prob6.tex The Hungarian team's solution for problem no. 6 at the 8th International Young Physicists' Tournament 4th - 11th June, 1995 Spala, Poland Reporter: Illés Farkas

6. Light curtain

A light curtain (light scatters on dust particles) is used in some theaters. Suggest the design of a light curtain, which allows its effective action with the minimum power supplied for one meter of stage width.

ABSTRACT

After the investigation of the traditional setup — the vertical light curtain — and its main parameters, a different version is introduced. The comparison shows that by this modification a more economical and effective light curtain can be obtained. However, this "new curtain" will still need to be enhanced for use in multi-storey theaters.

5 EXPERIMENTS AND OBSERVATIONS

In this phase we focused on the observation of light beams and were attempting to find the features most probable to be significant in our work later.

With the help of specialists at the Opera House in Budapest we were able to see a Svoboda light source in action. The light source itself is a box ($0.5 \times 0.5 \times 1m$ in size) with nine special light bulbs in it — each of them working on $24V$, $500W$. It was named after a Czech engineer who managed to develop light sources of high effectivity and intensity.

When switched on its light beam was horizontal and it was directed perpendicularly to the opposite wall (ca. 20 m far). One of the first things we noticed was the size of the light spot on the wall. It was just very little bigger than the $0.5 \times 1meter$ sized surface of the source — so the light beam at our feet was extremely parallel. Another important fact to note is that even though there was no additional dust used in our case this light beam was clearly visible in the air — unlike the laser beam which we were experimenting

with before. When looking into the Svoboda lamp we were blinded immediately.

We also wanted to gain information about the features of this special scattering. Naturally, there is always some dust in the air and inside a building the concentration of dust may be higher than "outside". Under the microscope such dust particles showed highly irregular shapes and their size was mostly close to $0.01mm$. These particles mainly reflect light and absorb a smaller portion of it, by which they are heated up.

According to our observations the scattering itself was isotropic. The intensity of light reaching our eyes depended only on the effective width of the light beam. This can be defined as the ratio of the width of the beam and the sine value of the angle of our observation (see Fig.1.).

A Belgian company called AVAB produces such light sources, too. One of their products, RZN 90, which was meant for the same purpose, has another arrangement of light bulbs. While the Svoboda lamp has nine bulbs in two rows (five and four in a row), RZN 90 has six in a line. We were also told that there were no significant differences between the effects produced by these light sources.

6 THE VERTICAL LIGHT CURTAIN

6.1 Description

The main goal of a light curtain is to hide the actor — in a rather attractive manner. This is achieved in such a way that the intensity of light leaving the curtain in the direction of the audience I^* is much higher than the intensity of light leaving the actor I_{actor}.

For further investigation we defined a number called the effective cross-section of dust, A,as the proportion of the original light intensity leaving the curtain towards the audience. Another important factor which we called the efficiency of the lamp α is given by the proportion electrical energy transformed into visible light. It is

always a property of the particular light source we are using.

Given a certain light source we cannot change the efficiency of the lamp, so α is a constant. We need to increase the proportion of light scattered by the curtain A and find an I^* value as low as possible for the actor to hide. According to this the power needed for one meter of stage width can be given by the formula

$$\frac{P}{l} = \alpha \frac{I^*}{A} \ .$$

6.2 The effective cross-section of dust

If there are ρ pieces of dust particles of size d in the curtain, we expect A to be proportional to both ρ and d^2 . We also expect A to be proportional to albedo of the particles a and to the effective width of the curtain x_{eff} and inversely proportional to the height of the stage h. So we set up the formula

$$A = \frac{kad^2\rho x_{\text{eff}}}{h} \ ,$$

where k is a coefficient indicating the dependency of A on the direction of the audience and the shape of the particles.

After this our main attempt was to fix the parameters so that the ratio of power per stage width unit:

$$\frac{P}{l} = \frac{I^* h}{kad^2\rho x_{\text{eff}}}$$

would become minimal.

The experiments with the light beam at the Opera House showed that the scattering was isotropic thus the coefficient k cannot be changed radically. Neither can the albedo of these particles, which is mostly around $0.7 - 0.9$ [2] , nor the diameter. But there still remains the possibility of injecting some extra dust or smoke, which leads to the next two parameters, I^* and x_{eff}. This is the point where our main concerns about the vertical curtain occurred.

Whenever there is a light curtain in action its two sides can be considered equivalent. What follows from this is that the intensity of light on the two sides — back and front — are the same (see Fig.2.a.). If there is an actor standing in the background I_{actor} will be at least one tenth of I^*. If ρ is very low dust is nearly transparent and almost all of I_{actor} will reach the eye of the spectators. But this ratio is not enough for the actor to remain hidden. To enhance the curtain additional dust or smoke could be injected but for this additional electrical power would be needed, too.

7 SUGGESTION FOR A NEW SETUP

Until this point only the traditional setup was discussed. The light curtain was vertical, similarly to any other curtain. With some simple changes this can be turned into a curtain more suitable for our purposes.

Turning the beam down to the level of the audience will obviously blind everyone. However, keeping the curtain just a little above that level, so that it will remain above the heads of the spectators, will change the situation significantly (see Fig.2.b.). First of all, the effective width of the curtain will be increased. When the spectators are fixing their eyes on the actor (or where they think he is) they will have to watch him through a much thicker scattering region. By this modification I_{actor} will be changed as well since the curtain itself will have no parts as close to the actor as before. All this can be done with the same light sources using not more electrical power than before.

Obviously, this modification on its own will not be applicable in theaters having more than one store. On the other hand, in open-air theaters this change will significantly raise the light curtain's effectivity.

8 ACKNOWLEDGMENTS

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9 LITERATURE

[1] Budó-Mátrai: Ksérleti Fizika III.
[2] Niethammer ‘88, Katalog für Bühnenbeleuchtung
6. FIGURES

Figure 10: The effective width of the light beam.

Figure 11: a The traditional setup. The vertical light curtain.

Figure 12: b The new light curtain. — lower background light intensity; — increased effective width of curtain; — same power / same light source.

prob8.tex **Problem 8**

The Rolling Carpet
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