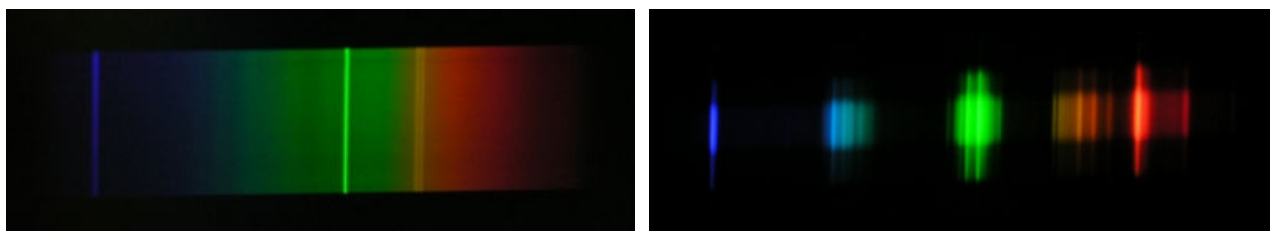


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Spectra around us **- playing with a spectroscope**

Have you already got your own spectroscope? If not, build a spectroscope following the instruction from here and point it at different sources of light. You will see that not every source of light shines in the same way. A spectroscope decomposes light that comes to you into components in a form of spectrum with use of diffraction grating. Two examples of such spectrum can be seen below:



We suggest here three exercises consisting in examining spectra of different sources of light, which can be done with use of your spectroscope. To do the exercise you will need a sheet of paper and something to write with, in order to put down the results of your observations. The spectra can also be photographed, but for the purpose of this exercise, a sheet of paper, a pen and possibly coloured felt-tips shall be just fine.

Suggested exercises:

- 1.** Observation of spectra of different sources of light and comparison of observation results with provided examples. This allows to identify different types of light bulbs – classical, energy-saving, fluorescent lamp.
- 2.** Identification of the observed spectrum lines in emission spectra.
- 3.** Observation of a yellow spectrum line of sodium.

4. Observation and identification of absorption lines in a spectrum of sunlight.

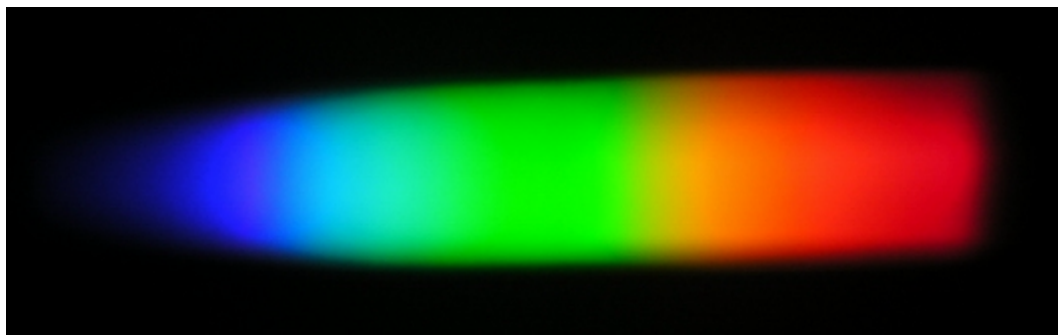
Part I: Observation of Spectra of Different Sources of Light and Their Comparison to Our Examples.

Point your spectroscope at different sources of light in your environment: light bulbs in your flat, street lamps, neon signs advertising shops and goods. Draw each observed spectrum and compare it to the spectra presented below. Does any spectrum match an exemplary one? If so, which of the examples?

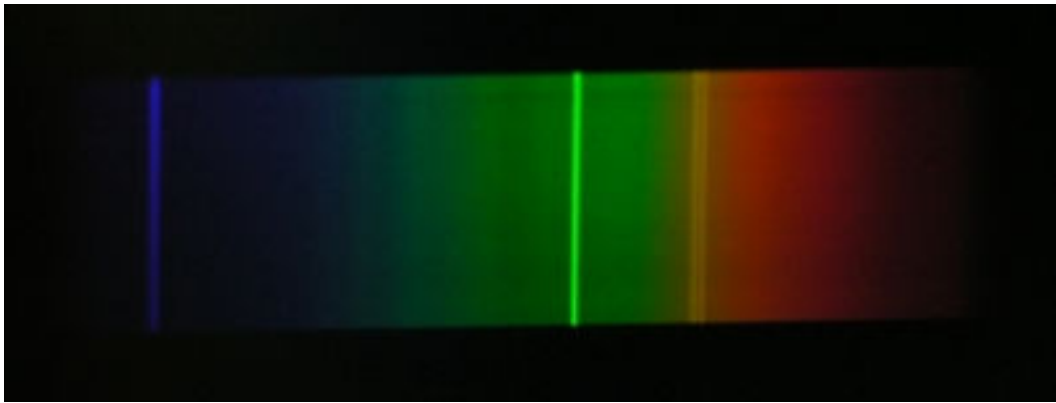
Let's start with a continuous spectrum. This is how a source, whose light is composed of all visible colours, shines:



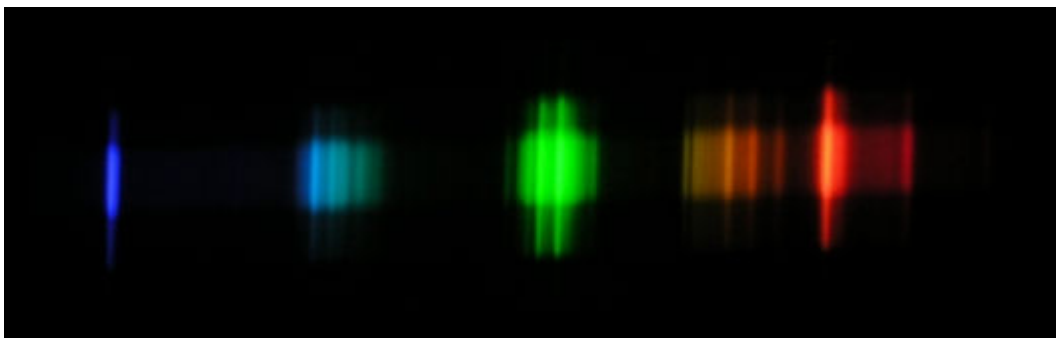
Below you will find photographs of spectra of different sources of light made with use of a home-made spectroscope and a digital camera. Your task is to compare spectra seen by you after pointing your spectroscope at light bulbs and lamps in your neighbourhood, with provided examples. For that purpose, it is recommended to print an image of a continuous spectrum and then draw on it a position of the observed spectrum lines.



Spectrum no. 1



Spectrum no. 2



Spectrum no. 3.



Spectrum no. 4.

Spectrum no. 1 – a classical bulb or a halogen bulb.

Spectrum no. 2 – a fluorescent lamp of the old type.

Spectrum no. 3 – a fluorescent lamp of the new type. It has a richer spectrum and its light is more like sunlight.

Spectrum no. 4 – an energy-saving bulb.

Discuss conclusions drawn from your observations with other pupils from your group.

Have you succeeded, basing on the spectrum, in defining what sources of light can be found in your neighbourhood? If you find a lamp whose spectrum differs from the ones presented in this exercise, you can search spectra of different lamps in the Internet.

Part II: Yellow Spectrum Line of Sodium

Thanks to observation of different sources of light by a spectroscope, we have learnt that light from some sources is not of a continuous character, but it is composed of clear spectrum lines. Spectra of emitted light are a kind of IDs of elements and particles. Each element and each particle has its own characteristic spectrum. Spectra are divided into emission ones, created when light is emitted by elements, and absorption ones, associated with absorption of light.

If you find the spectra of elements interesting, we recommend you to visit [Java animation](#) illustrating spectra of elements.

Apart from a spectroscope, you will need a candle and some salt to do this exercise.



Fig. 1: A spectroscope with a camera, prepared to photograph a spectrum of a candle

Try to find a bit burnt-out candle, in which there is a small depression in a stearin around the wick. Pour some salt around the wick and light your candle. The experiment shall be conducted in a darkened room or in the evening, in order to reduce the background impact, as the flame of a candle is not very bright. In a spectroscope you will see a clear, yellow line. This is a famous sodium doublet, two closely located lines (resolving power of our home-made spectroscope does not allow to separate them), which comes from sodium (Na) emission:

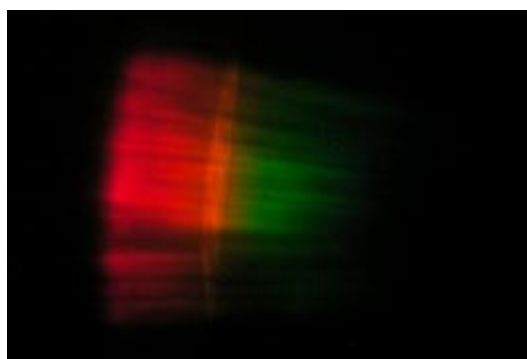


Fig. 2: A spectrum of a candle with a salted wax. An orange sodium line is clearly visible.

Think about a chemical formula of a table salt. Does it contain sodium?

Warning! Be extremely careful not to bring about fire!

Part III: Emission Spectra – Identification of Spectral Lines

Through analysis of light of distant stars with use of especially construed spectroscopes of extreme sensitivity, the astronomers not only examine a chemical composition of a star but can also estimate [age of a star](#), discover [extrasolar planetary systems](#) or even [measure the mass of a distant galaxy](#).

Identification of stellar spectrum lines is not that simple, that is why we will start from an easier task. Your task in this part is to identify lines observed in spectra of fluorescent lamps. Identification signifies defining what wavelength they match and ascribing emission coming from a given element or particle to each line, on the basis of information included in the exercise.

We will start by reminding of a continuous spectrum in comparison with a precise scale. It is the base that allows to estimate wavelengths of light corresponding to particular spectrum lines:

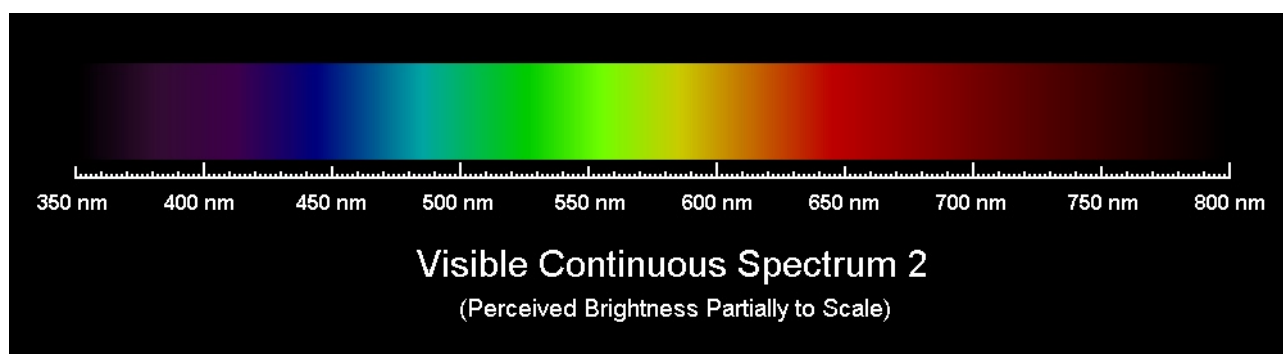


Fig. 3: Visible continuous spectrum

Print an image of a continuous spectrum and draw on it location of spectrum lines in spectra of lamps observed with your spectroscope. Below you will find some information on wavelength corresponding to emission lines in spectra of different lamps.

Details of spectra of different bulbs (source: Wikipedia):

1. spectrum of a fluorescent lamp of the old type:

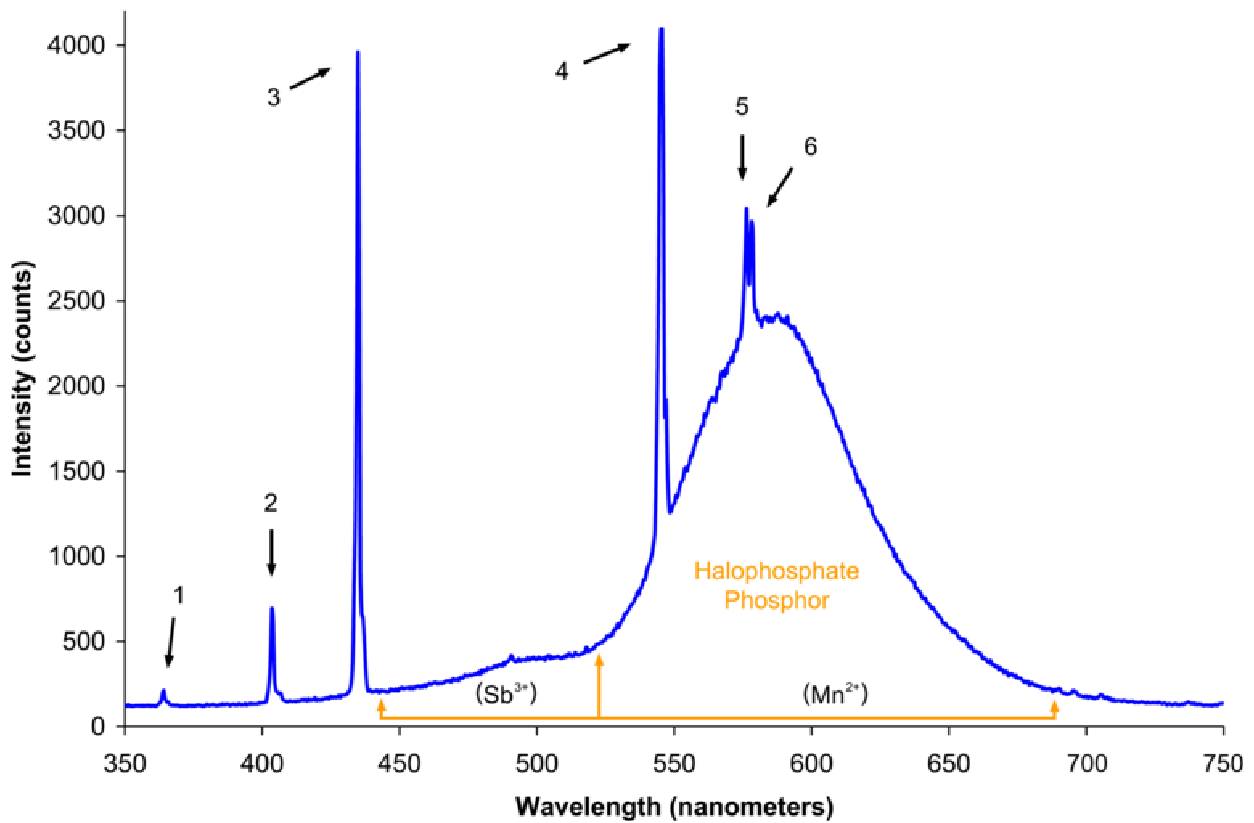


Fig. 4: Intensity of spectrum lines in wavelength function in a fluorescent lamp of the old type

Line number	Wavelength (nm)	Element
1	364.24	mercury
2	403.53	mercury
3	434.83	mercury
4	545.63	mercury
5	576.35	probably mercury
6	578.15	probably mercury

Table no. 1: Identification of peaks in a spectrum of a fluorescent lamp of the old type

As you can see, it is a simple spectrum, so you should have no problems to identify spectrum lines. Moreover, all spectrum lines in visible light come from one element – mercury.

2. Spectrum of a modern fluorescent lamp:

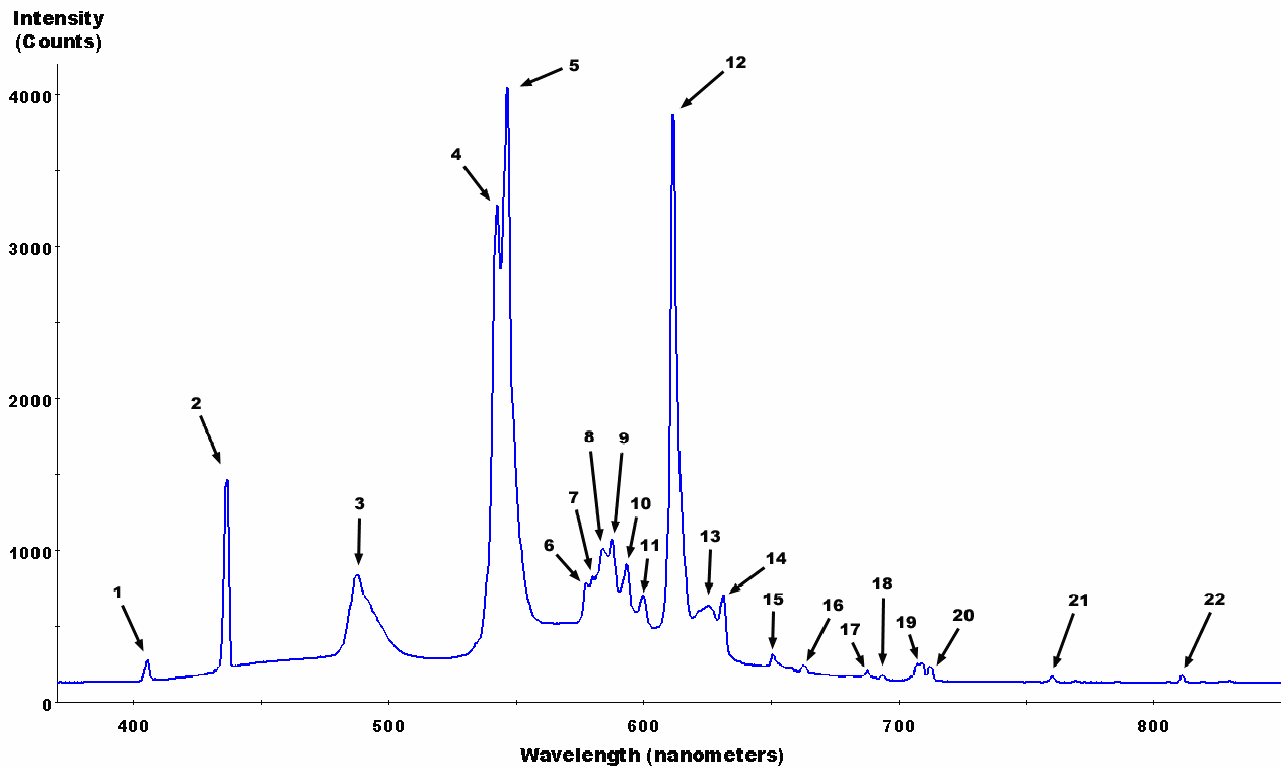


Fig. 5: Intensity of spectrum lines in wavelength function in a modern fluorescent lamp

Spectra of modern fluorescent lamps are much more complicated, because they shine with light similar to sunlight. Such spectrum has more lines, which makes an identification more difficult.

Peak number	Peak wavelength [nm]	Element
1	405.4	mercury
2	436.6	mercury
3	487.7	terbium Tb ³⁺
4	542.4	terbium Tb ³⁺
5	546.5	mercury
6	577.7	probably terbium Tb ³⁺ or mercury
7	580.2	mercury or terbium Tb ³⁺

8	584.0	probably terbium Tb ³⁺ or europium Eu ⁺³ :Y ₂ O ₃
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Table no. 2: Identification of peaks in a spectrum of a modern fluorescent lamp
continuation of a table no. 2:

Peak number	Peak wavelength [nm]	Element
9	587.6	probably europium Eu ⁺³ :Y ₂ O ₃
10	593.4	probably europium Eu ⁺³ :Y ₂ O ₃
11	599.7	probably europium Eu ⁺³ :Y ₂ O ₃
12	611.6	europium Eu ⁺³ :Y ₂ O ₃
13	625.7	probably terbium Tb ³⁺
14	631.1	probably europium Eu ⁺³ :Y ₂ O ₃
15	650.8	probably europium Eu ⁺³ :Y ₂ O ₃
16	662.6	probably europium Eu ⁺³ :Y ₂ O ₃
17	687.7	probably europium Eu ⁺³ :Y ₂ O ₃
18	693.7	probably europium Eu ⁺³ :Y ₂ O ₃
19	707 i 709	probably europium Eu ⁺³ :Y ₂ O ₃
20	712.3	probably europium Eu ⁺³ :Y ₂ O ₃
21	760.0	probably argon Ar

22	811.0	probably argon Ar
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Table no. 2 continuation: Identification of elements in a spectrum of a modern fluorescent lamp

Having all that data we can start doing our exercise:

I. compare spectrum observed by you with a picture of a continuous spectrum (Fig. 1) and check as precisely as possible which wavelength corresponds to each spectrum line;

II. try to identify the spectrum, that is to ascribe it to a particular type of a lamp. To achieve it, you have to compare location of the observed spectrum lines with location of spectrum lines of different lamps, by means of determined wavelengths of different spectrum lines. Beware of different scales in different figures!

III. look at the tables below the images of spectra and find elements whose emission is responsible for the particular lines;

IV. put down the results of your observations in a table:

Lamp type	Line description	Wavelength	Element	Distinctive features
e.g. halogen bulb	e.g. blue lines group, poor			

V. when you have completed your exercise, compare your results with your classmates.

Part IV: Observation and Identification of Absorption Lines in a Spectrum of Sunlight - Fraunhofer Lines.

To observe a spectrum of sunlight, you must build a spectroscope with a long tube. The longer the tube of a spectroscope, the better resolving power and the less significant influence of imprecision resulting from slit making. This exercise is based on observations with a spectroscope made of a 1-meter tube. Such tubes are easily accessible in the Internet and are quite cheap.

WARNING!!! Under no circumstances you should look at the Sun, because you can damage your eyesight.

It is not necessary to look directly at our daily star, in order to observe its spectrum. If in a nice, sunny day we point our spectroscope at a clear sky, we shall observe a spectrum of a diffused sunlight. On the continuous spectrum we should clearly see several dark lines. They are absorption lines coming from absorption of light by elements occurring in external layers of the Sun's atmosphere. They are known as Fraunhofer lines, because that is the name of one of their discoverers.

Below you can see a set prepared to photograph a spectrum of sunlight:



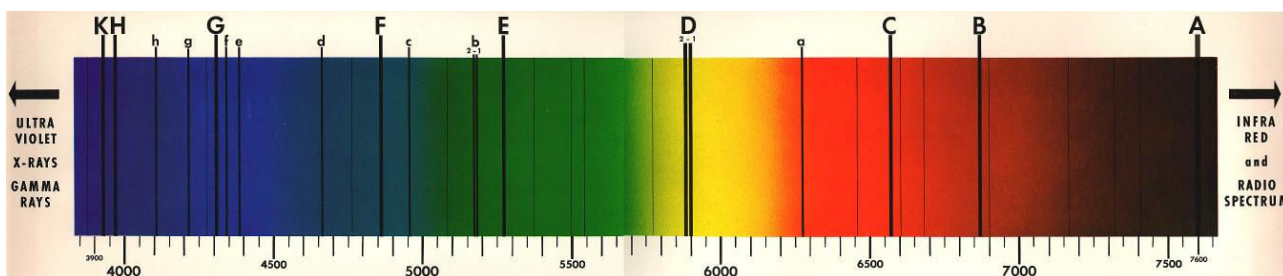
Fig. 6: Spectroscope with a camera prepared to photograph a spectrum of sunlight

It is recommended to cover your eyes/camera with some diaphragm, like the one visible in the photo, a sleeve made from a black cardboard fixed to a spectroscope. It will enable to enhance contrast and will improve spectrum visibility.

This photograph presents a spectrum of sunlight with Fraunhofer lines:



Unfortunately, each digital camera has built-in filters (which results in an image of colour) and the quality of such photograph is much worse than the image visible to the naked eye. For that reason, the best observation method in case of a spectrum of sunlight is to print an image of a continuous spectrum and to mark on it the lines seen by us, and then to compare our results with a spectrum placed below (source: www.harmsy.freeuk.com/fraunhofer.html):



Basing on the image and the table below try to identify the visible lines:

Line	Element	Wavelength [nm]
A – band	O ₂	759.4 - 762.1
B – band	O ₂	686.7 - 688.4
C	H	656.3
a – band	O ₂	627.6 - 628.7
D -1, 2	Na	589.6, 589.0
E	Fe	527.0
b -1, 2	Mg	518.4, 517.3
c	Fe	495.8
F	H	486.1
d	Fe	466.8
e	Fe	438.4
f	H	434.0

Line	Element	Wavelength [nm]
G	Fe i Ca	430.8
g	H	422.7
h	Ca	410.2
H	Ca	396.8
K	Ca	393.4

Can you identify sodium doublet D? These are absorption lines matching emission line of table salt, which have been observed in part II.

The last step is to compare your results with the ones of your classmates.