PROMOTING ENVIRONMENTAL PHYSICS ISSUES IN SCIENCE CENTRES AND AT SCIENCE EVENTS

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ABSTRACT

We consider that environmental physics issues could be interesting for students, but these topics are not included in the school curriculum. Organizing extracurricular physics events is of great importance as they present aspects that are related to everyday life and environment. We make an overview of experiments related to environmental physics displayed throughout different European science centres. We present experiments related to this topic performed during the annual event "Saturday of experiments" organized at the Babeş-Bolyai University – tsunamis, weather fronts, cyclones – and make suggestions for the possibility to display at science centres without the help of an animator.

INTRODUCTION

For students the process of learning physics is a very complex one, partly because of the abstract nature of many scientific concepts and of their mathematical representation. Topics of different curricula are related to simple physical models which in most of the cases do not relate to real-life situations. Because of their complexity, everyday life and environmental phenomena are difficult to be represented mathematically, so they are avoided in high school curricula. The other challenge of teaching these topics is to have an experiential approach to help better understanding. As for the moment we cannot have an influence on national educational policies, we try to summarise some informal learning activities to provide learning situations about our environment. Such informal learning activities are offered by science centres, different science events and student research projects. As an example of a science event we present the Saturday of experiments organized by the Faculty of Physics of the Babeş-Bolyai University and the EmpirX Association.

ENVIRONMENTAL PHYSICS IN SCIENCE CENTRES

Museums and science museums in special have a special educational role. In the case of museums the main motivational tools are intrinsic factors – such as curiosity, enjoyment in learning and mastery of challenge. Thus, learning in museums has a different character from that at schools, where extrinsic factors such as examinations, grades, approval of teachers are common motivators [1]. Mihaly Csikszentmihalyi has studied different intrinsically motivated activities [2]. He points out that this kind of learning is successful only when the challenge is close to but slightly greater than the skill level of the person and when feedback is immediate.

In the best museums, learning is a multisensory activity. Exhibits are visually exciting and most have a text to help explain the phenomena. But they also produce sounds and encourage touching. Because of this richness, museums and exhibits have the opportunity to connect with many different learning modes that people use.

We have made a short inventory – some of them by personal visits, some from the information provided by the scientific boards of the museums – of environmental physics exhibits in different European science museums. We have gathered information from the following ones: MUSE Trento, Italy, Phaeno Wolfsburg, Deutches Museum Munich, Germany, At-Bristol, Techniquest Cardiff, Wales, Science Museum London, UK, Technisches Museum Wien, Austria, NEMO Center, Amsterdam, Netherlands, Hiša Eksperimentov, Ljubljana, Csodák Palotája Budapest, Hungary. The playful atmosphere of science centres leads many people to think of them as places only for children. But “playing” is a serious matter in science education. It leads to the development of skills in observation and experimentation and the testing of ideas, and it provides an opportunity to independently discover order in nature.

Fig.1. Flow tank at Techniquest Cardiff [3]

We have found a diverse presentation of environmental physics related experiments, being hard to summarize them in one paper. Phenomena related to fluid dynamics have a special interest for us, as this is one of the topics which is avoided in our curriculum in high schools, not only in the Romanian educational system, but in the Hungarian as well. The most often presented phenomena are: turbulent and laminar flow, the Bermuda bubbles, vortices and tornados. The flow tank appears in many museums in the form of a tank of fluid with shiny mica crystals, inside which the visitor can move and rotate objects of different shapes with the help of a magnet, like the one shown in Fig.1. from Techniquest in Cardiff. With the help of these objects the visitor can experience the occurrence of turbulent flow and make connections with phenomena experienced in everyday life. In some cases turbulent flow is presented in connection with the atmospheric movements through a semi-spherical dome which can be rotated by the visitor (NEMO Center Amsterdam).

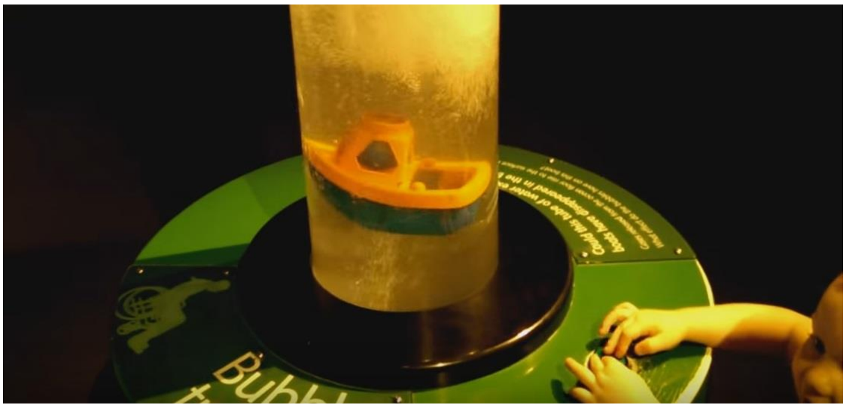

Fig.2. The Bermuda bubbles experiment in At-Bristol museum [4]

The mystery of the Bermuda triangle is a commonly known phenomenon where a number of aircrafts and ships are said to have disappeared under mysterious circumstances. We can argue about the accuracy of the data but our goal is just to find a possible explanation. Laboratory experiments have proven that bubbles can, indeed, sink a scale model ship by decreasing the density of the water [5]. Based on this, in many science museums the experiment is presented with the name: Bermuda bubbles, which consists of a large cylindrical tank filled with water and the visitor can adjust the amount of air released into from the bottom of the reservoir. The visitor can observe (Fig. 2.) how the model ship sinks to the bottom of the tank (At-Bristol). If the water is full of bubbles it is a much lighter fluid then ordinary water, so water full of bubbles cannot hold the ship.

SATURDAY OF EXPERIMENTS AT BABEŞ-BOLYAI UNIVERSITY

In our town, Cluj-Napoca, we do not have a functional science museum, but as one of the major cultural, academic and industrial centres of Romania there is a real need to have a science museum. We have tried to achieve something similar with the one-day event called *Saturday of experiments* which is organized once a year. It is organized by the Faculty of Physics at Babeş-Bolyai University in partnership with the EmpirX Association in the main building and the courtyard of the university every spring in April or May. In comparison with science centres it is a low budget event, as the exhibits are low-cost ones, they cannot be used individually, so each exhibit is presented by a guide. Even so, most of the exhibits are hands-on, thus the presence of an animator represents an advantage facing science centres, as the visitor has a person to ask his questions, to discuss the observed phenomena in detail, reaching a higher level of understanding. More than 60% of the visitors are high school students, as our aim is to keep their interest in physics alive. The animators are selected from among the students of the Physics Department, who are prepared in advance by their tutors, to present in pairs or teams a certain experiment and to reply to the visitors' questions. This is an excellent way to provide teaching practice for them. At each edition of the event, we present around 40-50 exhibits, many new ones as well, but there are some much enjoyed by the public, presented regularly. The visitor has free choice in both the experiments and the order of visit, similar to the science centres. We print out leaflets with the map of the event site and the location of each experiment. The event is with free entrance and it has become one of the main scientific events of the city, attracting more than 1000 visitors not only from Cluj County, but some schools are organizing trips for their students even from a distance of 300 km. The project *Saturday of experiments* was supported by grants from Bethlen Gábor Foundation, Cluj County Council and sponsorship from SKF Romania.

As first impression is always important, at the entrance to the event we project one of the main attractions of the day, like experiments with smoke rings or experiments with liquid nitrogen. Smoke rings are produced by a card box (about 80x80 cm base) with a hole of about 30 cm on the top. The bottom of the box is replaced by a membrane. The box is filled with smoke and rings are produced by hitting the membrane. We have used two boxes at the same time to observe the collision of the smoke rings, too. Liquid nitrogen is used for several experiments, like levitation of a magnet above a superconductor (Meissner effect), rapid freezing and crushing of different plants or placing inflated balloons into liquid nitrogen to observe the thermal contraction and expansion process of the air.

We have carried out a survey among the visitors about the most attractive exhibits in order to have a feedback of the event. Visitors were requested to complete a questionnaire at the end of their visit. They were asked to name the five most attractive exhibits. Among the most cited was the one called tsunami, which consists in a long water tank (dimension of the water tank: 297x12.8x35 cm), which is separated in two with a plexi glass. If at the beginning we make a difference of water level in the two sides, at the removal of the separator a soliton wave is formed which travels along the surface, as shown in Fig.3. A soliton is a wave-packet which maintains its shape while it propagates at a constant velocity. A remarkable quality of these solitary waves is that they collide with each other and yet preserve their shapes and speeds after the collision.

Fig.3. Soliton wave in a water tank, after the removal of the separator, presented at the Saturday of experiments event in 2015

In attracting talented students towards the study of physics, a significant role have the research projects realized by them. Inspired by the soliton waves, Vivien-Emőke Bartha and Botond Biró, students in Apáczai High School ran a project (simulation of known physical systems) using the experimental setup presented above to prove the relationship ($c = \sqrt{gH}$) between the travelling velocity of the soliton wave (c) and the depth of water before the separating glass is released (H), where g stands for the gravitational acceleration. They have found a very good correspondence between the theory and the measured data. They performed a two-dimensional computer simulation as well, which proved the formation of the soliton wave in such conditions [6]. In this project they were helped by a supervisor, a PhD student, Dávid Deritei, a former student of the high school. This project shows that science centres or science events may have long lasting influence on the interest in studying physics.

With the same setup we have presented weather fronts as well. For modelling the cold front we put cold water in the left side of the tank, and warm water into the right hand side (left panel of Fig. 4.). When releasing the separating glass, the water from the two sides mix together like in the right panel of Fig 4. The difference between cold and warm water can be highlighted by colouring the water in the left hand side. These experiments were inspired by the fruitful collaboration between the Physics Department of Babeş-Bolyai University and the Kármán Laboratory from ELTE University in Budapest. About similar experiments in this laboratory you can read in detail in the paper of Miklós Vincze: *Modelling climate change in the laboratory*, published in this same proceedings book of the conference.

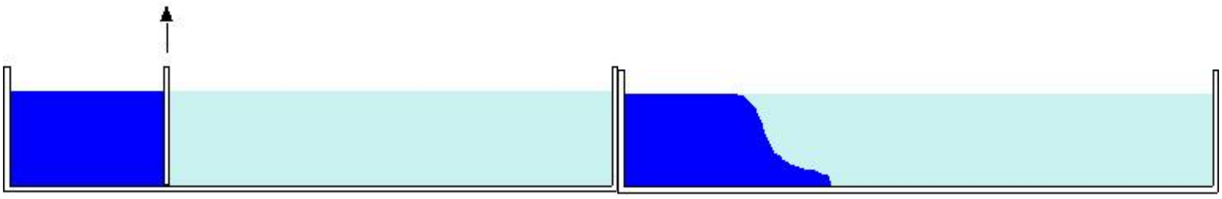

Fig.4. Left panel: Water tank separated in two by a glass with cold water in the left and warm in the right. Right panel: After removing the separator, the cold water moves similarly with the cold front [7]

Some atmospheric phenomena are intriguing, such as the von Kármán vortex street (Fig.5.). It is a repeated pattern of swirling vortices behind objects in a stream of a fluid. They appear on the two sides rotating in opposite direction and are caused by the unsteady separation of flow [8]. In order to save water, we use a cylindrical vessel with water on a rotating disc. We introduce the needle of a syringe that stands as an obstacle in the stream of water created by the rotation. The red ink released from the syringe is for visualizing the vortex street (left panel of Fig. 6). The syringe is moved slowly from the margin to the centre of the vessel, as the vortices can be seen for longer time. The von Kármán vortex street is visible behind the syringe as in the right panel of Fig. 6. Animators used to explain that vortex street is observable in our direct environment around a stone in a stream of water and could be tested with the help of some leaves dropped into the stream. Another example is the fluttering of a flag generated by the flagpole.

Fig.5. Landsat 7 satellite image in September 1999 above Selkirk Island, off South America. Credit: Bob Cahalan/NASA, USGS

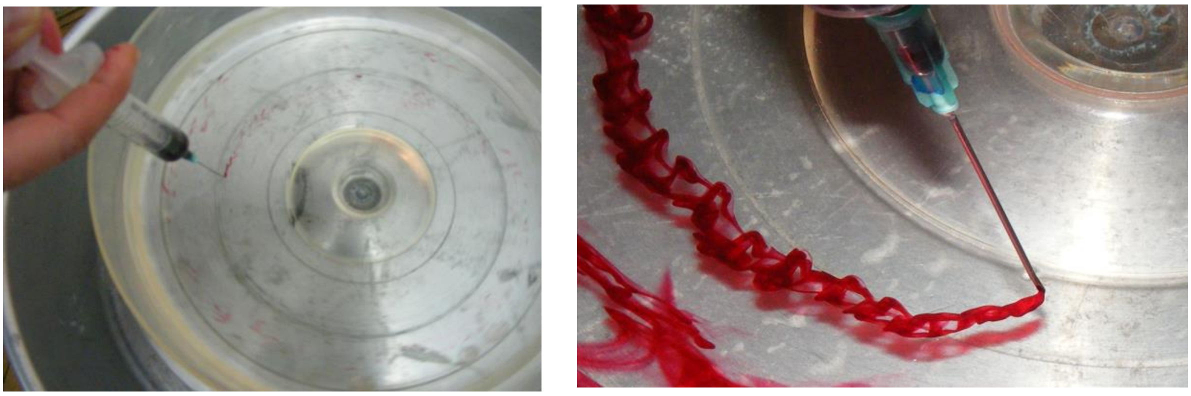

Fig.6. Left panel: rotating disc with cylindrical vessel with water, Right panel: von Kármán vortex street visible behind the syringe

According to our information, the latter two experiments presented above are not displayed in science museums, but because of their expressivity we propose them to be adapted in a hands-on manner. As for the case of the von Kármán vortex street experiment, the visitor could adjust the rotational velocity of the vessel, and to manoeuvre the syringe. With a robust construction, the experiment could be run safely even by a young student, in order to be displayed in a science museum.

CONCLUSIONS

Science museums have a diverse field of experiments, and in each case we have found a huge number of exhibits related to environmental physics: energy production and conversion, fluid dynamics, pollution, waste management. In this paper we presented only those related to fluid dynamics, as we think they are of great interest, because this topic is missing from the school curriculum, and related to it some new phenomena could be presented in science museums as hands-on experiments. We propose two experiments to be presented in this way: the tsunami and the von Kármán vortex street.

The *Saturday of experiments* science event has the following advantages: possibility for the visitor to ask questions about each exhibit, to have a discussion on the observed phenomena with a young scientist, it is a low budget event, the explanations can be adapted according to every age group and to the level of the individual knowledge. The event is a proper way to give the university students practice in both teaching and team building. Disadvantages of these events to the science centres: a lot of volunteers are needed, sometimes it is overcrowded at some exhibits, so some visitors could miss out some experiments, it is organized only once a year. The *Saturday of experiments* is a very good way to promote science in general and physics in particular, thus completing the formal educational tools and even leading to engage high school students in demanding research projects.

There are cases when science centres try to promote science in a more direct way. This is the case of Hiša Eksperimentov from Ljubljana, where each year a three-day long science festival is organized with a lot of volunteers engaged reaching outside the walls of the museum, and engaging the entire town centre into exciting science lectures, presentations and events. This way physics can reach the general public.

Science museums and science events as well, regard learning in a minimally guided approach, described under a variety of names: discovery learning, inquiry based learning or experiential learning. Formal education can use these methods only rarely, thus these events and institutions are excellent for deepening some existing structural competencies and knowledge [9].

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