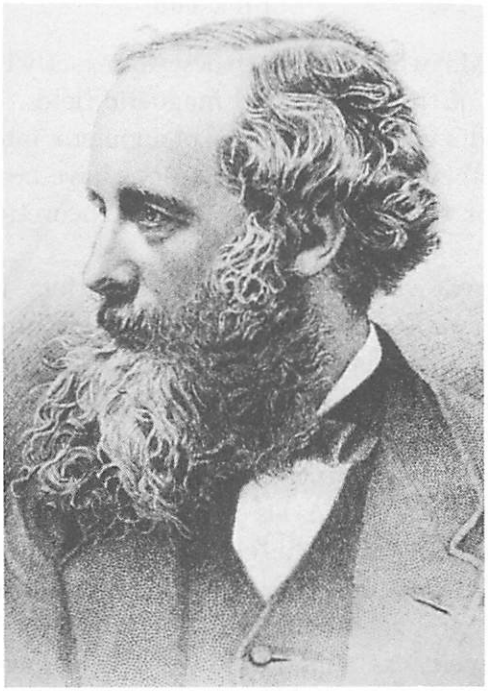


24 JAMES CLERK MAXWELL

1831-1879

The great British physicist James Clerk Maxwell is best known for his formulation of the set of four equations that express the basic laws of electricity and magnetism.

Those two fields had been investigated extensively for many years before Maxwell, and it was well known that they were closely related. However, although various laws of electricity and magnetism had been discovered that were true in special circumstances, before Maxwell there was no overall, unified theory. In his set of four short (though highly sophisticated)

equations, Maxwell was able to describe exactly the behavior and interaction of the electric and magnetic fields. By so doing, he transformed a confusing mass of phenomena into a single, comprehensive theory. Maxwell's equations have been employed extensively for the past century in both theoretical and applied science.

The great virtue of Maxwell's equations is that they are *general* equations, which hold under all circumstances. All the previously known laws of electricity and magnetism can be derived from Maxwell's equations, as well as a large number of other, previously unknown results.

The most important of these new results was deduced by Maxwell himself. From his equations it can be shown that periodic oscillations of the electromagnetic field are possible. Such oscillations, called electromagnetic waves, when once started will propagate outward through space. From his equations, Maxwell was able to show that the speed of such electromagnetic waves would be approximately 300,000 kilometers (186,000 miles) per second. Maxwell recognized that this was the same as the measured speed of light. From this, he correctly concluded that light itself consists of electromagnetic waves.

Thus, Maxwell's equations are not only the basic laws of electricity and magnetism, but are also the basic laws of optics! Indeed, all the previously known laws of optics can be deduced from his equations, as well as many facts and relationships previously undiscovered.

Visible light is not the only possible type of electromagnetic radiation. Maxwell's equations indicated that other electromagnetic waves, differing from visible light in their wavelength and frequency, might exist. These theoretical conclusions were later spectacularly confirmed by Heinrich Hertz, who was able both to produce and to detect the invisible waves whose existence Maxwell had predicted. A few years later, Guglielmo Marconi demonstrated that those invisible waves could be employed for wireless communication, and radio became a reality. Today, we use them for television as well.

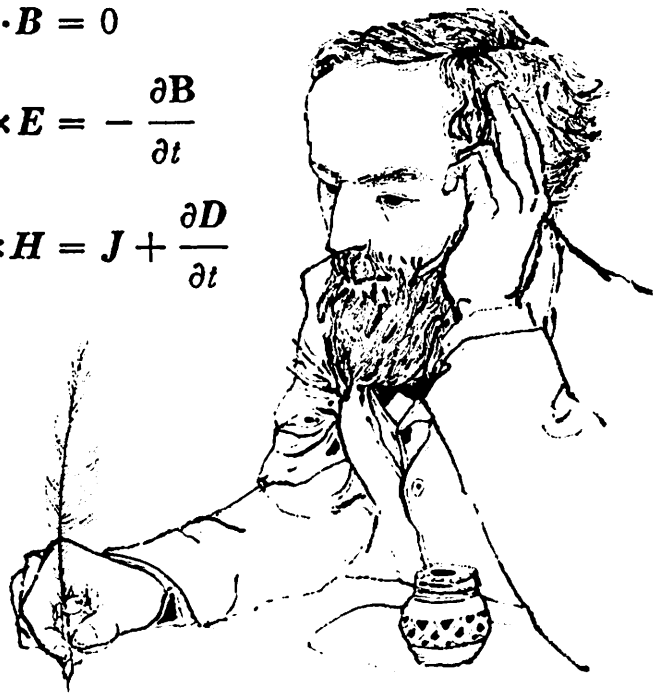
X-rays, gamma rays, infrared rays, and ultraviolet rays are other examples of electromagnetic radiation. All can be studied by means of Maxwell's equations.

$$\nabla \cdot \boldsymbol{D} = \rho$$

$$\nabla \cdot \boldsymbol{B} = 0$$

$$\nabla \times \boldsymbol{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J} + \frac{\partial \boldsymbol{D}}{\partial t}$$



Maxwell's equations are the basic laws of electricity and magnetism.

Although Maxwell's primary fame rests on his spectacular contributions to electromagnetism and optics, he made important contributions to many other fields of science, including astronomical theory and thermodynamics (the study of heat). One of his special interests was the kinetic theory of gases. Maxwell realized that not all of the molecules of a gas move at the same speed. Some molecules move slowly, some rapidly, some at

extremely high speeds. Maxwell worked out the formula which specifies (for any given temperature) what fraction of the molecules of a given gas will be moving at any specified velocity. This formula, called "the Maxwell distribution," is one of the most widely used of scientific equations, and has important applications in many branches of physics.

Maxwell was born in 1831, in Edinburgh, Scotland. He was extremely precocious: when only fifteen years old he presented a scientific paper to the Edinburgh Royal Society. He attended the University of Edinburgh and graduated from Cambridge University. Maxwell spent most of his adult life as a college professor, his last position being at Cambridge. He was married, but had no children. Maxwell is generally considered to be the greatest theoretical physicist in the whole interval between Newton and Einstein. His brilliant career was ended prematurely, in 1879, when he died of cancer, shortly before his forty-eighth birthday.