Chapter 5: Electrical Measurements

1. Measurement in physics:

The International System has seven base units : the meter, the kilogram, the second, the ampere, the kelvin, the mole , and the candela, which are supposed to quantify independent physical quantities. Each unit also has a symbol (in order for the base units: m, kg, s, A, K, mol, and cd). From these base units , derived units are deduced, for example, the International System unit of speed, the meter per second. Some of these units have a specific name. There are also official prefixes to designate units that are multiples and submultiples of a unit. For example, the submultiple of the meter equal to 0.01 m is called a centimeter (symbol cm) since the prefix corresponding to 10^{-2} is centi-. Units of measurement (in physics) are the basis of any qualitative representation of a phenomenon. They make it possible to establish the link between reality and a model by means of a linear measurement scale.

In the table below, the " SI Unit " column gives the unit in the international system which allows the quantity considered to be expressed.

Greatness	Name	Symbol	SI unit
electric current	ampere	HAS	HAS
electric charge	Coulomb	C	Ace
corner	degree	°	rad
temperature	degree Celsius	°C	K
energy	joule	I	kg·m2 /s2
mass	kilogram	kg	kg
volume	liter	L	m³
length	meter	m	m
strength	newton	N	kg.ms-2
magnetic field	Tesla	T	kg.s-2 .A-1
Time	second	s	s
Electrical resistance Ohm		ÿ	Kg.m2.s -3 .A-2
electric potential	volt	V	kg.m².s-3 .A-1
power	watt	W	kg.m².s-3
Conductivity	Siemens/meter	ÿ -1 .m-1 (S. m^{-1})	Kg-1 .m-3.s +3.A+2

2. Uncertainties in measurements

Any measurement of a physical quantity inevitably presents an uncertainty. This results from various errors that can be classified into two broad categories: systematic errors, which always occur in the same direction, and random errors, which vary in magnitude and direction and whose average tends towards zero.

The origin of these errors comes mainly from three factors:

- the experimenter;
- the measuring device (fidelity, sensitivity and accuracy);
- the measurement method.

NB: Measurements made with instruments are never exact. They always contain uncertainties.

It is appropriate to seek to eliminate systematic errors and to evaluate random errors.

- We can try to estimate the uncertainty a priori on a "single" determination, but in based on a good knowledge of the system.
- The overall accuracy of a measurement can be studied from a statistical study.

The second method can be used for interpretation at the group level. It is clear that a statistical study will be of no help in dealing with systematic errors.

2.1 Uncertainty in a direct measurement

a. Absolute uncertainty

It represents the largest absolute value of the error made on a measurement. If g is the result of the measurement G, the absolute uncertainty will be noted ÿg. We will write:

G = g ÿ ÿg Or g - ÿg ÿ G ÿ g + ÿg.

b. Relative uncertainty (uncertainty rate)

We want to compare the precision of two measurements; for this we consider the quantity ÿg / g. The lower this ratio, the more precise the measurement. It is often expressed as a %.

2.2 Uncertainty on a calculated quantity

Most often, we want to determine a quantity G which depends on measurable quantities X, Y, ... We then have a relation g = f(x, y,...) and we need to determine g knowing f(x, y,...), x, y, ÿx, ÿy,... We can achieve this quite easily by only considering the first-order variations, an acceptable approximation if ÿx, ÿy,... are small compared to x, y,..., and using differential calculus. There are two simple rules to implement and easy to demonstrate: the relative uncertainties (in %) of the two factors of a multiplication or a division are added, the absolute uncertainties of the two terms of a sum or a product are added.

Subsequently, for simplicity, we will consider a quantity G whose value g depends on the two measurements x and y assumed to be independent; f(x, y) is then assumed to be an exact total differential, hence:

$$dg \;\text{ÿ}\; \left(\frac{\text{ÿ}g}{\text{ÿ}x}\right)_y dx \;\text{ÿ}\; \left(\frac{\text{ÿ}g}{\text{ÿ}y}\right)_x dy$$

The transition to absolute uncertainty consists of taking the sum of the absolute values:

$$\text{ÿ}g \;\text{ÿ}\; \left|\frac{\text{ÿ}g}{\text{ÿ}x}\right|_y \text{ÿ}x \;\text{ÿ}\; \left|\frac{\text{ÿ}g}{\text{ÿ}y}\right|_x \text{ÿ}y$$

Some examples:

g = A x + B y	dg = A dx + B dy	ÿg = A ÿx + B ÿy.
g = A x - B y	dg = A dx - B dy	ÿg = A ÿx + B ÿy.

3. Presentation of results

An estimate of the uncertainties leads us to limit the number of figures significant when announcing the result of an experimental determination. The last figure given must be the first to be affected by error.

Examples:

- A length of 1 meter measured to the nearest millimeter should be written: L = 1.000 m.
- A volume of 30 milliliters measured to the nearest tenth of a milliliter will be written: V = 30.0 m ÿ.

If the result of a numerical calculation provides, for example, a value of 11.848 Volts with an absolute uncertainty of 0.17 Volts, we will write it: V = 12 Volts to within 0.02 Volts.

1. **Precision of a measuring device :** (or **accuracy) :** + small relative difference between 2 consecutive measures ÿG/G. Decimal level.

2. **Range of a device :** maximum measurement of which the device is capable.

3. **Sensitivity of a device :** ability to detect and amplify small variations in a physical quantity. Sensitivity of an instrument in a measurement area rather than in another one.

4. Measuring devices and their use

To work on an existing installation, you should obtain a measuring device. The most common tests are performed using a multimeter. This allows you to measure voltage, current, resistance, continuity, etc.

There's no point investing in a highly sophisticated device if you only occasionally work on your system. Always choose a model with a built-in fuse that protects the device in case of mishandling. Lower-end devices often lack this.

Caution! Be very careful when performing certain measurements under voltage.
Hold the test leads by their insulated ends. Never unplug the leads while they are being measured. Always move away from the live source before handling the measuring device.

4.1 Measuring devices

There are analog multimeters, i.e., those with a dial and a needle, and digital multimeters where the results appear on a liquid crystal display (Figure 5.1). Analog multimeters require more handling but are generally less expensive. The reading is less accurate than on a digital device, but sufficient for a domestic installation.

Digital multimeters are accurate and provide direct readings of values.

Multimeters are not recommended for high current measurements (0A maximum). In this case, a device called a current clamp is used. Simply pass the clamp around a conductor to determine the current flowing through it. It is not necessary to strip the conductor. The most advanced models can measure multi-conductor cables.

Some multimeters come with an optional current clamp that plugs into the test leads.

4.2 Measuring values

Before placing the measuring probes on the elements to be tested, you must know what you want to measure. To measure voltage, set the device to voltmeter mode. To measure current, set the device to ammeter mode.

Resistance and continuity are measured in ohmmeter mode, always with the power off. Voltage and current measurements are made on a live circuit.

a. Measuring a voltage

First, place the cord plugs in the appropriate terminal blocks. Typically, one cord is placed on the common and the other on the V symbol or a voltage value (300V, 1000V). Set the unit of measurement selector to AC or DC volts.

Place the test probes in parallel across the terminals of the device or item to be measured. The value appearing on the dial indicates the voltage between the terminals in volts.

With an analog multimeter, if you do not know the order of magnitude of the voltage to be measured, always start by measuring with the lead placed on the 1000V terminal, then change the scale if necessary.

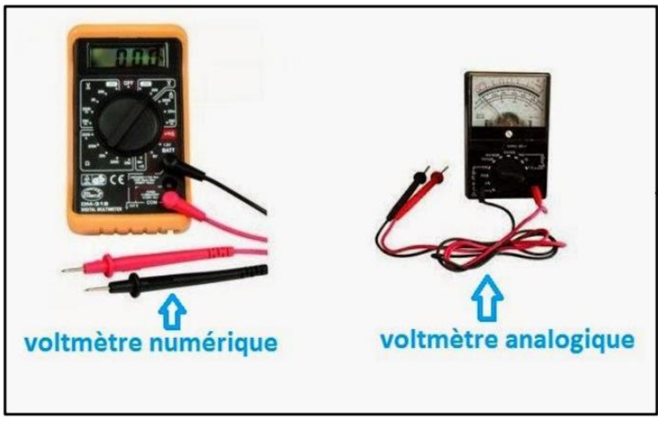
b. The measurement of an intensity

Measuring the current in an electrical circuit with a multimeter is difficult to achieve in domestic installations. Indeed, the measuring device must be placed in series with the device whose current you wish to measure. For safety reasons, always use a current clamp.

Digital multimeters are very practical: they require little handling and offer direct readings. They are sometimes even too precise for measurements to be made on an electrical installation.

Analog multimeters are built using older technology. Measurements are read by the position of the needle on a dial. This type of device requires more handling than a digital model. However, it is less expensive. It is sufficient for testing an electrical installation.

Multimeters can perform a wide range of measurements: AC or DC voltage, AC or DC current, resistance, and many other measurements, depending on the model. Always choose a model with an internal fuse to prevent damage to the device if mishandled.



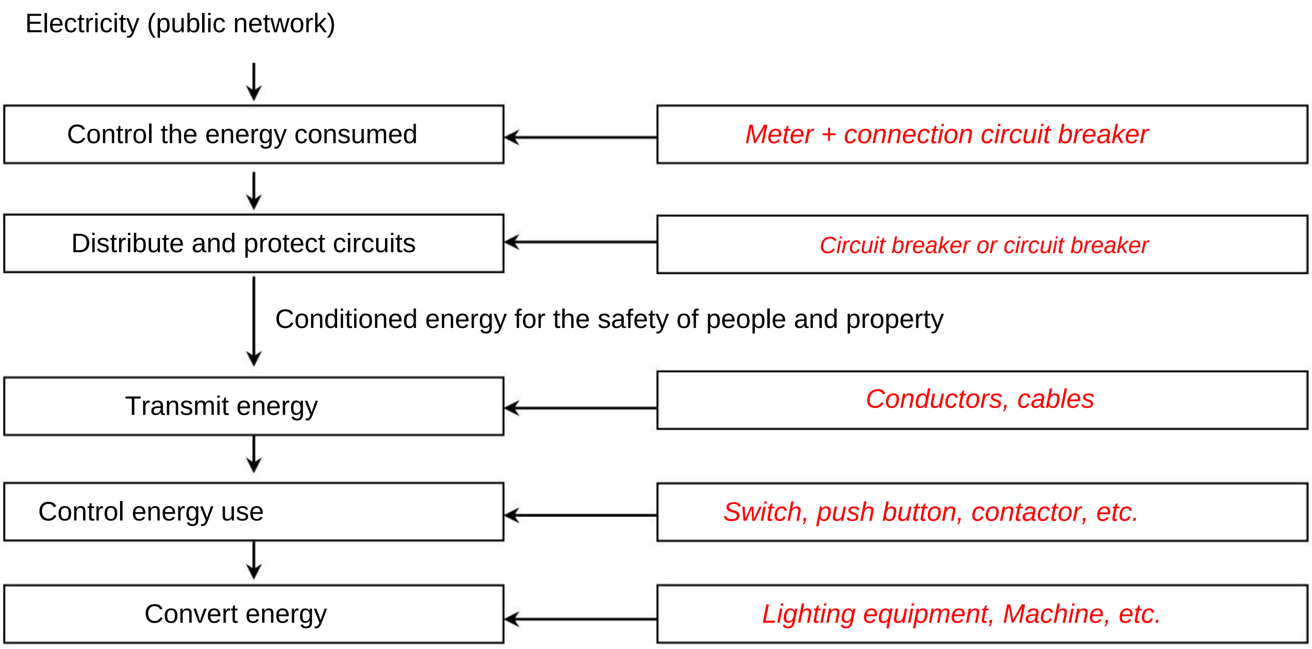
A voltmeter: a device of indication used to measure voltage. There are two types of voltmeters most commonly used: digital voltmeters and analog voltmeters.

Types of ammeters:

An ammeter (possibly): an indicator device used to give the order of magnitude of the current.

		
Ampèremètre numérique	Ampèremètres analogiques	Ampèremètres spéciaux

5. Wiring diagram of an electrical installation



To carry out a good electrical installation, you must:

1. Use equipment that is best suited to our needs.
2. Respect the rules and standards in force.

5.1 Some practical advice

- In all cases, respect the conductor sections - Also respect the wire colors
- When the conduits are in place, pass all the wires first. The connections will be made later

- Leave the wires protruding in the boxes and other devices by about 5 to 10 cm
- The screw terminals must be properly tightened, in order to avoid any risk of poor contact and therefore overheating.
- Use the appropriate tools in all cases - Mark the wires on the diagram as you make connections - Check the assembly carefully after completion, and then have it checked.

And also think about whoever comes after you at the workplace.

5.2 Calculation of wire section

a. Cables

Choosing the right cables means respecting the standardized colors according to the type of driver and use the sections adapted to the different types of circuit (lighting, socket).

b. Colors

Green and
yellow exclusively: earth

Light blue
only: neutral

Red (or black for multi-wire cables):
phase

New NFC 15-100 standard
All circuits without exception must be equipped with an earth conductor, including lighting circuits.

c. ***Conductor section***

CABLE RATING TABLE

Cable Cross Sectional Area (mm^2)	Typical Current Rating (amps)	Recommended Circuit Breaker Rating (amps)
1.5 mm^2	7.9 - 15.9A	8A
2.5 mm^2	15.9 - 22A	15A
4 mm^2	22 - 30A	20A
6 mm^2	30 - 39A	30A
10 mm^2	39 - 54A	40A
16 mm^2	54 - 72A	60A
25 mm^2	71 - 93A	80A
50 mm^2	117 - 147A	125A
70 mm^2	147 - 180A	150A
95 mm^2	180 - 216A	200A
120 mm^2	216 - 250A	225A
150 mm^2	250 - 287A	275A
185 mm^2	287 - 334A	300A
240 mm^2	334 - 400A	350A