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Physics and Art

as an example of teaching physics within a non - physical context

H. Joachim Schlichting University of Muenster (Germany)

Science is spectral analysis.
Art is light synthesis.

Karl Kraus

Physics and Art

In order to get a comprehensive description of the world, in art as well as in physics one tries to reduce the complexity of the world to a manageable size. But even if this operation is done as carefully as possible one cannot be certain of getting a representation of the world (nature, or reality) as it really is. As the perception itself is a product of the given cultural context [1] it can only provide us with a certain view of the world, the world view.

The description of the world from a physical or artistic perspective is the result of a more or less lengthy process of socialisation. Vice versa, both of the important cultural activities art as well as physics contribute in a specific manner to the formation of the world view of the members of a given culture. Many interactions on different levels can be recognized.

A closer view on paintings and drawings show numerous physical aspects. Only some of them can be given here:

Fig. 1: *Dynamism of a dog* of Giacomo Balla.

Fig. 2: Representation of a fast motion by a comic strip

- artistic reflection of physical achievements (e.g. the discoveries of Isaac Newton),
- physics as magic art: presentation of technical devices initiated by natural science (e.g. telescope, electrostatic machine, vacuum pump),
- artistic reflection of representations of natural sciences and its influence on the "view of life"
- representation of natural phenomena (rainbow, sunset, "sundogs", "sundollars" (solar pinhole images)),

- representation of natural catastrophes,
- representation of motion and other non static phenomena (e.g. sound),
- representation of physical, especially optical effects (colour, gloss, reflections),
- artistic play with the laws of nature,
- physical techniques in art (determination of age, techniques of restoration .)

In the following, we shall illustrate some of these examples. We assume that the detection of physical aspects within the paintings may not only help to elaborate the physical view and to learn to make use of physical knowledge within an unusual context but also may contribute to a more profound perception of the paintings.

Physical Aspects of selected paintings

Motion

The influence of art on perception can for instance be illustrated by comics, in which motion uses to be expressed by superimposing different stages of the image within the same representation (fig. 1). This has apparently been inspired by the photographical method of multiple exposure to show the motion of an object. Thus, a method, relying on physical concepts (as light rays, linear propagation of light etc.) has become a convention of seeing (fig. 2).

Perspective

The interaction between physics and art can also be demonstrated by the important role of the central perspective dominating art since the renaissance. Via the "camera obscura" it finally led to the invention of the photo camera which nowadays is regarded as the apparatus by which reality is represented objectively (fig.2).

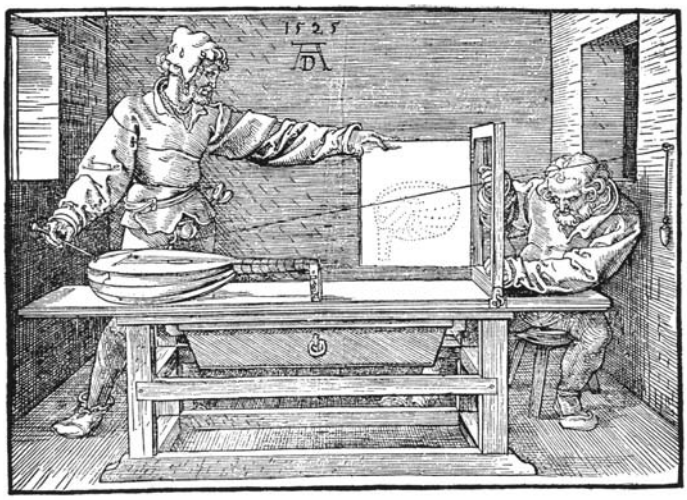

Fig. 3: *Der Zeichner der Laute* of Albrecht Duerer. The painter uses a stretched thread to get a true to scale mapping of the lute.

Fig. 4: In this drawing of a *Waterfall* of Mauritz C. Escher something must be wrong.

We will not investigate here the question whether the decisive impetus came from physical optics or from art. Anyway, the concept of light rays played an important role for both cultural activities, physics and art..

Within the domain of art Albrecht Duerer used a stretched thread to get a true to scale mapping of an object (fig. 3). Within physics Johannes Kepler used a similar construction of threads to explain the „sun dollars“ (pin hole images of the sun) [3]. But it should not be neglected that the concept of perspective basically is an optical illusion, by which real three dimensional objects are represented remarkably true by a two dimensional picture.

This illusion has been used repeatedly by painters to play with human perception of reality. A well known example is the *waterfall* of Mauritz C. Escher (fig. 4), which on a first view and by looking only at parts of the picture has nothing striking at all, but on a second more detailed view shows a severe offence of experience and a violation of natural laws.

Light and shadow

The technique of shade and shading as a means to get realistic representations of reality is of similar importance for painting as the perspective. The observer, in general, is so familiar with the shadow of an object that its missing is not only perceived as a restriction of realism but also may mislead the observer. A circle will be recognized as a sphere when it is shaded in an appropriate manner (fig. 5).
Therefore, the missing of shading at the sun or a lamp made of frosted glass (looked at from a certain distance) looks like a flat disk. Sometimes the shadows reveal the appearance of the original before it appears within the field of vision of the observer (Fig. 6).

Fig. 5: On this painting of Picasso the plastic effect is due to the shading.

Fig. 6: Coming events cast their shadows like on this painting of William Collins.

Fig. 7: On this picture of Viktor Vasarély two views switch one into the other while regarding it.

Fig. 8: When regarding this picture of René Magritte reversed, the tops of the waves change to valleys.

Similar as the concave the convex styling of a picture depends decisively on the distribution of light and shadow on the painting. This can for example be observed when pictures of plastic objects like in Fig. 8 are regarded upside down. The top of the waves flip into valleys and vice versa.

Fig. 9: Painting of Georg Friedrich Kersting. The shadow of the chair gets diffuse with growing distance.

Fig. 11: *La liseuse* from Claude Monet with “sundollars” on the dress.

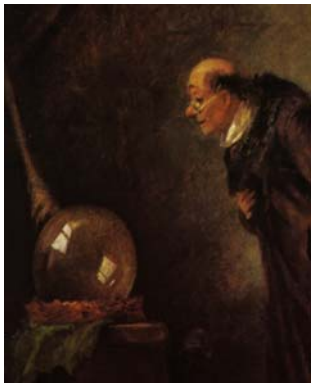

Fig. 10: "Der Alchimist" from Carl Spitzweg looking at a flask with reflections

In this respect, the predominant direction of the entering light has shaped our perception. The reversing of images of three dimensional objects may remind us of another phenomenon of turning over. If a three dimensional representation is not unique with respect to convexity or concavity there may appear irritating changes of the view, which sometimes are intentionally produced by the artist (Fig. 7).

Sometimes shadows are only outlined schematically. They appear distinct only near to the projection area and get the more out of focus the more distant they are (Fig. 9). At a very far distance, e.g. at a nearly horizontal illumination the shadow cannot be seen any longer, and the shadow of small objects adopts the shape of the light source.

Behind the latter phenomenon there is a physical problem which since the time of Aristotle attracted the interest of many scientists and finally was solved by Johannes Kepler [4].

Fig. 12: *The floor scrapers* of Gustave Caillebotte. The scraped floor looses the greenish gloss.

Fig. 13: *Impression: Sunrise* of Claude Monet with an impressive glitter path.

In nature there are many phenomena relying on this effect. For instance, the phenomenon of "sun dollars" (sun patches), small elliptical or circular light patches on the ground under the foliage of a tree, which are produced by small gaps between the leafs has attracted much attention of many painters especially of the impressionists (fig.10).

In physics shadows play an important role, too. Many discoveries concerning space and time were detected by the scientific evaluation of shadows. Let's only mention the sun dial, the first determination of the circumference of the earth by Erasthostenes and many other things[5].

Apart from shadows other light effects are also important for a true representation of world by paintings. For instance, the gloss and other phenomena of reflected light are real aspects of the perceived objects. Transparent glass objects would not at all be visible without their characteristic light reflections, e.g. of the windows or other light sources, which are mirrored in a distorted way typical for the shape of a given glass object (Fig. 10).

Fig. 16: *Goldfishes* of Henri Matisse. How many are in the glass?

Fig. 14: *Bar in the Folies Bergère of Édouard Manet*. The front mirror of the bar reveals with whom the young lady is talking. But something does not fit with the laws of optics.

Fig. 15: *The Forbidden Reproduction* of René Magritte.

Surfaces of metal and shining surfaces of wood very often show a gloss. When as in Fig. 12 the reflecting layer of a wooden surface is planed the specific gloss vanishes and the own colour of the wood can be seen by diffuse reflection. But why does the wooden floor gleam in a greenish gloss? This kind of gloss is similar to another common natural phenomenon, the glitter path of the sun (Fig. 13) which can be observed on the wavy surface of water especially when the sun is low [6].

The simplest well known special case of a true representation of an object is its reflection by a mirror. For children it is always a rather irritating experience, when they see themselves mirrored the wrong way round. But what do they expect? One answer to this question has been given by a painting of René Magritte (Fig. 15), which shows how a mirror picture would look like if the front and the backside of a person were not interchanged. It would be a rather interesting physical exercise to find out how the light rays had to travel to bring about this phenomenon.

Sometimes the painter plays with natural laws in such a careful way that it is not noticed at all at least not at the first view. You must have a certain understanding of physical optics to recognise that in Fig. 14 the mirror picture of the back of the lady is shifted in an unrealistic way to the right, although the observer is standing just in front of her, as may be seen in the mirror.

Even the phenomenon of refraction may be detected on paintings. Very often the candle light is focused by a glass of wine in a characteristic bright spot of light within the shadow area of the glass, or displacements due to the refraction of light are shown. Sometimes painted refraction phenomena appear to be more irritating than in reality as e.g. in Fig. 16. Different from reality where you easily can adjust your view to make sure how many fishes are in the glass, on a painting you have to accept the ambivalent perspective of the painter.

Colour and shadow

Gloss, e.g. the direct reflex of a shining object appears in the colour of the illuminating light source. Mostly the gloss is of a dazzling white colour because the sunlight is reflected by many different ways into the eyes, as e.g. in the case of the glitter path (see above). But the gloss of the floor on Fig. 12 appears greenish because the direct light entering by the window is blended by the indirect light scattered by the greenish walls.

Fig. 18: On this painting of Paul Cézanne the windows have different colours.

Fig. 19: *Der Moorgraben* of Heinrich Vogeler. The water gets lighter to the horizon.

Fig. 17: *The Jockeys* in front of the tribunes of Edgar Dégas cast bluish shadows.

Therefore, the walls have to be taken into account as light sources as well. Indeed, at places where the direct white light from outside is dominating the gloss is nearly white.

Fig. 20: *The Magpie* of Claude Monet. The yellowish snow of the sinking gets a bluish colour in the shadow of the fence.

Window panes reflect the light nearly like a plain mirror (but see e.g. [7]). They appear in a silvery white when the direct sunlight is reflected into your eyes. Sometimes the windows adopt a blue colour, sometimes they are black (Fig. 18). They are black when the window is opened and nearly all the incoming light is absorbed so that nearly no light comes from inside. The windows appear blue, when the blue sky is reflected into the eyes.

A brook directed to the horizon with a still surface also reflects the blue sky (Fig. 19). But it seems to be striking that the intensity of the blue decreases towards the horizon. Taking into account the laws of reflection this phenomenon clearly shows that the zenith emits a more intensive blue than the lower parts of the sky, which indeed is due to a well known physical fact.

The blue colour of the sky is also important for areas which are not illuminated by the sun, e.g. in the shadow of objects (Fig. 17). This problem often has been overlooked because the shadow uses to be regarded as colourless dark. Good painters do not trust their knowledge, they simply paint what they see. Only in the case of snow fields in the light of the low sun even the untrained eye is sometimes aware of the yellowish colour where the

snow is illuminated by direct sunlight and the bluish colour of the shadows where only scattered blue light of the sky is present.

Sometimes, a similar phenomenon may be observed in a room with slightly coloured window panes. We believe to see a white wall because we know that it is white, but as a consequence of this frequency shift, the "white" colour of our computer monitor appears reddish.

The bluish shadows on the paintings illustrate one important point. Not only the sun is a light source, but also the coloured objects which only emit the fraction of the white light which corresponds to their colour. Therefore, for the sensitive eye of the painter shadows are not inexpressive dark areas but a "festival of colours": the green of the leafs, the brown of the trunks, the yellow of the sand are dominating where the sunlight does not get (Fig. 21).

Fig. 21: *Avenue of the Park of St. Cloud.* Gabriele Muenter detects many colours in the shadow of the trees.

Artistic treat by a physical perspective

This small selection of paintings related in some respect to physics shows that unusual looking phenomena are not necessarily an expression of the artistic freedom of the artist. On the contrary, they demonstrate the careful observation and its conscious creative transposition by the painting. Regarding paintings from a physical standpoint often surprising aspects arise which, at the same time, may sharpen the physical view and contribute to a deeper perception of the work of art and therefore represent an additional artistic treat..

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