MULTIMEDIA TOOLS IN TEACHING PHYSICS

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Introduction

Shrinking schools programs of Physics in many European nations, a falling number of university students in this subject, a lowering share in overall science budget and a slowing rate of revolutionary inventions create the demand for new, cheap, fast and effective teaching methods. On the other hand, thanks to enlarging of consumer markets, improving of production methods and technology progress these methods are "at reach". We remember our secondary school lessons with heavy and rusted iron trolleys to study kinematics, clumsy and dusted wooden boxes to study acoustics and hardly shining Plücker tubes to study optics and atomic physics.

Now, computer-driven set-ups to study kinematics are machined in durable plastics and anodized aluminum and controlled by affordable computers with a specialized, however still cheap interfaces and software [1]. Existence of discrete levels in atomic emission now is "naked-eye" visible, by the use of any CD-plate and "economic lamps" [2]; polarization of day sky light due to Rayleigh scattering can be easily observed using plastic plates, like the envelope of the same CD; tunable acoustic columns, made out of 10 cm long bamboo piece as regional gifts in Argentina cost as low as 3 €. A number of internet places [3,4] and assemble these didactic tools.

A methodological problem arises how to incorporate these abundant "hardware" objects into didactics process. First, their availability and variety makes somewhat difficult to identify their goals, i.e. particular physical laws to be illustrated. Second, even if available, the lack of time often limits their use. Therefore, we resume below sets of "multimedia" tools in two subjects, available elsewhere [5,6].

Electromagnetism

Let's define two leading threads for electromagnetic thematics: - the first one historical one, the second – the summarizing one. For the first thread a good "excuse" can be the recent 200-years anniversary of Volta's pile (invented 1799), for the second – Maxwell equations.

Volta's anniversary was celebrated widely in Italy; his historical museum is placed in Como, with original batteries of two forms - a pile of coins and a file of glasses, see photo 1. As stated by Einstein in 1929 "Volta's pile became a starting point for a long series of discoveries in electromagnetism, so it is really difficult to overestimate its importance". The easiest way to build the Volta pile is just to use coins (unfortunately, new euro coins give very small – 0.1 V contact potential). However, numerous other ways of showing contact potential are easy – starting from well known "vegetable clock" and aluminum-made pencil sharpener, see photo 2.

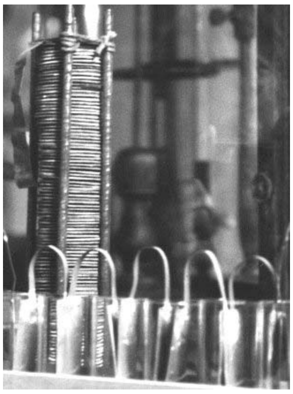


Photo 1a. Original batteries of Volta (Volta' museum, Como): a pile of coins separated by acid impregnated paper and a file of glasses with metal plates and acid.

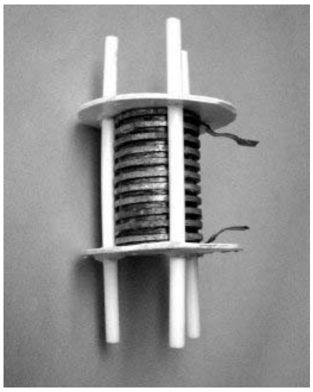
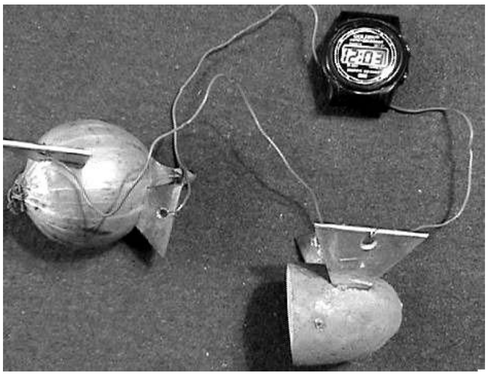


Photo 1b. Home-made reconstruction of Volta's pile – Polish coins, telephonic card and lollipop sticks are used. Differently from Volta's coins, modern ones get corroded even after a short use.



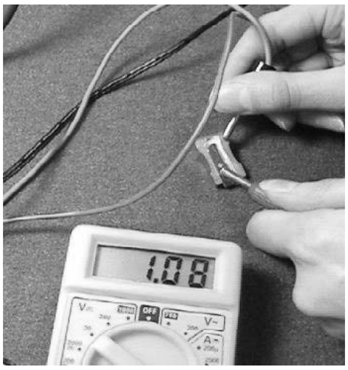


Photo 2. Different way of illustrating the electrochemical contact potential between two metals: a) a vegetable clock (with Cu and Al electrodes) b) Al-made pencil sharpener (a knife from stainless steel) giving (with saliva-wet paper) more than 1.0 V.

Volta's pile was historically second (after the electrostatic machine by Otto von Guernicke 1663) source of electric current. Modern generators use Faraday principle of generating current by rotating conductors in magnetic field. This way, practically implemented by A. Pacinotti in 1859 (but with patent issued to Z.T. Gramme in 1870) can be easily illustrated using a Helmholtz's coil – about 100 windings on about $1m^2$ internal surface frame, see Photo 3. This coil turned in Earth's magnetic field generates easily measurable (a few meV) "voltages". What is to be shown with "hardware" coil is that i) the voltage changes its sign with turning, ii) it rises in amplitude if the coil rotates quicker and iii) no voltage is generated if the coil is simple shifted in the Earths' field instead of being turned.

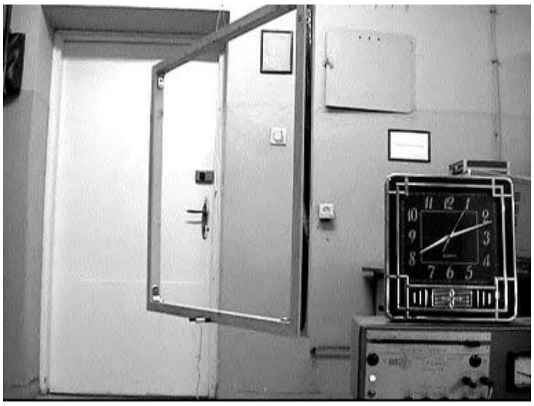


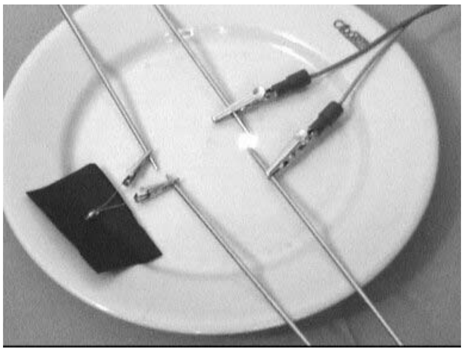
Photo 3. Helmholtz coil (a winding of about 100 turns of 1 mm diameter copper wire) can be used for:
a) showing the force momentum acting on it if the electrical current (3-5A) is supplied; b) the Faraday-Lenz current (a few meV), when turned around.

Other, in historical order, ways of generating electricity, can be also easily shown in class: Seebeck in 1821 thermoelectrical effect (just two different wires, a micro-voltmeter and the gas-lighter), piezoelectric (Pierre Curie 1880) – piezoelectric lighter. Photovoltaic effect can be very easily shown with photoluminescence diodes: just insert them into the voltmeter plug and illuminate. The voltage read corresponds to the photon energy (in eV) of the diode color (red, green) minus the *n-p* contact potential (0.8 V), see photo 4.

Hertz's proof of electromagnetic waves (1887), being the apex of studies on electromagnetism can be repeated using the piezoelectric lighter, two couples of wires and a small neon indicator (like in 200V tester - screwdriver, see photo 4. Using longer wires as antenna (say 1 m long each) the distance between the sender and receiver can be up to 1 m. Another way to show electromagnetic waves is to use the "plasma lamp", see photo 4b – a small neon lamp illuminates in the neighborhood, even is shielded by a piece of paper (but not aluminum). Electromagnetic waves (from 220 V line hidden in wall or from a TV monitor) are also detected by a small, semiconductor "screwdriver" 8 € worth.

Photo 4. Photoelectric effect shown with two light-emitting diodes: to the left a green one, to the right – a red one. The voltage read is that of light energy quanta, minus 0.8V for the *n-p* barrier. Obviously provided the light is enough intense, like day light and contains "sufficient" energy quanta (no voltage is read is a green diode is illuminated by a red laser). The voltmeter must be of high internal resistance – in these conditions the experiments reproduces exactly the characteristics of normal (i.e. "external", Hallwachs, 1888) photoelectric effect.

A second way of "collecting" experiments and multimedia files on electromagnetism is to follow single terms in Maxwell equations. The first law $\oint \mathbf{E} \circ d\mathbf{S} = Q_{\mathrm{int}} / \varepsilon_0$ can be shown using van der Graaf generator [1]. Van der Graaf generator builds up high electric fields (outside the sphere) thanks to the fact that it collects the charge through whiskers inside the sphere – where the field is zero (no internal charge), see photo 6. The first Maxwell law becomes then Coulomb $1/r^2$ law: two point charges attract themselves with the force higher when they get closer (they move towards each other with a rising acceleration). This is also simple to be shown with the Christmas-tree balls and the piezoelectric lighter, see photo 6.



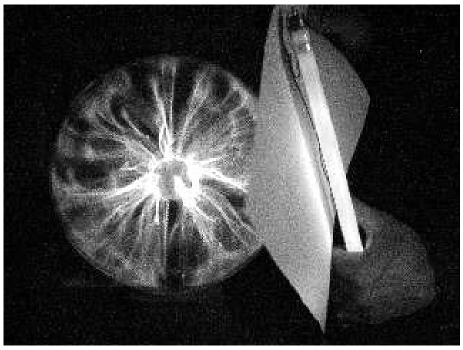
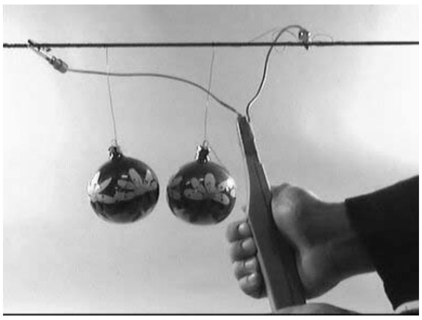


Photo 5. Proofs for existence of electromagnetic waves. a) Reproduction of Hertz's experiment with a piezoelectric lighter, four knitting wires and a small neon indicator - emitting light on the photo, which was taken at the moment do squeezing the lighter. The ceramic plate is to assure good electrical isolation. b) In the field of plasma ball (30 kHz generator inside) a neon lamp illuminates, even if isolated by a piece of paper.



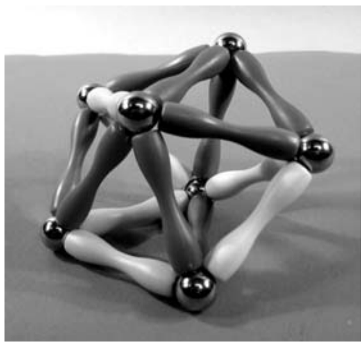


Photo 6. Illustration of the first and second Maxwell's laws (electrostatics and magnetostatics): a) van der Graff generator is based in Gauss; b) Coulomb law shown by colliding Christmas balls; c) magnetostatics – magnet sticks and iron balls – permanent magnets have always two poles.

We recall that the second Maxwell law $\oint \mathbf{B} \circ d\mathbf{S} = 0$, i.e. the non-existence of magnetic charges (monopoles) means that cutting a magnet in half we obtain always a two-pole magnet. Recently, a new toy is available, made of magnet (two-poles sticks) and iron balls – allowing to construct funny molecules, cages and so on, see fig.6c. A didactical hint is that as far as sticks are magnets (i.e. with attracting or repelling ends), the iron balls are always attracted, becoming multipoles, somewhat like feather pieces which get polarized (an $1/r^4$ potential) in the electrical field.

For Ampère's law $\oint \mathbf{B} \circ dl = \mu_0 i$ the instrument to be used are "amperometric tweezers", used by electricians, of about 20 € cost. Note, that the most frequently used tweezers measure AC currents – they perform integration of the magnetic field over the closed circulation path, like on the left side of the equation above, but it is much easier measure an AC magnetic flux (just using Faraday-Lenz principle i.e. making a transformator) than to measure a static magnetic field (necessitating a Hall probe). A convincing illustration of Ampere's law is to wind several times the wire around the tweezers "jaw" and show that the voltage read (usually 1 mV for 1A of AC current) is proportional to the number of windings.

Finally, for the Faraday-Lenz law $\oint \mathbf{E} \circ d\mathbf{l} = -\frac{d\phi_B}{dt}$ we recall the photo 3b and for the variable fields experiments on the electromagnetic waves.

Optics

Teaching of geometrical optics is reduced essentially to presenting Newton's law for thin lenses and studying different signs of solutions (i.e. when the image is real, when virtual and so on). This leaves outside several aspects, of essential importance like diopters (i.e. single curved refracting surfaces), non-spherical lenses, thick lenses and lenses with non-trivial refraction coefficients (i.e. for human-eye vision in water environment). Practically, all these phenomena are "inside" a glass of water, see photo 7, but it is useful to have them "at hand", even as a photo. Then, for example, a film showing the change of size and shape of the object seen through a thick lens depending on its position, is very useful [5].

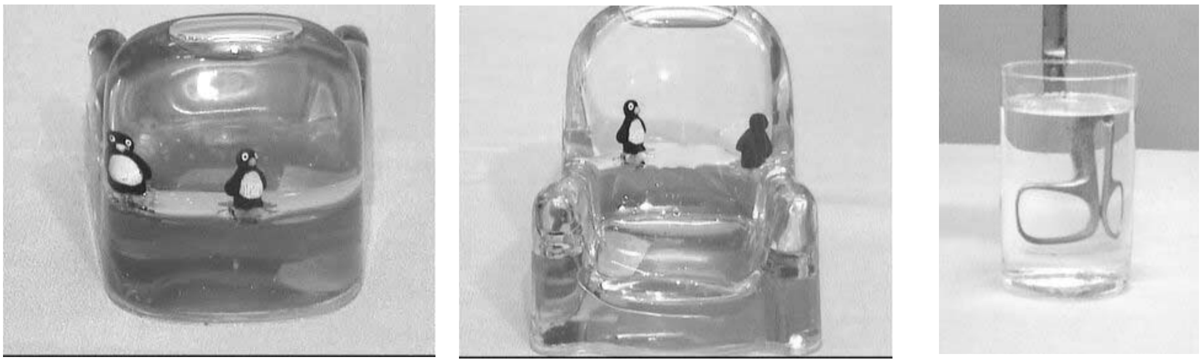


Photo 7. Diopters (semi-lenses) – photo a) and b) and a cylindrical thick lens (a glass of water). a) and b) – this is a chair-like support for mobile telephones – with two penguins floating inside; the backside of the chair is convex on one side and concave on another, with the curve radius changing: the size (horizontal) of penguins depend on their position and the directions of observation. c) a cylindrical lens changes the size only in one dimension; in a thick lens the magnification depends much on the position of the object relative to the optical axis. This what is called an "aberration" (spherical) for thin lenses becomes dominant for thick lenses.

In photo 8 we show how a convex lens can become diverging, if it is inserted in the optical medium with a higher refraction coefficient. In this case these are two liquids (a blue one and a transparent one) used in all "floating" objects gadgets; but the same effect can be obtained using air bubbles inside oil (0.5 cm layer on the bottom of a glass jar). It is difficult to overestimate the didactical importance of such simple experiments: they show that the equation of thin lenses is only an approximation, that the focal length needs a full $(n_1-n_2)/n_1$ ratio, that the cylindrical lens is similar to the spherical one, but acts only in one transversal dimension.

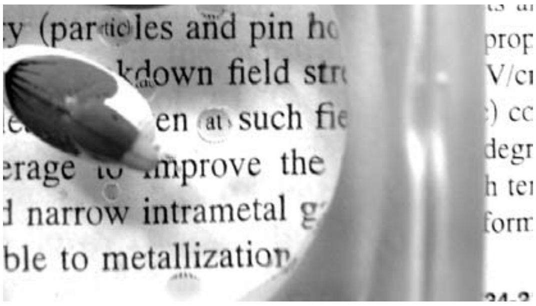


Photo 8. This is a rectangular ash-tray with the central part which is circular and convex, filled with two liquids and with two floating ducks. The convex circular part acts as a converging les, compare the text on right - smaller in size. If You agitate the ash-tray, to form bubbles of one liquid inside another, then these spherical bubbles, still being convex but containing a liquid with a lower refraction index act as *diverging* lenses. Passing on Verona railway station note also spherical “Romeo and Giulietta” sphere with a liquid inside. The filling of the sphere is not perfect – an air bubble inside acts as a diverging lens.

Archimedes law

It turns out in the didactical practise, even at the university level, that simple laws, as Archmimedes’ one are also not fully understood. A collection of objects to illustrate it contains a “vax lamp”, Galileo’s thermometer, Cartesius’ diver. The latter, a piece of cork floating under surface of water inside a plastic (i.e. squeezable) bottle one is another example of “more than uniformly accelerated movement – as its floating equilibrium depends on the volume of air trapped inside the cork, as soon as it sinks down because of the rise of air pressure above the water (due to squeezing the bottle) it moves down and finds higher hydrostatic pressure, which utterly comprises air inside the cork.

Multimedia formats

The reader at this point is probably astonished by the title “multimedia toys”: yes! we are convinced that as long as the real “objects” are cheap and easily available, it is much better to show them directly, for example an RF-detector screw-driver or a piece of cork balanced in a way to dive, than describe them by multimedia animations. However, the advantage of multimedia files (CD, video, internet) is that they allow: i) to divide the description into different levels of difficulty; ii) to insert animation and demonstration difficult to repeat in class (like rising hair in the high electrical field – an excellent demonstration of electric field lines perpendicular to “Gauss” surface but dangerous to be done in class); iii) to cheat – i.e. pre-pare experiment in a special way in order to enhance the effect (for example, with a “drinking bird”, the cooling effect due to evaporation from the “head” surface is more pronounced when using alcohol instead of water). Finally, multimedia collections (CD, video tape) allow to gather all objects at once, so are more compact and cheaper.

By all these objects – physical and virtual ones we mean “multimedia tools in teaching Physics”.

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