The Math and Physics History of Göttingen

From Gauss to Heisenberg

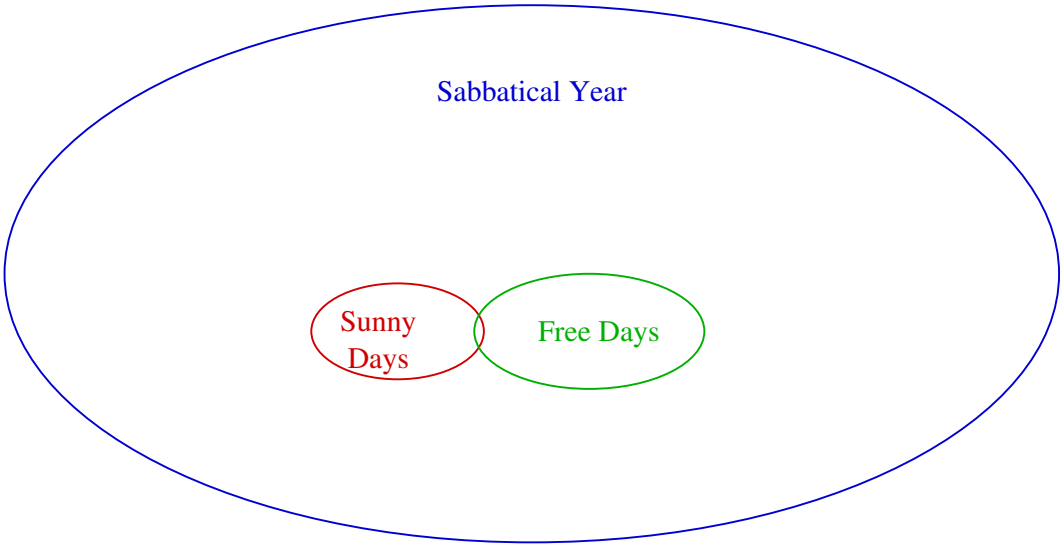
Ben Vollmayr-Lee

Coffee Talk, January 29, 2014

Göttingen

- A relatively prosperous trading city in the late Middle Ages
- Part of the Kingdom of Hannover after 1692
- Georg-August Universität founded in 1737 by King George II
- Currently has around 26,000 students. Town population is a little over 115,000.
- 45 Nobel Prize laureates either studied or taught at Göttingen.

Venn Diagram



The Gänseliesel Fountain

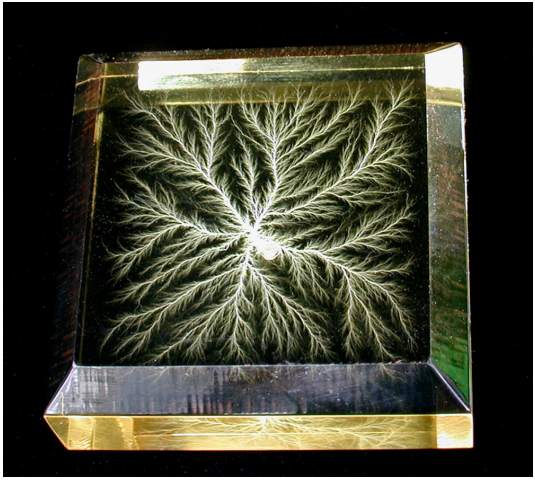
The Most Kissed Girl in the World

The Most Kissed Girl in the World

Georg Christoph Lichtenberg 1742–1799

- First experimental physics professorship in Germany.
- Was also a satirical writer.
- Did experiments on electricity and discovered Lichtenberg figures.

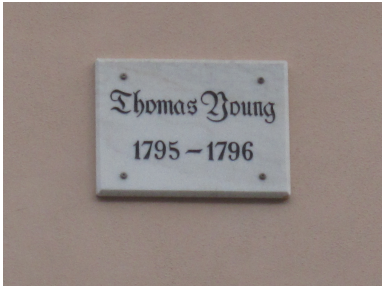
Georg Christoph Lichtenberg 1742–1799

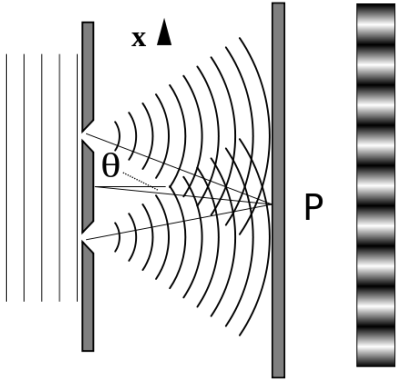


Georg Christoph Lichtenberg 1742–1799

Benjamin Franklin visited one summer.

Thomas Young 1773–1829





- Double slit experiment
- Helped decipher the Rosetta Stone
- Elasticity theory — Young's modulus

Carl Friedrich Gauss 1777–1855

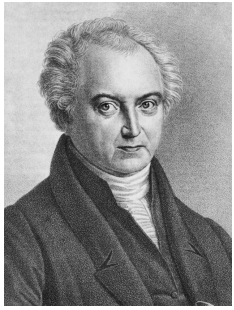
- At age 19, proved that a regular 17-gon could be constructed.
- Devised statistics and analysis methods to locate lost Ceres.
- Normal distribution named a gaussian.
- Showed any integer is a sum of at most three triangular numbers.
- Developed differential geometry: gaussian curvature.
- And of course Gauss's law.

Carl Friedrich Gauss 1777–1855

Göttingen Streets

Heinrich Wilhelm Olbers 1758–1840

- Student at Göttingen and friend of Gauss.
- One of the astronomers who re-discovered Ceres with Gauss's prediction.
- Also discovered Pollux and Vesta in asteroid belt.
- Posed Olber's Paradox: why isn't the night sky bright?



Heinrich Wilhelm Olbers 1758–1840

Cron und Lanz

Bernhard Riemann 1826–1866

- Developed non-Euclidean geometry to describe "curved space". Essential for Einstein when he developed general relativity.
- Made numerous contributions to number theory, analysis, and differential geometry.
- Riemann hypothesis one of the great open problems in math.

$$\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s}$$

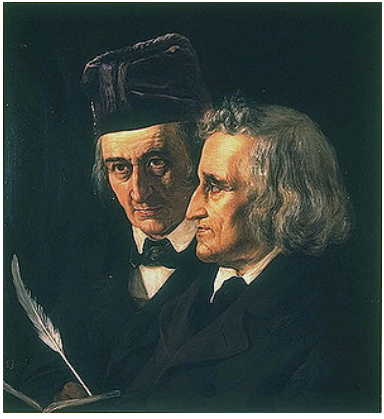
Bernhard Riemann 1826–1866

Wilhelm Weber 1804–1891

- Very fruitful collaboration with Gauss on electricity and magnetism.
- Observed in 1856 that $1/\sqrt{\mu_0 \epsilon_0}$ had the same value as the speed of light.
- Magnetic flux unit (symbol Wb) named after him.
- One of the Göttingen Seven.

Brothers Grimm: Jacob (1785–1863) and Wilhelm (1786–1859)

- Grimm's Fairy Tales were collected folk stories.
  - Cinderella
  - The Frog Prince
  - Hansel and Gretel
  - Rapunzel
  - Rumpelstilzchen
  - Sleeping Beauty
  - Snow White
- Established the field of Germanic studies
- Two of the Göttingen Seven



Brothers Grimm: Jacob (1785–1863) and Wilhelm (1786–1859)

Peter Gustav Lejeune Dirichlet 1805–1859

- Gauss's successor.
- Proved convergence of Fourier series, made contributions to number theory.
- Proved $\nabla^2 u = 0$ with $u(\mathbf{r})$ specified along the boundary gives a unique solution.

  $\Rightarrow$ Dirichlet boundary conditions.

Peter Gustav Lejeune Dirichlet 1805–1859

Alfred Clebsch 1833–1872

- In quantum mechanics addition of angular momentum,

$$\mathbf{J} = \mathbf{J}_1 + \mathbf{J}_2$$

you often need to express states of definite J^2 and J_z in a basis of definite J_1^2, $J_{1,z}$, J_2^2 and $J_{2,z}$, via

$$|j\ m\rangle = \sum_{m_1+m_2=m} C^{j_1 j_2 j}_{m_1 m_2 m} |j_1\ m_1; j_2\ m_2\rangle$$

The $C^{j_1 j_2 j}_{m_1 m_2 m}$ are the Clebsch-Gordan coefficients.

- Predates QM by over 50 years! Because it's really a group theory result.

Alfred Clebsch 1833–1872

Felix Klein 1849–1925

- Advocated the Erlangen Program to unify geometry.
- Built Göttingen into a major power in the early 1900's.
- Advocated admitting women, supervised the first woman to receive a Ph.D. in Göttingen.
- Conceived of the Klein bottle: a non-orientable closed surface.

Felix Klein 1849–1925

Emil Wiechert 1861–1928

- Known primarily as a geophysicist. Recruited by Klein to start the first geophysics institute.
- Developed seismographic techniques, inferred the layered structure of the Earth and the iron core.
- Known in physics for the Lienard-Wiechert potentials $V(\mathbf{r}, t)$ and $\vec{A}(\mathbf{r}, t)$ for a point charge undergoing arbitrary motion.

Emil Wiechert 1861–1928

David Hilbert 1862–1943

- The last great generalist! Identified 23 important problems at the turn of the century — known as Hilbert problems.
- Continued Klein's work attracting top talent.
- Made numerous contributions to many fields, often concerning fundamentals.
- Big contribution to physics: Hilbert space. Basically, allowed us to treat functions as vectors.
- Was very interested in general relativity and nearly beat Einstein to it.

David Hilbert 1862–1943

Hermann Minkowski 1864–1909

- Close friend of Hilbert. Recruited by him.
- Geometry expert. Brought geometry into various other fields.
- Saw the non-Euclidean spacetime geometry implied by Einstein's special relativity. Now called Minkowski spacetime.

Hermann Minkowski 1864–1909

Emmy Noether 1882–1935

- Recruited by Hilbert, assigned task of exploring energy conservation in general relativity.
- End result was Noether's Theorem, which connects symmetries to conservation laws. Huge impact on modern particle physics.
- Big battle over her right to earn the Habilitation.
- Best known in math for being a pioneer in abstract algebra.

Hermann Weyl 1885–1955

- Contemporary of Noether.
- Replaced Hilbert as the director of the math institute in 1930.
- Worked on many problems relating the group theory of symmetries to fundamental particle physics.

Hermann Weyl 1885–1955

Karl Schwarzschild 1873–1916

- Found in 1915 the first exact solution of Einstein's general relativity field equations.
- Describes the spacetime metric around a single, spherical, non-rotating object.
- Event horizon of a blackhole named Schwarzschild radius.
- Died in World War I.

Peter Debye 1884–1966

- Made many contributions on the boundary between physics and chemistry
- Debye-Hückel theory for charge screening in an ionic solution
- Corrected Einstein's treatment of low temperature solids
  $\Rightarrow$ Debye solid.
- Developed techniques including temperature effects in the study of crystal X-rays.

Peter Debye 1884–1966

Max Born 1882–1970

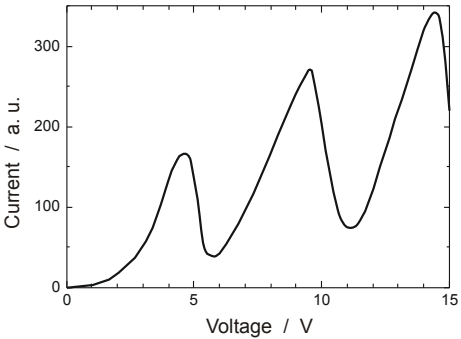
- A quiet giant in quantum mechanics. Played a role similar to Hilbert in math.
- Together with Heisenberg and Jordan, developed the matrix mechanics formulation of quantum mechanics.
- Developed the probabilistic interpretation of the wavefunction
- Continued to contribute to QM development with young scholars who came to Göttingen to work with him:

  Eugene Wigner, Leo Szilard, John von Neumann, Maria Goeppert-Mayer, Enrico Fermi, Wolfgang Pauli, and Edward Teller.

Max Born 1882–1970

James Franck 1882–1964

- Recruited to Göttingen by Born.
- Nobel Prize for Franck-Hertz experimment:

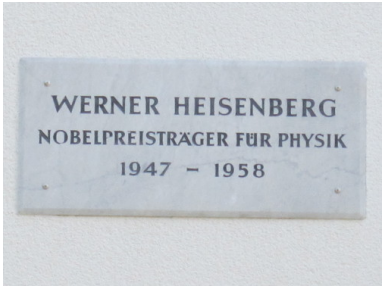


James Franck 1882–1964

Werner Heisenberg 1901–1976

- Wrote the first paper on the theory of quantum mechanics shortly after arriving in Göttingen.
- During his Ph.D. with Sommerfeld, who realized Heisenberg needed a younger, modern mentor. Sent him to Born.
- Published his first paper on QM alone, all the subsequent work on matrix mechanics was done in collaboration with Born and Jordan.
- Legacy is tainted by his wartime involvement in weapons programs.

Werner Heisenberg 1901–1976



Maria Goeppert-Mayer 1906–1972

- One of only two women to win the Nobel Prize in Physics.
- Göttingen native. Went on to get her Ph.D. with Born.
- Married American Joseph Mayer and moved with him to the US. No university would hire her.
- Meanwhile, she did her Nobel Prize winning work on nuclear shell theory without pay!

Maria Goeppert-Mayer 1906–1972

Max Delbrück 1906–1981

- First biophysicist! Lured Schrödinger, Gamov, and others into the field.
- Predicted Delbrück scattering: coherent elastic scattering of photons in the Coulomb field of heavy nuclei
- Became interested in biological problems. Won Nobel Prize for research with bacteriaphages.

1933

All academics who were Jewish or had Jewish spouses were expelled. Includes

- Max Born
- James Franck
- Eugene Wigner
- Leo Szilard
- Edward Teller
- Emmy Noether
- Richard Courant
- Hermann Weyl

Research at Göttingen simply stopped.

Post-War Göttingen

The effort to re-build German physics after the war was focussed in Göttingen. Brought together were

- Max Planck
- Werner Heisenberg
- Max von Laue
- Otto Hahn

and the Kaiser Wilhelm Society was renamed the Max Planck Society, which now runs over 80 Max Planck Institutes throughout Germany.

In 1957 the Göttingen Manifesto — signed by 18 prominent physicists — stated opposition to Germany developing a nuclear weapons program.

Göttingen Today

The university is still thriving (2009 Chemistry Nobel Prize). Max Planck Institutes for Dynamics & Self-Organization, Biophysical Chemistry, Experimental Medicine, and Study of Religious & Ethnic Diversity.

And a scale model solar system!