

Models for Physics Teachers from the World of Pictures and Sounds

Dorothy Sebestyen

Budapest Polytechnic, Hungary

sebestyen.dorottya@kvk.bmf.hu

Abstract

The cultural history of physics is an important part of teaching introductory physics for engineering students. This way pictures and sounds can also be part of the course. Paintings and “visible” sounds offer numerous possibilities to help like simple models to understand physical phenomena and laws.

The poster intends to show some examples from the world of pictures and sounds in many topics of physics. We can find some paintings and drawings, which can be models of scientific thinking and modeling itself. Numerous works of painters, who dealt with the relation of light and space, can be thought of as optical study. There are several other topics of physics, which can be reflected in paintings, like the uncertainty principle, concepts of nuclear physics, concepts of the theory of relativity, etc. The analysis of the sounds and making sound visible is also suitable to show many physical concepts – besides the sound wave itself. We can mention superposition, magnetostriction, the uncertainty principle, etc.

Introduction

“If we really want to say anything at all about nature, we must somehow pass from mathematical to everyday language.” (N. Bohr)

Visible and audible models can help to realize Bohr’s quoted thought. Paintings and the sounds of music and noises offer several possibilities to create associations in order to make physical phenomena or laws more understandable. Using these types of models we can widen the examples and at the same time we can emphasize the fact that we have only one culture (which includes both science and arts).

Using an arbitrary classification, this presentation shows some examples from the world of pictures and sounds as possible models in teaching physics.

Modeling in the mirror of paintings

The teacher, who uses a painting to illustrate a theory, selects one or more elements from the picture which are analogous to components of the theory, and in this way the painting becomes a model of the theory.

Actually we can say that *every painting is a model itself*. The painters create models of different parts of the real world: finally it depends on the observer what he or she sees looking at a painting – instead of colored patterns on a canvas.

What is Jan van Eyck’s painting, *The Arnolfini Marriage* modelling? The observer can see the main subject of the painting (the

marriage), or the image formed by the spherical mirror, perhaps the process of forming the image. Sometimes the light and shadows are the main points for the observer, or the illusion of depth, created by light and the size of the things. But we can be sure that the observer of the painting does not see just colored dots of paints.

M.C. Escher's work, *The Waterfall* can easily cause a false idea that it shows a real-life construction. But we can understand the essence of the picture – looking behind the surface, - if we know the impossibility of a waterfall, working like a perpetual mobile and the optical illusion which is applied. The difference between the “surface” and the essential facts is similar to the difference between *interpretations of the motions* given by Aristotle and Galileo. It is the same situation in the *process of modelling*: we have to highlight essential characteristics, which sometimes do not appear for us at the first sight.

Paintings as optical studies

There are several paintings, which can be thought of as optical studies.

M.C. Escher's work, *Three Spheres II* represents well *the reflecting characters of a surface of a sphere*. He shows, at the same time, how various spaces coincide in this mirror effect, where the maker is present at the center. *Observer and creator are not separate* but indivisibly connected.

In Vermeer's painting, *A woman Reading a Letter*, the window *reflects* the young woman's features. A bare wall reflects the light and envelops the woman in its luminosity. Here we also can realize that “...*light not only helps to model the forms of the figures, but is equal in importance to perspective in creating the illusion of depth.*” (1).

This way we are confirmed that the *art of perspective* is near to the optics.

From the numerous perspective paintings let us have here only one of the great Dutch landscapes, Hobbema's picture, *The Avenue, Middelharnis*, where the fantastic depth of the painting is also supported by the colors (e.g. we have a feeling that the blue coloring subjects are in the further distance).

Victor Vasarely has several works which we can use to show *the diffraction patterns*.

The title of Dali's work, *The Image Disappears* is able to tell us more than an allusion to the duality of the topic of the picture: the vision of *The Reader* by Vermeer whose outline appears in a second image, in Velasquez's face. The physics teacher can connect the title and the painting to the *dual wave-particle nature of light*. In the picture we can discover sometimes a reading woman, sometimes a face of a man, while they are models, in fact we see colored parts of the canvas. Similarly to light: it can behave like particles, or wave, while it is neither particle, nor wave, but “light”.

In the Manet's painting *A Bar at the Folies-Bergère*, the real world and a second one in the plane mirror complement each other. Beside the *mirror effect* this painting can be a model of the theory of *complementarity*.

Modern physics reflected in paintings

The idea of *four-dimensional space-time*, turned up in the first part of the 20th century, also impressed the painters. Salvador Dali wrote in 1935: "Nowadays physics is the new geometry of thinking." (2) In *The Persistence of Memory* the soft watch is "*the Camembert cheese of the space and time*" (Dali), and at the same time it reminds the viewer, who is familiar with special relativity, of *the time dilation*. According to an English professor "*the cheese/watch is the metaphor of the curvature of Einstein's space-time. Later, after the Second World War ... in the Dissolving of The Persistence of Memory ... he explodes the cheese into pieces. This picture was inspired also by science, nuclear physics, first of all the explosion of the atomic bomb.*" (2)

The *Raphaellesque Head Exploding* was inspired by Dali's knowledge of *nuclear physics*. Here the Madonna face is depicted in a state of nuclear fragmentation.

In *Time Transfixed* Magritte portrays a train emerging from a fireplace and a clock on the mantelpiece, indicating stopped time, as *symbols of relativity*.

The elements of quantum mechanics, "models" of *wave-particle duality* (for example of electrons) and *complementarity* can be recognized also in some of the paintings of the previous centuries. George Seurat's paintings consist of dots (particles) or they show continual pictures (wave), in what we can recognize figures, things, or landscape – depending on the position of the spectator.

Sounds of music and noise made visible as physical models

The resolution and the analysis of the sounds and making them visible are also suitable to model several physical concepts. Instead of the well-known illustrations of the basic concepts of acoustics, let me present here some other examples.

The difference between the typical *types of the sound* can be a model of the difference between the *types of light emission*, as it is written in an article about Einstein (3): „*Light sources such as the sun and tungsten filaments produce plenty of photons of the same frequency, but they are out of step – they produce the optical version of random noise. Get all the photons to be coherent – to play the same note at the same time – and the result will be a singular roar rather than a dull hiss.*" (3)

Nowadays we can analyze the sounds using a computer program and well selected examples, so we can show and easily explain the characteristics of different sounds. But we also can apply them to model

other physical laws. The basic ideas of the following examples originate from an excellent book and enclosed CD ROM (4).

Applying Fourier transformation, we can get a resolution of the complex tone (the sound of a musical instrument) to its spectral components - to the fundamental tone and overtones. We can think about this process, like one of the models for *the principle of superposition* which sometimes is mentioned as *Newton's fourth law*. In case of a sound source, several forces, which cause harmonic vibrations, are acting at the same time. The net influence of these forces produces a periodic vibration. The inverse process is the basis of the Fourier analysis: from a periodic motion we can determine the harmonic oscillations, from which it was created. The visible result can be seen using the mentioned computer program with three types of displaying following analysis of a sound.

The rate of the resolution has a limit because of *the Heisenberg uncertainty principle*. Here the uncertainty principle is expressed in terms of time interval and frequency.

Standing near to a transformer housing or a high-voltage transmission line we hear a typical humming sound associated with *magnetostriction*. The changing magnetic field causes change in the size of the iron plates or wires, and this is followed by the change of pressure in the air. We can make this effect visible by sound analysis (4).

One can think of *entropy* as a quantitative measure of the degree of the *lack of information*. Nowadays perhaps this is the best approach to make this quantity more familiar to our students: we can show it by presentation of the basis of the digital sound recordings. In this process we have to compress enormous quantity of data without a significant degree of information loss. The data compression depends on a given proportion of resolution and reduction of the sampling.

Conclusion

Numerous further examples could be quoted from the world of pictures and sounds which we can use as models of several physical phenomena and laws.

Summarizing let me mention two paintings.

What do we see in Salvador Dali's *Metamorphosis of Narcissus*? On the left side we see a sitting figure whose image is reflected on the pond water (like Narcissus in the mythological story), or a hand, holding an egg from where a flower is growing. If the latter image is not seen in this part of the painting, it is repeated, like an independent image, where we can not misunderstand this, like the main topic. Perhaps the depth of the space is the essential point, or the simultaneous depiction of the events which follow each other in the mythological story – in this case the time, the relative idea of the simultaneity is the essential element for the viewer.

Pieter de Hooch: *A Music Party in a Hall* tells us information about perspective, musical instruments (sounds) and Amsterdam (the hall is based on one of the interiors of the Town Hall in Amsterdam).

The paintings and the sounds can model something for us, and the main topic of them depends on our fantasy, and on the level of our literary and scientific knowledge. If these motivations are deep enough, in this case the aim is the decisive point of view, whether the observer wants to emphasize something, to use like a physical, or any other model.

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