Emmy Amalie Noether

Born: 23 March 1882 in Erlangen, Bavaria, Germany
Died: 14 April 1935 in Bryn Mawr, Pennsylvania, USA

Emmy Noether's father Max Noether was a distinguished mathematician and a professor at Erlangen. Her mother was Ida Kaufmann, from a wealthy Cologne family. Both Emmy's parents were of Jewish origin and Emmy was the eldest of their four children, the three younger children being boys.

Emmy Noether attended the Höhere Töchter Schule in Erlangen from 1889 until 1897. She studied German, English, French, arithmetic and was given piano lessons. She loved dancing and looked forward to parties with children of her father's university colleagues. At this stage her aim was to become a language teacher and after further study of English and French she took the examinations of the State of Bavaria and, in 1900, became a certificated teacher of English and French in Bavarian girls schools.

However Noether never became a language teacher. Instead she decided to take the difficult route for a woman of that time and study mathematics at university. Women were allowed to study at German universities unofficially and each professor had to give permission for his course. Noether obtained permission to sit in on courses at the University of Erlangen during 1900 to 1902. Then, having taken and passed the matriculation examination in Nürnberg in 1903, she went to the University of Göttingen. During 1903-04 she attended lectures by Blumenthal, Hilbert, Klein and Minkowski.

In 1904 Noether was permitted to matriculate at Erlangen and in 1907 was granted a doctorate after working under Paul Gordan. Hilbert's basis theorem of 1888 had given an existence result for finiteness of invariants in n variables. Gordan, however, took a constructive approach and looked at constructive methods to arrive at the same results. Noether's doctoral thesis followed this constructive approach of Gordan and listed systems of 331 covariant forms.

Having completed her doctorate the normal progression to an academic post would have been the habilitation. However this route was not open to women so Noether remained at Erlangen, helping her father who, particularly because of his own disabilities, was grateful for his daughter's help. Noether also worked on her own research, in particular she was influenced by Fischer who had succeeded Gordan in 1911. This influence took Noether towards Hilbert's abstract approach to the subject and away from the constructive approach of Gordan.

Noether's reputation grew quickly as her publications appeared. In 1908 she was elected to the Circolo Matematico di Palermo, then in 1909 she was invited to become a member of the Deutsche Mathematiker-Vereinigung and in the same year she was invited to address the annual meeting of the Society in Salzburg. In 1913 she lectured in Vienna.

In 1915 Hilbert and Klein invited Noether to return to Göttingen. They persuaded her to remain at Göttingen while they fought a battle to have her officially on the Faculty. In a long battle with the university authorities to allow Noether to obtain her habilitation there were many setbacks and it was not until 1919 that permission was granted. During this time Hilbert had allowed Noether to lecture by advertising her courses under his own name. For example a course given in the winter semester of 1916-17 appears in the catalogue as:-

Mathematical Physics Seminar: Professor Hilbert, with the assistance of Dr E Noether, Mondays from 4-6*, no tuition.*

Emmy Noether's first piece of work when she arrived in Göttingen in 1915 is a result in theoretical physics sometimes referred to as Noether's Theorem, which proves a relationship between symmetries in physics and conservation principles. This basic result in the general theory of relativity was praised by Einstein in a letter to Hilbert when he referred to Noether's

penetrating mathematical thinking.

It was her work in the theory of invariants which led to formulations for several concepts of Einstein's general theory of relativity.

At Göttingen, after 1919, Noether moved away from invariant theory to work on ideal theory, producing an abstract theory which helped develop ring theory into a major mathematical topic. *Idealtheorie in Ringbereichen* (1921) was of fundamental importance in the development of modern algebra. In this paper she gave the decomposition of ideals into intersections of primary ideals in any commutative ring with ascending chain condition. Lasker (the world chess champion) had already proved this result for polynomial rings.

In 1924 B L van der Waerden came to Göttingen and spent a year studying with Noether. After returning to Amsterdam van der Waerden wrote his book *Moderne Algebra* in two volumes. The major part of the second volume consists of Noether's work.

From 1927 on Noether collaborated with Helmut Hasse and Richard Brauer in work on non- commutative algebras.

In addition to teaching and research, Noether helped edit *Mathematische Annalen*. Much of her work appears in papers written by colleagues and students, rather than under her own name.

Further recognition of her outstanding mathematical contributions came with invitations to address the International Mathematical Congress at Bologna in 1928 and again at Zurich in 1932. In 1932 she also received, jointly with Artin, the Alfred Ackermann-Teubner Memorial Prize for the Advancement of Mathematical Knowledge.

In 1933 her mathematical achievements counted for nothing when the Nazis caused her dismissal from the University of Göttingen because she was Jewish. She accepted a visiting professorship at Bryn Mawr College in the USA and also lectured at the Institute for Advanced Study, Princeton in the USA.

Weyl in his Memorial Address [28] said:-

Her significance for algebra cannot be read entirely from her own papers, she had great stimulating power and many of her suggestions took shape only in the works of her pupils and co-workers.

In [26] van der Waerden writes:-

For Emmy Noether, relationships among numbers, functions, and operations became transparent, amenable to generalisation, and productive only after they have been dissociated from any particular objects and have been reduced to general conceptual relationships.

Article by: *J J O'Connor* and *E F Robertson*

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