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How to measure the Sun’s strength ?

Introduction: Bunsen’s photometer

In order to measure the strength of a star, astronomers use the photometer, which is an instrument used to measure the quantity of light in a given space and enable to determine the quantity of energy by time unit (the strength) of an unknown source compared to an identified source. Historically, many photometers were proposed to compare the different sources of light.

In this case, we will focus on that of Robert Bunsen (Fig. 1), a German chemist and physician of the 19th century. He made many devices, which he used in his experiments. The most well-known may be the lighter, and he also invented the photometer , which is used with oil drop.

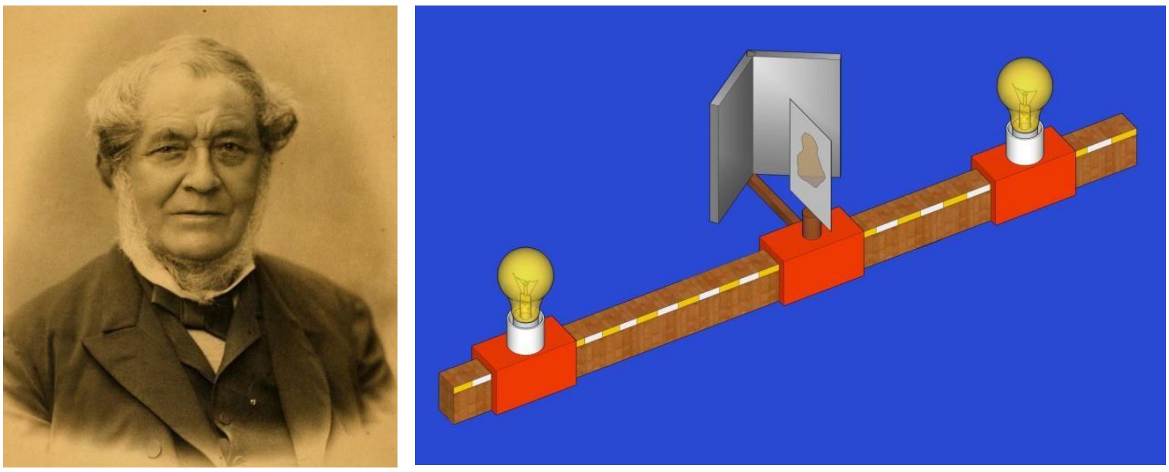

Fig.1 : Robert Wilhelm Bunsen and his photometer with oil drop

The photometer, invented by Bunsen, enabled people to compare the intensity of two sources of light, one is known and the other is unknown.

To make the experiment, you have to put two sources at the extremities of a measuring tape. We put a white ordinary paper with a small drop of oil between the two sources. The paper becomes semi-transparent in the stained area. When you move the paper between the two sources of light, there is a moment when the mark of oil is barely visible. In this position, brightness which attains both sides of the paper is the same.

The brightness is the luminous flux which comes to the surface by unit. Just like the luminous flux released from a light bulb and spreading radially in the surface of a sphere with a “d” ray and an area = 4 π d^2, the more we are away from the source, the more brightness is low. If the two sources are two bulbs of the same type, the number of lumens emitted by watt is similar, and in the calculations we can replace the luminous flux by the electric power.

In other words, if P_1 and P_2 are the electric powers of the two lamps and d_1 and d_2 the distances between the paper and each of the two light sources, the following conditions must be fulfilled:

$$\frac{P_1}{4\pi d_1^{\,2}} = \frac{P_2}{4\pi d_2^{\,2}} \rightarrow \frac{P_1}{d_1^{\,2}} = \frac{P_2}{d_2^{\,2}}$$

If, for example the two lamps are halogen lamps of 100 W and 60 W (Fig. 2), the position where the drop of oil is not visible will happen when:

$$\frac{100}{d_1^{\,2}} = \frac{60}{d_2^{\,2}}$$

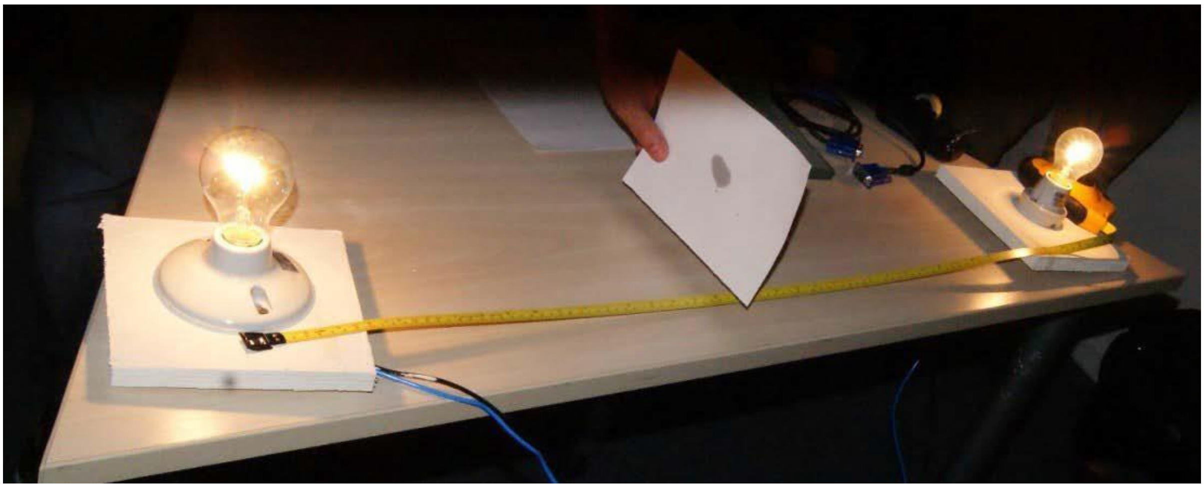

Fig.2 : Movement of the paper until the disappearance of the spot.

The experiment relative to the testing of the photometer with a drop of oil functionality is possible to make in the classroom. In this case, a standard electric lamp of 60 W may be compared to two other electric lamps of 40W and 100W.

To make the experiment, you should prepare a table (see table 1) in order to give the possibility to pupils to record the data with precision. The results are the same whatever are the type of the lamp and the color of light that is produced. The results have to be recorded in the table.

Table 1. Experiment of the strength estimation.

Used lamps			**Sample lamp**		
Type of lamp	Indicated lamp (W)	Distance lamp-paper (m)	Indicated strength (W)	Distance lamp- paper (m)	Calculated strength(W)
	40 W		60W		
	100 W		60W		

Experiment 1: Determination of the Sun's strength oil drop photometer

The most interesting use of Bunsen photometer is the determination of the Sun's strength or brightness. Thanks to the photometer with oil drop, we are going to calculate the strength of the Sun while comparing it to a lamp of 100 W (Fig. 3).

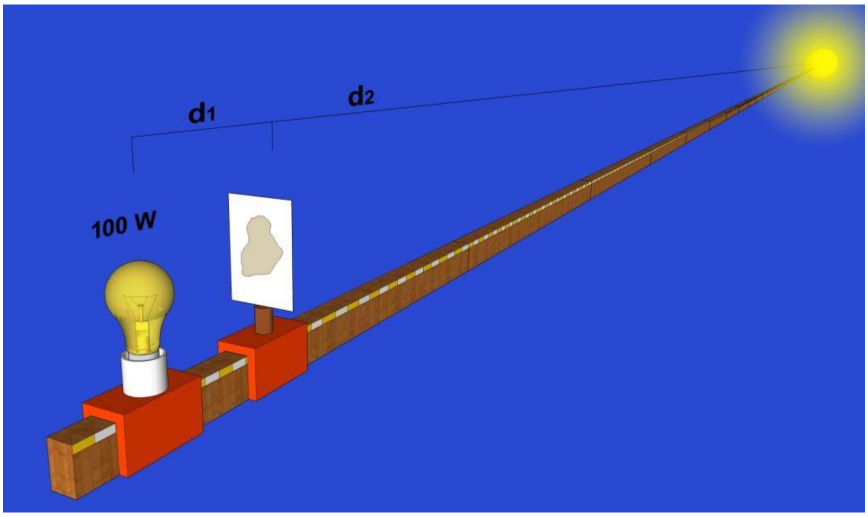

Fig. 3: Comparison of the Sun's strength with a lamp of 100W.

In a sunny day, take outside a photometer and a lamp of a 100W lamp (preferably the most luminous). Place the photometer between the Sun and the lamp with the same distance in both sides of the photometer where both appear clearly. Then measure the distance d_1 in meters from the photometer to the filament of the bulb (Fig. 4).

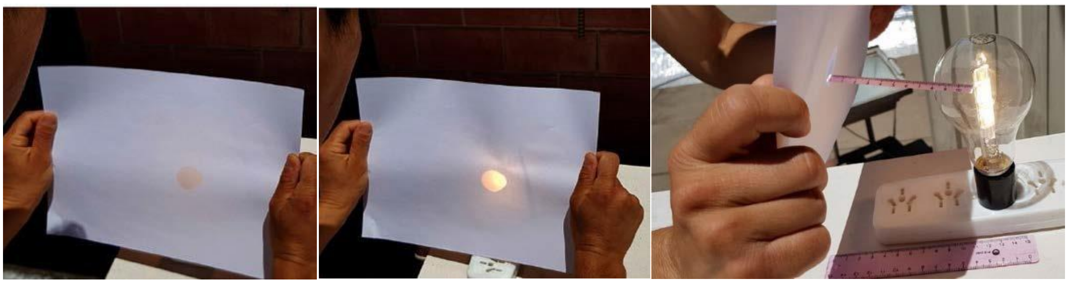

Fig. 4. When the spot is not visible, measure the distance between the paper and the filament of the bulb.

Knowing that the distance between the Sun and the Earth is approximately d_2 = 150 000 000 km, we can calculate the Sun's strength P with the inverse square law (the term 4π is simplified):

$$\frac{100W}{d_1^{\,2}} = \frac{P\,soleil}{d_2^{\,2}}$$

The calculated value of the Sun's strength must be close to the real Sun's brightness, which is $3{,}83.\ 10^{26}$ W.

Experiment 2 : Determination of the Sun's strength

We may make another experiment (Fig. 5) to make an estimation of the Sun's strength. We need to replace the paper with the drop of oil with our face.

In a sunny day, it is possible to compare the heat provided by the Sun in one cheek, and the heat provided by a lamp of 100 W in the other one. The distance between the lamp and the face has to be modified till the pupil (with closed eyes) reaches the same heat feeling in his skin which is in contact of both cheeks. While measuring the distance "d" between the bulb and the face and knowing the distance "R" with the Sun (150 x 10^9 m), we can estimate the brightness of the Sun with the same formula (Fig. 5).

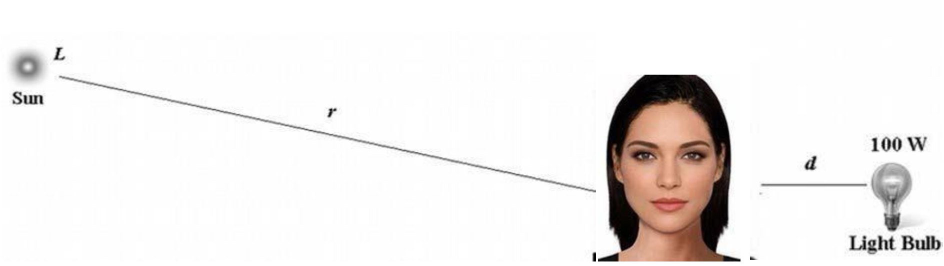

Fig. 5. Psun / R^2 = P / d^2

The “same sensation” signifies that both, the Sun and the lamp, have the same heat intensity. Supposing that the efficiency of the Sun and the electric lamp are similar to the wavelength, we may apply the inverse square law.

The distance value « d » will be about 10 cm. with this value, the result of the brightness of the Sun will be around 2,2 x 1026 W, slightly inferior to the real value. The reason is that the atmosphere is not transparent to the infrared radiation and that according to its wavelength; the Sun consequently appears less strong that it is in reality. But the simplicity of the method balances out the precision of the result.

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