**James Clerk Maxwell** (1831 – 1879)

*A Country Boy*

* James Maxwell was born in Edinburgh, Scotland.
* His parents (John Clerk Maxwell and Frances Cay) were relaxed and happy people.
* Neither James nor his father, were Maxwell’s. The Clerk line married into the lineage.

*Edinburgh Academy (1831-1847)*

* Maxwell’s mother died while he was still a young boy, in 1839.
* At the age of 10, Maxwell enrolled in Edinburgh Academy. He stayed with his father’s sister, Aunt Isabella.
* Here, he got the nickname, “Dafty” because of his clothes and accent.
* He met Lewis Campbell and Peter Guthrie Tait during this period, who would become lifelong friends. With them, he found sympathetic and interested peers.
* At 14, he produced his first scientific paper, on curves that can be drawn on paper using pins, string and a pencil. James Forbes read the paper out to the Royal Society.
* He met William Thompson (Lord Kelvin) in this time and the two became friends.
* He came 2nd in his class in the final year.

*Edinburgh University (1847-1850)*

* During this time, he would hone his scientific abilities with by performing experiments at home in the holidays. In one of these, he used polarised light to reveal the strain patterns of materials twisted and pushed in different ways. This was the birth of photoelasticity.
* He published two more scientific papers, both of which were read to the Royal Society by Phillip Kelland, Maxwell’s maths professor. One was an extension of the geometry paper he published earlier and the second detailed his discovery of photoelasticity above.

*Cambridge (1850-1854)*

* He first enrolled in Peterhouse College but later transferred to Trinity College.
* Maxwell met a lot of like-minded students and flourished.
* Here, he sat the famous Mathematical Tripos exam (which everyone had to take) for 3 days, plus the extra 4 days for the honours degree. (At 6 hours of solid writing per day) Then he sat the prestigious Smith’s Prize (for the best mathematicians). He came second in the Tripos (after an exceptionally gifted student, E.J. Routh) and the two students were declared joint equal for Smith’s Prize.

*Cambridge (1854-1856)*

* Maxwell stayed on at Cambridge as a bachelor-scholar for 2 years.
* He wanted to investigate colours and so invented what could have been the world’s first ophthalmoscope, if Hermann Helmholtz hadn’t invented one independently a year earlier. He wanted to explain how colour vision worked. Maxwell was the first person to realise that mixing lights (such as in a spinning multi-colour disk) is an additive process, adding various wavelengths of light, while mixing pigments is a subtractive process, where the pigments absorb light of various wavelengths. He made a colour disk which enabled him to mix and match colours finally resulting in a diagram called, “Maxwell’s Triangle” which allows for any colour to be derived through various combinations of the three primary colours in the corners, red, green and blue. He also modelled his results geometrically. He also later made a “colour box” which allowed one to extract colours from white sunlight.
* In 1855, Maxwell produced a stunning paper on electricity and magnetism which he called *On Faraday’s Lines of Force*. At this time most people thought of electricity and magnetism as acting *at a distance*. Michael Faraday argued that they worked by producing *lines of force*. Maxwell came up with an ingenious fluid flow analogy and found a way of representing lines (electric and magnetic) of force mathematically as continuous lines of force. But this only worked for static electrical and magnetic effects.
* Maxwell’s father died in 1856.

*Aberdeen (1856-1860)*

* Maxwell took a job at Marischal College in Aberdeen University.
* In 1857, Maxwell turned his attention to Saturn’s rings in response to the prestigious Adam’s Prize offered by St John’s College at Cambridge. Specifically, why and how were they stable? Maxwell first showed that a solid ring couldn’t be stable except in a bizarre arrangement where four-fifths of the mass was concentrated in one point on the circumference. Next, he showed that fluid rings would break up into separate blobs. He then showed mathematically, that Saturn’ rings must consist of many separate bodies orbiting independently. He won the Adam’s Prize. His was the only entry.
* While at Aberdeen, he met Katherine Mary Dewar (the College Principal’s daughter) and they were married in June, 1858.
* In 1859, Maxwell solved a problem in the kinetic theory of gases (specifically, he came up with a way of analysing molecular motions) by creating the first ever statistical law in physics, the Maxwell distribution of molecular velocities. This was truly monumental and led to statistical mechanics, a better understanding of thermodynamics and to the use of probability distributions in quantum mechanics. This law also made a surprising prediction that the viscosity of a gas is independent to its pressure. He and his wife proved this by experiment a few years later.
* In 1860, Aberdeen University merged with King’s College and Maxwell lost his job.
* In the same year, Maxwell was awarded the Rumford Medal by the Royal Society of London, its highest award for physics.

*London (1860-1862)*

* Maxwell started work at King’s College in London.
* At this time Maxwell met Faraday at the Royal Institution.
* In 1861, in a lecture given at the Royal Institution, (with a little luck) he showed the world’s first photograph. Thanks to the stroke of luck, it was many years before anyone could replicate the feat.
* In 1861, Maxwell was elected to the Royal Society.
* Using another analogy, this time with cells, small wheels between them and an elastic-like spring back force, he wrote up the full mathematical description of his theory which described all known electromagnetic phenomena. This model also predicted two new physical phenomena. First, *displacement current*, which is like a little twitch of current whenever electromotive force was applied to an insulator. Second, this twitching would have a flow-on effect in the form of transverse waves which were comprised of electric and magnetic fields changing at right angles to the direction of the wave. He called these *electromagnetic waves*. He published his electromagnetic theory in *On Physical Lines of Force* which came in four parts. Parts 1 and 2 came in 1861, while parts 3 and 4 came in early 1862. But he still hadn’t found the actual mechanism by which electromagnetism works.

*London (1862-1865)*

* At this time the British Association for the Advancement of Science asked Maxwell to lead a team to develop a coherent set of measurement units for electricity and magnetism. He went beyond this and in 1863 developed a systematic way of defining all physical quantities with reference to M, L, and T. This is called the Gaussian system although Karl Friedrich Gauss’ input was far less than Maxwell’s.
* In 1865 he published *A Dynamical Theory of the Electromagnetic Field* which revolutionised electromagnetism. Maxwell knew he wouldn’t be able to find the *true mechanism* by which electromagnetism works but he needed more than his analogies; something based on the laws of dynamics. He found what he needed in the Lagrange method, a mathematical system developed by Joseph-Louis Lagrange. He ended up with 4 simple, succinct equations when applied to a point in empty space.
  + Equation 1 states that the electric force around the point has, on average, no inward or outward tendency. I.e. there is no charge.
  + Equation 2 says the same for the magnetic force.
  + The first two equations also imply the law for static fields: that the forces between electric charges and between magnetic poles vary inversely with the square of the distance separating them.
  + Equation 3 says that when the magnetic force changes it wraps a circular electric force around itself.
  + Equation 4 says that when the electric force changes it wraps a circular magnetic force around itself.
  + In equations 3 and 4, the constant c appears and corresponds exactly to the speed of light.

*Glenlair (1865-1871)*

* Maxwell resigned from Kings College in 1865 and moved with his wife back to his childhood home.
* While he was at Glenlair, he wrote many more important and influential scientific papers.
* When Maxwell wrote *The Theory of Heat,* he created an entity called *Maxwell’s Demon*, which was an imaginary, molecule-sized being that controlled a shutter between two containers, allowing only fast-moving atoms from one to go into the other (and only slow moving atoms to go the other way). This results in one side (the side gaining the faster-moving atoms) getting hotter, thereby breaking the second law of thermodynamics which says that heat cannot flow from a colder body to a hotter one. Maxwell gave two explanations of why this cannot happen. First, thermodynamics is a statistical law and so applies to molecules *en masse*, not individuals. Second, in order to do what Maxwell’s Demon does, he would need to know the positions and velocities of the atoms, but the very act of acquiring information about a system increases its entropy in proportion to the amount of information gathered.
* James Forbes died around 1868 and Maxwell applied for his position at St Andrews University in Edinburgh. He was passed over for this.
* In 1871, he was asked to accept a new professorship in experimental physics at Cambridge University. He accepted this.

*Cambridge (1871-1879)*

* Maxwell supervised the design and construction of the new laboratory. Experimental work began in 1874 and at Maxwell’s suggestion it was formally named the Cavendish, commemorating both the Duke and his great uncle, Henry Cavendish.
* In 1873, he published his 1,000 page book *Treatise on Electricity and Magnetism* which explained every known facet of electromagnetism.
* After a couple of years of heartburn that steadily became more severe, Maxwell died on 5 November, 1879 of abdominal cancer.