates its ability to resist the flow of an electrical current. The greater the resistance, the greater the voltage required to force the electrical current through the resistor. Ohm's Law describes this phenomenon perfectly.

As to the colour code[1] at right, it is made up of four bars. The first three indicate the resistance, in ohms (Ω) while the last one indicates the precision of this resistance. It goes without saying that the more precise the resistor, the greater its cost.

	1er anneau gauche	2e anneau gauche	Dernier anneau gauche	Anneau droite
Couleur	1er chiffre	2e chiffre	Multiplicateur	Tolérance
noir	0	0	$10^0=1$	
marron	1	1	10^1	± 1 %
rouge	2	2	10^2	± 2 %
orange	3	3	10^3	
jaune	4	4	10^4	
vert	5	5	10^5	± 0,5 %
bleu	6	6	10^6	± 0,25 %
violet	7	7	10^7	± 0,10 %
gris	8	8	10^8	± 0,05 %
blanc	9	9	10^9	
or			0,1	± 5 %
argent			0,01	± 10 %
(absent)				± 20 %

[1] www.Wikipedia.org (resistance)

Variable resistor (directed laboratory)

The variable resistor is a much used part in electronics. You have surely had the opportunity to use one many times. Every time you turn a knob to regulate the sound volume of a device, it is highly likely that you are turning a variable resistor. There are also variable resistors whose cursors move in a straight line, like the controls of some audio systems.

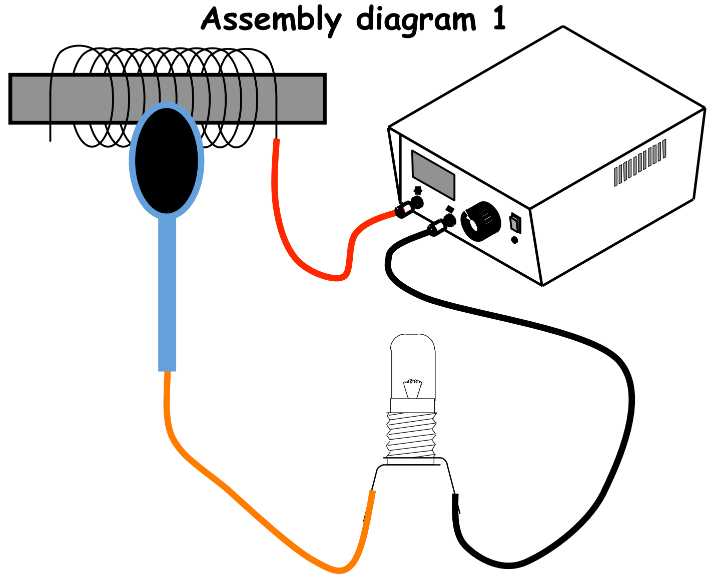
It is possible to simulate a variable resistor using rolled nichrome wire and a small metallic spoon.

Using a variable resistor (2 contacts)

Materials 1

- 1 power supply (10 volts)
- 3 alligator clip wires
- 1 (non coloured) 12 volt incandescent light bulb
- 1 roll of n° 28 nichrome[2] wire
- 1 small metal spoon

Assembly diagram 1



Manipulation 1

1. Assemble the above circuit.
2. Press the spoon to the rightmost extremity of the wire roll.
3. Turn on the power and adjust it to the maximum.
4. Slide the spoon towards the left, keeping it in constant contact with the wire roll.
5. Observe the light intensity of the bulb and note your observations.

[2] Nickel chrome alloy used as a heating element.

Observations (manipulation 1)
____
____
____

Analysis of phenomenon 1

Question 1

When the spoon is slid over the roll, at which extremity is the light intensity greatest?

____

Question 2

Why does the light intensity weaken when moving the spoon to the left?

____

____

Question 3

What would happen if the roll had twice as many turns of wire?

____

____

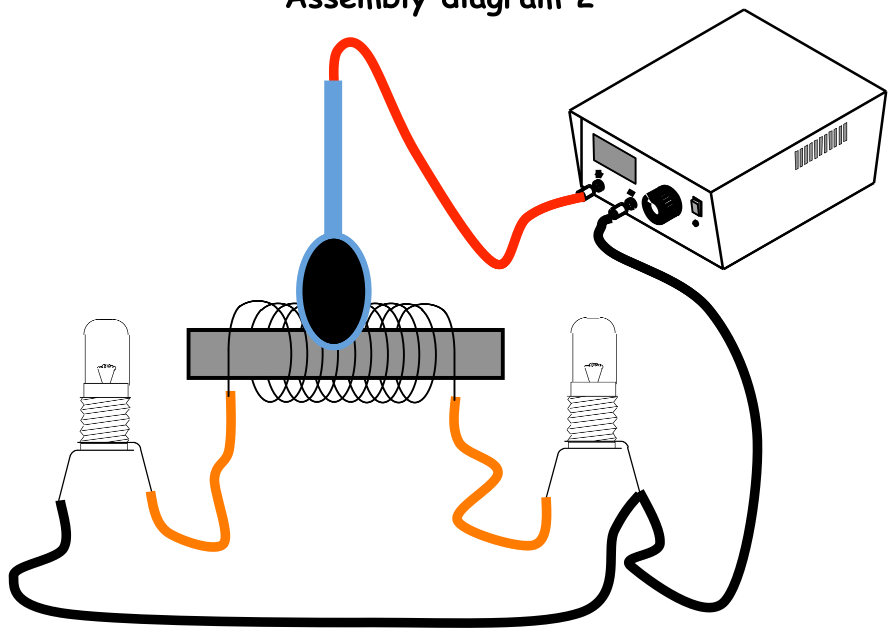
Question 4

Nichrome conducts electrical current relatively poorly when compared to copper. What result would we obtain if we replaced the nichrome wire with copper wire of the same length and width?

____

____

Using a variable resistor (3 contacts)

Materials 2	**Assembly diagram 2**
• 1 power supply • 5 alligator clip wires • 2 non coloured incandescent light • 1 roll of n° 28 nichrome[3] wire • 1 small metal spoon	

Manipulation 2

1. Assemble the above circuit.
2. Press the spoon to the rightmost extremity of the wire roll.
3. Turn on the power and adjust the light intensity of the right hand bulb to the maximum.
4. Slide the spoon from left to right while maintaining contact with the wire roll.
5. Observe the light intensity of the bulbs and note your observations.

Observations (manipulation 2)
____
____
____

[3] Nickel chrome alloy used as a heating element.

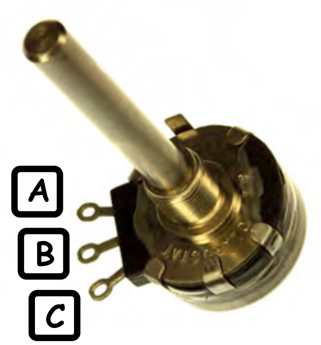
Analysis of phenomenon 2

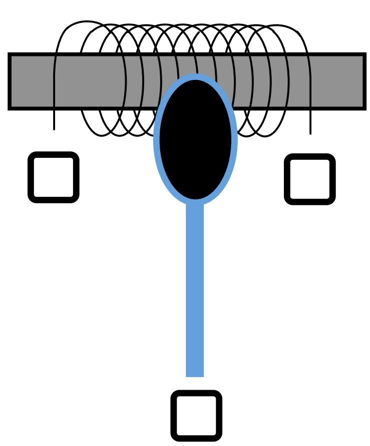
Question 1

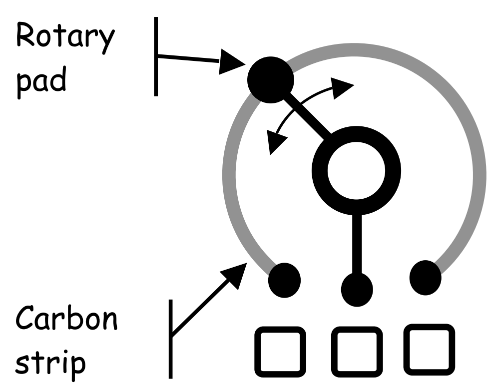
Describe the distribution of the electric current at the contact point between the wire roll and the spoon. What promotes one path rather than the other?

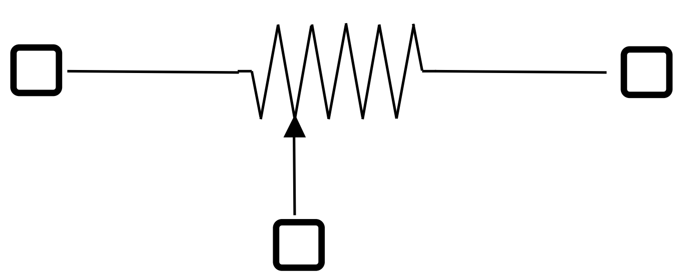
Conclusion

In the case of our variable resistor, the nichrome roll is replaced with a carbon substrate and the spoon, by a rotary pad. Using letters, associate the resistor terminals to: its simplified drawing, its model and its symbol.





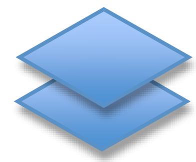




Capacitor (directed laboratory)

A little theory

The capacitor is a master part in the field of electronics, notably in our Gaussmeter. It can have many uses. It can be used in circuits used to filter signals of a specific frequency or in oscillators, for instance. These applications are too complex for us, however. Let's simplify things by saying that a capacitor accumulates electrical charges like a toilet tank accumulates the water necessary to flush. The quantity of charge a capacitor can accumulate is defined as its capacity. Essentially, a capacitor is made up of two conductive plates placed face to face, without touching. Each of the terminals of the capacitor is connected to one of these plates. There are two ways to increase the capacity of a capacitor to accumulate charges: increase the surface area of the plates or bring the plates closer together.



Ceramic capacitors are made according to this model, and their capacity is not very large.

The unit of measure for capacity (C) is the farad(F). This unit, however, is not well adapted to the capacitors that we will be using. As a comparison, it would be like using kilometres to measure the thickness of a piece of board!!! In electronics, we hardly ever see the farad (F), rather we will see:

- 1 microfarad → (1 μF) → 1×10^{-6} F → 0.000 001 F (electrolytic)
- 1 nanofarad → (1 nF) → 1×10^{-9} F → 0.000 000 001 F (ceramic)
- 1 picofarad → (1 pF) → 1×10^{-12} F → 0.000 000 000 001 F (ceramic)

Electrolytic capacitors have a much greater reservoir for charges. That is why the microfarad (μF) is used in their case. In this type of capacitor, the plate is rolled, like the paper in a toilet paper roll. That's why it has a cylindrical shape. In addition, the plate soaks in an electrolytic solution (electrolyte) that forms a thin insulating layer once the capacitor is powered. This thin layer corresponds to a situation where the distance between the plates is very small. That is why electrolytic capacitors are so powerful.

The polarity of a capacitor is very important. If the connection is reversed, the insulating layer we spoke of earlier does not form and the capacitor will short circuit. At that point, the electrolyte heats up and the internal pressure of the capacitor can increase until its envelope yields violently. A **mini explosion** may then occur. In that case watch your eyes!

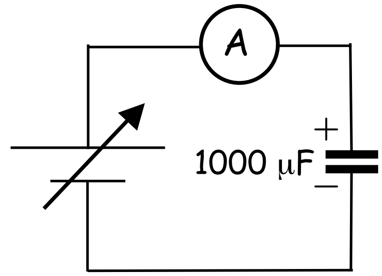
Charge and discharge of a capacitor

Materials

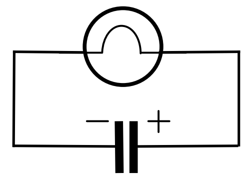
- 1 variable supply
- 1 ammeter
- 3 alligator clip wires
- 1 protected LED or 1 - 2 V incandescent light bulb
- 1 electrolytic capacitor (≈ 1000 μF, minimum 10 V)

Assembly diagram

Charging the capacitor



Discharging the capacitor



Manipulations

1. Assemble the capacitor charge circuit (left hand circuit).
2. Adjust the power source to the minimum and power it on.
3. Power on the ammeter.
4. Increase the voltage of the source a little at a time until you get to 10V, all the while observing the ammeter.
5. Note your observations.
6. Disconnect the capacitor without lowering the voltage from the source.
7. Connect the capacitor onto the protected LED (light bulb) like in the right hand circuit and observe.
8. Note your observations.
9. Start over as necessary.

Protected LED or lightbulb

Observations while charging

____

Observations while discharging

____

____

Analysis of the phenomenon

Question 1
What does the ammeter tell us while it is charging?

____

Question 2
Why does the intensity of the current drop when we stop increasing the voltage?

____

____

Question 3
What is the voltage at the capacitor terminals at the end of charging?

____

Question 4
Given the length of time the light bulb operates during discharge, what can we conclude about the amount of charge stored by the capacitor?

____

Question 5
In your opinion, what differentiates a capacitor from a battery?

____

____

Conclusion (what is important to remember about capacitors)

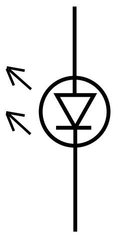
____

____

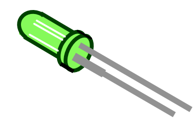
____

Diode (directed laboratory)

A bit of theory



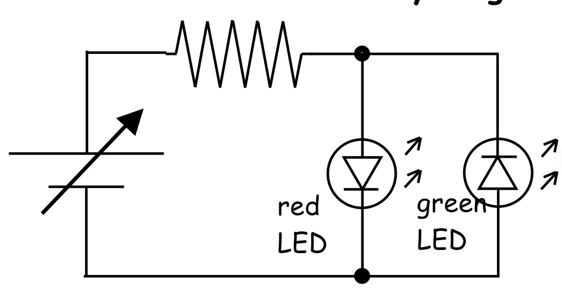
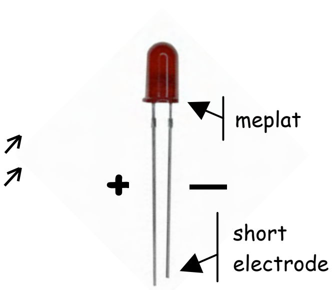
A diode is a very simple component. We could make an analogy to a turnstile found at the entrance of some stores. As with the turnstile, the diode allows the electrical charges through in a single direction. On its symbol, at left, the arrow indicates the conventional direction of the electrical current (namely from the positive terminal to the negative terminal of the supply).



The most popular diodes are those that emit light. They are called **l**ight **e**mitting **d**iodes or simply LED. They are found as a indicator lights on many devices, like our Gaussmeter. They also make up the light segments on the display of a microwave. Some also emit light that is invisible to the naked eye. That is the case of our television remotes, which transmit using an infrared LED (have you ever looked at the end of your working TV remote with your cell phone's camera?)

Diodes do not all emit light, however. There are sturdier ones that allow the passage of much greater current than an LED does. They are used, among other things, to convert alternating current to direct current or simply to direct the current towards a device to supply it.

Using a light emitting diode

Materials 1	Assembly diagram 1
• 1 (10 V) source • 1 resistor (≈ 250 Ω) • 5 alligator clip wires • 1 red LED • 1 green LED	

Manipulation 1

1. Assemble the above circuit.
2. Adjust the power supply on, to 10V.
3. Interchange the two wires connected to the supply terminals several times.
4. Observe and note your observations.

Observations (manipulation 1)
____
____
____

Analysis of phenomenon 1

Question 1
Why do the LEDs behave as they do?

____

____

Question 2
How do we recognise the negative electrode (cathode) of the diode?

____

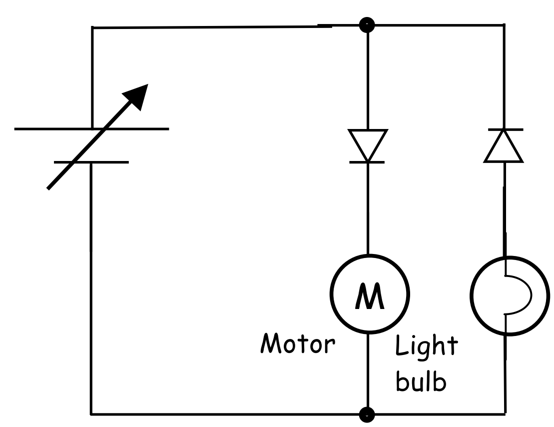
____

Using an ordinary diode

Materials 2

- 1 (10 V) source
- 6 alligator clip wires
- 2 ordinary diodes
- 1 electric motor (about 10 V)
- 1 electric light bulb (about 10V)

Assembly diagram 2



Manipulation 2

1. Assemble the above circuit.
2. Adjust the power supply on, to 10V.
3. Interchange the two wires connected to the supply terminals several times.
4. Observe and note your observations.

Observations (manipulation 2)

____

____

____

Analysis of phenomenon 2

Question 1

What are the similarities and differences with the previous circuit made up of LEDs?

____

____

____

Conclusion (what is important to remember about diodes)

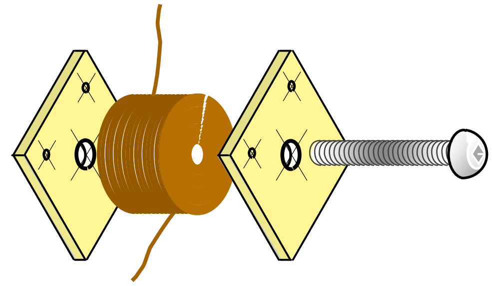
____

____

____

Solenoid (directed laboratory)

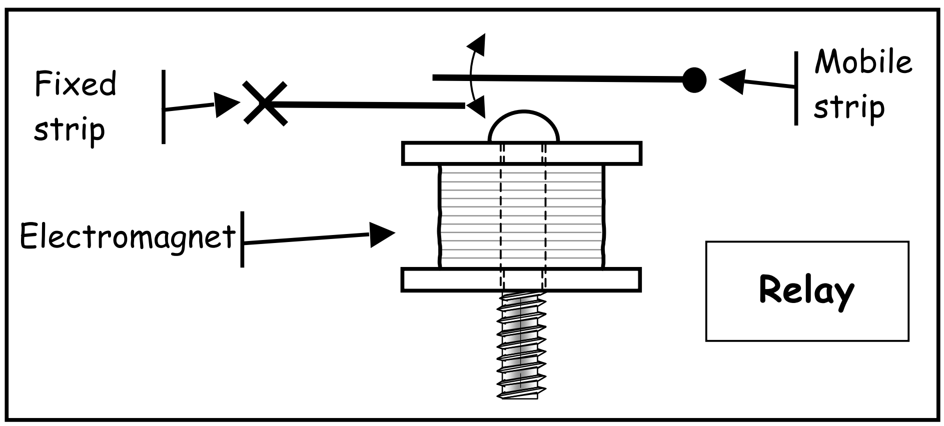
A little bit of theory



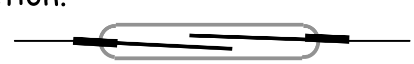
The solenoid is a well known component. When it is equipped with a ferromagnetic core, it is called an electromagnet. You have probably all had the occasion to experiment with an electromagnet. Otherwise, here is a drawing of an electromagnet at right, drawn from the Reed switch motor (RSM) activity. It is the basis of its operation.

The operation of a relay

A nice application of the electromagnet is the electromagnetic relay. It is very practical and its operation, simple. On the drawing at right, you can see that we have added two ferromagnetic strips above the magnet. The left one is fixed, that is well attached to its support. The right hand one is free to turn on its axis. It can therefore move to go touch the fixed strip as the arrow indicates. That is precisely what happens when the electromagnet is powered on. When a weak current is sent through the electromagnet, a magnetic field appears around it. The mobile strip moves down and comes into contact with the fixed strip. The two strips are a kind of switch which works using a magnetic field. It is therefore possible to allow another current to flow through this switch. If the strips are sturdy, very strong voltage can flow through it. When the supply of the electromagnet is cut off, a spring (or something else) brings the mobile strip back to its original position. To sum up, here is how a relay works:

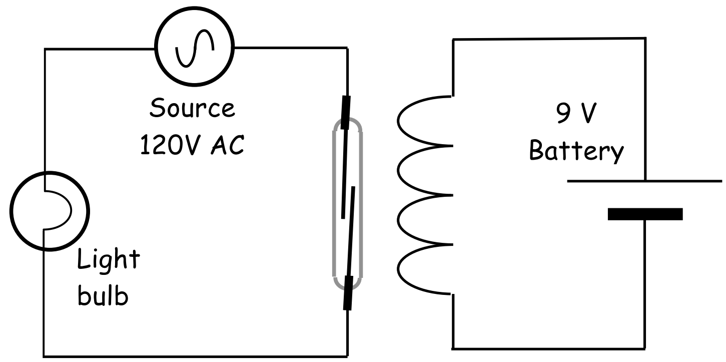


In the experiment that follows, we have replaced the strips by a magnetic switch (Reed switch). Glass protected strips offer better protection.



A weak current feeds the electromagnet → A magnetic field appears around the electromagnet → The mobile strip is attracted by the electromagnet → The mobile strip moves down and comes into contact with the fixed strip → A strong current can flow through the two strips

Using a relay

Materials 1	Assembly drawing 1
• 1 - 120V assembly including · 1 - 120V AC current · 1 magnetic switch · 1 - 120V AC light bulb • 1 magnet • 1 - 9V battery • 1 electromagnet (from the RSM) • 2 alligator clip wires	

Manipulation 1

1. **(CAREFUL! 120 VOLTS)** Check the 120V assembly in order to ensure that the magnetic switch is intact and there are no bare wires. If you are not sure, ask your teacher or technical personnel for help.
2. Connect the assembly to a 120V plug.
3. Check that the 120V assembly is operating by moving the magnet closer to the magnetic switch.
4. If the assembly is operational, assemble the right hand circuit without connecting the battery.
5. Position the electromagnet in such as way that its core is as close as possible to one of the strips of the magnetic switch.
6. Connect and disconnect the battery and observe.

Observations (manipulation 1)

____

____

____

Analysis of phenomenon 1

Question 1
What is the voltage of the primary, direct current, circuit?

____

Question 2
Write Ohm's law and isolate variable I.

____

Question 3
The electrical intensity (I) is the output (number of charges per second) of electrical charges flowing through a body. During electrocution, the greater the output of these charges, the greater the tissue-damaging heat that is released.
Using the equation isolated previously (Ohm's Law) explain why the 120 volts from this area is more dangerous than the voltage in a 9V battery. For the purposes of the calculation, let's suppose that the resistance of the body is 1000 Ω.

____

____

Question 4
Using the equation isolated previously, explain why having damp fingers makes an electrical current more dangerous when touching conductors.

____

____

Question 5
Knowing that strong electrical intensity releases a large amount of heat, what characteristics should a switch controlling a high intensity circuit have?

____

____

Question 6
In your opinion, why do we use relays in the circuit controlling the ignition of a car or in the control circuit of an elevator?

____

____

Conclusion 1 (What is important to remember about relays)

____

____

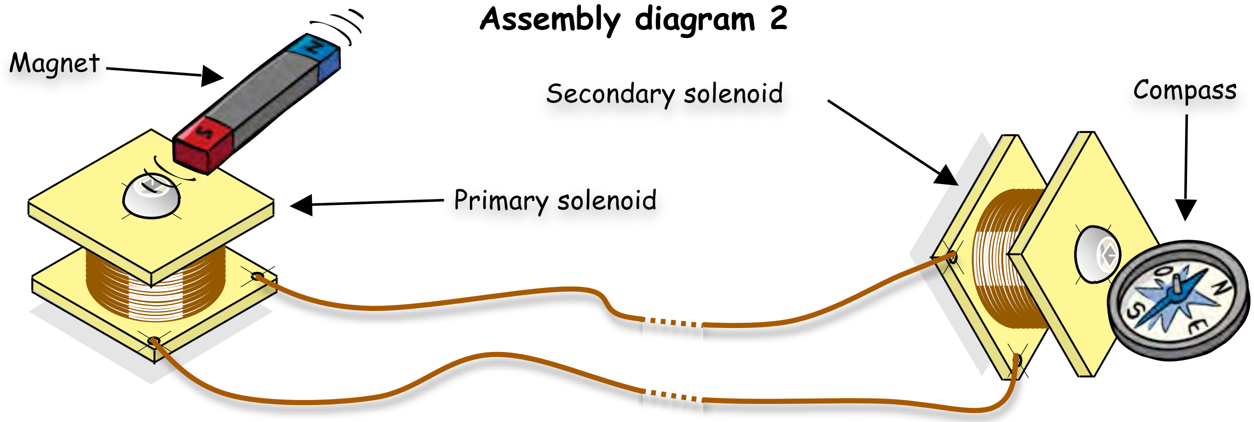
You now know that when an electrical current flows through a solenoid, it generates a magnetic field around itself. What you may not know is that the reverse is also possible. A magnetic field can also generate an electrical current under certain conditions. This principle is the basis of operation of our Gaussmeter: we are talking about electromagnetic induction.

Electromagnetic induction

Materials 2

- 2 solenoids (electromagnet from the RSM)
- 1 (rare earth) powerful magnet
- 1 compass
- 2 long (≈ 1 metre long) alligator clip wires (or 2 shorter alligator clips connected end to end)

Assembly diagram 2



Manipulation 2

1. Assemble the circuit from the previous page.
2. Place the compass flat, just at the axle of the secondary solenoid. (To do so, it must be placed on a non magnetic support, like a piece of wood).
3. The compass will naturally indicate the terrestrial magnetic north (if there is no remanent magnetisation in the core). Turn the **secondary solenoid - compass** system in such a way as to have the needle of the compass perpendicular to the axle of the solenoid.
4. Move the magnet of the primary solenoid back and forth quickly.
5. Observe the compass and note your observations.
6. In the same way, bring the primary solenoid magnet closer and do not move it.
7. Observe the compass and note your observations.

Observations 2a (When the magnet is moved back and forth as close as possible to the primary circuit)

____

____

Observations 2b (When the magnet is stationary, as close as possible to the primary)

____

____

Analysis of phenomenon 2

Question 1

What does the oscillation of the compass needle tell us?

____

____

Question 2
Is the presence of a stationary magnet close to the primary solenoid sufficient to induce current into the circuit?

____

____

Question 3
What must we do to induce current into the circuit?

____

____

Question 4
The electrical current generated by Hydro-Quebec is alternating current. Devices supplied by this alternating current generate a variable magnetic field. It is as if there were magnets moving inside them (see the primary solenoid on assembly diagram 2). **Which component inside the Gaussmeter will be able to detect these variable magnetic fields?**

____

Question 5
Will the Gaussmeter be able to detect the magnetic field of a stationary magnet?

____

Conclusion 2 (What is important to remember about electromagnetic induction)

____

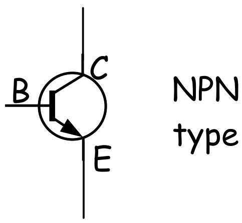
____

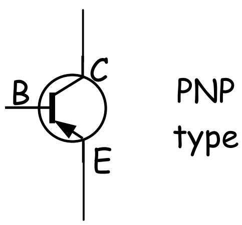
____

Transistor (directed laboratory)

A little bit of theory

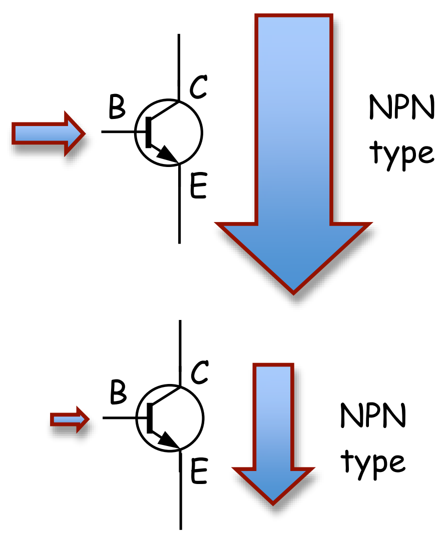
The transistor is at the base of modern electronics. Our Gaussmeter includes one as such, but its integrated circuit includes a great many. The image at right represents the transistor used in our circuit. There are several families of transistors (field effect, Darlington, etc...) but we will limit ourselves to the bipolar type. We will not deal with how they are made (their internal structure). You will have the occasion to broach these topics in electro technique in college, or in physics at university.





Bipolar transistors are divided into two types, **PNP** (positive, negative, positive) and **NPN** (negative, positive, negative). PNPs and NPNs can carry out the same task and their characteristics are generally equivalent. One or the other is used in relation to the architecture of the circuit.

In the course of this experiment, we will limit ourselves to the NPN type, since we will use it in the circuit for our Gaussmeter. This type of transistor has 3 electrodes: the **base (B)**, the **collector(C)**, and the **emitter (E)**. On its symbol, the arrow indicates the conventional direction of the current (namely from the positive terminal to the negative terminal of the source). Basically, the transistor acts as an **amplifier** of the intensity of the current. When a small current arrives by the base, the transistor allows a proportional, but much greater, current through its collector and its emitter. If the current from the base diminishes, the larger current will diminish proportionally.



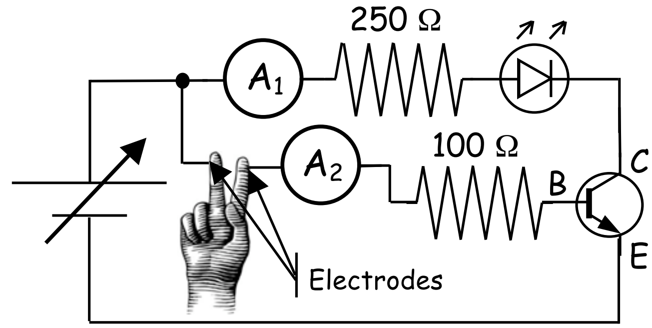
The following experiment will allow you to highlight the amplification power of the transistor. The circuit that you will assemble may be used as a **humidity detector**. With this circuit, we can check to see if the earth in a flower pot is wet enough, or if your hands are damp. Since transistors can be placed one after the other, imagine their collective power of amplification...

Amplification of a transistor

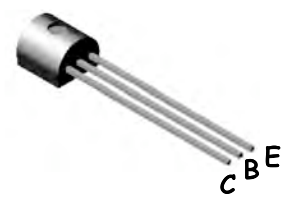
Materials

- 1 variable source of current
- 1 ammeter (mode: 20 mA)
- 1 NPN (2N4401) transistor
- 1 ≈250 Ω resistor
- 1 ≈100 Ω resistor
- 7 alligator clip wires
- 1 LED
- 1 damp hand

Assembly diagram



Manipulations



1. Assemble the circuit above, introducing the ammeter in position "A_1" (see transistor diagram).
2. Adjust the source voltage to 9 volts.
3. Check the circuit by touching the two electrodes together (the LED should light up at full power).
4. Close your fist a moment so as to make your hand damp.
5. Apply the electrodes to your damp fingers as in the diagram above.
6. Position your fingers so as to obtain a constant intensity.
7. Note the intensity of the ammeter.
8. Repeat steps 4 to 7, this time placing the ammeter in position "A_2".
9. Just for fun, check to see if the current can pass through two people's bodies (form a loop by holding your team-mate's hand).

Data table	
Intensity of the current of the ammeter in position "A_1" (ampere)	
Intensity of the current of the ammeter in position "A_2" (ampere)	

Analysis of the phenomenon

Question 1
In which position does the ammeter measure a greater intensity?

____

Question 2
Calculate the ratio of the measured intensities (greater intensity /lesser intensity).

Question 3
What is the significance of the ratio calculated in the previous question?

____

____

Question 4
In the Gaussmeter circuit, what will the transistor be used for?

____

____

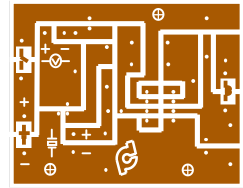
Conclusion (What is important to remember about transistors)

____

____

____

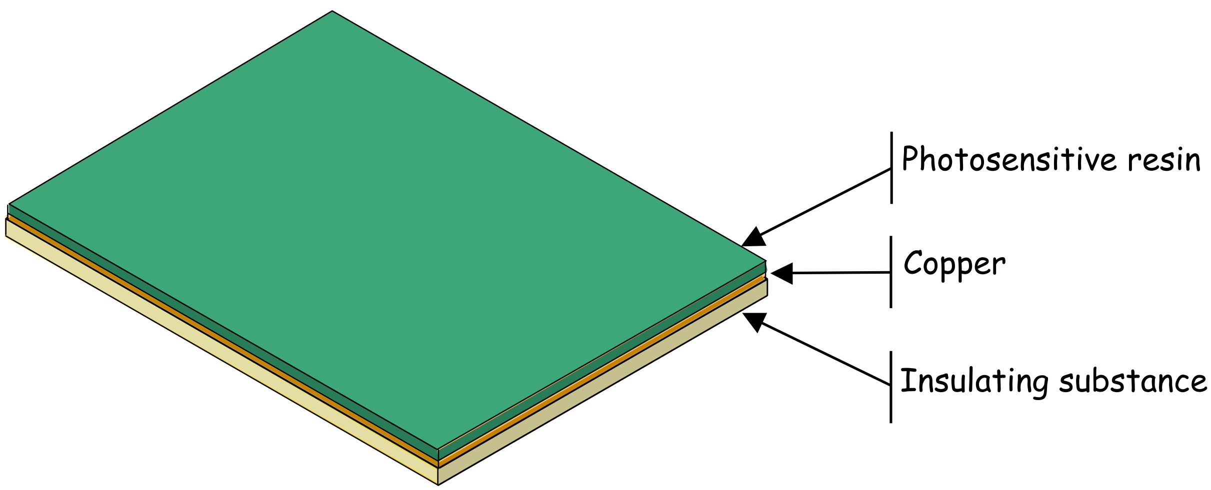
Making the printed circuit plate



The first step you will have to go through while making your Gaussmeter is the fabrication of the printed circuit plate. We will use chemical substances as well as ultraviolet (UV) rays in the course of the process. Though our method will be less sophisticated than in a factory environment, it is nonetheless interesting to see how the professionals proceed. Here then, is a short report on the subject.

Fabrication of a factory made printed circuit
http://www.youtube.com/watch?v=r6z_Zz4MD5c&feature=related

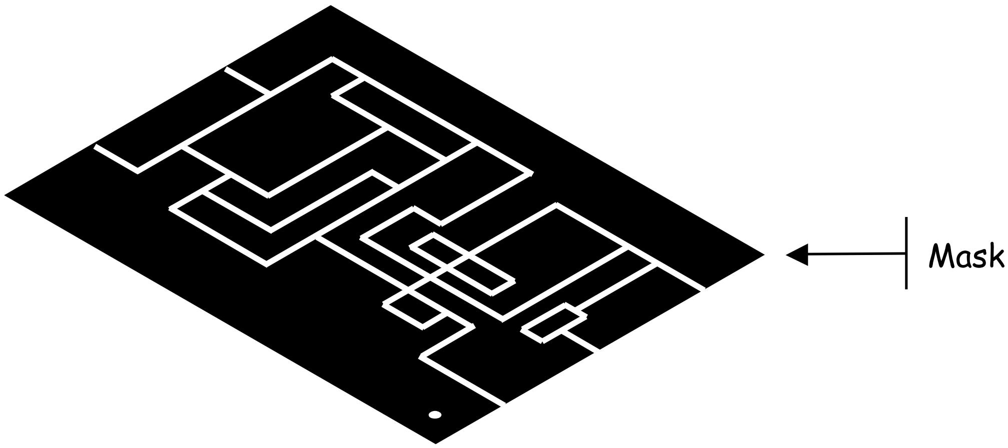
Fabrication of a printed circuit using a photosensitive plate
Photosensitive plates are made up of three distinct layers. The first layer, generally green, is a resin, sensitive to ultraviolet rays (photosensitive resin). The second is a thin layer of copper, which is an excellent conductor of electricity. The last layer is made up of an insulating, heat resistant substance (example: thermosetting plastics such as epoxy or fibreglass).



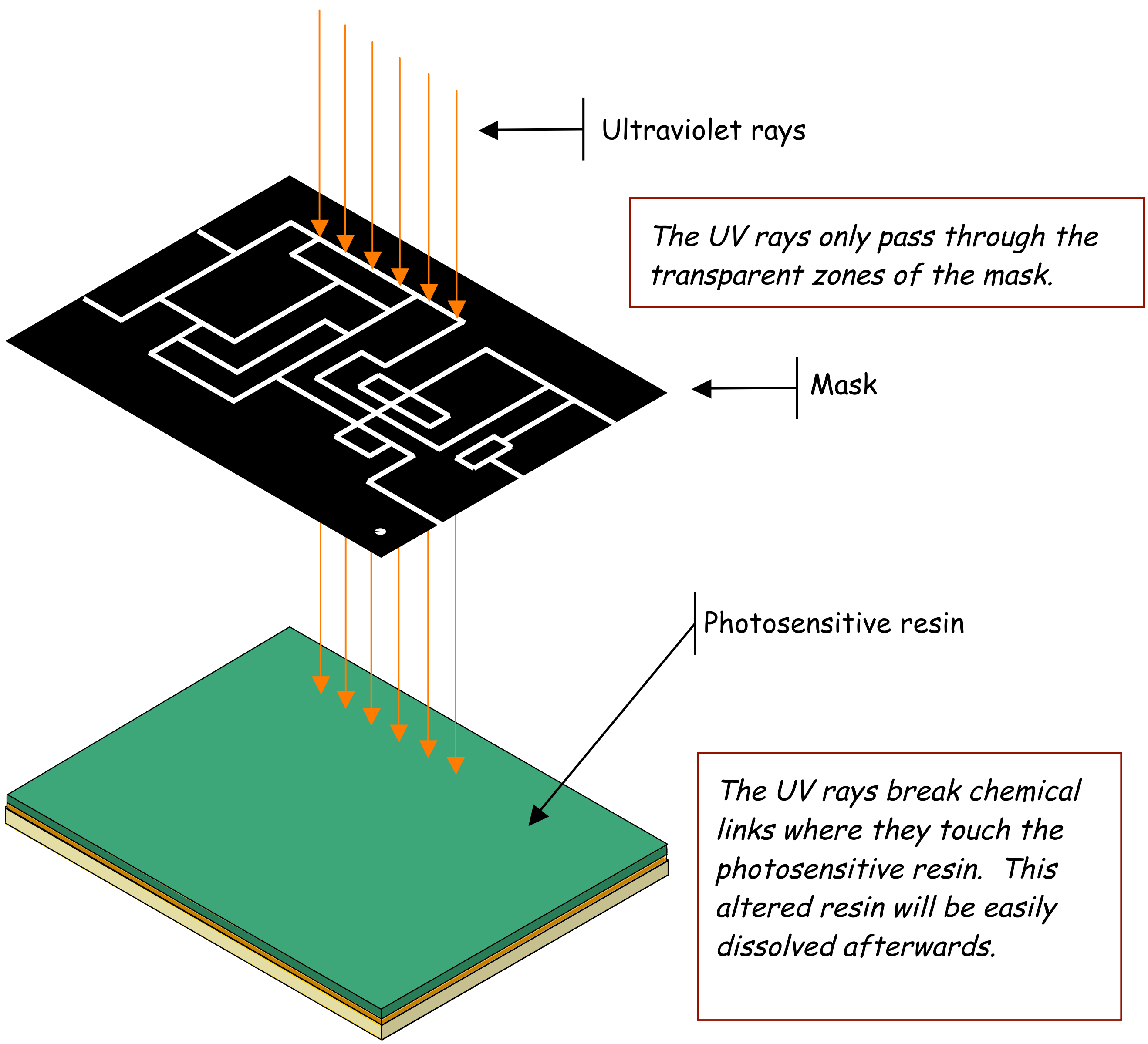
On the following pages, you will find a summary of the process you will use when making your printed circuit plate for the Gaussmeter. The process includes six steps:

1. printing the mask on an acetate (reticle);
2. irradiating the photosensitive resin using ultraviolet rays (UV);
3. dissolving the photosensitive resin exposed to the UV rays;
4. engraving the circuit by withdrawing the copper not protected by the photosensitive resin;
5. baring the copper by withdrawing the rest of the non exposed photosensitive resin;
6. tinning the copper to prevent oxidation and for ease of soldering.

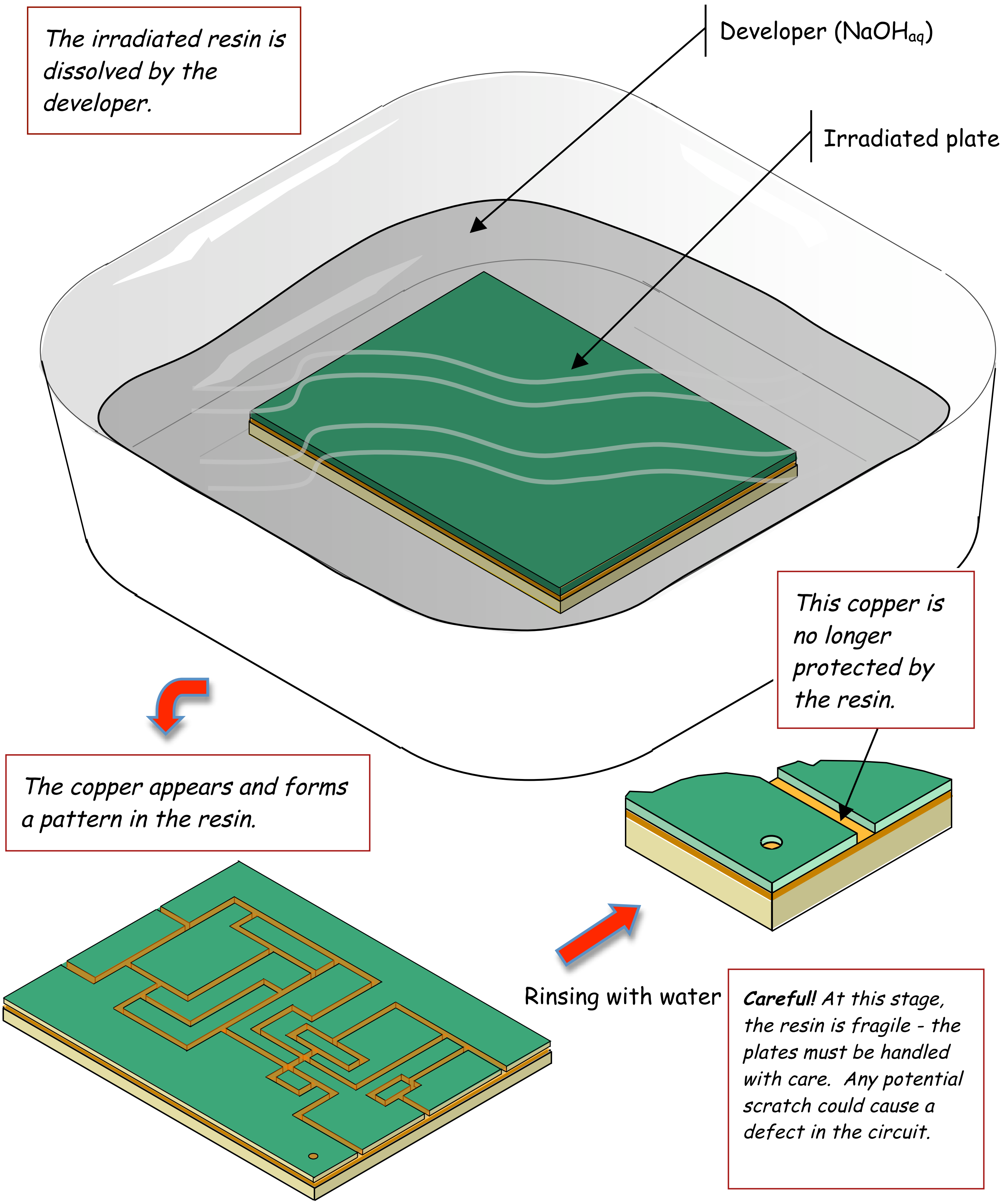
Printing the mask on a transparency (acetate)



Irradiating the photosensitive resin using ultraviolet rays



Developing the plate by dissolving the exposed resin



Engraving the plate by withdrawing the non protected copper

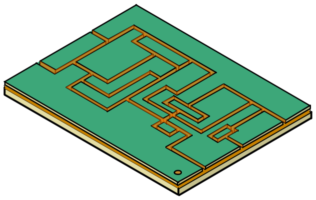
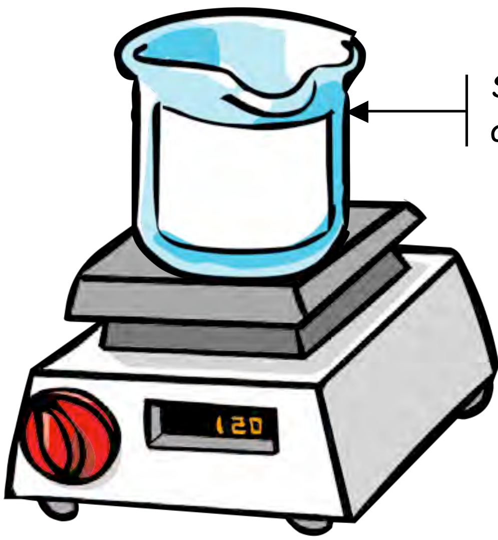


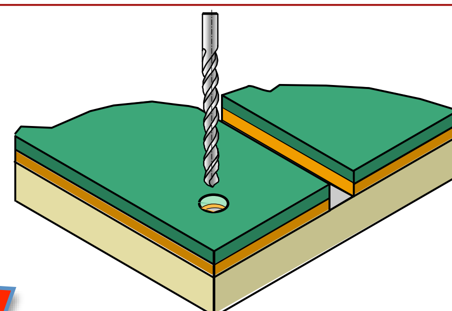
Plate with certain areas where the copper is not protected.

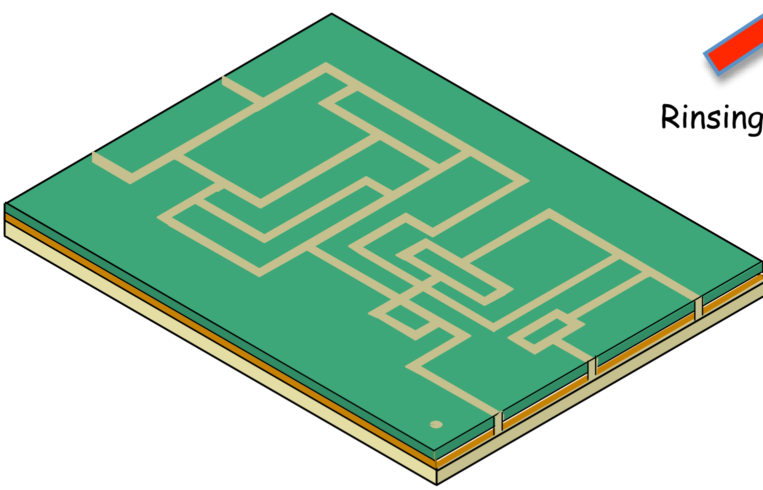


Sodium persulfate solution at 40 °C on an agitating hot plate.

The exposed copper is dissolved and forms insulating borders

Note: *This is the ideal time to drill the holes necessary to affixing the components to the plate (The holes are very visible and the bit will be guided by them). The resin has done its work and can now be removed.*





Rinsing with water

Baring the copper by withdrawing the remaining resin

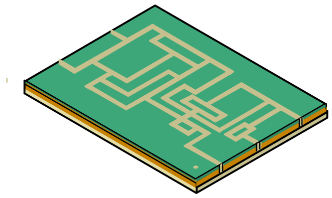
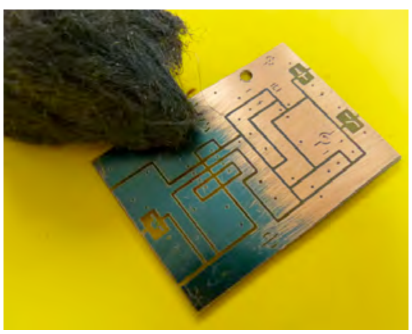
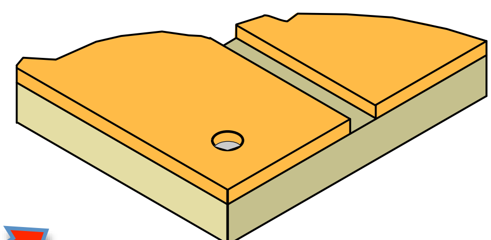


Plate made up of well delimited conductive areas, covered with resin

The resin is completely withdrawn by rubbing with steel wool .



Careful! *At this stage, the copper must remain perfectly clean. You must avoid touching the copper with your fingers, since oils could then contaminate the surface and prevent the tin from depositing at the next step.*



Rinsing with water

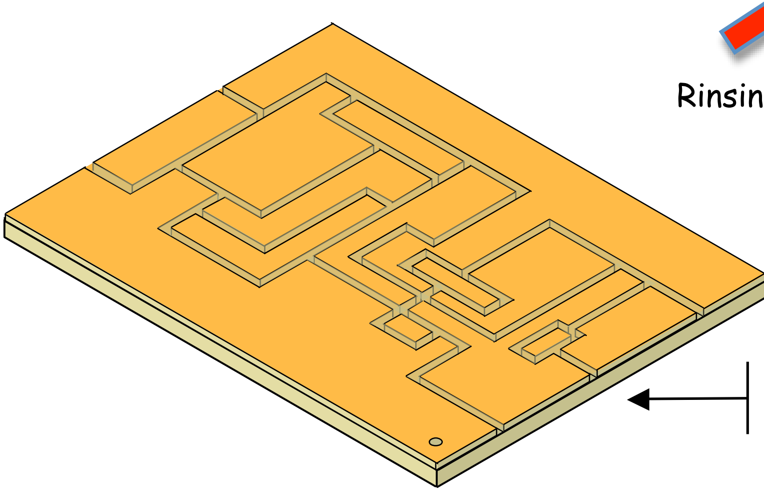
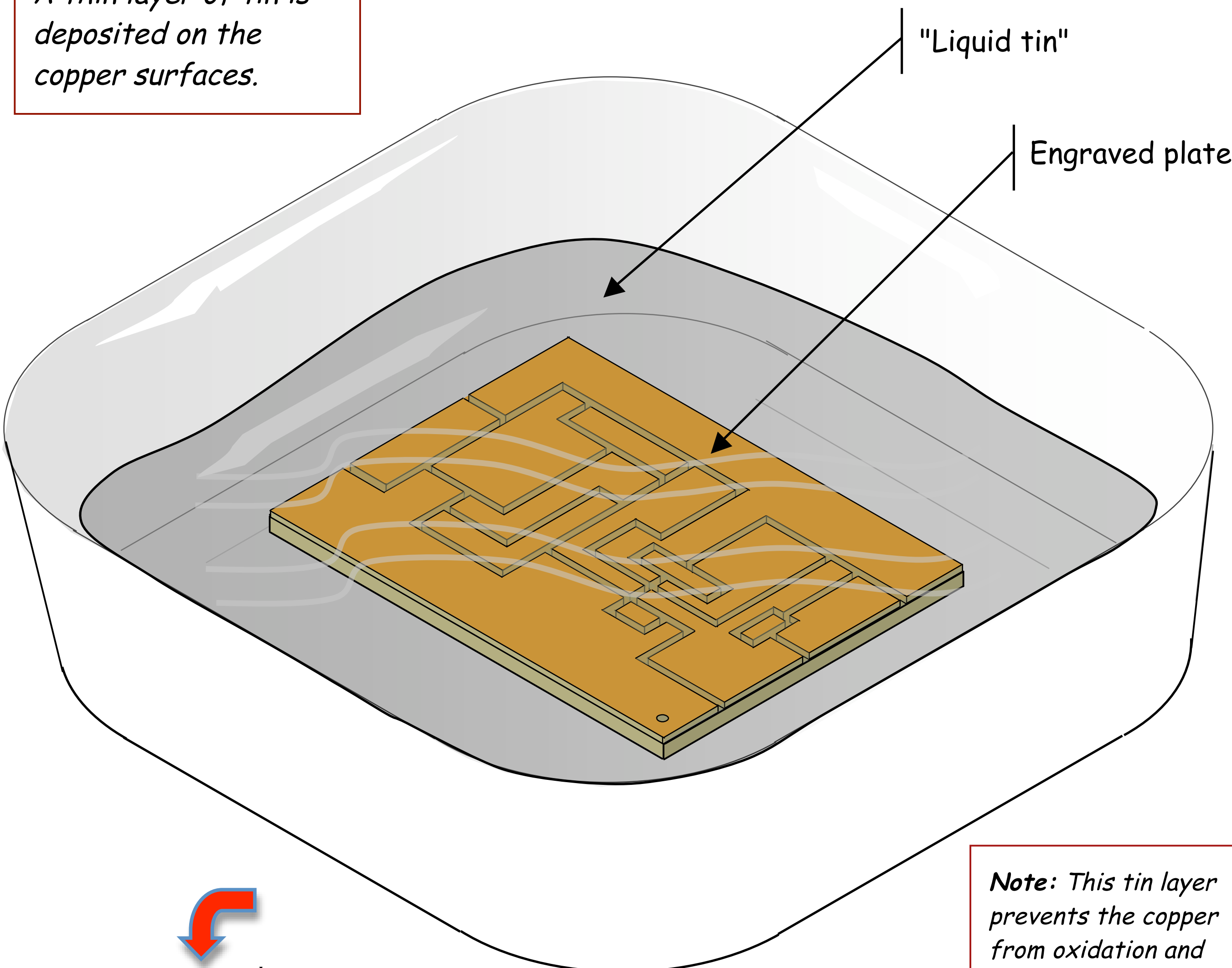


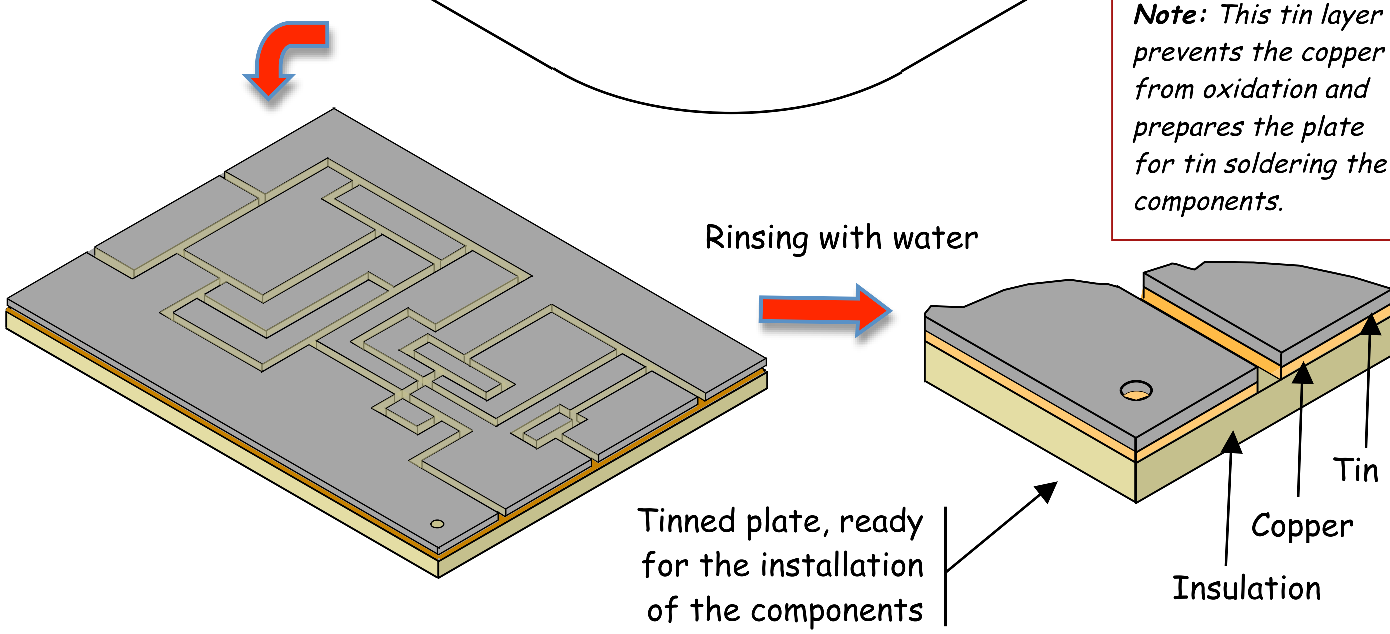
Plate made up of well delimited conductive areas of copper.

Tinning the plate using a "liquid tin" solution

A thin layer of tin is deposited on the copper surfaces.

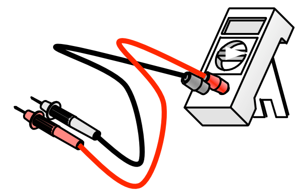


Note: *This tin layer prevents the copper from oxidation and prepares the plate for tin soldering the components.*

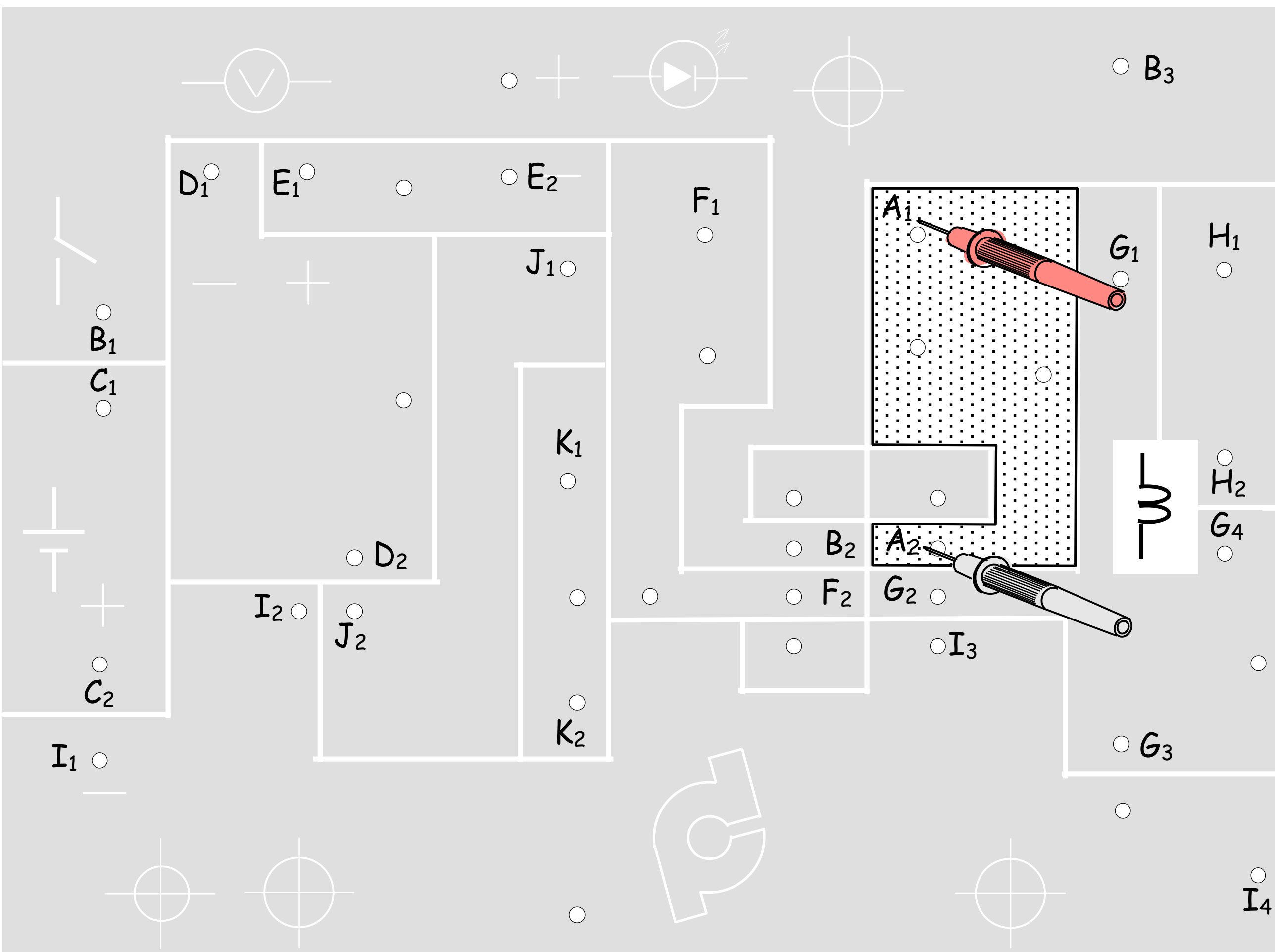


Controlling the state of conductivity of a printed circuit plate

As an example, here is the Gaussmeter's printed circuit. In this drawing, the grey areas are conductive and tinned. The white lines are insulating borders stripped of conductor.

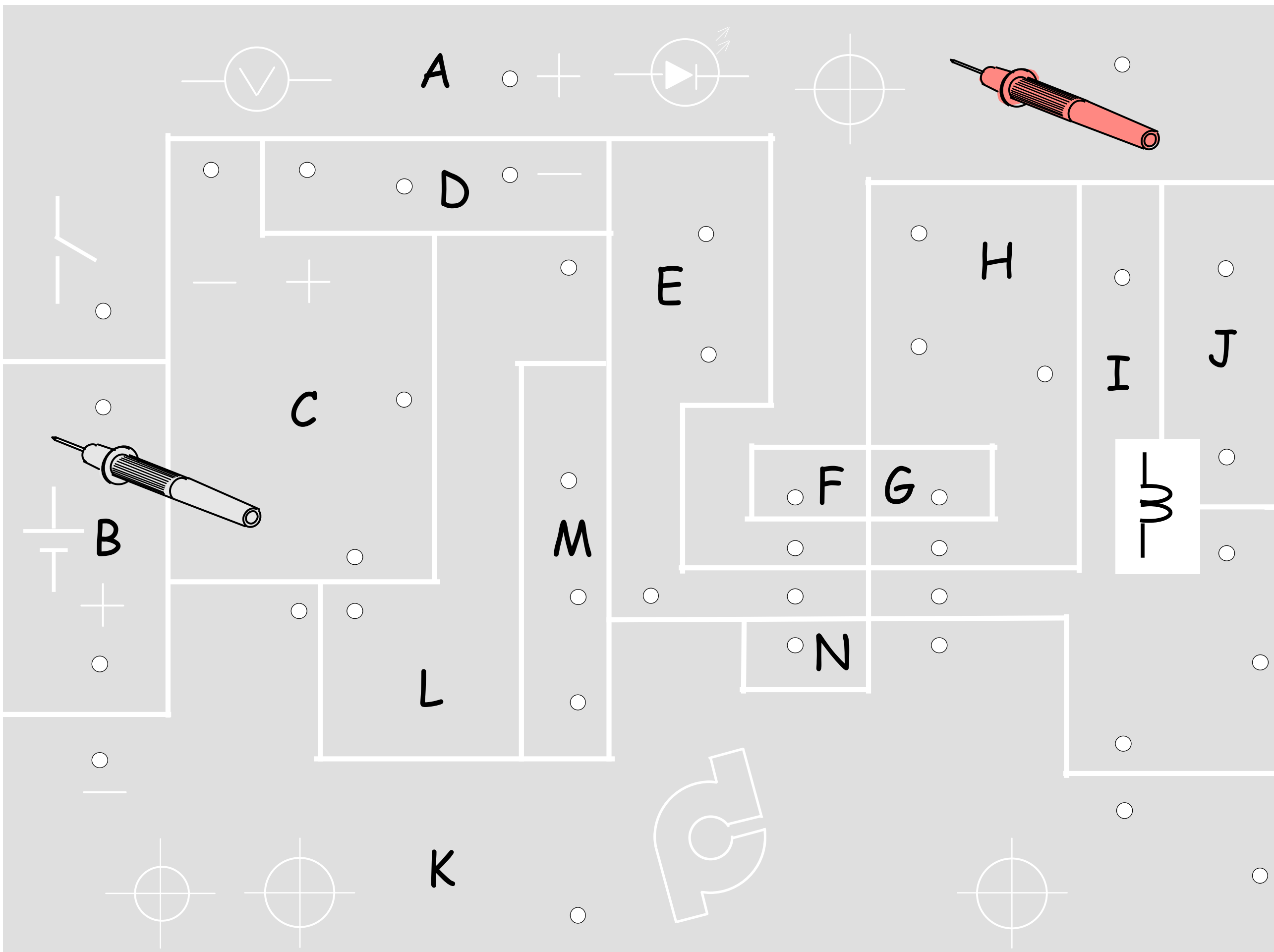


First, we must verify the electrical conductivity of each area. A fabrication defect may arise if the photosensitive resin is scratched before the engraving stage. Let's take textured area "A" below as an example: we need to test the conductivity between two distant points using a multi-meter in conduction mode. If the conductivity is good, we tick the control points in the table below. When the area has a more complex shape, additional measurements are necessary. If there were a defect, a dab of solder may re-establish conduction.



Verification table for good conductivity in each area							
Control points	✔	Control points	✔	Control points	✔	Control points	✔
A_1 to A_2		B_1 to B_2		B_1 to B_3		C_1 to C_2	
D_1 to D_2		E_1 to E_2		F_1 to F_2		G_1 to G_2	
G_1 to G_3		G_1 to G_4		H_1 to H_2		I_1 to I_2	
I_1 to I_3		I_1 to I_4		J_1 to J_2		K_1 to K_2	

Secondly, we need to test if the borders insulate correctly. A fabrication defect may arise when we superimpose the masks or when we print them. This time, we need to check that electrical current does not travel between adjacent areas (see example below between areas **A** and **B**). If the insulation is adequate, we will tick the control points in the table below. If there were a defect, it would be possible to separate the two areas by scratching the borders using the point of a plastics knife.



Verification table for border insulation							
Control points	✓	Control points	✓	Control points	✓	Control points	✓
A and B		A and C		A and D		A and E	
A and F		A and G		A and H		A and I	
A and J		K and B		K and C		K and L	
K and M		K and E		K and N		K and I	
B and C		C and D		C and L		D and L	
D and E		L and E		L and M		M and E	
E and N		E and I		E and H		N and I	
F and G		F and H		G and H		H and I	
I and J							

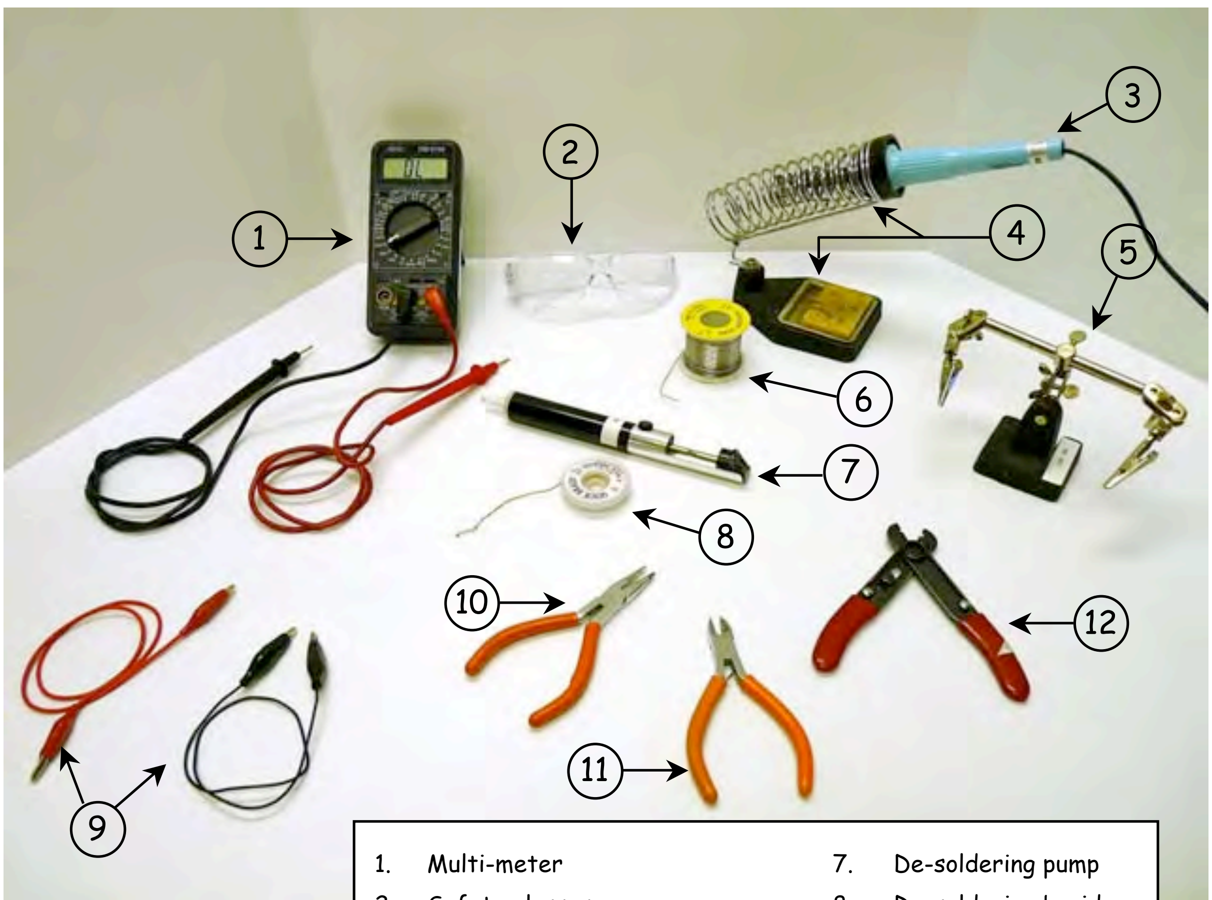
Tin soldering

Tin soldering is based on a few basic principles. Its primary aim is to ensure excellent electrical conductivity between various conductors (metallic electrodes of a component, printed circuit, wire...).

To carry out a perfect solder, you must always keep one thing in mind: **the temperature of the two conductors must be superior to the fusion point of the flux.** To attain the required temperature, we need to promote the transfer of heat from the hot iron to the conductors.

In the case of solders on a printed circuit, we need to verify the state of its conductivity **before placing the components.**

Equipment used for soldering and validation

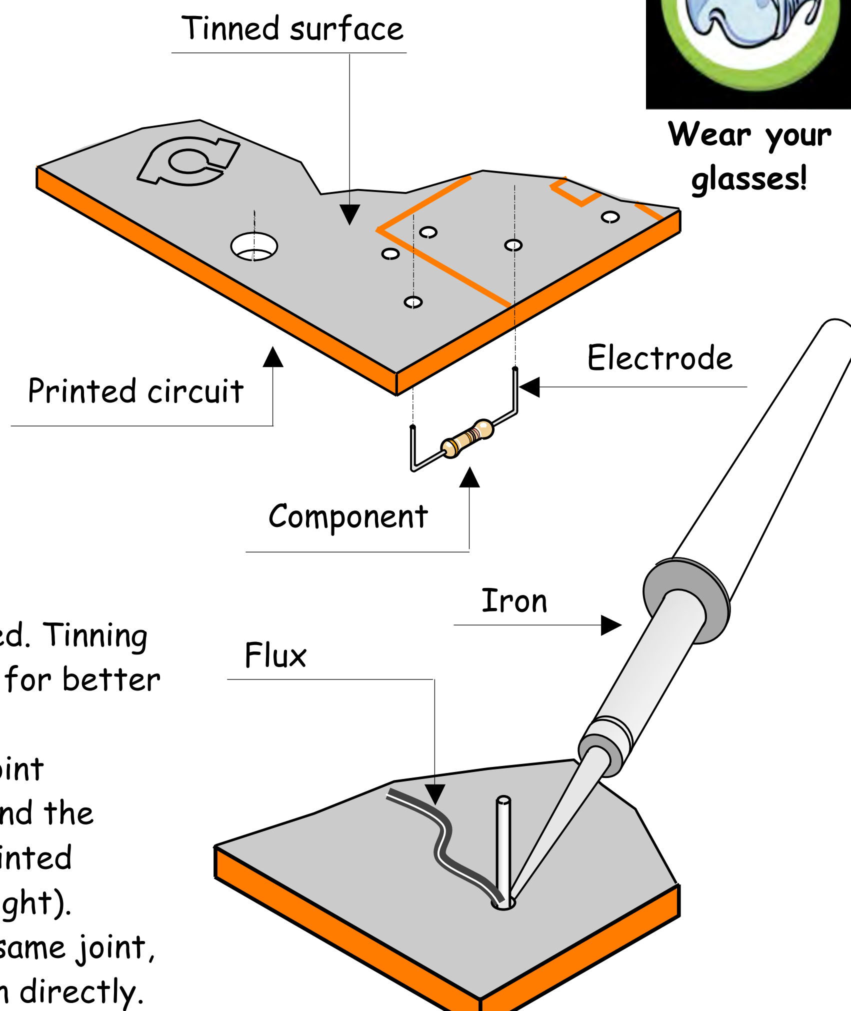


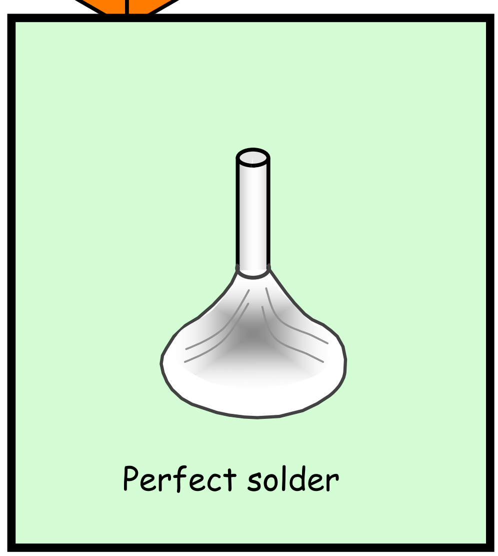
1.	Multi-meter	7.	De-soldering pump
2.	Safety glasses	8.	De-soldering braid
3.	Soldering iron	9.	Alligator clip wires
4.	Iron stand and sponge	10.	Needle nosed pliers
5.	Soldering vise	11.	Wire cutters
6.	Flux (tin)	12.	Wire strippers

How to carry out a good solder

Wear your glasses!

1. Connect the iron and wait (5 to 10 minutes) until it attains its operating temperature.
2. Prepare the component to be soldered by inserting its electrodes into the holes in the circuit (see image at right).
3. Clean the hot iron on a wet sponge.
4. Tin the iron, that is melt a little flux onto it. This liquid tin will increase the contact surface between the iron and the conductors to be soldered. Tinning the soldering iron allows for better thermal conduction.
5. Lean the iron onto the joint between the electrode and the tinned surface of the printed circuit (see drawing at right).
6. Apply the flux onto the same joint, without touching the iron directly. **The flux must melt onto the electrode and onto the tinned surface.** If you don't succeed in doing so, the necessary temperature was not attained and your solder will not be satisfactory.
7. After a satisfactory solder (volcano shaped), cut the electrodes just above the solder. (Cutting in the solder could damage it. Do not twist the electrode after soldering, fissures could appear).

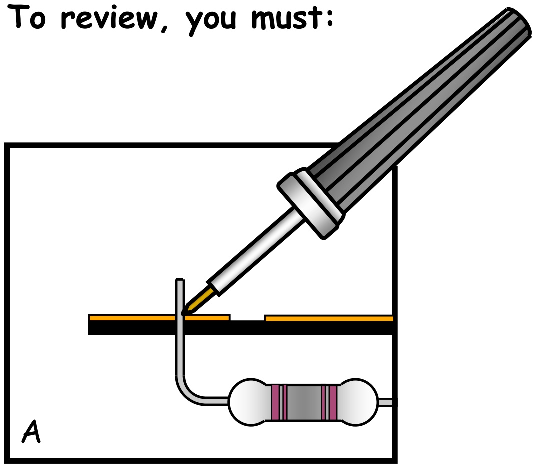




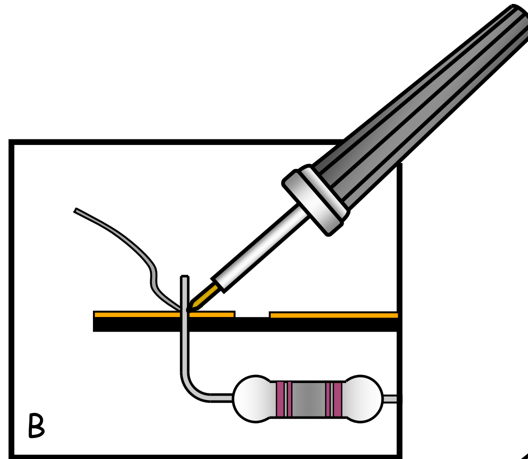
Perfect solder

Here is how the check a solder using a multi meter in conduction mode.

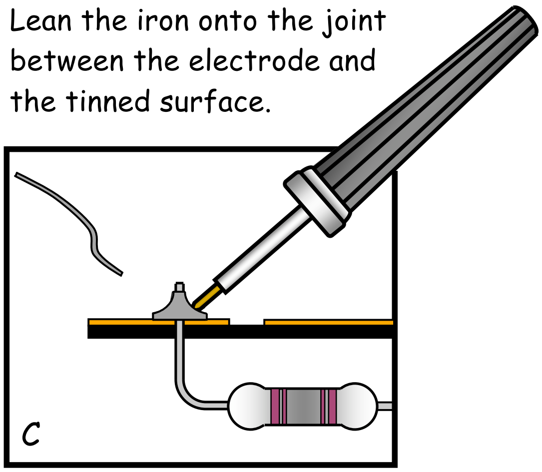
To review, you must:



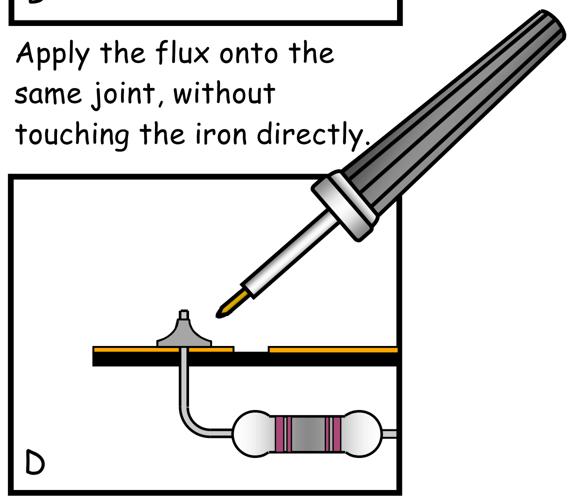
Lean the iron onto the joint between the electrode and the tinned surface.



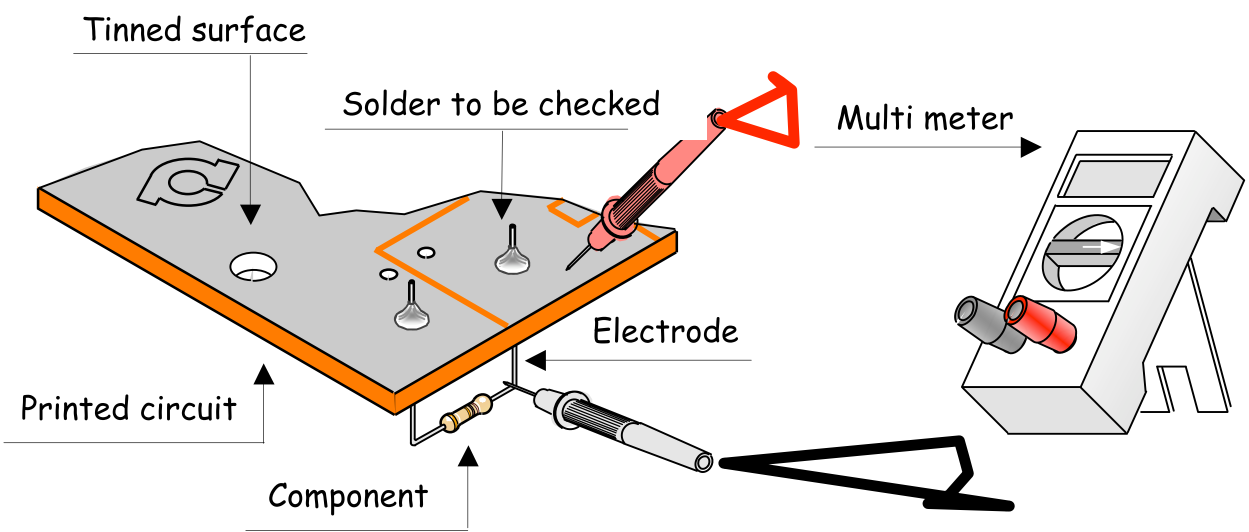
Apply the flux onto the same joint, without touching the iron directly.



The flux melts on the electrode and the tinned surface.

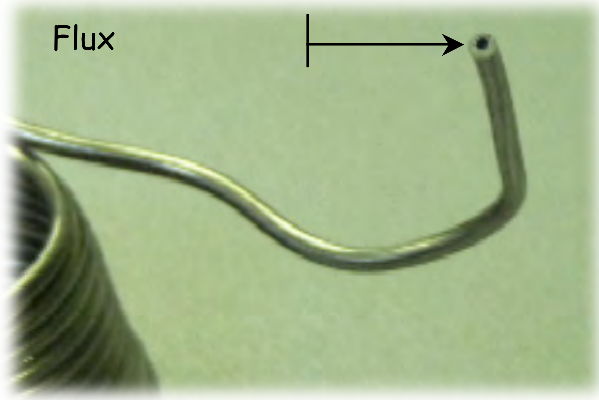


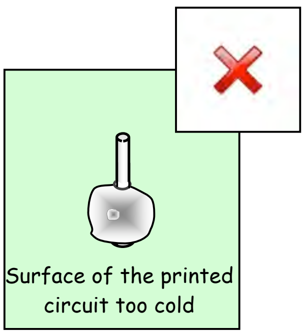
Here is a satisfactory solder (volcano shaped).



Traps to be avoided.

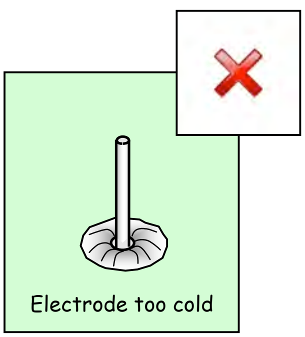
If the solder becomes dull, it is a sign of oxidation (reaction of oxygen with air) due to being heated too long. In this case, the solder will not be of good quality. You will have to heat it again to add flux. The chemical cleaning agent found in the flux will make the oxidised layer disappear.





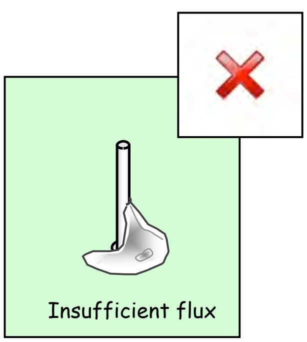
Surface of the printed circuit too cold

In this case, the electrode of the component is good and hot. The tin adheres perfectly to it and forms a ball. There is not, however, any tin on the surface of the printed circuit plate. The surface of the plate was not hot enough.



Electrode too cold

In this case, the surface of the plate was good and hot. The tin adheres perfectly to it and forms a flattened crater. There is not, however, any tin on the electrode of the component. The electrode was not hot enough.



Insufficient flux

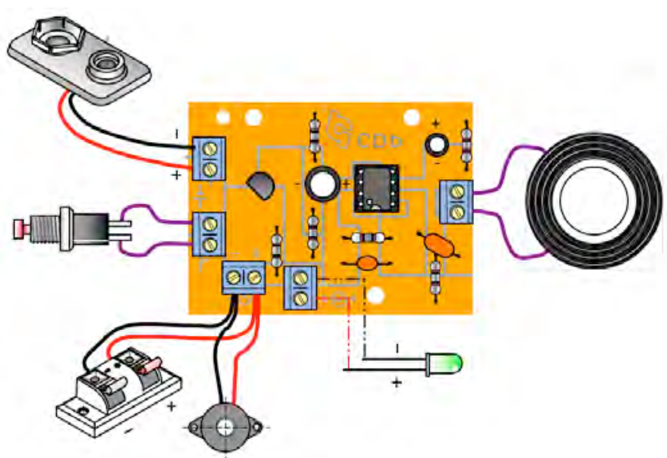
In this case, the tin adheres well both to the plate and to the electrode. This solder will likely be functional, but it may eventually become defective. Since this solder is not as solid as a complete solder, it is subject to cracking, because of vibration for instance.

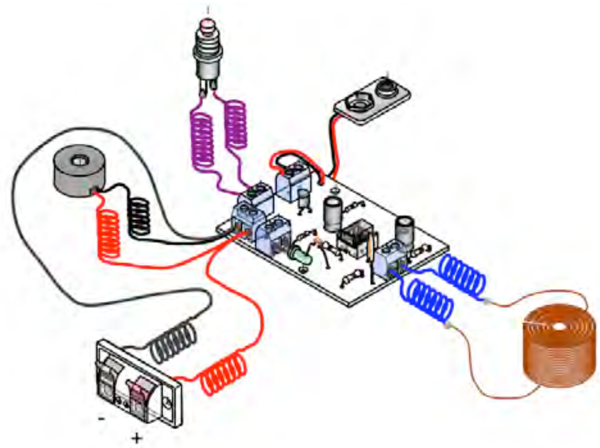
Making the Gaussmeter circuit

Now it's time to make the Gaussmeter circuit. To do so, you will have to carry out various tasks:

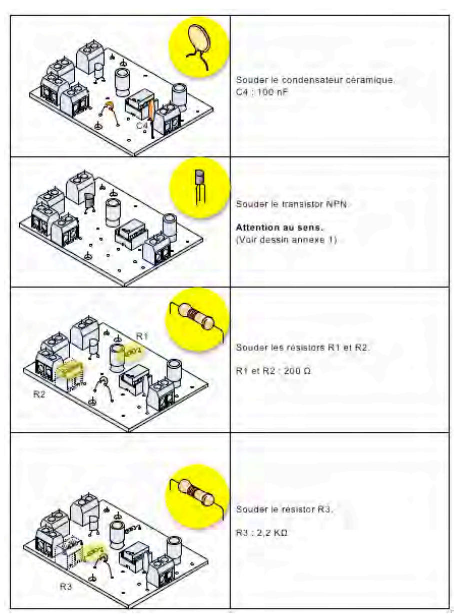
1. Make the printed circuit plate using a manufacturing range and drawings.
2. Make a solenoid. This solenoid will capture the electromagnetic fields by the induction phenomenon seen earlier.
3. Solder the components onto the circuit plate.
4. Connect the external components to the printed circuit.
5. Verify the state of operation of the circuit.

Technical drawings





Fabrication ranges



Specifications booklet for the Gaussmeter housing

Global function

Using the design process described on the following pages, each team must design a housing for the Gaussmeter circuit, while respecting the following parameters.

Please only take into account the items that are not ticked for your design. For those that are ticked, ☑ the necessary choices have already been made.

☑	a)	**) In terms of the *physical aspect*** *(effect the object has on elements from nature: water, air, soil, rays, etc.)* **the housing must:** • be made from materials adapted to normal usage conditions inside a building.
☐	b)	**In terms of the *technical aspect*** *(constraints related to operation: contacts with other technical objects, imposed components),* **the housing must:** • allow the circuit to be disassembled; • allow for the easy replacement of the battery; • allow for a voltmeter to be connected to it; • allow for the installation of a switch; • allow the LED to be visible; • foresee the placement of a piezoelectric warning device; • maximise the induction phenomenon in the solenoid.
☐	c)	**In terms of the *human aspect*** *(security, ergonomics, aesthetics, ethics)* **the housing must:** • allow the usage of the Gaussmeter with a single hand; • not have any sharp edges or pointed elements.
☑	d)	**In terms of the *industrial aspect*** *(production: workshop, tools, labour, manufacturing delays)* **the housing must:** • be carried out with the materials and tools available in the workshop.
☑	e)	**) In terms of the *economic aspect*** *(costing, etc.)* **the housing must:** • be made from simple, affordable elements in order to minimise costs.
☑	f)	**In terms of the *environmental aspect*,** *(impact of the object on the environment: recycling at end of life, lifecycle, etc.)* **the housing must:** • be made from sturdy elements that will ensure durability.

Design of the housing and assembly of the Gaussmeter

1. Outline the problem in terms of the drawings, ranges and specifications booklet.

____

____

____

2. Simmer my ideas (texts and sketches)

3. Evaluate my ideas and choose (justify the choice)

Draw the retained solution on the next page

(Use the elements from Annex 1)

Your choice and its justification

____

____

____

4. Carry out a prototype of the retained solution

<table>
<tr><td colspan="2"> Note all decisions made.

____

____________________</td></tr>
<tr><td>Design and/or construction problems

____
____
____
____________________</td><td>Adjustments or modifications

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____________________</td></tr>
</table>

5. Carry out a test of the Gaussmeter

Evaluate the efficacy and improve the solution

<table>
<tr><td> Tests carried out and results obtained

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____________________</td><td> Improvements

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</table>

Integration and reinvestment

In light of your study of electronics, build a network of concepts related to electronic components. This exercise will allow you to appreciate the path travelled while studying this fascinating world.	**Word bank:** resistor, base, Henry, amplifier, resistance, solenoid, farad, transistor, integrated circuit, LED, NPN, ohm, PNP, diode, inductance, variable resistor, capacity, colour code, ceramic capacitor, emitter, polarised, relay, charge accumulator, induction, chip, collector, turnstile, electrolytic capacitor

Network of concepts

Electronics

Study of the configuration and intensity of electromagnetic fields

Many devices that surround us use alternating current. These devices are apt to emit electromagnetic fields. What is the intensity and configuration of these fields?

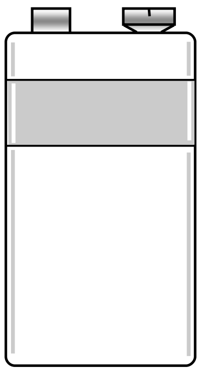
Electrical installations from electricity suppliers such as Hydro Quebec also operate on alternating current. What is the intensity of the electromagnetic fields around these high tension lines? It would also be interesting to study these fields. **Careful, stay away from the restricted zones at these facilities.**

Complete the table below keeping in mind that you will have to make a presentation to present your conclusions.

Device	Gaussmeter voltage (V)	Distance (m)	Note
Facility	**Gaussmeter voltage (V)**	**Distance (m)**	**Note**

Annex 1 (Gaussmeter components)

(Battery, switch, printed circuit warning device and solenoid to be cut out)



Scale 1=1