Tracking down “energy hogs”

1 Basic physics principles

1.1 Conventional electricity meter

In a conventional electricity meter, electric current flows through coils past an aluminum disk. This flow of current induces eddy currents in the aluminum disk that generate torque. The disk rotates at a speed that is proportional to the voltage and current. The meter is therefore a practically loss-free electric motor connected in parallel to the power supply grid with negligibly small power output. The number of rotations is a measure of the energy consumption and can be read off via a mechanical counter mechanism calibrated in Ws or kWh.
Referring to the “consumption” of energy is actually incorrect because according to the law of conservation of energy, energy can only be converted. In a closed system, energy is neither lost nor is new energy gained. However, because the term “energy consumption” has found its way into colloquial and commercial language, it is also used here.

1.2 Digital ammeters

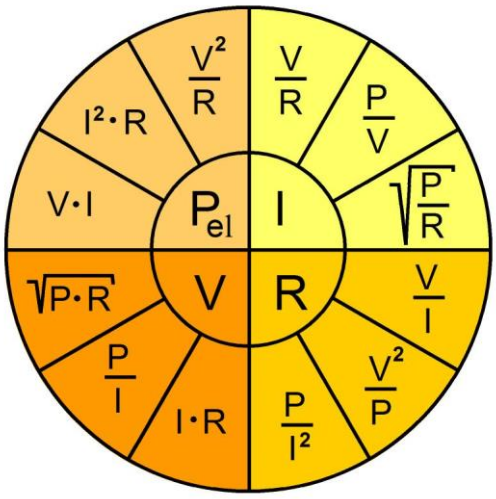
Digital ammeters such as are used in this experiment measure direct current, voltage, and time and calculate the energy from this.

1.3 Students’ prior knowledge

Students need to be familiar with and understand the following formulas.

Electric power	P_{el} = voltage · current = V · I [VA = watt]
Electrical energy or work	$E_{el} = W_{el}$ = voltage · current · time = V · I · t [Ws]

The illustration at the right provides an overview of other interrelationships between the quantities current (I) measured in amperes (A), voltage (V) measured in volts (V), ohmic resistance (R) measured in ohms (Ω), and electric power (P_{el}) in watts (W).



2 Ideas for teaching

2.1 Learning objectives

The students will:

- come to understand how ammeters function.
- be able to estimate the power consumption of everyday objects.
- develop ideas for reducing their own power consumption.

2.2 Possible teaching plan

Students could be introduced to the concept of power measurement by means of the conventional "electricity meter." This type of meter should be familiar to the students, so it offers a suitable introduction to the topic. Depending on the amount of time that can be scheduled for this topic, the students should investigate how various ammeters function. In any case, how the digital ammeters used in the experiment work should be discussed. Depending on the curriculum and grade, reference could be made to the problem of the precise determination of the root mean square (rms) values in the case of alternating current.
At the beginning of the teaching unit, the class is shown how the digital ammeters work. The teacher can demonstrate this part of the lesson. The class as a whole should enter the measured values in the table.
As soon as it has become absolutely clear to the students how power consumption is measured, they can measure the available devices in pairs or in groups.

2.3 Motivation

The clear relevance to everyday life provides a good introduction to the topic. The students' interest can be piqued for economic reasons (key phrase: "saving money") and ecological reasons (key phrase: "protecting the environment").
The topic of energy conservation is also ubiquitous in the media and in current discussions (key phrase: "energy transition"). The students should also be encouraged to examine this topic outside of school.
It is particularly important to point out to the students that they can make their own contribution. The precise extent of their contribution will be quantitatively determined in the course of this sequence of lessons.

2.4 Possibilities for variation

The students can determine the power consumption of their own devices at home by at least reading the manufacturers' data. Students who are particularly interested could borrow the school's ammeters to conduct the measurements.
It is also possible to research the power consumption of devices that are not present in the home.

3 Notes on conducting the experiment

3.1 Facilities

This experiment can be conducted in any classroom. If necessary, students should bring in suitable devices from home or the teacher must provide them.

3.2 Time required

It is best to divide the class into groups according to the number of devices and have the groups measure their device in turn. Including the water boiling experiment using three different devices, **about 90 minutes** are needed for 16 devices. Alternatively, the class can jointly conduct just the water boiling experiment, and the students can measure the other devices individually at home. The analysis would then be carried out jointly with all students in a teaching period.

3.3 Safety aspects

The experiment should be conducted at school only under teacher supervision. The applicable safety guidelines for your school must be observed. The teacher should point out to the students that the provided materials may be used only according to the respective instructions.
Observe the applicable safety guidelines for your school concerning the use of electrical devices and electricity.
If parts of the experiment are conducted at home, the students should be reminded to work carefully with electricity (120 V to 220 V, depending on the country) and the electrical devices. If the school's ammeters are borrowed, the students should be reminded to handle these devices carefully.

3.4 Apparatus and materials

- 1 desktop PC
- 1 digital electric power consumption meter
- 1 television
- 1 hotplate
- 1 immersion heater
- 1 pot
- 1 electric kettle
- Water
- Optional: stereo system, notebook, charger (for smartphone, tablet, or notebook)

Ammeter requirements: It is important that the energy consumption be displayed with a resolution in Ws (watt seconds). Many devices show kWh (kilowatt hours) only with a resolution of 100 Ws, which is not adequate, for example, for measuring consumption of stand-by electronic systems over reasonable periods.