

WHO WAS WHO IN TRANSPORT PHENOMENA

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When lecturing on the subject of transport phenomena, I have often enlivened the presentation by giving some biographical information about the people after whom the famous equations, dimensionless groups, and theories were named. When I started doing this, I found that it was relatively easy to get information about the well-known physicists who established the fundamentals of the subject, but that it was relatively difficult to find accurate biographical data about the engineers and applied scientists who have developed much of the subject. The documentation on fluid dynamicists seems to be rather plentiful, that on workers in the field of heat transfer somewhat less so, and that on persons involved in diffusion quite sparse. What follows is an attempt to assemble a modest set of “microbiographies” which might be useful until a more comprehensive compilation can be made.

Most of this material has been assembled from secondary sources, and for each person I have indicated those sources (biographical citations are given at the bottom of the next page). It has been difficult to decide who should be included in this listing. Quite arbitrarily I decided to exclude persons who are still living, even though their contributions merit recognition. I have tried to include the names that are encountered frequently in textbooks, names with which any student of chemical engineering should be familiar. In addition, I have included a handful of less-familiar persons, either because I feel some important contribution has been overlooked or just because of curiosity on my part. I’ve tried to be particularly attentive to persons working in the area of diffusion. Almost all of the persons listed in this tabulation are cited in *Transport Phenomena*, by Bird, Stewart, and Lightfoot, (Wiley, New York, 2nd ed., 2002), where more detailed comments are given about their scholarly contributions.

Extra emphasis has been placed on those who have developed the kinetic theories for transport phenomena. The reason for this decision is that it is the molecular theories that

provide the “glue” that binds the various topics together into a coherent subject. It is also the subject to which we ultimately have to turn when controversies arise that cannot be settled by continuum arguments alone.

It would be very easy to enlarge the list by including the authors of exceptional treatises (such as H. Lamb, H.S. Carslaw, M. Jakob, H. Schlichting, and W. Jost). Attention could also be paid to those many people who have, through painstaking experiments, provided the basic data on transport properties and transfer coefficients.

Doing accurate and responsible investigations into the history of science is demanding and time-consuming work, and it requires individuals with excellent knowledge of historical research techniques. It may also require a certain amount of travel to gain access to original sources and to conduct interviews. The field of history of engineering is particularly undermanned and engineering societies should be pushing for more work in this area.

Comments on these “microbiographies” would be greatly appreciated; corrigenda can be sent to me at my e-mail address (bird@enr.wisc.edu). Finally, I would like to dedicate this work to the memory of my late colleague, Prof. W. Robert Marshall, who often expressed a desire to contribute to the history of chemical engineering. He felt that there were many interesting and important stories to be told.



*R. Byron Bird retired in 1992 after forty years of teaching—one year at Cornell and thirty-nine years at Wisconsin. The book *Transport Phenomena*, which he wrote with colleagues Warren Stewart and Ed Lightfoot, was the first textbook on the subject specifically prepared for undergraduate chemical engineering students. He also coauthored *Dynamics of Polymeric Liquids* with Bob Armstrong (MIT), Ole Hassager (DTU), and Chuck Curtiss (UW).*

■ **Jerome Howard Arnold (1907-1974)**

The “Arnold problem”: unsteady-state evaporation

- Studied at Iowa State College, University of Minnesota, and MIT (ScD 1931) with Warren K. Lewis
 - 1931-1944 taught at MIT, University of Minnesota, Linsly Institute of Technology, University of North Dakota, and University of Iowa
 - Books: *Chemical Engineering Stoichiometry* (1941) and *Chemical Engineering Thermodynamics* (1953)
 - 1944-1948 worked with Standard Oil of California
 - 1956-1960 was director of Contra Costa Transit District
- SOURCES: AMS 1965, MIT

■ **Daniel Bernoulli (1700-1782)**

The “Bernoulli equation”: $\frac{1}{2}v^2 + \int \left(\frac{1}{\rho}\right) dp + gz = \text{const.}$

Early developments in kinetic theory of gases

- Studied in Heidelberg, Strasbourg, and Basel
- Became Doctor of Medicine in 1721
- At Academy of Sciences in St. Petersburg until 1732; lectured on medicine, mechanics, physics
- In 1732 moved to Basel as professor of anatomy and botany, in 1743 became professor of physiology and in 1750 became professor of physics
- In 1738 published *Hydrodynamica*, in which the “idea” of the Bernoulli equation was given (later derived by Euler)

- Won 10 prizes of the Academy of Sciences in Paris for work on astronomy, gravitation, tides, magnetism, ocean currents
- SOURCES: DSB, RI, SGBKT

■ **Jean Baptiste Biot (1774-1862)**

The “Biot number” in heat transfer

The “Biot-Savart law” in electromagnetism

- Educated at the École Polytechnique
 - 1797 appointed professor of mathematics at the U. of Beauvais
 - 1800 became professor of physics at the Collège de France
 - 1803 elected to the Académie Française
 - After 1804 investigated heat conduction in rods
 - 1840 awarded Rumford Medal from the Royal Society for his development of a simple nondestructive test to determine sugar concentration
- SOURCE: EB, BS

■ **Ludwig Eduard Boltzmann (1844-1906)**

“Stefan-Boltzmann law”: $q_b^{(e)} = \sigma T^4$

“Maxwell-Boltzmann distribution of velocities”

“Boltzmann equation” for $f(\mathbf{r}, \mathbf{v}, t)$ of gas kinetic theory

The “Boltzmann constant”: k

Entropy-probability connection: $S = k \log W$

General formula for stress tensor for linear viscoelastic

SOURCES

AMS	<i>American Men of Science</i>	KK	Kagaku Kōgakkai
ARFM	<i>Annual Reviews of Fluid Mechanics</i>	KSZ	Klafter, J., M.F. Shesinger, and G. Zumofen, <i>Physics Today</i> , February , 33 (1996)
BES	<i>Biographical Encyclopedia of Scientists</i>	LBMP	Broda, E., <i>Ludwig Boltzmann: Man, Physicist, Philosopher</i> , Ox Bow Press, Woodbridge, CT (1983)
BMFRS	<i>Biographical Memoirs of Fellows of the Royal Society</i>	LN	Kronig, R., Ed., <i>Leerboek der Natuurkunde</i> , Scheltema & Holkema, Amsterdam (1961)
BS	Baehr, H.D. and K. Stephan, <i>Heat and Mass Transfer</i> , Springer, Berlin (1998)	MD	Dresden, Max, <i>H.A. Kramers: Between Tradition and Revolution</i> , Springer, Berlin (1987)
CBC	Curtiss, C.F., R.B. Bird, and P.R. Certain, <i>J. Phys. Chem.</i> , 86 , 6A (1982)	MIT	Massachusetts Institute of Technology
CC	Chapman, S., and T.G. Cowling, <i>Mathematical Theory of Non-Uniform Gases</i> , 3rd ed., Cambridge University Press, 407 (1970)	MJL	Lighthill, M.J., <i>Physics Today</i> , May , 65 (1988)
CCLB	Cercignani, C., <i>Ludwig Boltzmann: The Man Who Trusted Atoms</i> , Clarendon Press, New York, NY (1998)	MHMSE	<i>McGraw-Hill Modern Scientists and Engineers</i> (1980)
DSB	Gillispie, C.C., Ed., <i>Dictionary of Scientific Biography</i> , Scribner, New York, NY (1970-1990)	NAS	<i>Biographical Memoirs</i> , National Academy of Sciences
EAM	Mason, E.A., <i>Contemp. Phys.</i> , 12 , 179 (1971)	NTCS	McMurray, E.J., Ed., <i>Notable Twentieth Century Scientists</i> , Gale Research Inc., New York, NY (1995)
EB	<i>Encyclopedia Britannica</i> (1974)	NTN	<i>Nederlands Tijdschrift voor Natuurkunde</i> , 27 , 145 (1961)
ELC	Cussler, E.L., <i>Diffusion</i> , 2nd. ed., Cambridge (1997)	PAMD	Dalitz, R.H., <i>The Collected Works of P.A.M. Dirac</i> , Cambridge University Press (1995)
EPW	Wigner, E.P., <i>Symmetries and Reflections</i> , Ox Bow Press, Woodbridge, CT (1979) (Wigner’s original Hungarian name was Jenő Pal Wigner)	PFN	Neméni, P.F., <i>Archive for History of Exact Sciences</i> , 2 , 52 (1962)
GKB	Batchelor, G.K. <i>J. Fluid Mech.</i> , 70 , 625 (1975)	RBB	Bird, R.B., <i>Physics Today</i> , 42 (10), 13 (1989)
HCÓ	Öttinger, H.C., <i>Stochastic Processes in Polymeric Fluids</i> , Springer, Berlin, 293 (1996)	RBL	Lindsay, R.B., historical introduction to Rayleigh’s <i>Theory of Sound</i> , Dover, New York, NY (1945)
HCE	<i>History of Chemical Engineering</i> , American Chemical Society, Washington, DC (1980)	RI	Rouse, H., and S. Ince, <i>History of Hydraulics</i> , Dover, New York, NY (1957)
HE	Eyring, Henry, <i>Ann. Revs. Phys. Chem.</i> , 28 , 1 (1977)	RM	Mezaki, Dr. Reiji, of the Mitsubishi Research Center, in personal communication.
HJM	Merk, H.J., <i>Stofoverdracht in Laminare Grenslagen door Gedwongen Convectie</i> , Uitgeverij Excelsior, ’s Gravenhage (1957)	RNB	Bracewell, R.N., <i>Scientific American</i> , 260 (6) 86, 92 (1989)
JH	Herivel, J., <i>Joseph Fourier: The Man and the Physicist</i> , Clarendon Press (1975)	SGB	Brush, S.G., translator’s introduction to Boltzmann’s <i>Lectures on Gas Theory</i> , University of California Press (1964)
JM	Meixner, J., and H.G. Reik, <i>Handbuch der Physik</i> , 3(2), Springer, 413 (1959)	SGBKT	Brush, S.G., <i>Amer. Journ. Physics</i> , 30 , 269 (1962)
JOH	Hirschfelder, J.O., <i>Ann. Revs. Phys. Chem.</i> , 34 , 1 (1983)	UM	University of Michigan archives
KGD	Denbigh, K.G., <i>Thermodynamics of the Steady State</i> , Methuen, London (1951)	WWAH	<i>Who Was Who in American History: Science and Technology</i> , Marquis, Chicago (1976)
		WWWS	<i>World Who’s Who in Science</i> , Ed. A.G. Debus, Marquis, Chicago (1968)

Note: This material was used as the basis for a presentation on Nov. 17, 1998, at the annual meeting of AIChE held in Miami Beach, FL.,

materials (the “Boltzmann superposition principle”)

- Doctorate in Wien 1866, with J. Stefan
- Held professorships in Wien, Graz, München, Leipzig
- His *Vorlesungen über Gastheorie*, Part I (1896) and Part II (1898), is a masterpiece of technical presentation. In the preface to Part II, because of increasing attacks by the “energeticists” (mainly Ostwald and Mach), he states, “I am convinced that these attacks are merely based on a misunderstanding and that the role of gas theory in science has not yet played out... In my opinion, it would be a great tragedy for science if the (kinetic) theory of gases were temporarily thrown into oblivion because of a momentary hostile attitude toward it... I am conscious of being only an individual struggling weakly against the stream of time...”
- Elected to the National Academy of Sciences (USA) in 1904
- Was a lively, witty, clear, and stimulating teacher with outstanding blackboard technique and excellent lecture demonstrations
- Lise Meitner, who attended his lectures during the period 1902-1905, said, “He was a good teacher. His lectures were the most beautiful and stimulating I have ever heard... He was himself so enthusiastic about all he was teaching that we left every lecture with the feeling that an entirely new and wonderful world was being opened to us. He also loved to insert personal remarks into his lectures.”
- Other students of his were Nernst, Smoluchowski, Ehrenfest
- He was extraordinarily friendly and enjoyed assisting others
- He often invited students to his home and played the piano for them (he had studied with Anton Bruckner (1824-1896))
- He enjoyed ice skating and swimming
- His suicide in 1906, possibly because of health problems or discouragement because his kinetic theory was still being attacked, was an enormous tragedy for science
- S=klogW is on his gravestone in Vienna

SOURCES: DSB, SGB, SGBKT, LBMPP, CCLB

■ Joseph Valentin Boussinesq (1842-1929)

“Eddy viscosity” for turbulent flow

The “Boussinesq approximation”: buoyancy effects

- Never studied formally - self taught
- 1867 was awarded a doctor's degree
- 1873 was appointed to a professorship in Lille
- Later moved to Paris
- Published *Théorie Analytique de la Chaleur* in two volumes (1901, 1903)

SOURCE: BS

■ Henri Coenraad Brinkman (1908-1961)

The “Brinkman number”: $(Br = \mu V^2 / k \Delta T)$; a related dimensionless group is the “Nahme-Griffith number”

Fluid heating by viscous dissipation

Flow in porous media

Plasma physics

- 1932 received a doctor's degree with Professor H.A. Kramers
- 1932-1935 studied with Professor F. Zernike in Groningen
- 1935 moved to BPM Laboratories in Amsterdam
- 1949-1954 taught at the university in Bandung, Indonesia, during which time he wrote *The Application of Spinor Invariants to Atomic Physics*
- 1954 moved to TNO and was also head of the FOM Instituut voor Plasma Fysica

SOURCE: NTN

■ Auguste-Louis Cauchy (Baron) (1789-1857)

(pronounced “Koh-shee,” with accent on second syllable)

“Cauchy-Riemann equations” in complex variable theory

“Cauchy's equation of motion” in terms of the stress tensor

“Cauchy's second equation of motion”: symmetry of the stress tensor

- 1800, as a military engineer, worked on fortifications at Cherbourg for

Napoléon's planned invasion of England

- Professor at École Polytechnique, professor at the Collège de France, and member of the Académie Française
- Was dismissed from all three when he refused to take the loyalty oath following the revolution in 1830
- 1822 laid the foundations of the theory of elasticity
- Was in exile in Switzerland, Turin, and Prague
- Allowed to return to France in 1838. After the revolution of 1848 his professorship at the Sorbonne was reinstated

SOURCE: EB, BS

■ Sydney Chapman (1888-1970)

Rigorous kinetic theory for monatomic gases (generally known as the “Chapman-Enskog theory”)

First experiments on thermal diffusion in gases

Kinetic theory of plasmas

The “Chapman-Jouguet condition” in theory of flames and detonations

- His father was chief cashier of a textile firm
- 1908 MS in mathematics from Manchester
- 1911 1st Class in Mathematics Tripos at Cambridge, was a college lecturer there during the period 1914-1916
- 1911-1914 and 1916-1918 did geomagnetism at the Greenwich Observatory
- 1919-1924 was professor of mathematics at the University of Manchester, successor to Sir Horace Lamb
- 1924-1954 taught at Imperial College of the University of London
- After 1954 was at the High Altitude Observatory (Boulder, CO) and the Geophysical Institute (Alaska)
- The *Mathematical Theory of Nonuniform Gases* by Chapman and Cowling went through three editions and was very influential
- Elected fellow of the Royal Society in 1919
- Elected foreign member of the Nat. Academy of Science, USA, in 1946
- Was fond of cycling, swimming, and hiking
- Known for his persistence, kindness, integrity, and simplicity

SOURCES: DSB, SGBKT

■ Thomas Hamilton Chilton (1899-1972)

“Chilton-Colburn relations”

- Son of a Methodist minister
- As a youth worked in a printing shop
- Started college at the University of Alabama and finished up at Columbia University with a Ch.E. degree in 1922
- 1925-1959 career at Du Pont in Wilmington
- 1943 awarded honorary doctorate from the University of Delaware
- During WWII served on the Manhattan Project
- Was present for the first nuclear pile at the University of Chicago
- 1950 elected vice president of AIChE, and president in 1951
- After retirement held visiting professorships at Berkeley, Kyoto and Nagoya (Japan), U. of New South Wales, Nancy and Toulouse (France), Georgia Tech, U. of Delaware, U. of Virginia, Birla Inst. of Technology (India), U. of Alabama, U. of Massachusetts, U. of Puerto Rico, U. of Natal (South Africa), U. of South Carolina
- Hobbies included photography and classical music
- Founder of the Auto License Plates Collectors of America
- Was a splendid researcher, scholar, teacher, remembered for his high ethical standards and his ability to inspire others

SOURCE: NAE

■ Alan Philip Colburn (1904-1955)

The “Chilton-Colburn relations”

The “Colburn j-factors”

Simultaneous heat and mass transfer

- 1926 BS, 1927 MS, 1929 PhD at the University of Wisconsin (first PhD student of Olaf Andreas Hougen)

- 1929-1938 did research at Du Pont in Wilmington
 - 1938-1955 professorial career at the University of Delaware (1938-1941 associate professor, 1941-1955 professor, 1947-1950 assistant to president, 1950-1955 provost)
 - AIChE: 1936 Walker Award, 1948 Professional Progress Award
 - 1944-1947 director of AIChE
 - ASME chairman, Heat Transfer Division
- SOURCE: WWWAH

■ Stanley (“Stan”) Corrsin (1920-1986)

Interaction of turbulent fluctuations and chemical reactions
The “Corrsin equation” for the propagation of the double temperature correlation and for the double concentration correlation in chemically reacting systems

- 1940 BS mechanical engineering, University of Pennsylvania
 - 1942 MS and 1947 PhD aeronautics Cal-Tech
 - 1947-1986 on faculty of Johns Hopkins U., where he had a distinguished career and established a formidable group in the field of turbulence
 - 1963 elected to American Academy of Arts and Sciences
 - 1974 honorary doctorate, Université de Lyon
 - 1980 elected to the National Academy of Engineering
- SOURCE: NAE

■ Gerhard Damköhler (1908-1944)

The “Damköhler number” for the first-order heterogeneous reactions (there are other Damköhler numbers as well)

- His publication “Einfluss von Diffusion, Strömung, und Wärmetransport auf die Ausbeute von chemischen Reaktionen,” in *Der Chemie-Ingenieur*, Leipzig, 359 (1937) was a key publication in chemical reaction engineering
- SOURCE: BS

■ Peter Victor Danckwerts (1916-1984)

Residence-time distribution and mixing
Diffusion and chemical reactions
Role of diffusion in gas absorption

- 1935-1939 studied chemistry at Oxford
 - 1939-1940 worked in a small chemical company
 - 1940-1945 was bomb disposal officer at the Port of London during the Blitz; later was assigned to similar work outside of England; was wounded in a mine field in Italy
 - 1948 received an MS at MIT
 - 1948-1954 was on staff at Cambridge University
 - 1954-1956 served at the Industrial Group of the United Kingdom Atomic Energy Authority at Risley
 - 1956-1959 served as professor of chemical engineering science at Imperial College in London
 - 1959-1977 held the Shell Chair at Cambridge University
 - 1965-1966 was president of the Institution of Chemical Engineers
 - 1952-1983 served as executive editor of *Chemical Engineering Science*
 - 1970 published his treatise *Gas-Liquid Reactions*
 - 1978 elected to National Academy of Engineering
- SOURCES: NAE, BMFRS

■ Paul Adrien Maurice Dirac (1902-1984)

As a graduate student at Cambridge, studied the dissociation of a gas in a temperature gradient
Suggested the concepts “separative capacity” and “value function” for comparing separation processes

- Began studying electrical engineering at the University of Bristol
- Went to Cambridge in 1923, where he became a professor in 1932
- Published his relativistic wave equation in 1928
- Received the Nobel Prize in physics in 1933
- Elected to the U.S. National Academy of Sciences in 1949

SOURCES: LN, PAMD

■ Carl Henry Eckart (1902-1973)

Thermodynamics of irreversible processes applied to flowing fluid mixtures
Geophysical hydrodynamics

- BS, MS in engineering at Washington University
 - 1925 PhD at Princeton
 - Early in his career he was deeply involved in the development of the quantum mechanics of the 1920s and 1930s
 - Series of four papers in 1940 on thermodynamics of irreversible processes applied to transport phenomena in fluids (*Phys. Rev.*, volumes 58, 73) was extremely influential
 - 1953 elected to National Academy of Sciences and in 1966 received the NAS Alexander Agassiz Medal
 - 1965-1969 vice chancellor of the University of California San Diego
- SOURCES: NAS, JM, DSB

■ Albert Einstein (1879-1955)

“Einstein’s viscosity formula” for dilute suspensions of neutrally buoyant spheres $\mu = \mu_0 [1 + (5/2)\phi]$ [in original publication, the factor 5/2 was missing]

Theory of Brownian motion and translational diffusivity (Brownian motion was first observed in 1789 by Jan Ingenhousz 1730-1799)

- Born in Ulm, Germany
 - Educated in Germany, Italy, and Switzerland
 - At the Züricher Polytechnikum he was next-to-the-bottom student. He disliked lectures and exams. He liked to read.
 - 1902-1909 he served as an examiner in the patent office in Bern
 - 1905 published theory on special relativity (received doctorate from Zürich in same year)
 - Held professorships in Bern, Zürich, and Prague
 - 1914 appointed director of Kaiser Wilhelm Institute for Physics
 - 1921 Nobel Prize for “photoelectric effect” (relativity was not mentioned)
 - 1933 fled Hitler Germany and went to the Institute for Advanced Study, Princeton, New Jersey
 - 1942 elected to National Academy of Sciences
- SOURCE: NAS

■ David Enskog (1884-1947) (pronounced roughly “Ayn-skohg”)

Developed the modern kinetic theory of gases (the “Chapman-Enskog theory”)

First theoretical prediction of thermal diffusion in gases
Developed the “Enskog kinetic theory for dense gases”
First derivation for dilatational viscosity of dense gases

- 1917 doctorate at Uppsala, dissertation on the solution of the Boltzmann equation for the kinetic theory of gases
 - In 1930 was appointed professor at the Royal Institute of Technology in Stockholm (Sydney Chapman wrote a letter of recommendation for this professorial appointment. Later Chapman said that “his transfer to a university chair seemed rather to bring him new duties than increased leisure...”)
- SOURCES: DSB, CC, SGBKT

■ Henry Eyring (1901-1981)

Transport properties of liquids based on simple physical models

First molecular theory for non-Newtonian viscosity

- Father had a 14,000-acre cattle ranch in Mexico
- 1923 BS in mining engineering from the University of Arizona
- 1924 MS in metallurgy from the University of Arizona
- 1927 PhD in chemistry (Berkeley) with Professor G.E. Gibson
- 1927 instructor in chemistry at the University of Wisconsin, then had

postdoctoral year with Professor F. Daniels

- 1929-1930 NRC fellow at Kaiser Wilhelm Institute in Berlin with Professor Michael Polányi
- Taught at Berkeley (1930-1931), Princeton (1931-1946), and the U. of Utah (1947-1981) and served at the latter as dean of the Graduate School
- 1945 elected to the National Academy of Sciences
- He heeded his father's excellent advice, "to be dedicated to the truth, wherever one finds it, and to live in such a way as to make one comfortable in the company of good people."
- He was thoughtful of all people, regardless of their rank or station. He is said to have remarked that one should be good to people whom you pass "on the way up because you will want them to be good to you when they pass you on their way up and when you are on your way down."

SOURCES: NAS, JOH, HE, DSB

■ John Thomas Fanning (1837-1911)

Fanning friction factor (f)

- Studied architecture and civil engineering until 1861
- Served in the U.S. Civil War, going from a lieutenant to a lieutenant colonel
- After the Civil War, became prominent in engineering, particularly water works and water power in the northeastern part of the United States and later in the West and Midwest
- Author of *A Practical Treatise on Hydraulic and Water-Supply Engineering*, D. Van Nostrand, New York, NY (1877); also 14th Ed. (1899)

SOURCE: WWWAH

■ Adolf Eugen Fick (1829-1901)

"Fick's first law of diffusion": $\mathbf{j}_A = -D_{AB} \nabla c_A$

"Fick's second law of diffusion": $\partial c_A / \partial t = D_{AB} \nabla^2 c_A$

- Studied medicine in Marburg and Berlin
- Doctorate in 1851 on visual errors due to astigmatism
- 1852-1868 was in Zürich (1861-1868 as professor)
- 1855 published "Fick's law of diffusion"
- 1868 moved to Marburg
- 1878-1879 rector of the University of Würzburg
- Postulated equations for diffusion by analogy with heat conduction — not by experiment
- Published *Die Medizinische Physik*, the first biophysics book (1856) — dealt with molecular physics, diffusion, hemodynamics, sound, origin of heat in the human body, optics, etc.

SOURCES: EB, DSB, ELC

■ Jean-Baptiste-Joseph Fourier (Baron) (1768-1830)

Establishment of the basic equations for heat conduction

The "Fourier number": (Fo)

"Fourier series," "Fourier integral"

- Orphaned at age nine, he was placed in a local military school run by Benedictine monks
- 1794 was among the first students at École Normale in Paris
- 1795 became a teacher at École Polytechnique
- 1798 accompanied Napoleon to Egypt and was secretary of the Institut d'Égypte, doing research on Egyptian antiquities
- Gained fame as an Egyptologist and contributed substantially to the compilation and publication of *Description de l'Égypte* (1808-1925), a 21-volume work on the culture and history of Egypt
- 1802-1814 was prefect of Isère (began his book on heat conduction in 1807)
- 1809 was made a baron by Napoleon
- 1815 became director of the Statistical Bureau of the Seine
- 1817 elected to the Académie des Sciences
- 1822 published *Théorie Analytique de Chaleur*
- 1826 was elected to Académie Française and Académie de Médecine
- The name "Fourier" is on the list of 72 names on the Eiffel Tower

SOURCES: EB, DSB, RNB, JH

■ William Froude (1810-1879) (rhymes with "food")

The "Froude number": Fr

"Froude's law of similarity": first proposed by F. Reech 1831

- Studied seven years at Oriel College, Oxford
- Elected fellow of the Royal Society in 1870
- Honorary doctorate from the University of Glasgow in 1876
- Worked as a civil engineer (railways and ocean steamships)
- Retired from active practice at age 36
- Did resistance studies on scale models and worked on screw propellers
- In 1870 received £2,000 to have a towing tank (250 feet in length) built on his own property

SOURCES: DSB

■ Thomas Graham (1805-1869)

"Graham's laws of diffusion"

- Son of a prosperous manufacturer
- 1819 entered the University of Glasgow
- 1826 received MA in chemistry from the University of Glasgow and then worked two years in a laboratory at the University of Edinburgh
- 1824 and 1833 published works on diffusion, later also works on effusion
- 1830 named professor of chemistry at Anderson's College (later the Royal College of Science and Technology)
- 1834 became a fellow of the Royal Society
- 1837 named professor of chemistry, University College, London
- 1834 named Master of the Mint
- Was well liked by students and was in demand as a consultant

SOURCES: DSB, EAM, ELC

■ Franz Grashof (1826-1893) (pronounced "grahss-hoff")

The "Grashof number": $Gr = \rho g b^3 \Delta \rho / \mu^2$

- 1844 went to Gewerbe-Institut in Berlin to study mathematics
- For one year he was an army volunteer
- Shipped out as an apprentice seaman on a sailing vessel; returned in 1851 and decided to become a teacher
- 1852 resumed studies in Berlin
- 1854 became teacher of mathematics and mechanics at the Gewerbe-Institut. He was also director of the Office of Weights and Measures
- In 1856 was one of 23 founders of VDI (Verein Deutscher Ingenieure). He was made director of the society and editor of the *Zeitschrift*. The Grashof Medal of VDI is named after him.
- 1860 received an honorary doctorate
- During 1863-1891 was professor of applied mechanics at the Polytechnikum, Karlsruhe; was known for the clarity and precision of his lecturing
- 1871-1886 published *Theoretische Maschinenlehre* (three volumes)

SOURCE: DSB

■ Shirôji Hatta (1895-1973)

The "Hatta number"

Absorption with chemical reactions

- 1916-1919 was an undergraduate in applied chemistry at Tôkyô Teikoku Daigaku
- 1919 took employment at Mitsubishi Shipbuilding Company
- 1925-1958 taught at Tôhoku Daigaku
- 1928 proposed the "Hatta number," published in 1932 in volume 35 of *Kôgyôkagaku Zasshi*
- 1936-1938 was editor-in-chief of *Kagaku Kôgaku*
- 1939-1940 was vice president of Kagaku Kôgakkai
- 1940 saw the publication of the textbook *Kagaku Kôgaku*, by S. Uchida, S. Kamei, and S. Hatta, Maruzen, Tôkyô
- 1954 was appointed Dean of Engineering
- 1955-1957 was president of Kagaku Kôgakkai
- 1959 accepted a position at Chiyoda Chemical Engineering and Construction Company, Ltd.
- His hobby was playing the Japanese board game "go"

SOURCES: KK, BS, RM

■ Ralph Wilmarth Higbie (1908-1941)

Early work on "penetration theory"

- BS 1934, MS 1929, ScD 1934 in chemical engineering at the University of Michigan
 - Worked at E.I. du Pont de Nemours & Company, Belle, WV, and at Eagle-Picher Lead Company in Joplin, MO
 - 1935 article in *Trans. AIChE* on gas absorption in falling films
 - 1935-1938 instructor in chemical engineering, University of Arkansas at Fayetteville
 - 1938-1941 assistant professor of chemical engineering at the University of North Dakota at Grand Forks
- SOURCES: UM

■ Joseph ("Joe") Oakland Hirschfelder (1911-1990)

Kinetic theory of multicomponent gas mixtures

First derivation of Maxwell-Stefan equations from kinetic theory of multicomponent dilute gas mixtures

Theory of gas-mixture thermal conductivity, based on a model of a multicomponent reacting gas mixture

Theory of flames and detonation

Calculation of transport coefficients for realistic force laws

Determination of intermolecular forces from measurements of gas transport properties

(Most of this work was done in close collaboration with

Professor Charles Francis Curtiss, University of Wisconsin)

- 1927-1931 undergraduate education at Minnesota and Yale
 - 1931-1936 graduate study at Princeton, coadvised by Henry Eyring in chemistry and Eugene Paul Wigner in physics
 - 1937-1941 research associate in chemistry at the University of Wisconsin
 - 1941-1990 on the faculty of the chemistry department at the University of Wisconsin
 - 1942-1945 involved in government research at NDRC in Washington, D.C., and at Los Alamos
 - 1946 founding director of the Theoretical Chemistry Institute at the University of Wisconsin
 - 1950 senior author of *The Effects of Atomic Weapons*
 - 1953 elected to National Academy of Sciences
 - 1954 senior author of *Molecular Theory of Gases and Liquids*
 - 1976 received the National Medal of Science
- SOURCES: NAS, JOH, CBC, MHMSE

■ Jan Ingenhousz (1730-1799)

(rhymes with "swingin' moose")

Predated Brown for observation of "Brownian motion"

Made the first quantitative measurements of heat conduction in rods

Did experiments in America (with Benjamin Franklin) on lightning rods

- 1772-1779 was court physician to Austrian Empress Maria Theresa
- Discoverer of photosynthesis

SOURCES: DSB, EB, KSZ

■ Gustav Andreas Johannes Jaumann (1863-1924)

(pronounced "yow-mahn")

Proposed the "equation of change for entropy"

$$\rho \frac{D\hat{S}}{Dt} = -(\nabla \cdot \mathbf{s}) + \mathbf{g}_s$$

Formulated the "Jaumann derivative": corotational derivative

$$\frac{D\Lambda}{Dt} = \frac{D\Lambda}{Dt} - \{\mathbf{w} \cdot \Lambda\} - \{\mathbf{w} \cdot \Lambda\}^t \quad \left(\text{where } \mathbf{w} = \frac{1}{2} [\nabla \times \mathbf{v}] \right)$$

(actually proposed earlier by S. Zaremba)

- Author of *Die Grundlagen der Bewegungslehre*, Barth, Leipzig (1905).

He is listed as being "Professor der Physik an der Deutschen Technischen Hochschule in Brünn" (today Brno in the Czech Republic)

- His article in *Wiener Akad. Sitz. (Math-Naturw. Klasse)*, **120**(2A) 385 (1911) was an extensive summary of the "field equations" of physics, including the equation of change for entropy in nonequilibrium systems (including "entropy flux": \mathbf{s} , and "entropy production": \mathbf{g}_s)

SOURCES: KGD, JM

■ Gustav Robert Kirchhoff (1824-1887)

"Kirchhoff's radiation laws" for emissivity and absorptivity

- Published his famous laws for electrical networks while still a student at the university in Königsberg
- 1850 appointed professor in Breslau
- 1854 received professorship in Heidelberg
- 1875 became professor of theoretical physics at the University of Berlin (where he was one of the founders of mathematical physics)

SOURCE: BS

■ John ("Jack") Gamble Kirkwood (1907-1959)

Kinetic theory of the transport properties of liquids

Derived modified Maxwell-Stefan equations for diffusion in monatomic liquid mixtures

Kinetic theory of polymers: non-Newtonian viscosity, complex viscosity, diffusion

Thermodynamics of irreversible processes (multicomponent)

- Graduated from the U. of Chicago at the age of 19 in December of 1926
- Received his PhD from MIT's chemistry department in June of 1929
- Did postdoctoral work with Debye in Leipzig
- 1942 elected to the National Academy of Sciences. From 1955-1958 he served as foreign secretary. He was quite good in French
- 1942-1945 government work on explosives, detonations and shock waves
- Taught at Cornell University (1934-1937 and 1938-1947), the University of Chicago (1937-1938), Cal-Tech (1947-1951), and Yale (1951-1959). He served as Chairman of Chemistry and as Director of Science at Yale.
- His article with Bryce Crawford in *J. Phys. Chem.* (1952) was the first discussion of the application of the thermodynamics of irreversible processes to multicomponent mixtures of gases or liquids

SOURCE: NAS

■ Martin Hans Christian Knudsen (1871-1949)

"Knudsen flow" (free molecule flow)

"Knudsen number": (K_n)

"Knudsen manometer"

- 1890 entered the University of Copenhagen
- 1896 received MS in physics
- 1901-1912 docent in physics at Copenhagen
- 1912-1941 professor of physics at the University of Copenhagen (and also gave some lectures at the Technical University)
- 1934 *The Kinetic Theory of Gases* was published (based on lectures at the University of Glasgow in 1933)
- Most of his career was in the field of hydrography
- Was vice president of the Central Committee for Oceanic Research
- 1908-1948 edited the *Bulletin Hydrographique*

SOURCE: DSB

■ Hendrik Anthony Kramers (1894-1952)

"Kramers-Kistemaker effect": diffusional slip, when there is a concentration gradient along a wall

Kinetic theory of polymer chains in dilute solution

Contributions to the theory of Brownian movement

"Kramers-Kronig relations": originally developed for polarizability, they are also used in viscoelasticity to interrelate the real and imaginary parts of the complex

viscosity: $\eta^* = \eta' - i\eta''$

- 1912 matriculated in Leiden to study with professor Ehrenfest
 - 1916 completed “doctoral” exam; taught high school for a few months
 - 1916-1926 completed work for the doctorate at Copenhagen and then continued working with Niels Bohr
 - 1926-1934 professor of physics at the University of Utrecht
 - 1934-1952 professor of physics at the University of Leiden
 - 1946-1950 president of the Internat. Union of Pure and Applied Physics
 - The “K” of the WKB method for solving differential equations
 - Known for attacking very difficult and fundamental problems. He was highly respected by the leading theoretical physicists of his day and made many contributions in the development of quantum theory
- SOURCES: MD, RBB, DSB

■ Johann Heinrich Lambert (1728-1777)

“Lambert’s Law of absorption”

“Lambert’s cosine law” in radiation

- son of a tailor, largely self-educated
 - Known for his work *Photometria, Sive de Mensura et Gradibus Luminis, Colorum, et Umbrae*, Augsburg (1760)
 - 1759 became a member of the Bavarian Academy of Science
 - 1761 he proved that π and e are not rational numbers
 - 1765 became a member of the Berlin Academy of Science
- SOURCE: BS

■ Lev Davydovich Landau (1908-1968)

Flow of liquid helium

Equations of superfluid dynamics

- Entered Baku University at the age of 14
 - 1927 was awarded the doctorate at the age of 19
 - 1929-1931 studied in Germany, Switzerland, Great Britain, and Denmark (with Niels Bohr)
 - 1932-1937 head of the theoretical department at the Ukrainian Physico-technical Institute
 - 1937 appointed head of the theoretical department, Institute for Physical Problems, Academy of Sciences, USSR
 - 1960 elected foreign member of the National Academy of Sciences, USA
 - 1962 received the Nobel Prize for his work on liquid helium
 - 1962 (December) was in a disastrous car-truck collision near Moscow
 - His books on theoretical physics, coauthored with E.M. Lifshitz, are world-famous. The volume titled *Fluid Mechanics* is still the best book available on advanced transport phenomena. According to his coauthor, Landau was not very familiar with fluid dynamics when they started writing the book, and Landau “set about thinking through it *ab initio* and deriving [the] basic results” — this explains why there are so many interesting and different approaches in the book
- SOURCE: MHMSE

■ Warren (“Doc”) Kendall Lewis (1882-1975)

The “Lewis number” $Le = \alpha / \mathcal{D}_{AB}$ or its reciprocal

The “Lewis relation”: $Le = 1$

The “Lewis-Whitman film theory”

- 1905 BS at MIT, 1908 PhD in chemistry at Breslau
- Worked as a chemist in a tannery in New Hampshire
- 1911 joined the MIT faculty
- 1920 appointed the first head of the ChE department at MIT
- In 1923 the influential book, *Principles of Chemical Engineering* by Walker, Lewis, and McAdams, was published, providing a unifying influence on the field
- 1938 elected to National Academy of Sciences
- 1966 elected to National Academy of Engineering
- In *Chemical Engineering Progress* 44(1), 17 (1948) one finds the following comments of J. Howard Arnold: “I do not believe that Lewis ever used this group [Le]. I do know that he contested the application of boundary-layer theory to the problems of simultaneous heat and material

transfer, and that this theory ultimately demonstrated the lack of rigor in the Lewis analogy. The designation of $\alpha / \mathcal{D}_{AB}$ as the Lewis group is highly inappropriate and does not merit general acceptance.” (Of course, it has gained widespread acceptance, particularly in the field of combustion.)

- Some workers in the field of combustion assume (incorrectly) that the Lewis number was named for Bernard Lewis (1899-1993), who for many years was a major figure in the field of combustion research.

SOURCES: MHMSE, NAE, HCE 1980 (chapters 4 and 7)

■ James Clerk Maxwell (1831-1879)

Kinetic theory of gases

“Maxwell-Stefan equations” for binary diffusion

Established the theory of linear viscoelasticity

“Maxwell-Boltzmann equation” of gas kinetic theory

Thermal conductivity of composite solids

Slip of gases at a wall (viscous slip and thermal slip)

- 1854 graduated with honors at Trinity College, Cambridge
- 1856 became professor of natural philosophy, Aberdeen
- 1860 moved on to King’s College, London, and published his kinetic theory of gases
- 1864 *A Dynamical Theory of the Electromagnetic Field* was published, the work for which he is most famous
- 1871 became the first Cavendish Professor at Cambridge
- 1877 published the *Theory of Heat*
- Not considered to be a good teacher, but was very friendly and mild-mannered. He had deep religious convictions

SOURCES: EB, DSB, SGBKT

■ Hendrik (“Henk”) Jacobus Merk (1920-1988)

First derivation of Maxwell-Stefan equations for multicomponent diffusion from irreversible thermodynamics

- 1940-1942 enrolled at Technische Hogeschool Delft in mechanical engineering. His studies were interrupted by World War II
- 1945-1952 completed studies in Delft; received degree in engineering physics
- 1957 received a doctor’s degree with Professor J.A. Prins
- 1953-1987 was a professor at Technische Hogeschool Delft

SOURCE: HJM

■ Claude-Louis-Marie-Henri Navier (1785-1836)

(pronounced “Nah-vyay,” with second syllable accented)

Obtained “Navier-Stokes equations” before Stokes by (faulty) molecular arguments

- Was a civil engineer whose specialty was road and bridge building
- 1821 established the equations for equilibrium and vibration of elastic solids
- Best-known work was a treatise on bridges, however, a bridge over the Seine in Paris — designed by him — collapsed because of the settling of one pier
- He is included as one of the 72 names of notables inscribed on the Eiffel Tower

SOURCES: PFN, RI

■ (Sir) Isaac Newton (1643-1727)

Newton’s “law of viscosity”: $\tau_{yx} = -\mu (dv_x/dy)$

Newton’s “law of cooling”: $q = hA\Delta T$

Equations of motion of dynamics

- Had a traumatic childhood because of death of his father and remarriage of his mother
- 1661 matriculated at Cambridge
- 1667 was a fellow at Trinity College
- 1669 was appointed Lucasian Professor and resigned in 1701
- 1696 became Warden of the Mint
- 1703 became president of the Royal Society

- 1705 was knighted by Queen Anne
- 1707 was elected to the Académie des Sciences (France)
- In Section IX of Book II of the *Principia* (1687), Newton wrote the following: “The resistance arising from the want of lubricity in the parts of a fluid is, other things being equal, proportional to the velocity with which the parts of the fluid are separated from one another.” This statement is taken to be the precursor to Newton’s “law of viscosity.”
- M.J. Lighthill has this to say about Newton’s contributions to fluid dynamics, “...one does observe some falling off of quality both in the reasoning and in its relation to observation when one plows onward to the part of Book II of the *Principia* which treats of the dynamics of fluid media. Two theories are given, of which we can at least say that neither was worthy of being enshrined forever in a book destined to be treated as the scientific equivalent of holy writ. The dense-medium theory rested on the unspoken, undefended, erroneous assumption that fluid motions can be superposed linearly, and predicts correspondingly unrealistic flows. The better known rarefied medium theory is put forward in a properly tentative manner, but nevertheless it was treated with exaggerated reverence (as if it were a physical theory of real fluids) for over two centuries, and has recently been resuscitated.”
SOURCES: EB, DSB, MJL, PFN

■ (Amalie) Emmy Noether (1882-1935)

“Noether’s theorem” shows how the conservation laws for energy, momentum, and angular momentum may be derived from the equations of motion plus the notions of homogeneity of time, homogeneity of space, and isotropy of space, respectively

- Specialities were abstract algebra, hypercomplex numbers, rings, and ideals
- 1900-1902 was a “nonmatriculated auditor” at Erlangen
- 1902-1904 was a “nonmatriculated auditor” at Göttingen
- 1904-1907 studied at Erlangen, doctorate summa cum laude
- 1915 invited by Hilbert to Göttingen and in 1919 did Habilitation
- 1922-1933 was a “nichtbeamteter ausserordentlicher Professor” (an unofficial adjunct professor — without salary!)
- Dismissed from her job at the beginning of Hitler’s program of religious persecution
- Became professor of mathematics at Bryn Mawr
- In Herman Weyl’s memorial tribute, he referred to her as a paragon of vitality, and said “she stood on the earth with a certain sturdy humor and courage for life.”
- “Noether’s theorem” can be found in *Nachr. Kgl. Ges. Wiss. Göttingen (Math.-Phys. Kl.)*, 235 (1918); see also Chapter 2 of Landau and Lifschitz’s *Mechanics*.
- There are questions of the assignment of priorities for Noether’s theorem (see H. van Dam and E.P. Wigner, *Phys. Rev.* **B138**, B1578, fn 6).
- Crater on the moon was named after her (located at 66.6°N Lat. 113.5°W Long.)

SOURCES: NTCS, EPW

■ Ernst Kraft Wilhelm Nusselt (1882-1957)

First major researcher on convective heat and mass transfer
Analogous behavior of heat- and mass-transfer processes
Dimensionless presentation of heat- and mass-transfer data
The “Nusselt number”: $Nu = hD/k$

Film condensation

Radiant heat transfer

- Doctorate at the Technische Hochschule in München in 1907
- 1907-1909 was assistant to Mollier at Technische Hochschule in Dresden
- After two years in industry, returned to Dresden in 1913 and

remained there until 1917

- 1915 published “Das Grundgesetz des Wärmeüberganges” in *Gesundheits-Ingenieur*, in volume 38 — dealing with natural and forced convection and showing how to use dimensional analysis to generalize experimental data
- Discussed film condensation of steam
- 1918-1919 was at BASF Ludwigshafen
- 1920 became professor at Technische Hochschule in Karlsruhe
- 1925-1952 was professor of theoretical mechanics at München
- 1930 discussed the analogies between heat and mass transfer
- Published *Technische Thermodynamik*, (Volume I in 1934 and Volume II in 1944)
- He was an exacting taskmaster with students and an avid mountain climber, but was not a colorful or exciting lecturer
SOURCE: DSB

■ Lars Onsager (1903-1976)

Nonequilibrium thermodynamics

“Onsager reciprocal relations”

Separation of isotopes by thermal diffusion

Turbulence

- 1920-1925 studied chemical engineering at the T.H. in Trondheim
- 1926-1928 studied with Debye in Zürich
- 1928 went to Johns Hopkins as an associate in chemistry and was dismissed after one year for very poor teaching
- 1928-1933 taught at Brown University. While there in 1931, he published his famous papers on irreversible thermodynamics
- 1933 moved to Yale (because he was terminated at Brown). He sent his work on irreversible thermodynamics to Trondheim to get a doctorate, but the material was deemed unworthy of a degree. Then he submitted a thesis, *Solutions of the Mathieu Equation of Period 4π and Certain Related Functions* (1935) to the chemistry department at Yale, which enabled him to get an assistant professorship there.
- 1942 announced the evaluation of the partition function for the Ising model for a two-dimensional ferromagnet (according to Wolfgang Pauli, the only noteworthy advance in physics during WWII).
- His two courses on statistical mechanics were referred to by students as “Advanced Norwegian I and II,” *i.e.* his lectures were difficult to follow
- Made many friendships because of his kindness, warmth, and integrity
- 1947 elected to the National Academy of Sciences
- 1960 received an honorary doctorate from Trondheim
- 1968 received the Nobel Prize (for his work on irreversible thermodynamics) and the National Medal of Science
SOURCES: NAS, BES

■ Jean-Claude-Eugène Péclet (1793-1857)

(pronounced “Pay-clay,” with second syllable accented)

The “Péclet number”: $Pe = RePr$

- Was educated at the École Normale
- Became a professor in Marseille in 1816
- Founder of, and professor at, the École Centrale
- Was head at the École Normale
- Author of several books, including *Traité de la Chaleur et de ses Applications* in 1829 and its revised edition in 1843
- Determined (with Fourier) thermal conductivities of various materials up to 100°C
SOURCE: WWWS

■ Robert (“Bob”) Lamar Pigford (1917-1988)

Diffusion and convection; diffusion and chemical reactions

Rate of atmospheric dispersion of clouds of droplets

Interphase diffusion

Isotope separation

Transient behavior of mass transfer equipment

- 1938 received BS degree from Mississippi State College
 - 1940 granted MS in chemistry at University of Illinois
 - 1942 granted PhD in chemistry, did thesis on mass transfer with Professor H. Fraser Johnstone
 - 1941-1947 worked in the engineering department of E.I. du Pont de Nemours and Company, Inc.
 - 1947 named chairman of the Chemical Engineering Department at University of Delaware; on faculty there 1947-1966; 1975-1988
 - 1966-1975 served on the faculty at Berkeley
 - Coauthored *The Application of Differential Equations to Chemical Engineering* with W.R. Marshall Jr. and *Absorption and Extraction* with T.K. Sherwood (and a third edition with C.R. Wilke)
 - Elected to the National Academy of Engineering in 1971
 - Elected to the National Academy of Sciences in 1977
 - Founding editor of *Industrial and Engineering Chemistry Research*
 - Hobbies included playing the clarinet, operating a ham radio, making furniture, and fabricating electronic devices
 - A scholarly leader with a warm and refined personality
- SOURCE: NAE

■ Max Karl Ernst Ludwig Planck (1858-1947)

"Planck's distribution law" for black-body radiation

"Planck's constant" h

"Fokker-Planck equation"

Derivation of Stefan-Boltzmann constant: $\sigma = \frac{2}{15} \pi^5 k_B^4 / h^3 c^2$

- Oct. 19, 1900, proposed his distribution law for the radiant energy of emission from black bodies as an empiricism
- Dec. 14, 1900, presented a derivation of his distribution law by introducing the notion of quantization of energy
- His book, *Vorlesungen über die Theorie der Wärmestrahlung* 2nd Ed. (1913), is a careful presentation of the derivation of the Planck distribution for black-body radiation. In this book he had this to say about the idea of "emission of quanta": "It is true that we shall not thereby prove that this hypothesis represents the only possible or even the most adequate expression of the elementary dynamical law of the vibrations of the oscillators. On the contrary, I think it very probable that it may be greatly improved as regards form and contents. There is, however, no method of testing its admissibility except by the investigation of its consequences, and as long as no contradiction in itself or with experiment is discovered in it, and as long as no more adequate hypothesis can be advanced to replace it, it may justly claim a certain importance."
- 1918 was awarded the Nobel Prize for proposing quantization
- When asked in 1931 how he came to formulate the idea of quantization of energy, he said, "It was an act of desperation. For six years I struggled with the black-body theory. I knew the problem was fundamental and I knew the answer. I had to find a theoretical explanation at any cost, except of the inviolability of the two laws of thermodynamics." (Quoted from A. Hermann in *The Genesis of the Quantum Theory*, 1971.)
- 1926 elected to the National Academy of Sciences, USA
- 1930 became president of the Kaiser Wilhelm Institute
- During WWII he was an outspoken opponent of Adolf Hitler (his eldest son was executed for involvement in a plan to assassinate Hitler). In about May of 1933, he had a very unsatisfactory audience with Hitler, trying to dissuade him from his policies of religious persecution. He had to resign the presidency of the Kaiser Wilhelm Society in 1937.
- He was rescued by the U.S. Armed Forces and restored as president of the Kaiser Wilhelm Society (later renamed the Max Planck Society).
- A peak in the Dolomites is named after him, because he made its first ascent.
- He had a well-developed interest in music. He had a harmonium built with 104 tones in each octave. He had the piano technique of a professional. He preferred Schubert, Schumann, and Brahms.
- He had a respect for the law, a trust in established institutions, a strong sense of duty, and absolute honesty. He valued a clear conscience as extremely important.

- His private library and all his correspondence were destroyed in a 1944 Allied air raid of Berlin.

SOURCES: DSB, EB, BES, LN, HCÖ

■ Ludwig Prandtl (1875-1953) (*pronounced "Prah-n-tl"*)

"Prandtl boundary-layer theory" (some prior work on this was done by L. Lorenz of Denmark)

"Prandtl mixing length" in turbulence

"Von Kármán-Prandtl equation" for f(Re) for tubes

"Prandtl number": Pr = ν/α

- 1898 graduated from Technische Hochschule in Munich
- 1900 doctorate in physics at Munich
- 1901 became professor at the Technische Hochschule in Hannover
- 1904 named head of the Institut für Technische Physik at the University of Göttingen; proposed the boundary-layer idea
- 1925 became head of the Kaiser Wilhelm Institute for Fluid Mechanics
- Had perfect pitch and enjoyed playing the piano
- A rather turgid lecturer, because he could not make a statement without qualifying it

SOURCES: EB, DSB, BES, ARFM (19)

■ Osborne Reynolds (1842-1912)

"Reynolds number": Re = $DV\rho/\mu$ (named by A. Sommerfeld in 1908)

Laminar-turbulent transition

Theory of lubrication

"Reynolds stresses"

Transport of heat by turbulent motion

Heat transfer between solids and fluids

"Reynolds transport theorem" (just a special case of the three-dimensional Leibniz formula)

- 1867 graduated from Queens College, Cambridge
- 1868 named first professor of engineering in Owens College, Manchester, and served there 37 years
- 1877 named a fellow of the Royal Society
- 1883 did the famous experiments on instability of tube flow
- Was an active member of the Manchester Literary and Philosophical Society, in which he served as secretary and president

SOURCES: EB, ARFM (22) (article by N. Rott), DSB

■ Ernst Heinrich Wilhelm Schmidt (1892-1975)

Heat and mass transfer

"Schmidt number" Sc

- Studied civil engineering at the T.H. in Dresden and the T.H. in München, then switched to electrical engineering at the university in München, receiving the doctor of engineering degree in 1921
- 1925 became professor in Gdansk, Poland
- 1945-1952 was professor at the T.H. in Braunschweig
- 1952 became professor at the T.H. in Munich as successor to Nusselt
- 1956-1968 was rector of the T.H. in Munich
- Author of *Technische Thermodynamik*, 10th ed. (1963), and *Wasserdampfafeln*, 6th ed. (1963)

SOURCES: WWWS, BS

■ Thomas ("Tom") Kilgore Sherwood (1903-1976)

The "Sherwood number," Sh, was appropriately named in honor of his many distinguished contributions to the field of mass transfer; however, it may be argued that this dimensionless group first originated with Nusselt and should therefore bear the latter's name

- 1923 BS in chemical engineering from McGill University
- 1929 ScD in chemical engineering from MIT, with W.K. Lewis
- 1930-1969 was on the faculty in chemical engineering at MIT
- After retiring from MIT, became professor of ChE at Berkeley

- 1948 elected to American Academy of Arts and Sciences
 - 1958 elected to National Academy of Sciences
 - 1964 chosen as a founding member of National Academy of Engineering
 - Coauthor of books: *Absorption and Extraction, Mass Transfer, The Properties of Gases and Liquids, A Course in Process Design, The Role of Diffusion in Catalysis*
 - AIChE awards included the William H. Walker Award, the Founders' Award, and the Warren K. Lewis Award. He also received the Murphree Award from the American Chemical Society
 - Hoyt C. Hottel, author of the NAE memoir, said, "He had warmth, charm, orderliness, and a conscience that drove him to use his talents to the fullest to advance chemical engineering in theory and practice."
- SOURCE: NAE

■ **Charles Soret (1854-1904)** (*"So-reh," accent on second syllable*)

First to measure the thermal diffusion effect in liquids in 1879, the "Soret effect." C. Ludwig, however, published on this phenomenon in 1856 in Sitzber. K. Akad. Wien.

- A Swiss mineralogist

■ **Thomas Edward Stanton (1865-1931)**

"Stanton number": $St = Nu / RePr$

- Studied with Reynolds at the University of Manchester
- In 1899 became a professor of engineering at the University of Bristol
- Worked on aerodynamics and airplane construction

SOURCE: BS

■ **Josef Stefan (1835-1893)**

"Maxwell-Stefan equations" for multicomponent diffusion in a mixture of N gases:

$$\nabla x_{\alpha} = \sum_{\beta=1}^N \frac{x_{\alpha} x_{\beta}}{\sum_{\alpha\beta}} (v_{\beta} - v_{\alpha})$$

Established empirically the "Stefan-Boltzmann equation":

$$q_b^{(e)} = \sigma T^4$$

The "Stefan problem": heat conduction with phase change and moving boundary; earlier work by F. Neumann of the University of Königsberg had not been published

Relation between surface tension and evaporation

- Had to help out his illiterate Slovenian parents on a farm
- 1853 enrolled at the university in Wien
- 1865 elected to the Imperial Academy of Sciences in Austria, was vice-president from 1885 to 1893
- 1876-1877 was rector magnificus of the University of Vienna
- Deduced the surface temperature of the sun as 6,000°C

SOURCE: DSB

■ **George Gabriel Stokes (1819-1903)**

"Navier-Stokes equation"

"Stokes flow" (creeping flow)

"Stokes law" for flow around a sphere

- 1849 appointed, at the age of 30, as Lucasian Professor at Cambridge
- 1851 elected to Royal Society of London
- 1854-1888 served as secretary for the Royal Society
- 1884 elected as president of the Royal Society
- 1883 elected to the National Academy of Sciences, USA
- Worked on geodesy, wave theory of light, fluorescence

SOURCE: RI

■ **John William Strutt, Lord Rayleigh (1842-1919)**

Established the field of acoustics

The "Rayleigh number": $Ra = GrPr$

"Rayleigh-Jeans theory" of radiant energy flux

"Rayleigh scattering"

- Poor health as a youth; had to withdraw from Eaton and Harrow
- 1861 entered Trinity College, Cambridge
- 1865 received a BS degree as "Senior Wrangler"
- 1871 took extended vacation on houseboat on the Nile because of rheumatic fever, during the trip he started on the *Theory of Sound*, Vol. I (1877) and Vol. II (1878)
- 1873 became the third Baron Rayleigh and built a lab next to his home
- 1879-1884 succeeded Maxwell as the second Cavendish Professor
- 1884 became secretary of the Royal Society
- 1904 received the Nobel Prize for isolating argon
- 1905 became president of the Royal Society
- 1908-1919 served as chancellor of Cambridge University

SOURCES: EB, RBL, LN

■ **Geoffrey Ingram ("G.I.") Taylor (1886-1975)**

"Taylor diffusion"

"Taylor vortices"

Statistical theory of turbulence

- In 1905 matriculated at Trinity College, Cambridge
- 1911 temporary readership at Cambridge
- 1912 went on HMS Scotia on a six-month expedition in the North Atlantic Ocean
- After 1923 was a Royal Society professor at Cavendish Laboratory in Cambridge
- During WWII was involved with the Manhattan Project and witnessed the first nuclear explosion at Alamogordo
- Retired in 1952, but continued doing research for an additional 20 years
- Well known for a series of movies illustrating fluid flow phenomena

SOURCES: GKB, DSB, ARFM (29)

■ **Ernest William Thiele (1895-1993)**

The "Thiele modulus"

Catalyst effectiveness factors

The "McCabe-Thiele diagram"

- 1919 BS in chemical engineering from the University of Illinois
- 1925 ScD in chemical engineering at MIT
- 1925-1960 associate director of research for Standard Oil of Indiana
- 1960-1970 professor of ChE at the University of Notre Dame
- 1971 honorary DEng from the University of Notre Dame
- 1980 elected to the National Academy of Engineering
- A kind and gentle person and a very good listener
- Wrote and spoke French and German, enjoyed traveling to Europe and visiting France and Germany

SOURCE: NAE

■ **Moritz Weber (1871-1951)** (*pronounced "Vay-ber"*)

The "Weber number": $We = \rho V^2 D / \sigma$

- Professor of naval architecture in Berlin
- Responsible for naming the Froude number
- *Die Grundlagen der Ähnlichkeitsmechanik u. ihre Verwertung bei Modellversuchen* (1919)
- Weber number named by Franz Eisner (1895-1933)

SOURCE: RI

■ **Wilhelm Carl Werner Otto Franz Wien (1864-1928)**

(pronounced "Veen")

"Wien's displacement law" of radiation

- 1890 became assistant to Hermann v. Helmholtz in Berlin
- 1896 became professor of physics at Technische Hochschule in Aachen
- 1899 moved to Würzburg as professor
- 1911 received Nobel Prize for physics for his work on radiation
- 1920 appointed professor in Munich

SOURCE: BS □