

Title: Physics in the kitchen

Topics: Temperature measurements, efficiency	Time: 90 Minutes	Age: 13-16
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Differentiation:

Guidelines, ICT support etc.:

If possible, use a thermal imager – images can be displayed on the PC and the data -projector.

Equipment needed for this activity:

Induction cooker, electric cooker, electric kettle, water, oil, pots, Pyrex, protective equipment, stopwatch, thermometer, thermal imager

Required knowledge:

Ph – temperature, energy – units,
M - expressions

Health and Safety:

Working with hot items, cookers

Learning outcomes for this activity:

All

- Students can explain the data on the label
- Students do percent calculation

Most

- Students can solve numerous problems listed.
- Students carry out laboratory tasks

Some

- Pupils compare the effectiveness of different sources of heat, draws graphs and histograms.

Lesson description

Motivation

Equipment of the 21st century household. What would be our kitchen without electricity?

The main activity

Students work with energy labels; find out the price of energy by using the Internet.

Students carry out the laboratory work.

Final activity

Students discuss the efficiency of heating liquids on various types of cookers, study the gradual heating of liquids using a thermal imaging camera.

Motivation





1. Compare the kitchen in figure 1 and the kitchen in figure 2 !
2. Make a list of the appliances that you have in the kitchen. Determine which of them are equipped with energy labels.

Task 1: What do the details on refrigerator energy label say?

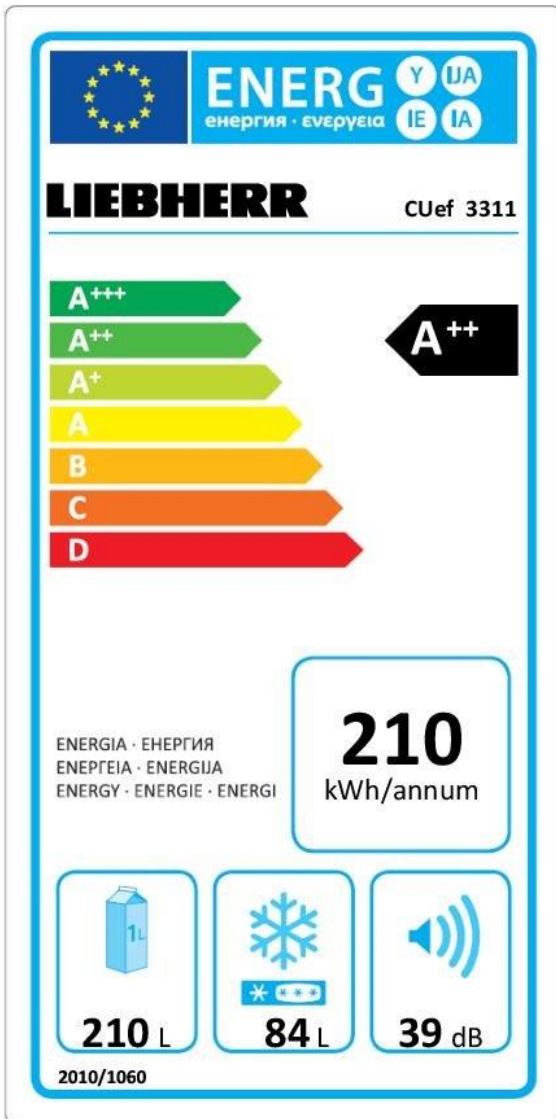
The appliance is classified by the efficiency index. It characterizes the energy consumption per litre of the appliance in comparison with the useful output..

Consumption is derived under ideal operational conditions - ambient temperature of 20 ° C and filling the refrigerator usable space at 70%. Currently manufactured are only refrigerators class A or higher.

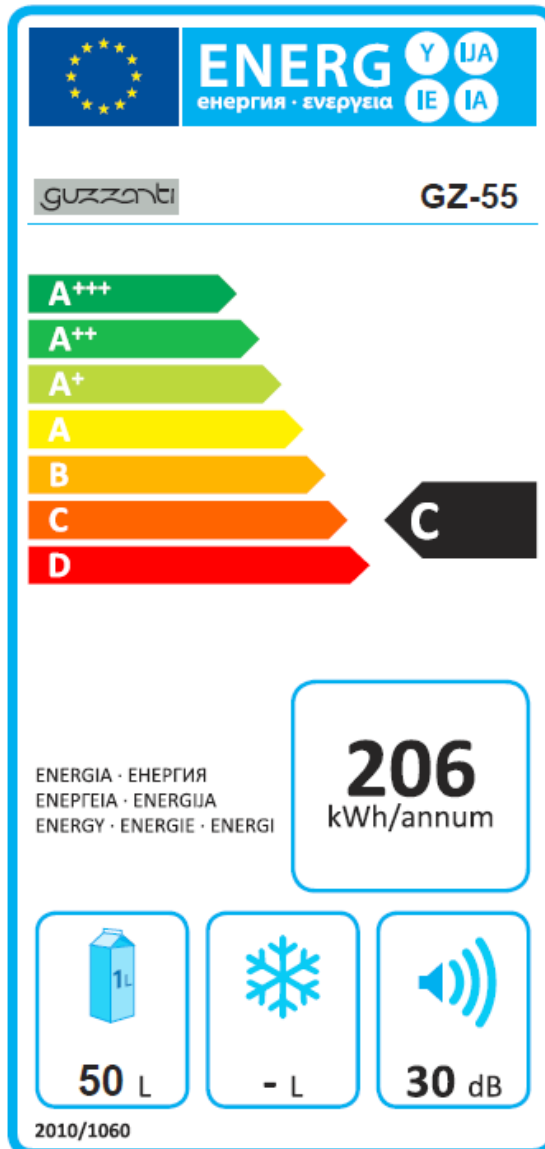
The energy label

- a) Refrigerator with a freezer
- b) refrigerator

Compare the two items!



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Learn more about energy labels at
https://en.wikipedia.org/wiki/European_Union_energy_label

Physics and energy consumption

To find the quality (efficiency) of machines we should determine their effectiveness. To operate a machine needs more power supply than is required for the performance because it has to overcome the effect of resistive forces. The efficiency of the device is determined as the ratio of the supplied power (consumption) and performance conducted

Efficiency is always less than one, is given in percentage.

Example 1:

To heat 2 litres of water from 10 °C to 100 °C we need an energy of 600 000 J. How long will it take to boil water in a kettle with 2000 Watt consumption and 85% efficiency?

Write:

$$P_p = 2000 \text{ W}$$

$$W = 600\,000 \text{ J}$$

$$\eta = 0.85$$

$$\tau = ? \text{ s}$$

$$t_1 = 10 \text{ °C}$$

$$t_2 = 100 \text{ °C}$$

Efficiency = useful power output/total power input

$$\text{Output } P = \frac{W}{\tau}$$

W ...work (J), τ ...time (s)

$$\tau = \frac{W}{P} = \frac{W}{\eta \cdot P_p}$$

P_p ... input (W), η ... efficiency

$$\tau = \frac{600000}{0,85 \cdot 2000} = 353$$

$$\tau = 353 \text{ s} = 5.9 \text{ min}$$

(Information about the water temperature in this example is redundant.)

Laboratory work

Equipment needed for this activity:

Induction cooker, electric cooker, electric kettle, gas cooker, water, oil, pots, Pyrex, protective equipment, stopwatch, thermometer, thermal imager

Tasks:

1. Compare the efficiency of heating a certain amount of water on different types of cookers.
2. Calculate in CZK (EUR) the cost of energy required for heating.

Progress of work:

Task 1 Compare the efficiency of heating a certain amount of water on different types of cookers.

The selected amount of water for heating is 0.5 litre = 500 ml

- a) Gradually heat 500 ml of water in an ordinary pot with a lid and in the same pot without a lid on a gas stove.
- b) Heat in the same pot 500 ml of water on the electric stove - with and without lid.
- c) Compare the boiling time with or without the lid on the same source of heat.
- d) Calculate the energy consumed in each case.
- e) Calculate energy saving in case of using the lid in percent.
- f) Calculate the necessary energy costs in CZK (EUR).

Data you need to put in your worksheet:

Weight of water - m (kg)

Initial water temperature - t_0 (°C)

The resulting water temperature - t (°C)

Specific heat capacity of water - $c = 4180 \text{ J} \cdot \text{kg} \cdot \text{K}^{-1}$

Calculation of heat needed to heat the water - Q (J) $Q = mc(t - t_0)$

(formula, result)

Power of cookers - P_0 (nominal value indicated on the appliance) (W)

Heating time - τ (s)

Calculation of the total energy supplied during the heating - $W = P_0 \tau$ (J)

(formula, result)

Calculation of cookers efficiency - η (%) $\eta = (Q / W) \cdot 100\%$

Additional task:

Measure the temperature rise in fixed time intervals (e.g., after 30 seconds). The measured temperature fill in a table and draw a graph of the increase in water temperature over time.

Time (s)	0	30	60	90	120	150	180
Water temperature (°C)							

Graph (use the software Excel)

Examples of measured values:

Measuring the efficiency of electric water heating stoves

Water weight - m 0.55 kg

Initial water temperature - t_0 25 ° C

The resulting water temperature - t 90 ° C

Specific heat capacity of water - c 4180 J·kg·K⁻¹

Calculation of heat needed to heat the water - Q

(formula, result) $Q = mc (t - t_0) \approx 149435$ J

Power induction cookers - P_0 2200 W

The heating time - τ 128 s

Calculation of the total energy supplied during the heating - E $W = P_0 \tau \approx 281600$ J

(formula result)

Calculation of cookers efficiency - η

(formula result)

$$\eta = (Q / W) \cdot 100\% \approx 53\%$$

Task 2: Calculate in CZK the cost of energy required for heating

Progress of work:

Find the unit price of gas and electricity unit on Internet.

For example:

Gas - price per unit 11.00 CZK / m³

Electricity - price per unit 3.50 CZK / kWh

The outcome of task 2 summarize in a table. Compare the prize of the energy.

Task 3 – Work out a summary table

Gas

Pot with (without) lid:

Heating time

Energy needed to heat up water to the boiling point

Cost of energy required for heating water to the boiling point

Saving on heating to the point with lid

Saving on heating to the point with lid - percentage

Electricity

Pot with (without) lid:

Heating time

Energy needed to heat up water to boiling point

Cost of energy required for heating water to the boiling point

Saving on heating to the point with lid

Saving on heating to the point with lid - Percentage

Induction cooker

Pot with (without) lid:

Heating time

Energy needed to heat up water to the boiling point

Cost of energy required for heating water to the boiling point

Saving on heating to the point with lid

Saving on heating to the point with lid - percentage

Example - table supplemented with data

Gas

numerical value of the unit

Pot with lid:

Heating time

245 s

Energy needed to heat up water to the boiling point

0.012 m³

Cost of energy required for heating water to the boiling point

0.13 CZK

Pot without lid:

Heating time 285 s

Energy needed to heat up water to the boiling point

0.014 m³

Cost of energy required for heating water to the boiling point

0.15 CZK

Saving on heating to the point with lid

0.02 CZK

Saving on heating to the point with lid - percentage

16.7%

Electricity

Pot with lid:

Heating time	360 s
Energy needed to heat up water to boiling point	0, 19 kWh
Cost of energy required for heating water to the boiling point	0.67 CZK

Pot without lid:

Heating time	375 s
Energy needed to heat up water to the boiling point	0.21 kWh
Cost of energy required for heating water to the boiling point	0.74 CZK

Saving on heating to the point with lid	0.07 CZK
Saving on heating to the point with a lid - percentage	10.5%

Comparison of the efficiency of various types of cookers:

The following table shows the efficiency of the various cookers, which are used for the heating of 1.9 liters of water from the temperature of 20 °C to the boiling point).

Technology	Time required for heating	Energy	Efficiency
Induction cooker	4 minutes 46 seconds	745 kJ	83 to 90 %
Electricity cooker	9 minutes 0 seconds	1120 kJ	45 %
Gas	6 minutes 2 seconds	1220 kJ	55 %

Note: In the table only the efficiency of the cooker itself is considered. The efficiency of the transmission and distribution system of gas and electricity is not taken in the account (www.nazeleno.cz).

Discussion:

1. Describe the advantages and disadvantages of each cooker that was used in your laboratory work.
2. Try to create as many cases as possible in which you can use the data from the table.
3. Construct appropriate graphs (histograms), from which it will be clear which types of a cooker can be recommended for use in the household due to their efficiency.
4. Prepare a poster or a power point presentation with the results of your measurements.

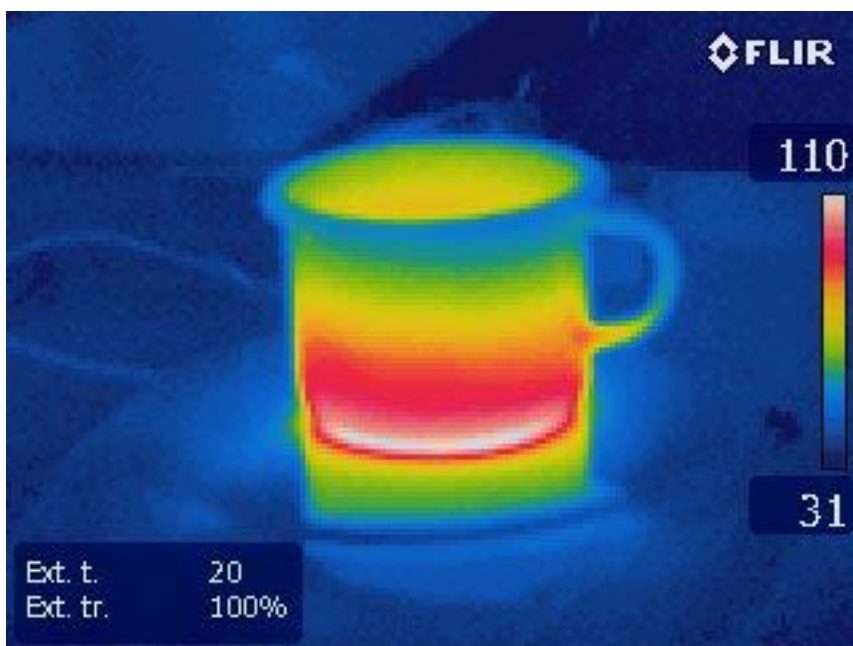
Additional activity

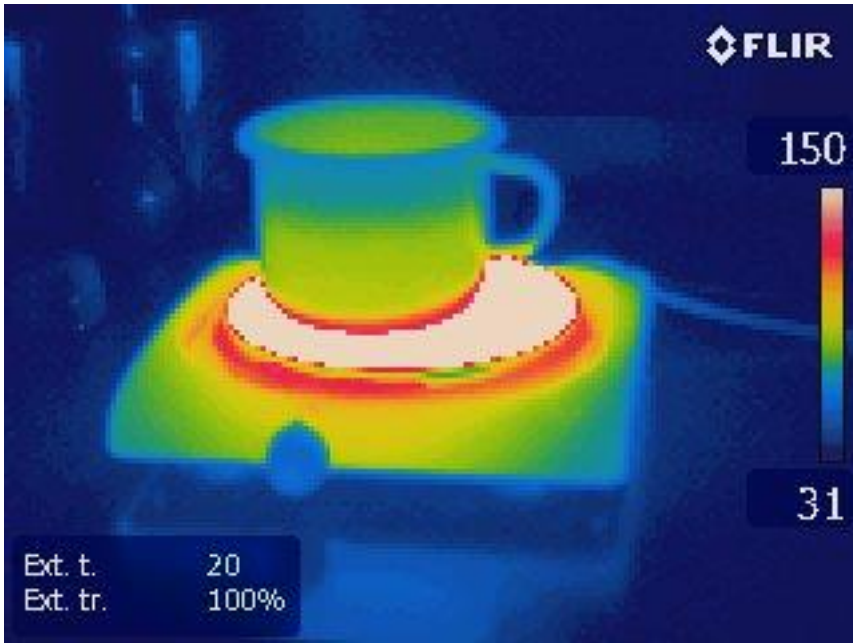
Study the process of heating the water on a electric cooker and an induction cooker.

What do you observe?

What conclusion do you come up with?

When answering the question you can study the pictures below. The picture a) shows heating a pot with water on a induction cooker, the picture b) on an electric cooker.





Study the process of heating oil under the same conditions. Discuss your observations.

Worksheet

Electric cooker

	Pot with lid	Pot without lid
Weight of water - m (kg)		
Initial water temperature - t_0 (°C)		
The resulting water temperature - t (°C)		
Heat needed to heat the water - Q (J)		
Power of cookers - P_0 (nominal value indicated on the appliance) (W)		
Heating time - τ (s)		
Calculation of the total energy supplied during the heating - $W = P_0 \tau$ (J)		
Calculation of cookers efficiency - η (%)		

Specific heat capacity of water - $c = 4180 \text{ J} \cdot \text{kg} \cdot \text{K}^{-1}$

Calculation of heat needed to heat the water - Q (J) $Q = mc(t - t_0)$

Calculation of the total energy supplied during the heating - $W = P_0 \tau$ (J)

Calculation of cookers efficiency - η (%) $\eta = (Q / W) \cdot 100\%$

Gas cooker

	Pot with lid	Pot without lid
Weight of water - m (kg)		
Initial water temperature - t_0 (°C)		
The resulting water temperature - t (°C)		
Heat needed to heat the water - Q (J)		
Power of cookers - P_0 (nominal value indicated on the appliance) (W)		

Heating time - τ (s)		
Calculation of the total energy supplied during the heating - $W = P_0 \tau$ (J)		
Calculation of cookers efficiency - η (%)		

Induction cooker

	Pot with lid	Pot without lid
Weight of water - m (kg)		
Initial water temperature - t_0 (°C)		
The resulting water temperature - t (°C)		
Heat needed to heat the water - Q (J)		
Power of cookers - P_0 (nominal value indicated on the appliance) (W)		
Heating time - τ (s)		
Calculation of the total energy supplied during the heating - $W = P_0 \tau$ (J)		
Calculation of cookers efficiency - η (%)		