2007

Fresnel's Lighthouse Lenses

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Recommended Citation
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Citation: The Physics Teacher 45, 550 (2007); doi: 10.1119/1.2809148
View online: http://dx.doi.org/10.1119/1.2809148
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Published by the American Association of Physics Teachers

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One of the rewards of walking up the scores of steps winding around the inside of the shaft of a lighthouse is turning inward and examining the glass optical system. This arrangement of prisms, lenses, and reflectors is used to project the light from a relatively small source in a beam that can be seen far at sea.

In Fig. 1, reproduced from an 1860 American edition of an earlier French text, the light source is an Argand light burning whale oil. A circular wick is enclosed in a chimney to provide a draft to produce a brighter light; the design is credited to a Swiss engineer, Aimé Argand, in 1784. Argand is said to have used a parabolic reflector behind the light source to collect the light and project it forward.

In 1822, Augustin Jean Fresnel (1788-1827) published a memoir on lighthouse design in which he proposed the use of short focal length lenses to project the light from the burner, thus allowing more of the light to be gathered into the beam. To keep down the weight of the lenses and to reduce the absorption of light by them, circular disks of glass were removed from the back of the lens forming the familiar shape shown at A in Fig. 1. These are sometimes called echelon lenses, but we usually refer to them as Fresnel lenses. Figure 2 shows a complete lighthouse lens in which there are eight flat Fresnel lens assemblies. The entire system of lenses rotates, sending eight beams of light whirling through the darkness. The clockwork-(later electric) driven mechanism is at the lower right-hand corner. The vanes of a governor system can be seen at the top of this mechanism. The figure represents

Fig. 1. The echelon lens that Fresnel invented in 1822 for use in lighthouses.

Fig. 2. An 1855 lighthouse system using Fresnel lenses.
a lighthouse exhibited at the Universal Exhibition in Paris in 1855; the lens system was about 3 m high.

Figure 1 shows reflectors being used to add the spill light that goes above and below the Fresnel lenses to the output of the lighthouse. However, Fig. 2 shows the standard configuration in which prisms are used to refract this light outward. Note that this extra light goes out in all directions and is not part of the eight beams.

A full-scale lighthouse lens system has on the order of 1000 pieces of glass, cast and polished individually and set into brass frames. A well-designed system can use about 85% of the available light.

Stage lighting instruments also require that maximal use be made of a single light source. Both the lighthouse lens and the ellipsoidal theater spotlight are interesting parallel problems in applied optics that fit well into introductory physics courses, especially those for nonscience students.

References


3. Ref. 1, p. 309.


PACS codes: 01.65.+g, 42.00.00