The "Wander Fly" Magic Wand and Czech Physics Teacher

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The magic wand called Wander Fly promises to make a wizard of you that can levitate beautiful glittering objects in a few moments. It really works! It is a simple Van de Graaff generator. Since the toy is nowadays available in the Czech Republic it could become an interesting and cheap requisite for physics education. This contribution describes some possibilities of its use that may come into mind of any teacher (not only a Czech one). It also presents how to replace the original levitating objects made of a thin foil that get easily damaged. It also mentions shortly how to find out some properties of the "magic wand" with approximate quantitative measurements also on the high-school level.

What is the Wander fly wand and what can it do?

The "Magic wand" (see Fig. 1) is a toy that is probably mostly sold (and offered on the Internet) in the USA under various names: Wander Fly or Wander Fly Stick, Fun Fly Stick or Magic Wand. It is made, which is not a surprise, in China. The instructions state that it is a "mini Van de Graaff generator". It enables one to levitate shiny objects made of silvery foil (Fig. 2): it charges them so that they repulse themselves from the wand; the electrostatic force allows counterbalancing their weight. Kids surely enjoy a lot of fun with the wand. But couldn't it be used for something else than playing Harry Potter?

Fig. 1 Magic wand

Questions of a Czech physics teacher

If a Czech physics teacher gets the wand in his hand, a row of questions undoubtedly crosses his mind. This I presume at least from myself.

The first reaction in my case was not a question but a shout: "Wow, I want that!" A more professional reaction follows then and these questions come with it:

- What can it do?
- What are its characteristics?
- How does it work? What is inside?
- What could it be used for? (in teaching physics, of course.)

- Couldn't be some parts of it replaced with something cheaper?

Fig. 2 The charged end of the wand repels a foil ring that was previously charged with the wand

The last question is inspired by the fact that the flying objects are made of a really thin foil that may probably get torn in the course of time – a spare set of three objects costs five dollars. The instrument itself is otherwise very cheap – it costs about seventeen dollars. But the delivery from the USA may increase the costs a lot.

Fortunately many Czech Internet shops began to offer this toy. Some of them at quite a high prize of over one thousand of Czech crowns. But during the preparation of this article I already found three sellers (all of them from Moravia) offering the magic wand for only 299 CZK plus postage. I will not give their names in this article so that it is not marked as an advertisement; they can be easily found on the Internet. Just mind that you will find all sorts of different things under the collocation "magic wand". (The collocation "levitating magic wand" works better.)

Let us rather have a look at some properties of the magic wand – and thus answer at least partly some of the above mentioned questions.

What charge does the wand generate?

The English manual states unambiguously that the wand generates a negative charge and thus it charges the foil objects negatively. A physics teacher would rather check it himself – and he finds out that a plastic rod that was charged by friction does not repel the object that was charged by the wand, but it *attracts it*. We can verify the same with an indicator with bipolar transistors that was demonstrated and described at the Inventions Fair before [1] (Fig. 3). It is thus inadvisable to trust the English manual of the magic wand!

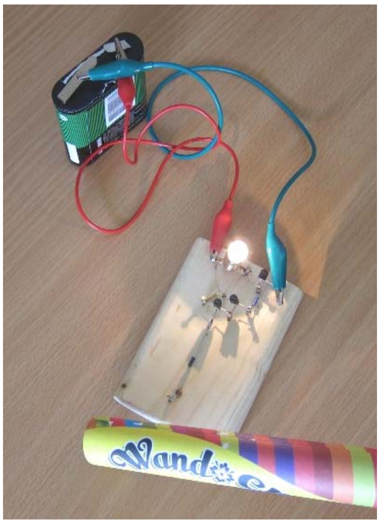

Fig. 3The indicator with transistors shows that the magic wand generates a positive charge on its end

What is inside?

What can we judge by the principle of the device if the manual is so unreliable? I must admit that I had expected some electronics inside the wand such as in some battery-powered gas lighters. But if we dismantle the wand (although the manual discourages us from that) we find out that there is no electronics inside. The first impression is that there is almost nothing inside (Fig. 4).

Fig. 4 The inside of the magic wand

A belt, two small pulleys, a small motor and some metal strips are there. So the manual did not lie in this point – the device really works on the principle of a Van de Graaff generator.

The belt does not rub against anything near the motor in contrast to the school Van de Graaff generator. An explanation how exactly the charge is generated in this toy (probably thanks to the contact of the belt with the plastic pulley) would need a more detailed research and analysis. Let us postpone this. For now let us only note that it might occur to a Czech physics teacher that the charge extraction at the end of the wand with only one tip is probably not very effective. Wouldn’t the device work better with more tips there? What about winding a thin wire rope around the metal strip so that the endings of individual wires are near to the surface of the belt, as Fig. 5 shows?

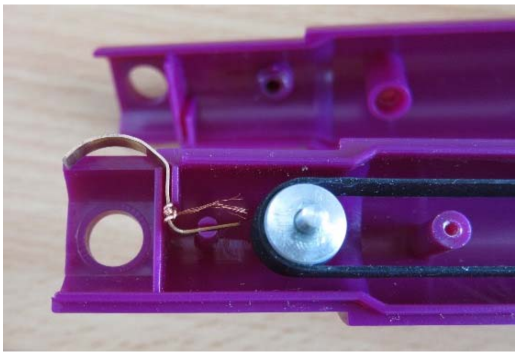

Fig. 5 Proposal how to improve charge draining from the generator belt

This modification definitely did not destroy the device. Just on the contrary – the measurements that are described in the following paragraphs seem to indicate that the toy generates charge faster then. (But up to now I have compared only one modified and one unmodified piece which means that this is rather a proposal that will need to be verified or disproved by further tests and measurements. So take this suggestion rather as an inspiration for how the device could be improved. There is obviously a vast space for innovations for Czech physics teachers and their students.)

Measuring the magic wand

We do already know the sign of the charge generated by the device – but what about other properties? *What is the amount* of charge at the end of the wand for example?

Measuring with an electrometer answers this question. In my case it yielded a value of about 200 nC. It can also answer a similar question: What is the quantity of charge on the levitating thin-foil object? The values were about sixty to ninety nanocoulombs for an object with a diameter of about twenty centimetres in my case.

The values stated above (and also other information such as the weight of the levitating object) could be used to estimate the magnitude of the electric field near the rod. Similar questions might possibly be the topic of some student works or projects.

But let us have a look at another measurement that can be surprisingly done in a very simple way. It will answer the question *how fast* the device generates charge. Or more precisely, because the device naturally does not produce charge from nothing, how fast does it transport the charge from the handle (where we touch a metal part of the wand with our hand next to the switch) to the tip of the wand.

Charge in time means current naturally. Couldn't this current be measured with an ammeter? (In a sensitive range, of course. The device surely does not give a coulomb per second for the ammeter to indicate one ampere to us. Even if there were only some tens of milliamperes, with the high voltage given the wand would not be a toy but a life-threatening weapon.)

Surprisingly, the current can be measured with an ordinary few hundred crowns' worth multimeter. In the range of 200 microamperes it can measure even tenths of μA. When we connect it to both poles of the toy, as Fig. 6 shows, it indicates just several tenths of microamperes when the device is running. (And the current was even 1.2 μA after the above mentioned modification.))

Fig. 6 Measuring the current provided by the magic wand. (The photograph does not show the decimal point in front of the last digit; the readout is 0.4 μA*).*

Let us note that small currents can be measured more precisely using the voltage ranges of the multimeter (as it has been shown in [2]). There is a 10 MΩ internal resistor (this value has to be checked for a particular multimeter) connected in measuring circuits of these ranges. Current of 0.4 μA causes voltage drop of 4 V across this resistor – and multimeter indicates 4 V.

Czech spare parts

Let us have a look at the question if something from the original delivery can be replaced. Foil flying objects can be charged and repelled also with charged plastic rod which is stated also in the manual. (Yet it is not so comfortable as with the magic wand.) But what about the objects themselves – when the foil gets torn?

The firs idea, to use aluminium foil, does not work unfortunately; aluminium foil is hopelessly heavy for levitation. What works is a space blanket that is sold in sport, camping and other shops. For a few dollars you get three square meters (220 × 140 cm) of foil weighing about 40 g. Objects cut out of it are nicely charged by the magic wand and levitate above it. The original foil seems to be a little thinner and objects made of it may levitate somewhat better but the space blanket is nevertheless very well useable.

Fig. 7 Charging of a tin with the magic wand

Levitation – and then what? Proposals on further experiments

What is a magic wand good for except for playing at a wizard? For many things whenever we need to charge something. A can for example, see Fig. 7. (We remove the paper top of the wand to do this and touch the can with the metal strip that drains charge from the belt.) We can use the charged can to do all common experiments: a strip of aluminium foil is repelled from the can, a glow or fluorescent lamp flashes when put near to the can, we get an electric shock if we touch the can etc.

An interesting (and obviously an attractive and pupils-motivating) alternative is to charge a man instead of a can. It is enough if he/she holds the magic wand in one hand touching the metal next to the switch and touches the grounding (the pin of a wall socket for example) with the metal strip at the tip of the magic wand (Fig. 8). In this case the man is charged negatively (positive charge is taken to the ground, negative charges pass from the metal next to the switch of the wand to the man). He/she has to stand on an insulating underlay of course such as a polystyrene board for example, or to have shoes with well-insulating soles.

Fig. 8 Magic wand charges a man – the result is demonstrated by hair or foil strips

Strips of foil indicate that the man is charged. If we are charged and hold an object made of a thin foil, it is repelled away from us; it can also levitate above our hand as it levitated above the tip of the magic wand.

We can also demonstrate that the electric field in a hollow of conductor is zero using foil strips. We only need to form a "hollow" between our head and our hand, as it is shown in Fig. 9.

Fig. 9 A foil strip in a "hollow" between the head and the hand is hanging down because the electric field is (approximately) zero there. (The strip on the other side is repelled from the head indicating that the man is really charged.)

Let us note that we can charge ourselves up to several μC with the magic wand in this way. (We measured up to 5 μC.) So we get a relatively significant electric shock with an audible spark when discharging; it is better to hold some metal object and discharge ourselves through it.

An impressive variant is to let two people stand on an insulating underlay. One holds the magic wand in his hand; the other touches the metal strip at the tip of the wand. The experimenters are charged with charges of opposite polarities. (The wand transports the charge from one experimenter to the other.) Mutual discharge with an audible and visible spark can be appropriately demonstrated using two ladles that the experimenters move near to each other with the rounded parts. (If we used some tipped objects, the charge would be emitted prematurely into the air and the spark would be far less intensive and impressive.) Do not expect sparks like from the induction electricity: the voltage between charged experimenters can be estimated to a few tens of kilovolts (approximately up to 50 kV), so the spark has a maximal length of a little more than a centimetre.

Conclusion

We have tried to show by the preceding rows and experiments that the magic wand Wander Fly can be quite a useful aid. I hope that some of these proposals can inspire you how to "electrify" your physics lessons even more.

Reference

[1] Dvořák L.: *Netradiční měřicí přístroje 2*. In: Sborník z konference Veletrh nápadů učitelů fyziky 7. Prometheus, Praha, 2002, s. 143-148.
[2] Dvořák L.: *Netradiční měřicí přístroje 4*. In: Sborník konference Veletrh nápadů učitelů fyziky 14. MU Brno, 2009, s. 82-86. (available online in English at http://vnuf.cz/papers/09_06_Dvorak.pdf)