Field lines in art and physics

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Abstract. The physical space surrounding us is not empty, it is filled by objects and fields. Macroscopic objects are visible, but fields can only be detected with sensitive instruments rather than the naked eye. Physicists introduced visual clues (field lines, trajectories, streamlines, equipotential surfaces) based on helpful mathematical concepts to characterize (the mostly invisible) physical fields. These illustrations are used in high school-level physics, but – due to their abstract nature – are not easily understood by students. Most of the confusion is caused by students mistaking the plotted auxiliary concepts for physical reality. We can help their understanding by drawing parallels between the visual representation of fields and the technical methods used by a painter to express the subject.

1. Introduction

The space surrounding us is not empty [1] in the physics point of view, since sets of particles of different qualities (like bodies and media) and fields (like force fields, streamlines and vortices) are present. The bodies or media of macroscopic measures are generally visible (except in cases when the absolute refractive indexes are the same). The force fields are invisible for us, to detect them we need special measuring devices. To characterise the force fields scientists made helpful notions mostly mathematical ones that can be presented visually, like field lines, trajectories, flow lines, equipotential surfaces, like in Figure 1. These illustrations are used in secondary physics classes, and the deeper understanding for the students is generally not an easy task, mostly because of their abstract nature.

Figure 1. The parallel streamlines of a friction free flow, also showing the velocity vectors (self-made figure)
One of the major motives of the confusion is that the students consider these helpful notions as physical reality. In fact, these are systems of lines in plan or space to help to understand reality better. With them, we can turn the invisible characteristics into visible ones adjusting them to the defined quantities. We can make the understanding easier if we draw a parallel between the characterization of the visualization of scientific fields and technical solution of the substantive expression in fine art. When we use this method, we need to make an emphasis on the essential difference. The goal of the visualisation in science is to provide objective quantitative description [2]. All physicists draw the same (or very similar) figure regarding the same force field. Art due to its nature commentates a subjective point of view. Each artist depicts the truth through his on emotion-based filter, so despite the same theme the art-pieces can be very different in different interpretations by diverse artists. We can perceive that the same artist revisits a theme several times and the art-pieces are considerably different. The motive can be like the effect of the momentary mood of the creator.

2. Drawing parallel between the scientific and artistic fields

2.1. Central fields
When teaching physics, we put emphasis on the study of the fields in electrostatics. The source of the field is the electric charge. We introduce in the case of a single charge the field strength vectors defined in any point of the field, the field-lines, the equipotential surfaces, and the relations of all these. Later we expand the description to more complex cases. We can define the central of a charge field two ways. We can either describe it with some calculations based on Coulomb’s law or we can just illustrate with an experiment (Figure 2.).

![Figure 2](image)

*Figure 2.* The typical course book figure of the central field, the experimental spectacle and *Street Light* by G Balla (1909), [3]

This is how to make the experiment. We pour oil into a glass saucer forming a shallow layer only. We immerse a metal rod in the middle, and we attach it to a static machine, like a Wimhurst machine. We strew semolina into the oil. The grains become small dipoles; therefore, they get settled facing the opposite poles to one another, thus they form the electric field lines. If we let some light shine through, we can project the structure. We show it in Figure 2b. We can easily demonstrate that the source of the field is the charge, which is the centre of the structure. The density of the filed lines is big near the source, and it decreases still in a radial setting as we get farther. It implies that the field is getting weaker, so the field strength is getting smaller.

The structure mentioned above is illustrative, but it is not equivalent with the central field. It is because the semolina granules are not perfectly following the radial structure, so they do not give the exact direction in each of the points. The uncertainty of the density distribution does not provide accurate information to enable us to derive the punctual value of the field strength vector. If we vary the size of the granules in our experiment, the spectacle varies, even though it still characterizes the density and the central structure very well.
The central electrostatic field and the light-distribution surrounding a point-lamp are not identical, but they show similarities. G. Balla (Italian futurist artist) created a painting (Figure 3c) in 1909, which masterly illustrates this mentioned similarity. The light spreading centrally from the lamp is visualized with little colourful dashes set radially. The luminous intensity is decreasing from the centre, which is also demonstrated in an illustrious way. It gives special curiosity to the painting (and the artist) that the latest results of physics of the period are represented. The tiny colourful dashes representing light refer to the well-known facts on white light: it is a composite of colours and photon refers to the particle nature of light. We can catch the glimpse of the moon, which has more meanings. One is that it suggests nightshift. The other is that it is kin to the lamp: as a secondary light source it reflects the sunlight. Thus, the artificial light as the great achievement of mankind with its surrounding traits is ruling the picture along with the natural light present.

The rising sun and the seeds are symbols on Vintage Sower at Sunset by Vincent van Gogh. The primary energy source for the plant to grow from the seed is the Sun. The flow departed from the Sun reaches the earth and recolours it. The design of the flow is very similar to the field lines of the single charge. This central design is used in more of the paintings, as you can see in Figure 3.

![Figure 3. Vintage Sower at Sunset by Vincent Van Gogh (1988) oil on canvas, 64x80cm [4] and Willows at Sunset by Vincent Van Gogh (1888) oil on cardboard, 31.5x34.5cm [5]](image)

### 2.2. Streamlines

We characterize the flow of a continuous medium by streamlines plotted by appointed minute volumes in the medium. We call these trajectories or flow lines. These are curves, and if we draw the tangent of the curve in any point of the flow-field, we get the velocity of the particles. We illustrate the speed by the density of the streamlines. We show it on Figure 4.

![Figure 4. Streamlines regarding a flow of the continuous medium with velocity vectors (self-made figure)](image)
In slow, viscous flow cases we can observe that fluids move in laminar way with constant speed. In this case the streamlines and the trajectories are similar: they are parallel lines, as you can see in Figure 1. In cases of great speed, especially if hurdles are in the stream the order is split up: the streamlines become curves, they haywire, and they become very hard to be tracked, like in Figure 5.

![Figure 5](image1.png)

**Figure 5.** As the speed of the flow increases the parallel lines curve and haywire (self-made figure)

In this case we talk about turbulent flow. The streamline-setting is utterly different, their nature is different. Figure 6. shows laminar and turbulent flows.

![Figure 6](image2.png)

**Figure 6.** Slow, laminar flow around a hurdle, and Karman vortices behind one [6], [7]

The representation of flows is often present is paintings. To perceive certain motions of media, like flows of rivers, waterfalls or winds, the artist quits the moment. He visualizes the space in its motion, so that he can open opportunity to present even deeper content. In Van Gogh’s Starry Night (Figure 7a), the turbulent flow indicates a coming storm or a high-powered wind. In the painting the Karman vortices are in the focus. Also, in Figure 7b we can see in parallel the Karman vortices that are generated behind mountains in an intense flow. As we have seen Karman vortices behind mountains, we can also observe them behind islands, like in NASA satellite pictures, in Figure 7c.
Art often expands beyond portraying natural phenomena, like when it uses visualization of turbulent flows of great speed to gain emotional effect. Depicting stormy wind or sweeping flood is associated in many of us with the feeling of uncertainty and fear.

The only straight line is the bridge providing the perspective on Edvard Norton’s art-piece, The Scream (Figure 8). The artist is a Norwegian expressionist painter. Everything else on the painting is waving, swirling, flowing, eddying, which gives a huge approval to cause global fickleness and insecurity. The original title as: The scream of nature, as we can read in the artist’s memorandum. According to his memoir he observed the sunset in the Oslo fjord tired and sick, he found the scenery frightening in a sentiment way, and it seemed to scream. Based on analysers the atmospheric phenomenon that touched the heart of the artist was due to the eruption of the Krakatau volcano. Sensing the swirling red sky was observable for one day lifespan only, according to studies of H. Gibson the reason behind the peculiar red sky is another phenomenon: the stratospheric polar clouds formed 20-30 km high in the wintertime.

Figure 7. Starry Night Vincent Van Gogh (vortices highlighted in red by the authors) and vortices behind mountain peaks in 2016 and islands in 1999 respectively from the NASA website [8], [9], [10]
2.3. **The curved spacetime**

In the Einstein theory of gravity there is no gravitational field. The pretense interaction attributed as gravity is caused by the curving of spacetime. So, the effect of materialistic objects is known based on the special theory of relativity. But we face difficulties if we want to illustrate it. Exemplifying the curving of the 2-dimensional surfaces is an easier task: we can make models of cylindric surfaces, and we can study the similarities and the differences between plan and curved surfaces. We can see the curving if we step out to a 3-dimensional space and quit from the 2D surface. We could do the same with spacetime including 1 time and 3 space dimensions, if we could step out to a 5th dimension. But it is not possible for us.

It is a herculean task for an artist to signify space that is modified by the presence of matter. The Mercury passing in front of the Sun by G. Balla (Figure 9) shows the orbital motion of the planet with expressing the modified space structure around it. The fragmented shapes propound the inhomogeneity of space, whereas the spiral refers to change of the path in time, pretty much like a time-lapse recording.

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**Figure 8.** *The Scream* from E. Munch (1893) and colourful clouds in the sky [11]

**Figure 9.** *Mercury passing in front of the Sun* from G. Balla, (1914) oil on canvas [12] and the model we refer to when illustrating the structure of spacetime, 2017 [13]
3. The direct effects of field lines onto fine art

The examples mentioned before are to demonstrate similarities of space interpretation between art (especially paintings) and physics. In today’s modern art it is not unique if the focus of an art piece is reinterpreting certain notions of science, like entropy, energy, velocity, etc.

László Pirk is a contemporary Hungarian artist, a painter. His series called Fuga is based on the magnetic field lines. The paintings make connections among music, science, physics, the elementary existence of light and artistic painting. Analysing his painting, the “Fuga 2” is not only a good example of integration of art and science (like in STEAM pedagogy). It is also highly beneficial for the students in physics classes for influencing their philosophy, helping them to gain better attitude towards the subject.

![Figure 10: Fuga 2. by L Pirk, oil on canvas (2018), [14] (with the artist’s agreement)](image)

4. Conclusion

One of the most important factors of imparting physics knowledge is that it should be easily restructured. The notions we intend to evolve should not be rigid or inflexible. Bearing in mind that they should be interpreted in punctual, accurate and exact ways. If we introduce scientific notions in a brand-new way in new contexts and other situations too, we can offer to achieve a more creative, integrated knowledge for our students [15]. En passant, we can provide higher level motivation for students whose personal interest focuses on other subjects. We have flashed a few possibilities in fine art and physics, each of our examples were dedicated to central and magnetic fields, streamlines and spacetime.

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