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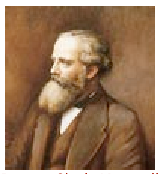
The greatest equations ever

Critical Point: October 2004

Maxwell's equations of electromagnetism and the Euler equation top a poll to find the greatest equations of all time. Robert P Crease discusses the results of his reader survey

Earlier this year I asked readers to send me their shortlists of great equations. I also asked them to explain why their nominations belonged on the list and why, if at all, the topic matters (*Physics World* May p19).



James Clerk Maxwell

I received about 120 responses -- including single candidates as well as lists -- proposing about 50 different equations. They ranged from obvious classics to "overlooked" candidates, personal favourites and equations invented by the respondents themselves.

Several people inquired about the difference between formulae, theorems and equations -- and which I meant. Generally, I think of a formula as something that obeys the rules of a syntax. In this sense, $E = mc^2$ is a formula, but so is $E = mc^3$. A theorem, in contrast, is a conclusion derived from more basic principles -- Pythagoras's theorem being a good example. An equation proper is generally a formula that states observed facts and is thus empirically true. The equation that describes the Balmer series of lines in the visible spectrum is a good example, as are chemical equations that embody observations about reactions seen in a laboratory.

However, these distinctions are not really so neat. Many classic physics equations -- including $E = mc^2$ and Schrödinger's equation -- were not conclusions drawn from statements about observations. Rather, they were conclusions based on reasoning from other equations and information; they are therefore more like theorems. And theorems can be equation-like for their strong empirical content and value.

It thus makes sense to classify both kinds as equations, which is exactly what respondent David Walton from the University of Manchester did. He distinguished between equations (such as $F = ma$) that comprise axiomatic models that "define the interrelationships between various observables for all circumstances" and equations that are approximate models (such as Hooke's law), which define "the interrelationships between the various observables over a defined range and within a defined accuracy". I therefore interpreted the term "equation" loosely.

Simplicity

Respondents had many different criteria for greatness in equations. Half a dozen people were so impressed with simplicity that they proposed 1 + 1 = 2.

"I know that other equations have done more, express greater power [and have a] broader understanding of the universe," wrote Richard Harrison from Calgary in Canada, "but there's something to be said for the beauty of the simplest things of their kind." He then recalled how 1 + 1 = 2 was the first equation he taught his son. "I remember [him] holding up the index finger of each hand as he learned the expression, and the moment of wonder when he saw that the two fingers, separated by his whole body, could be joined in a single concept in his mind."

Neil Blackie also voted for 1 + 1 = 2. "For this equation to come into being there had to be the invention of a method for representing a physical reality, quantities had to be given names and symbols," he argued. "There had to be a system to show how these quantities could be grouped together or taken apart. The writing down of this equation gave us the ability to present ideas, to discuss concepts, which led to an ever-expanding sphere of knowledge."

Other simple equations that were proposed included $v = H_0 d$, which

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