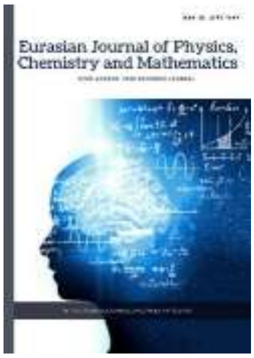

Avicenna questions of geometric optics

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The essence is reflected in your being,
She will not be able to be a secret for a long time,
Not because the essence of any nature
In the act, as if in a mirror, it is visible

ABSTRACT

The article briefly reveals some of the views of the famous medieval scientist-encyclopedist Abu Ali ibn Sina (Avicenna, 980-1037) about acoustics in Physics. Based on the study of natural sciences from the physical part of the treatise "Sawdust of Nature" ("Kurozai Tabiyet"), specially dedicated to acoustics.It is characteristic that it is in this treatise that Avicenna treats some problems of acoustics from the point of view of the "science of nature" Physics" of that tim.

In the medieval East, many prominent scientists addressed the problems of acoustics: such as Abu Nasr al-Farabi, Abu Ali ibn al-Haysam and Avicenna himself. It received a special development in the Middle Ages in connection with the development of music theory issues. It was also considered in a philosophical aspect.

The article has an interdisciplinary character, written at the junction of the subject of physics and history, taking into account historical and scientific analysis.

Keywords: physics of acoustics, natural sciences, analogy with pyrrhine mechanical motion, history, civilization, primary elements of nature, sound vibrations, echoes.sound, violent movement, Averroes (Ibn Rushd), Abu Nasr al Farabi, Abu Ali ibn al-Haysam, Ibn Sina (Avicenna)

Several sections of Avicenna's encyclopedic works are devoted to the issues of geometric optics: "The Book of Knowledge", "The Book of Healing", "The Canon of Medicine", the treatise "Sawdust of Nature" written in the form of questions and answers, as well as his scientific correspondence with Aburaikhon Beruni regarding Aristotle's "Physics". The treatise "Sawdust of Nature" consists of four sections and is devoted to various issues of natural science. The fourth section is devoted mainly to physics issues .

Let's consider four questions from the fourth section "Sawdust of nature", devoted to the problems of geometric optics.

In the second chapter of this section, Avicenna considers the following question: Why is the air visible in a dark room, but not in the field?

Answer: The air in the room can be seen because it is dark in it. And since it is light in the field (during the day), it is impossible to see [him] there. The proof of this is that the sunbeam, penetrating into the room, falls on the wall. It becomes brighter by reflecting the beam, and the air is not visible. Therefore, it is clear that because of the darkness in the room [in it], it is possible to see the air, and since it is light in the field, it is impossible to see it there.

Naturally, we don't see air everywhere. Avicenna here means dust motes illuminated by the rays of the Sun.

Avicenna claims that if a sunbeam, penetrating into a dark room, falls on a wall, it is reflected. We can clearly see this bright spot on the wall. "In the same way," says ot, "the air in the room becomes visible in the place where the sunbeam passes: the air reflects the ray and we see it." In fact, sunlight is scattered in the air by small dust particles. We observe this diffused light in a darkened room. In the field, due to the bright lighting, this phenomenon cannot be observed.

Both here and later we will see that Avicenna quite satisfactorily explains various optical phenomena. (For example, the phenomena of reflection and refraction of rays, the mechanism of vision, etc.). but in this case, he naturally could not yet correctly explain the effect described by him, because the concept of scattered light and a dust tube in a dark room appeared only much later. Avicenna reduces the explanation of this effect to the phenomenon of light reflection, and in this sense he is partly right, since the larger the reflection and the size of the beam of light in a dark room, the greater the effect of the dust tube will be.

It should be noted that the mathematical description of the law of reflection and refraction of rays was carried out only in Europe during the Renaissance. If we omit the mathematical side of the description of these phenomena, then Avicenna's explanation completely coincides with the theory adopted several centuries later.

Let us now turn to the seventh chapter of this section.

Question: Why does the flame of a campfire seem bigger from afar than it really is, and other things seem smaller from afar?

Answer: Because the air that is around the flame in the vicinity of it seems very bright, because the flame [is] far away. The feeling of its brightness is erroneous. It is impossible to distinguish the glow [of the air] around the flame from the flame itself. It seems to the [Observer] that this glow of the air refers to the [flame itself]. That's why [he] sees the flame as bigger than it really is.

The reason that [usually] things from afar seem smaller [in size], and large in the vicinity, is that these things are observed at some angle, which is formed by the lines of rays coming from the eye. The farther away [from the observer the observed] thing is, the smaller the angle, and it seems smaller [in size], and the closer the thing is, the larger this angle, and it seems large [in size].

Avicenna says "about the air" that is around the flame of fire, but now we know that the light of the fire is scattered by dust particles in the air. This creates the effect that Avicenna writes about.

Avicenna's answer to the question of why "other things" (meaning solids) seem smaller from afar than they actually are can be explained as follows.

Let's assume in Figure 1: A is the observer's eye, VS is the observed object "thing", from a height h, r is the distance from the observer to the object, is the angle at which the object is observed.

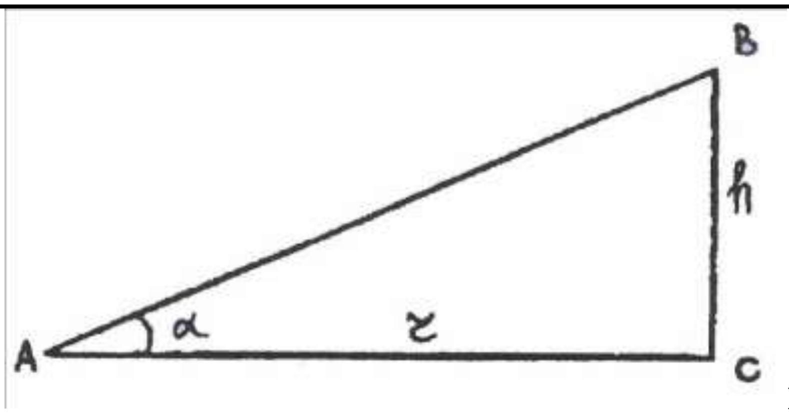

Fig. 1.

$h = rtg\alpha$, $\alpha \to 0 \Rightarrow tg\alpha \approx 0$

$$h = r \cdot \alpha \Rightarrow \alpha = \frac{h}{r} \quad \text{..................}(1)$$

It can be seen from (1) that when magnified, the observed object is observed at a smaller angle, and the observer sees the observed object as smaller than it actually is.

This phenomenon can be explained using the following drawing

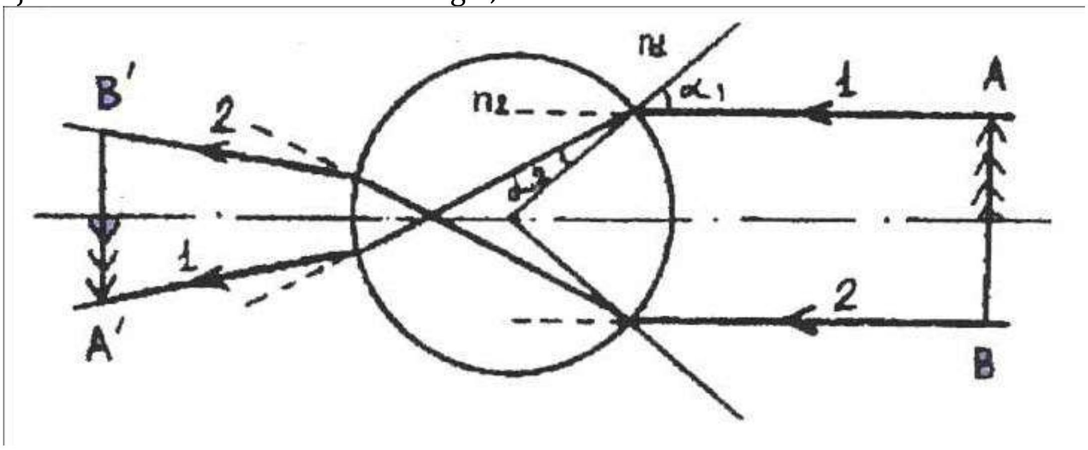

Fig. 2.

$$h' = 2 \cdot r' \cdot tg\frac{\alpha}{2}$$

$$\Rightarrow \frac{h'}{h} = \frac{r'}{r} \Rightarrow h' = \frac{r'}{r} \cdot h$$

$$h = 2 \cdot r \cdot tg\frac{\alpha}{2}$$

Where h- is the height of the observed object,h[1]- is the height of the observed object on the retina of the eye,r[1]- is the distance to the object.

$h = Const$, $r' = Const$,

$$h' = \frac{Const_1 \cdot Const_2}{r} = \frac{A}{r}$$

- some constant value

It is clear that with an increase r,h it will decrease.

Avicenna's explanation is as follows. The reason that objects observed from afar seem smaller is that they are observed at some angle formed by lines of imaginary rays from the eye. The further away this object is from the observer, the smaller this angle. Therefore, the object seems smaller than it actually is.

We see, therefore, that Avicenna's answer practically does not differ from the answer that any physically literate person would give to this question.

In the eighth chapter, Avicenna discusses the following question: Why do objects behind spherical crystal look inverted?

Answer: Because the rays coming from the eye ("eye rays") and passing through the spherical crystal do not fall into the set place. Those that come from the right go to the left and vice versa, i.e. those that come from above go down. Thus, from whatever side [the rays] fall, they go in the opposite direction. For this reason, the [mentioned] rays intersect at one point, pass through each other, and after reaching the observed object, form a cone. If the rays hit the set place, the object does not appear to be upside down, but since [they] do not fall into this place, the object appears to be upside down. An example of this. When a person deliberately looks askance at something, this one thing [he] sees as two, because the rays from both eyes do not go to the set place. The beam from the right eye goes to the left, and the beam from the left eye goes to the right, and [they] will intersect at one point.

Two rays pass through this one thing. Therefore, one object is seen as two. If the rays continuously go to the set place, then the [observed] object will be visible as one, [not two]. Therefore, it is clear that why objects [observed] through spherical crystal seem to be inverted.

In this chapter, as we can see, Avicenna discusses the reflection and refraction of rays.

It should be noted that when Avicenna speaks of rays coming from the eyes ("eye rays"), he does not mean that the rays come out of the eyes. On the contrary, he himself criticizes scientists who claim that a person sees because rays come from his eyes. Here is what he says about this: "Some of the predecessors of the great philosopher Aristotle thought that rays and light emanate from the eyes, which reach bodies, and bodies are thus felt, become visible. This is absurd, for in what eye can there be so much light that he can see the whole world from heaven to earth? Another group of doctors, who wanted to clarify this opinion without falling into absurdity, argued as follows: a small light comes out of the eyes, which mixes with the light of the air, and thus the rays of the air become an instrument of vision, and with its help you can see things. But even this is absurd, because if the air would become sighted when combined with this light, then with a large accumulation of people, the visual power of the air would increase. It became clear that a person with poor eyesight would see with the help of other people, and not independently..."

From the point of view of modern physical representations, its concept can be interpreted as follows:

Let in Fig. 3 AB is the observed object, and A|B| is its image in a spherical crystal.

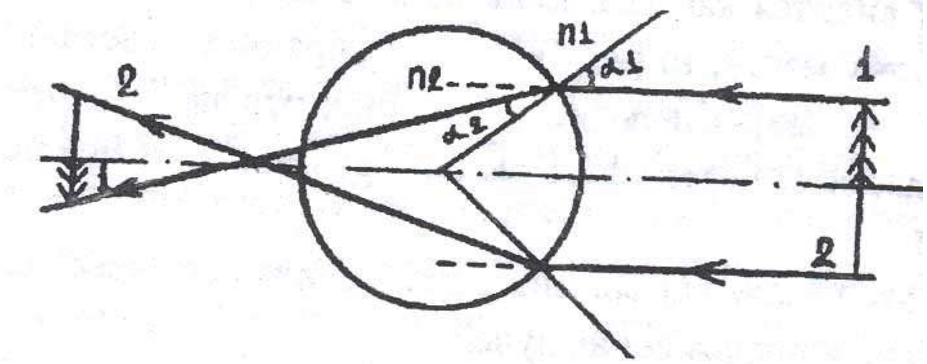

Fig. 3.

It follows from Figures 3 and 4 that when an object is observed through a refractive medium, i.e. spherical crystal, the object looks inverted. The ray that was right before passing through the crystal becomes left and vice versa, which exactly corresponds to Ibn Sina's answer.

Depending on the refractive index of the medium, n2 rays will intersect either inside the medium (Fig. 3) or outside the medium (Fig. 4). Moreover, n2 in Fig. 3 is greater than n2 in Fig. 4. It is easy to show, based on the law of refraction of light:

Here α_1- is the angle between the incident beam and the normal to the medium,α_2- the angle between the refracted beam and the normal to the medium.

From here $Sin\alpha_2 = \frac{n_1}{n_2} \cdot Sin\alpha_1$

If the refractive index of the air ,n=1 then:

$$Sin\alpha_2 = \frac{1}{n_2} \cdot Sin\alpha_1$$

It follows from this that the larger n2, the smaller and will be α_2, i.e. the intersection of the rays with increasing n2 will occur closer to the center of the spherical breaking medium.

In the sixteenth chapter, Avicenna addresses one of the most interesting problems of geometric optics – the nature of the mirage.

Question: Why is the mirage visible from afar, but when you get closer you see the earth, and the mirage is not visible?
Answer: Because when people look at the plain, they see the place that is opposite their eyes. People do not see the surface of the earth in the lowlands, but when they reach this place, they will find wet earth in the lowlands. And if the place is above the lowlands, then they see its surface. Above it, they see the air filled with steam: vapors rising from the ground, illuminated by sunlight. They are seen white and light. From afar, it seems that there is water where the vapors actually are. But people see the surface of the earth in such a way that its color and real appearance prevails over the color of vapors, and they do not notice vapors. Therefore, for this reason, you see a mirage from afar and do not see the earth.

Indeed, the nature of the mirage is very interesting. Avicenna's answer is typical of medieval science. But some aspects of his explanation of the nature of the mirage still have not lost their significance. Indeed, an important role in this deception of vision is played by the observed area of the earth, the surrounding atmosphere saturated with vapors. The refractive index of such an atmosphere saturated with vapors differs from one, the refractive index of air. It refracts rays falling from a distant lake, forest, etc., as shown in Figure 4., and creates favorable conditions for observing this object. It should be noted that the reason for the change in the refractive index may be not only water vapor, but also a temperature gradient.

Fig.4.

An area of the atmosphere with a changing refractive index.
The line along which a person looks in the case when the indicator of surprise is constant everywhere.
Rays coming from a distant object in the case when a medium with varying refractive indices is encountered on their way.

In the end, regarding the influence of Ibn Sina's works on the work of scientists of the subsequent generation of East and West, we can say that a comprehensive and in-depth study of the "Avicenna school" will give much unexplored aspects of his work and will constitute a separate difficult scientific work for Avicenna scholars.

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