Microwave Journal

In Search of Maxwell

Friday the 13th of December 1996 was a lucky day. Daylight, such as it was, found me traveling south from Syracuse on Route 81 in a cold windy rain. I was going to visit an old friend from Cornell, L. Pearce Williams, Professor Emeritus, History of Science and Technology, Cornell University. Pearce was going to loan me his copy of the very rare book, *The Life of James Clerk Maxwell* by Lewis Campbell and William Garnett, published in 1882.

On the way home, I bought a scanner and an extra 2 GByte hard drive, modern miracles of the time. I finished scanning and OCR-ing (Optical Character Recognition) in February 1997. Later, when it became available, I converted the result to Adobe Acrobat .pdf format. This rare book is now available to everyone by visiting my company's web site, www.sonnetsoftware.com, for a free download.

My rendering of the book caught the attention of some key people. One is David Forfar, a trustee of the James Clerk Maxwell Foundation.[1] Another is Capt. (ret.) Duncan Ferguson, owner of Maxwell's life-long home in rural Scotland.[2] They both warmly invited me to visit. Last summer, I was able to accept their kind invitations. This story is about that trip… in search of Maxwell.

ARRIVAL

On the taxi ride from the airport, I was gently informed that the correct pronunciation of Edinburgh is "Ed-in-burr-ah," with a lightly rolled "rr." And, just for reference, the correct pronunciation of Clerk is the same as we Americans pronounce "Clark." Little known, "Clerk" is not his middle name; it is more accurately part of his last name. Today, we might be tempted to write it as a hyphenated last name (which is exactly what P.G. Tait, a very close friend of Maxwell, always did).

I asked the cab driver if he had ever heard of James Clerk Maxwell, and he said no, but that if he were someone famous, there is undoubtedly a statue for him somewhere around Edinburgh. It turned out that while there are many statues around Edinburgh, Maxwell unfortunately is not among them, at least for now.

During my stay in Scotland I found that perhaps two thirds of those I asked would have no idea who this JCM fellow was. As one of the three greatest physicists of all time, this is a sad situation, but one that we will perhaps discuss another day.

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OLD 31

On the first morning, as we (my wife, my son and I) walked from our bed and breakfast, we passed the nearest Maxwell site, "Old 31," 31 Heriot Row (see ***Figure 1***). At 10 years old, Maxwell was sent here to live with his aunt. He attended Edinburgh Academy, about a 20 minute walk downhill to the north. Today, two families live at Old 31. I decided to respect their privacy and did not ring the doorbell, so I have no idea if they realize the significance of their home. Incidentally, the home of Robert Louis Stevenson (*Treasure Island*, *Strange Case of Dr. Jekyll and Mr. Hyde*), born 19 years after Maxwell, is just several doors down the same street.

The daughter of Maxwell's aunt, his cousin Jemima, would become a world-class artist. We are especially fortunate that she made numerous paintings of Maxwell in his youth.

▲ *Fig. 1 Maxwell's home while attending Edinburgh Academy.*

▲ *Fig. 2 Watercolor by Maxwell's cousin showing his arrival in Edinburgh (second from left).*

▲ *Fig. 3 Maxwell's birthplace.*

Her depiction of young Maxwell arriving at Old 31 on that cold November evening is shown in ***Figure 2***.

MAXWELL'S BIRTHPLACE

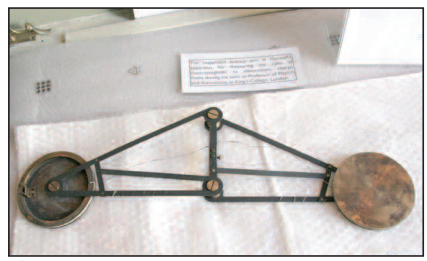
Down the block and around the corner, we arrive at Maxwell's birthplace, 14 India Street (see ***Figure 3***). We are especially fortunate in that 14 India Street was acquired by the James Clerk Maxwell Foundation[1] (the Foundation's tenant at this location is the International Centre for Mathematical Sciences). When the Foundation was in the process of acquiring 14 India Street, there was resistance from local residents who had no knowledge of Maxwell and his importance. Fortunately, one government official involved in the decision was well aware of Maxwell and came to the rescue.

The Foundation maintains a well equipped meeting room on the second floor. If you have a small meeting in Edinburgh, they would be pleased to hear from you. The room in which Maxwell was most likely born is immediately adjacent to the meeting room.

The first floor is the real treasure. Here the foundation displays an amazing collection of Maxwell artifacts. It is not open on regular hours, but if you contact the Foundation, they are happy to open it on request. This is an absolute must visit site for any Maxwell aficionado. Special thanks to David Ritchie (introduced to me by David Forfar) for hosting me on my visit to the museum.

There is a common misperception that Maxwell did mostly theoretical work and very few experiments. This is not the case, as even a cursory inspection of the Foundation's exhibits shows.

Perhaps the most significant artifact is the apparatus Maxwell used to measure electrostatic and magnetostatic constants, and thus determine the speed of light (see ***Figure 4***). Maxwell joked that the only use he made of light in the experiment was to read the dials on his apparatus.



▲ *Fig. 4 Apparatus used by Maxwell to determine the speed of light based on electrostatics and magnetostatics.*

The value Maxwell calculated (in 1861) for the speed of light is 193,088 miles per second. The best-known mechanical measurement was 195,647 miles per second. These values are so close, it seems that one could consider Maxwell's equations to have been at least partially validated. However, no one really took notice.

First, Maxwell was very modest. He realized his work was "great guns," but he did not actively and publicly promote it as such. Second, Maxwell had 20 equations in 20 variables (he did not have formal use of div and curl), with what we today call magnetic vector potential as primary. Maxwell's equations were simply too complicated. Third, when he published the equations in their complete form (1865), he made no attempt to connect them back to the lord and ruler over all physics at that time, Isaac Newton. There was no mechanical model, no connection to f = ma.

As a result, no one realized the significance of Maxwell's equations until over 20 years after Maxwell's 1865 publication and almost a decade after his death. This is when Hertz independently derived them in their modern form (by applying corrections to the then popular "action at a distance") and went on to experimentally confirm that light is indeed an electromagnetic wave.

The abstract concept of using what came to be known as "fields," with absolutely no connection to Newton and f = ma, revolutionized physics. Maxwell was in fact the inspiration for Einstein and his (field) theories of relativity. Freeing physics from the confining womb of Newtonian mechanics led directly to all the major developments of 20th century physics. It was actually this much more significant but lesser realized accomplishment, and not Maxwell's successful unification of the electric and magnetic forces per se, that was Maxwell's most significant legacy.

Another set of artifacts on display at 14 India Street are the negatives for the first color photograph, shown in ***Figure 5***. Maxwell had used simple experiments while a student at Edinburgh and Cambridge to determine

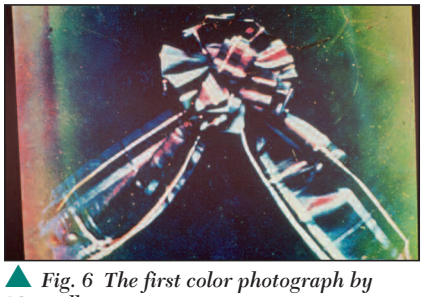
that the three primary colors of light are red, green and blue. So he got the idea to take three photographs through appropriate filters, then simultaneously project them through three projectors, as shown in ***Figure 6***.

There was just one problem, not realized until much later. The colloidal photographic process used at that time had no sensitivity to red. However, there are clearly large amounts of red in the photograph. A little detective work shows that the negative would have been sensitive to ultraviolet and the filter is transparent to ultraviolet. In addition, the red in the pictured ribbon was also reflective to ultraviolet. Maxwell was lucky.

EDINBURGH ACADEMY

A pleasant 20 minute walk north takes us to Edinburgh Academy. On my first visit, there was equipment and people everywhere (see ***Figure 7***). It just happened that the Academy was being used as a movie set for the day and as we were being politely but firmly escorted out by a guard, we were saved by an Academy employee, who then showed us around areas not being used for the movie. We then set up a meeting time with Rob Cowie, Academy Alumni Relations. If you visit, be sure to give Rob a call first.

▲ *Fig. 5 Negatives for the first color photograph.*



▲ *Fig. 6 The first color photograph by Maxwell.*

▲ *Fig. 7 Edinburgh Academy.*

The Academy was founded as an innovative and leading edge educational institution for its time. Even so, appropriate for this time period, memorization was the principle part of much of Maxwell's education. For example, the Academy boys (and at that time, it was just boys) were expected to be able to conjugate 800 irregular Greek verbs by the age of 12. Maxwell intensely disliked memorization; he called it "muggery." Maxwell performed poorly the first three years. In his second three years there, he found course work that required understanding, rather than just memorization, and he started making the medal lists. (In fact, a number of his medals are on display at the 14 India Street museum.)

Maxwell's first day of classes entailed a small social "adjustment." Maxwell spoke with a "country boy" Corsock accent, he wore clothing that simply did not fit in with the popular "city boy" styles and he was the new kid in class. The result is graphically depicted in a newspaper clipping on display at 14 India Street (see ***Figure 8***). On Maxwell's first day at school, he got beat up.

Today Edinburgh Academy is still a leading edge educational institution, as evidenced by its construction (presently underway) of a new state-of-the-art auditorium and laboratory facility to be named for Maxwell. In an appropriate note of irony that Maxwell himself would have appreciated, it is located only a few meters from the likely location of that first day's most memorable experience.

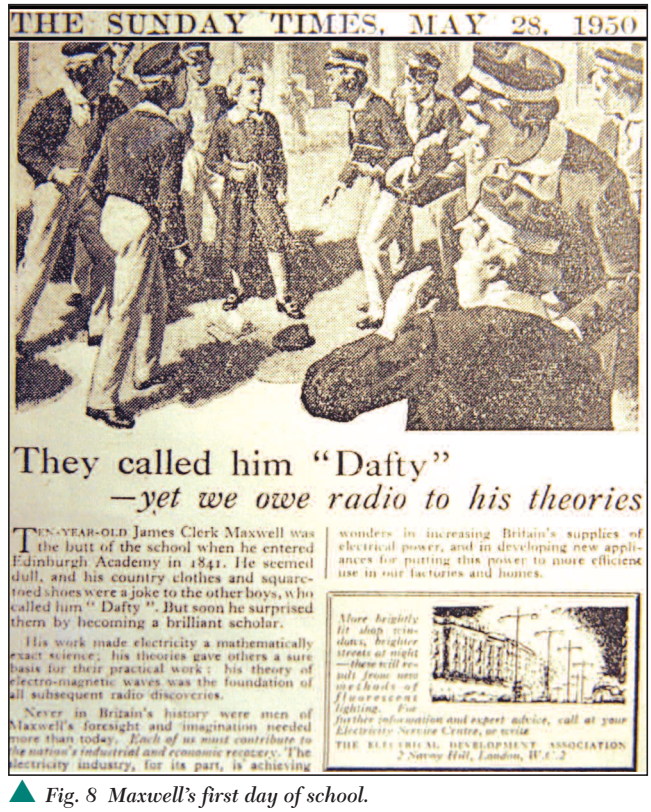
ON TO GLENLAIR

Maxwell spent most of his time at Glenlair, the family estate in very remote south-western Scotland. We traveled by train for one hour from Edinburgh to Lockerbie, then one more hour by car to Glenlair.

While in Lockerbie, we spent several hours visiting memorials to the victims of the Pan Am 103 disaster, where a terrorist bomb took down a 747 with 288 people including 35 Syracuse University students. I had just finished two years as a visiting professor at SU when that happened. The Maxwell connection: Henrietta Ferguson, the wife of the present owner of Glenlair, spent her Christmas holiday preparing meals for the first responders.

Maxwell's career took him to Edinburgh, Aberdeen, London and Cambridge. However, Maxwell always viewed Glenlair as home and he would return here whenever possible. For example, Maxwell wrote the founding document of modern electromagnetics, his two volume treatise on *Electricity and Magnetism*, at Glenlair House.

Today, Glenlair House itself is in a sorry state, as shown in ***Figure 9***. There was a fire in 1929. The fire trucks came, but they had no water. All the firemen could do was to help carry things out of the house. In spite of attempts to halt the decay, the building is now in danger of being lost forever. The present owner, Capt.


THE SUNDAY TIMES, MAY 28, 1950

They called him "Dafty"
—yet we owe radio to his theories

TEN-YEAR-OLD James Clerk Maxwell was the butt of the school when he entered Edinburgh Academy in 1841. He seemed dull, and his country clothes and square-toed shoes were a joke to the other boys, who called him "Dafty". But soon he surprised them by becoming a brilliant scholar.

His work made electricity a mathematically exact science; his theories gave others a sure basis for their practical work; his theory of electro-magnetic waves was the foundation of all subsequent radio discoveries.

Never in Britain's history were men of Maxwell's foresight and imagination needed more than today. *Each of us must contribute to the nation's industrial and economic recovery.* The electricity industry, for its part, is achieving wonders in increasing Britain's supplies of electrical power, and in developing new appliances for putting this power to more efficient use in our factories and homes.

More brightly lit shop windows, brighter streets at night—these will result from new methods of fluorescent lighting. For further information and expert advice, call at your Electricity Service Centre, or write THE ELECTRICAL DEVELOPMENT ASSOCIATION 2 Savoy Hill, London, W.C.2

▲ *Fig. 8 Maxwell's first day of school.*

THE LIFE OF JAMES CLERK MAXWELL

Presented by James C. Rautio, IEEE/MTT Distinguished Microwave Lecturer

James Clerk Maxwell stands shoulder to shoulder with Newton and Einstein, yet even those of us who have spent decades working with Maxwell's equations are almost totally unfamiliar with his life and times. This presentation, from the viewpoint of a microwave engineer, draws on many sources in providing an understanding of James Maxwell himself. What was Maxwell like as an infant? What was the tragedy at eight years old that profoundly influenced his life? What unique means of transportation did young Maxwell use to escape a cruel tutor? What memorable event occurred on his first day of school? When did he publish his first papers, and what were they about? What did Maxwell have to do with the rings of Saturn? Why did he lose his job as a professor? Why did he have a hard time getting another job? What was his wife like? What is Maxwell's legacy to us? The answers to these questions provide insight into Maxwell the person and add an extra dimension to those four simple equations we have studied ever since. There are no equations in this presentation. The presentation is appropriate for anyone with a general interest in the origins of modern physics. For electronic handouts for the lecture, visit www.sonnetsoftware.com and click on the large "Distinguished Microwave Lecture Series" button at the bottom of the "News" section.

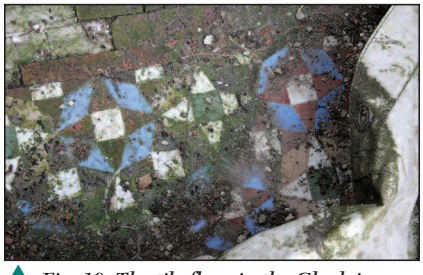
Duncan Ferguson, has established a Scottish Trust[2] to oversee a hoped-for stabilization/preservation of the property. Donations are welcome.

The present owner lives in the gardener's cottage nearby. We spent several nights in the nicely restored servant's quarters, now known as Glenlair Lodge, attached to Glenlair House. At night, we listened carefully for Maxwell's ghost, or perhaps even Maxwell's mythical demon opening and closing doors, but we heard nothing. During the visit, we made an appropriate donation to the restoration fund.

This is the place where Maxwell set pen to paper, founded electromagnetics and set the stage for the rest of the 20th century physics. Having worked in electromagnetics for a quarter of a century, I find the emotions of such a visit beyond description. Visiting Glenlair was really a religious pilgrimage.

Notice the small foyer at the main entrance to Glenlair House (center, ***Figure 9***). This was built by Maxwell.

▲ *Fig. 9 Maxwell's home, Glenlair House, today.*



▲ *Fig. 10 The tile floor in the Glenlair House foyer.*

I walked through that door (as Maxwell himself undoubtedly did many times), turned right, looked down and pulled back a tarp. A beautiful floor appeared (see ***Figure 10***), with tile colors of white, red, green and blue. These seem like odd colors, until we remember Maxwell's work with the primary colors of light mentioned above. This speculation is my own. I have not seen this point discussed elsewhere.

The Glenlair estate is a peaceful, rural paradise. Abundant wildlife, forest, field, cattle and sheep fill the countryside. I can see Maxwell working through some equations, then going for a walk, talking with some neighbors, then returning to his work. Genius happened here.

▲ *Fig. 11 Maxwell's final resting place.*

The Glenlair duck pond provided an escape for young Maxwell, literally. His mother died tragically when he was eight years old. They then hired a tutor. However, the tutor physically mistreated the young boy. One day, he escaped the tutor's punishments by taking to a tub in the pond, much to the amusement of his family.

Maxwell himself said nothing about the mistreatment. However, when one of his aunts discovered what was happening, the tutor was immediately dismissed and it was then that Maxwell was sent to live in Edinburgh at Old 31.

There is no tub here today, so escape is no longer possible, and the ducks are fake. Capt. Ferguson, who restored the pond himself, once had live ducks. However, some animal rights activists released mink on a nearby farm and those mink then ate Glenlair's ducks.

GRAVESITE

There is a small memorial marker for Maxwell on the floor, next to Newton's, in Westminster Abbey, but Maxwell is not buried there. His final resting place is near Glenlair in the ruins of a very small church built in the 1500s, around the time of Mary Queen of Scots (with whom Maxwell's ancestors had significant interaction) (see ***Figure 11***). There is one marker for all four; his father, his mother, his wife and himself. They are not listed in the order of death, suggesting it was put in place at a later date. In addition, the marker has no birth dates and it has a modern appearance. We do not know who placed the stone, or when.

The gravesite is in the side yard of a much larger church built by Maxwell's father and which is in use today. Inside, the pew that the Maxwell family occupied is all the

way to the back on the right. That area is today used for storage.

If you visit the church, be sure to get in touch with Sam Callander. He is caretaker and unofficial historian of the church and lives just down the street. He will be very happy to show you around and also let you enjoy his large collection of Maxwellia. He speaks with a strong Corsock Scottish accent, probably very much like Maxwell himself.

CONCLUSION

Maxwell died at the age of 48 of stomach cancer. This is the same disease that had taken his mother precisely 40 years before. While Maxwell himself was mortal, he launched a never-ending wave that spread throughout all the dimensions of the physics of the 20th century and whose influence will continue to be felt for the centuries to come. In this way, Maxwell is indeed immortal. We all benefit from his having lived, even those of us who haven't the faintest idea who he is. ■

References

1. http://www.clerkmaxwellfoundation.org/.
2. http://www.glenlair.org.uk/.

James C. Rautio *received his BSEE degree from Cornell University in 1978, his MS degree in systems engineering from the University of Pennsylvania in 1982 and his PhD in electrical engineering from Syracuse University in 1986. From 1978 to 1986, he worked for General Electric, first at the Valley Forge Space Division, then at the Syracuse Electronics Laboratory. At this time he developed microwave design and measurement software, and designed microwave circuits on alumina and GaAs. From 1986 to 1988, he was a visiting professor at both Syracuse University and at Cornell University. In 1988, he went full time with Sonnet Software, a company he had founded in 1983. In 1995, Sonnet was listed on the* INC *500 list of the fastest growing privately held US companies, the first microwave software company ever to be so listed. Today, Sonnet is the leading vendor of 3-D planar high frequency electromagnetic analysis software. He was elected a fellow of the IEEE in 2000 and received the IEEE MTT Microwave Application Award in 2001 and is an adjunct professor at Syracuse University.*