Alexander Graham Bell & the Assassination of President Garfield: Teaching the Physics of Early Attempts at Medical Imaging

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Abstract

When U.S. President James Garfield was shot in 1881, physicians were unable to determine if the bullet had entered a vital organ. This knowledge was needed quickly to decide the medical treatment required to save Garfield's life. Alexander Graham Bell believed that he could use his recent invention, the telephone, with another relatively new development, the induction balance, to detect the location of the bullet. Over a decade before the discovery of x-rays, this attempt at non-intrusive medical imaging failed. However, the apparatus provides students with a way to learn several aspects of electromagnetism and AC circuits in a context that should be motivating to medical students who are studying physics. Even the reasons for the failure are directly related to understanding magnetic fields. We are in the process of developing such a lesson.

Introduction

This paper connects well with a plenary lecture at this conference on the state of the art and the use of magnetism for non-invasive bodies. (Swithenby, 2009) We discuss the first attempt to try to use magnetism for non-invasive medical imaging and our progress on preparing teaching-learning materials about this rather unique (and somewhat forgotten) incident in the application of physics to medicine.

This effort is part of a larger project which we have called Modern Miracle Medical Machines. It's a series of lessons that are context-based and aimed at students who will want to study either human or veterinary medicine. We have been creating relatively short activities that could fit into a standard physics course for these students. We're not trying to build a curriculum at this point but trying to create some instructional materials that emphasize the relevance of physics that they are learning their careers.

We have developed or are developing lessons on several topics. The most complete set of lessons focuses on vision defects and using wavefront aberrometry to diagnose those defects. The positron emission tomography, which emphasizes tomography much more than the positron, is essentially done. The lesson on Magnetic Resonance Imaging (MRI) will be completed soon, while one on Computer Aided Tomography (CT Scans) still needs some work. All of them will be available on our website, http://web.phys.ksu.edu/mmmm, relatively soon.

Now to the story - James Garfield was President of the United States in the 1880s. Much different than today, when the president wanted to travel at that time he took the train. He was standing apparently by himself on a train platform in Buffalo, New York, when a person who was upset because he had not been appointed as an ambassador approached the President and shot him.

The bullet lodged fairly deeply in Garfield who was a relatively large man. The doctors wanted to know how close it was to vital organs so they would know whether they could

remove it with the available surgical techniques. At that time no non-intrusive ways to determine the location were available to the physicians. The common method of locating a bullet in a body at that time was for the physician to stick his finger into the hole created as the bullet entered. (They were essentially all men in those days.) And, of course, they did not have surgical gloves. Nor did they did understand the need for sterilization. This invasive probing led to infection and to an end to the story only 80 days later.

Bell's Concept

While the physicians were using their rather crude methods, Alexander Graham Bell, inventor of the telephone, had a different idea about locating the bullet. We think that this early attempt at medical imaging is a rather interesting attempt to apply physics to medicine. And, it connects physics to history and social relevance. Thus, our long-term goal is to have students be able to replicate what Bell attempted, understand the underlying physics and understand why it did not work.

We originally learned about this event in an opening of a book on the history of medical imaging, but the physics was not described very well there. (Kelves, 1997) See also (Kuhfeld, 1991). Fortunately for this purpose, Google has digitized the *American Journal of Science* magazine back to the beginning. As is shown in Figure 1, Alexander Graham Bell presented this paper at a meeting of the American Association for the Advancement of Science in Montreal in 1882, and it later appeared in several printed formats. (Bell, 1882a, 1882b, 1882c, 1883) So, the paper was presented and printed very shortly after Garfield had died. (All of the papers are available from Google Books. The URLs are very long and not included here. They will be available of our web site.)

In this paper he described his attempt to try to find the bullet in Garfield. His basic scheme was to construct some inductance coils which he moved over Garfield's body. These coils would be connected to some oscillating source which would generate an audio frequency and would be connected to Bell's relatively new invention, the telephone. If a coil came close to the metal bullet, the inductance would change and, thus, the frequency which was oscillating the telephone would also change. Then, Bell would have devised a great new application for the telephone.

The Apparatus

The first difficulty is that the inductance change will be extremely small. Because this change is small, any change in frequency will be difficult to hear. But, Bell had a solution to this problem -- use a bridge circuit. Then, he starts with a balanced bridge and no sound coming through the telephone. When the induction changes in one part of the bridge, sound occurs in the telephone. It is very easy (or much easier) to hear a change from no sound to a little sound than it is to hear a slight change in sound.

This idea was not totally new. Bell had already started using similar circuits because of what he called disturbing noises in telephones. Telephone wires and telegraph wires were frequently run side by side. The currents in the telegraph wires were causing "disturbing noises" in the telephone. So, he had set up some bridge circuits to decrease the noise. The basic system had been invented by D. E. Hughes a few years

earlier. (Hughes, 1879) The Hughes' paper states, " … two separate induction-coils, each having its primary and secondary coils, were joined together in such a manner that the induced current in one coil was made to neutralize the induced current in the opposite coil, thus forming an induction balance."

The general apparatus is shown in Figure 2 which is also Figure 2 from Bell's paper. It contains two sets of induction coils and a telephone earpiece. We are still trying to understand the details. However, it seems that Bell obtained audio frequency alternating current using the microphone and the clock. Each time the clock ticks the microphone closes a bit and chopped current goes through the whole circuit.

Figure 3 shows a schematic of an improved version. Bell's caption which is in the middle of this figure says that this was the arrangement that he used with Garfield on July 26, 1881. This version has two sets of coils and a small chopper that creates the oscillating current. Some capacitors which are not well explained are apparently needed to do some filtering.

The statement in the paper is that for some unknown cause he really could not get it to work. So he went back to the drawing board and refined his apparatus again. As Figure 4 shows he now used sliding coils. They could slide back and forth in order to get his bridge to balance. He tried again on Garfield. This time, all of the circuitry was placed in a neighboring room so that the physical noise of the electromagnet bouncing back and forth would not be heard. A drawing (Figure 5) shows his assistant moving the coils around while Bell is listening.

Bell's Lack of Success

The failure is described in Bell's words from his *American Journal of Science* paper. He noted an "area of feeble sound [that] was due to some external cause. … I was by no means satisfied however, with the results obtained, for no such effects had been observed before in our experiments with bullets."

These results were not what Bell was expecting. Because the results did not match his expectations, he returned to a previous experiment – locating a bullet that was buried in a piece of meat and found that he could detect the location. Even with the first apparatus, before he tried it on Garfield, he had tried it with bullets buried in sand, shooting bullets into carcasses of meat and even with veterans of the Civil War who had shrapnel. His system worked with all of them, but it did not work with Garfield.

Now by this time Bell was rather perplexed. And so he went on August 2 to make sure that no extraneous metal was lying around. Of course, when he ran his experiment to try to find the bullet, he did indeed ask that all the metal be removed. The surgeons had told him that they were sure that no metal was in the room. However, another new invention was present – the innerspring mattress. Garfield being President had the latest and greatest mattress. He had a mattress underneath him that was made out of horse hair but underneath the horse hair was a set of springs - just as most American mattresses have these days. However, then such a mattress was a new idea; Bell did not know about them.

Thus, under the President was an evenly distributed layer of metal completely destroying Bell's attempt at medical imaging. At about the time of this discovery Bell had to leave Washington. He left an assistant in charge to try to figure out how they were going to deal with this issue. Moving Garfield apparently was not an option at that point. He had been lying there for quite awhile. He was a very ill and relatively large person. He died before Bell and his associates were able to figure out what to do.

Teaching About and with this Incident

We would like to create a set of experiments to have students conduct measurements similar to the ones Bell completed. We recognize that our students will have significantly better equipment than was available to Bell and his assistants. So far we have experimented with both telephone receivers and oscilloscope detectors. Because the signal can be rather weak, the oscilloscope has some advantage but, of course, it is not historically accurate. We have also learned that with modern day detection, we can get some results with just one pair of coils. We do not need the bridge circuit. But we would like the students to work with the bridge as well. We do plan to use an audio oscillator for convenience in most experiments. However, it would be good for students to understand how one could create an oscillating current with a chopping device

In following our usual procedure we will conduct some research on how students use their existing knowledge to understand the physics underlying Bell's efforts. Then we will create the lessons and test them to be sure that they are meeting our goals.

Conclusions

Alexander Graham Bell's attempt to locate a bullet in President James Garfield was an interesting application of basic properties of electromagnetism. Almost 20 years before the discovery of X-rays, he applied physics in an attempt to conduct non-intrusive medical imaging. He was foiled only because of another recent advance in technology, the innerspring mattress.

The basic physics of Bell's concept is accessible to today's undergraduates. Building a set of lessons to help students understand this event, why it might succeed, and why it did not in this case can help students learn physics of electromagnetism. In addition the lessons can show connection between basic science and applications to other societal issues.

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Figure 1: A reproduction of the first page of Bell's paper which appeared in the *American Journal of Science* in 1882.

Figure 2: Bell's initial design for an apparatus to find the location of the bullet.

Figure 3: An improved version which was used on President Garfield on July 26, 1881.

Figure 4: Another refinement which was used on August 1, 1881.

Figure 5: A drawing of the final attempt to detect the bullet. Note that the part of the apparatus which makes noise is in an adjoining room. This drawing appeared in Frank Leslie's illustrated newspaper, v. 52, no. 1351 (1881 August 20), pp. 412-413. Original caption: "The attempted assassination of the president - the discovery of the location of the bullet by means of Professor Bell's induction-balance / from a sketch by William A. Skinkle." (Downloaded from the U.S. Library of Congress.)