

An Academic Career in Engineering

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Outline

- Graduate school in engineering
 - What is it like?
 - Knowing that, why apply?
 - How to get in, how to survive?
- Graduate schools in EE and MEMS
- Life as an engineering professor



The M.S. Degree

- The M.S. in engineering is highly sought after by industry and good programs are available at *dozens* of universities
- The “M” in M.S. means “Master” ... and it really means that!

M.S.-level recruiting is much more targeted; some companies view the M.S. degree as the *de facto* entry-level professional degree

A co-terminal B.S./M.S. ...



M.S. Degrees Aren't Standardized

- Stanford: no report or thesis
 - Why? 600 or more MSEE students and less than 50 professors!
 - Many M.S.-level project courses provide the design experience; degree is highly valued by industry
- Berkeley, MIT: project is typically required
 - M.S. is a way station on the way to the Ph.D. for most students, or a consolation prize after failing the Ph.D. qualifying exam
 - M.S. isn't even required for a Ph.D. in EECS at Berkeley



Goals of Graduate Education

- Learn more core technical knowledge
 - You take fewer, more intensive courses
 - You actually learn (a.k.a. “master” the material)
- Learn how to discover new knowledge
 - Can this be taught? Not clear!
 - The proof that you’ve arrived: a Ph.D.* thesis
Ph.D. = doctor of philosophy ... in EE?



Why Ph.D.s are Valued by Industry

- Clear vision into the future and the ability to push the boundaries of technology
- Networked to fellow students and faculty
- Strong technical skills, including a deep knowledge of micro/nanofabrication
- “Proof-tested” in a high-stress environment: pre-screening by admission and oral exams
 - The Ph.D. in engineering is excellent training for start-up or large company success in the specific field ... and increasingly, is viewed by consulting firms and financial institutions in the same way



Graduate School

- Can be a *very tough* time, depending on your research progress, group dynamics,
- Major contrast with medical and law school:
 - Little in common with other students: don't take same course sequence, fragmented into research groups
- Can be the “best time of your life” ... freedom to explore, no responsibilities, little or no money ... but will likely be supported by research/teaching assistantships or fellowships at most schools (in the Ph.D. program)



The Gauntlet, Step 1

- The Ph.D. Oral Screening Exam a.k.a. the qualifying exam (Stanford) or prelim exam (Berkeley)
 - Stanford: 10, one-on-one 10 minute oral exams by 10 different professors in one-day in four technical areas, offered once per year
 - Berkeley: 1, 1 hour oral exam by three professors covering three technical areas offered twice per year
- The “experience”
 - Lifetime stress peak (for most)
 - Usually get two chances to pass, with second timers having the benefit from input from advisor (if they have one)



The Gauntlet, Step 2

- Thesis Defense (Stanford)
 - Taken near filing the thesis as a “shake-down”
 - 4 professors, 3-5+ hours, first hour is open
- Qualifying Exam (Berkeley)
 - Taken after the thesis is underway to verify that the research plan is doable
 - 3-4 professors, 1.5-3 hours (typically around 2 hrs)
- Failure happens occasionally and a second chance is usually given



What is a Ph.D. Thesis?

- The product of “independent investigation under faculty supervision”
- Certified by a committee of professors
- Varies depending on field
 - Length 80-450 pages
 - Time required varies (experimental vs. theory): my students average around 5.5 years from B.S. to Ph.D.



Is a Ph.D. for You?

- Just going to a “terminal point” in academic career ... family expectations
- Want to (have to?) teach → Ph.D. is the “union card” for an academic career
- Highly motivated to explore new areas, want to “make your mark” on a field, have “your own agenda” ... good signs



Are Advisors Important?

- From Carnegie-Mellon's "How to Survive as a Graduate Student" talk by Brian Noble, *et al*

The three most important factors in your career are:

- *Your Advisor*
- *Your Advisor*
- *Your Advisor*



<http://www.cs.cmu.edu/afs/cs/user/bnoble/Web/survival/slides.pdf>

Selecting an Advisor

- Done at admissions (rarely), usually during the first year or two depending on many factors, some out of your (and the advisor's) control
- Gathering information
 - Visit the school and talk with several faculty AND their graduate students
 - Where are their ex-students?
 - Do a literature search: read the papers!



Selecting an Advisor (Cont.)

- Academic age: Pre-Tenure
 - Plus: energy, enthusiasm, bright ideas, and has time for you
 - Minus: may not make tenure, may move to another school (see my c.v.), may be *too involved* in your project ... can be a real problem, relatively unknown (lacks connections), possibly unstable funding



Selecting an Advisor (Cont.)

- Academic age: senior professor
 - Plus: well-known, relatively stable funding, well-connected, has no time to look over your shoulder
 - Minus: less time for you, may manage group through postdocs or senior student (s); often incredibly busy with campus and outside commitments; is he/she burnt out? in good health?



Research Group Culture

- Organization:
 - Ph.D. students as “sub-group leaders” in charge of several M.S. students?
 - Check ratio of Ph.D./M.S. students
 - Postdocs? Industrial visitors?
- Range of projects: narrow or broad
- Funding sources: industry, government mix - consortium funds?



Risk Factors

- Start-up Companies
 - Does your advisor have a spin-off company? Does the company have any on-going ties with the university group? How are conflicts of interest handled?
 - Will your advisor go on leave to a start-up and leave you neglected or even an orphan?
 - Note: large groups can cover for a missing faculty member *much* better
- “Promotion”
 - Could your advisor end up Dept. Chair ... or Lab Director ... or Dean ... or *the Faculty Director of a Nanofab?*



Yes, I've Co-Founded a Start-Up

- Silicon Clocks, Inc., Fremont, California
- Based on UC Berkeley research on MEMS resonators for timing (i.e., clock) applications
- Founded 2004; funded Feb. 2006
- Acquired by Silicon Labs, April 2010



In Dec. 2009, I became Faculty Director of the SNF, an anchor node of the NNIN, and have spent many, many hours working to improve its performance. I will serve until 2014 and have reduced the size of my research group to accommodate the time commitment.



The Stanford Nanofabrication Facility

- 10,500 ft² of class 100 cleanroom space with separate floors for fan deck and support equipment.
- 100, 150, and 200 mm wafer processing
- 250 active users in any given month.
 - 175 Stanford academic users
 - 25 non-Stanford academic users
 - 50 industrial users.



- industrial users are primarily from small, local startups, but also several large companies (Intel, HP, IBM, Applied Materials, Bosch, and others).



NNIN

Sf

SNF Milestones

- 1965** Integrated Circuits Lab is established in the McCullough Building.
- 1985** IC Lab moves to the newly completed CIS building (now the Paul G. Allen Building).
- 1994** Stanford is a founding member and co-prime institution (with Cornell) of the five university cooperative National Nanofabrication Users Network (NNUN).
- 2004** Stanford is a founding member and co-prime institution (with Cornell) of the 14-university cooperative National Nanotechnology Infrastructure Network (NNIN).
- 2010** The Stanford Nano Center opens with characterization tools and nano-patterning labs facilities complementary to SNF.
- 2010** Stanford is awarded a National Science Foundation ARI-R2 grant for renovation and expansion of the SNF during 2010 - 2013.



My Experience

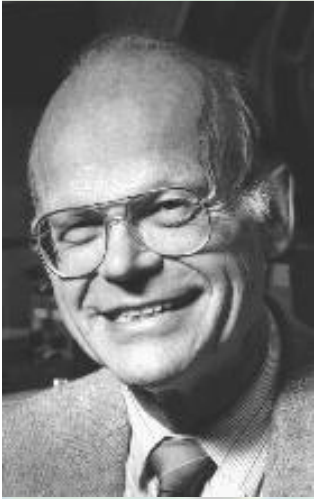
- B.S. physics from Harvey Mudd College
- Applied to: Berkeley, Stanford, UCLA, USC ... for a M.S. degree in communication theory with intention to work for Hewlett-Packard (I interned there)
- Chose Berkeley over Stanford by calling “Mudders” who’d gone to each school; offered a one-year fellowship
- TA’ed a lab class (electronics for non-majors ... E40) and found out I loved teaching
- Discovered that the professor I wanted to work with had terminal cancer, took a class from Richard S. Muller in device physics, was invited into his group
- Changed my mind about the Ph.D. and switched into solid-state devices and decided to go for prelim exam ... and passed!



My Academic Genealogy

- Richard S. Muller, Ph.D., Caltech 1962
Professor, UC Berkeley 1962 -
- R. David Middlebrook, Ph.D. Stanford 1955
Professor, Caltech, 1960 -
- Joseph M. Pettit, Ph.D., Stanford 1942
(Dean of Engineering, Stanford, 1958-1972,
President of Georgia Tech, 1972-1986)
- Frederick E. Terman, Ph.D., MIT 1920
(Dean of Engineering, Stanford, 1944-1958)
- Vannevar Bush, Ph.D., MIT 1916
(Chairman, NACA 1939-1941, Director, OSRD, 1941-1945,
helped establish the U.S. National Science Foundation)
- Arthur E. Kennelly, Chief Electrical Asst.,
Edison Lab, Menlo Park, NJ, 1887-94 (no Ph.D.)
later Professor at Harvard and MIT
- Thomas A. Edison (1847-1931) ... no degree!





Richard S. Muller

Ph.D. (Caltech, 1962)

Born in New Jersey and educated in New Jersey and California

- Mechanical Engineer (Stevens Institute of Technology, 1955)
- M.S. in Electrical Engineering (Caltech, 1957)
- Ph.D. in Electrical Engineering (Caltech, 1962)
- Professor at the University of California at Berkeley (1962 -)
- Co-wrote *Device Electronics for Integrated Circuits* with Ted Kamins of HP Labs
- Co-founded BSAC with Prof. White and helped found the MEMS field
- Received many awards: UC Berkeley Citation (1994), IEEE Cleo Brunetti Award with Roger Howe (1998), IEEE Millennium Medal (2000), NAE, Life Fellow of IEEE, IEEE/ASME Journal of MEMS Editor in Chief, ...

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Where to Go?

- The graduate school rankings: *a first cut* with the usual qualifications
- Narrowing down your list:
 - Your specific interests
 - Geography and connections to specific industry (e.g., the Ohio EE grad schools (e.g., Case, OSU, Cincinnati) and their strong ties to Midwest high-tech industry)
- Going international
 - Many grad programs are now in English in Asia and Europe and they're looking for Americans* ... but can't get them

* Defined as "graduates of U.S. schools"

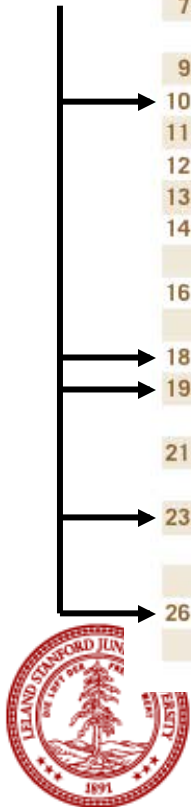


Schools of Engineering

THE TOP SCHOOLS

Rank/School	Overall score	Peer assessment score (5.0 highest)	Recruiter assessment score (5.0 highest)	'06 average quantitative GRE score	'06 acceptance rate	'06 Ph.D. students/faculty	'06 faculty membership in National Academy of Engineering	'06 engineering school research expenditures (in millions)	'06 research expenditures per faculty member (in thousands)	Ph.D.'s granted 2005-2006	'06 total graduate engineering enrollment
1. Massachusetts Institute of Technology	100	4.9	4.8	779	22.2%	4.2	12.7%	\$234.5	\$644.3	288	2,662
2. Stanford University (CA)	99	4.8	4.7	781	31.2%	7.3	16.9%	\$152.4	\$725.8	247	3,243
3. University of California–Berkeley	87	4.8	4.5	771	18.4%	5.5	16.9%	\$119.8	\$493.0	206	1,639
4. Georgia Institute of Technology	83	4.4	4.3	763	34.9%	4.2	5.0%	\$203.7	\$423.4	315	3,925
5. University of Illinois–Urbana-Champaign	82	4.5	4.3	772	27.3%	4.1	3.5%	\$200.1	\$483.4	240	2,472
6. Carnegie Mellon University (PA)	80	4.2	4.2	775	22.3%	4.5	10.1%	\$159.0	\$760.6	142	1,634
7. California Institute of Technology	79	4.6	4.6	790	9.8%	5.7	10.5%	\$80.9	\$817.2	71	601
University of Southern California (Viterbi)	79	3.5	3.7	754	48.8%	5.6	15.7%	\$169.8	\$999.0	151	3,805
9. University of Michigan–Ann Arbor	76	4.4	4.2	772	40.0%	4.1	3.8%	\$145.7	\$484.2	218	2,450
10. Cornell University (NY)	75	4.3	4.2	785	24.3%	4.2	9.9%	\$118.7	\$608.7	122	1,295
11. University of Texas–Austin	74	4.2	4.1	763	29.7%	3.6	8.8%	\$124.1	\$516.9	191	2,125
12. Purdue University–West Lafayette (IN)	73	4.1	4.1	757	30.4%	3.8	3.6%	\$121.8	\$364.8	209	2,255
13. University of California–San Diego (Jacobs)	72	3.7	3.9	765	22.0%	4.9	10.1%	\$138.6	\$845.0	106	1,195
14. Texas A&M University–College Station (Look)	68	3.7	3.7	751	37.9%	2.9	3.7%	\$196.1	\$692.8	153	2,265
University of Wisconsin–Madison	68	4.1	4.0	776	22.8%	3.7	4.1%	\$121.4	\$549.2	114	1,515
16. University of California–Los Angeles (Samueli)	67	3.7	3.7	764	35.8%	5.3	11.8%	\$89.2	\$598.7	142	1,295
University of Maryland–College Park (Clark)	67	3.6	3.6	758	24.5%	4.2	6.1%	\$151.6	\$665.1	165	1,878
18. Princeton University (NJ)	65	4.1	4.1	784	17.7%	3.9	11.5%	\$52.1	\$410.5	81	500
19. Columbia University (Fu Foundation) (NY)	62	3.6	3.7	773	29.4%	4.1	10.2%	\$84.4	\$634.5	84	1,394
University of California–Santa Barbara	62	3.4	3.5	776	24.9%	4.3	17.2%	\$81.1	\$610.1	107	674
21. Northwestern University (McCormick) (IL)	61	3.9	3.8	770	27.6%	3.7	5.0%	\$89.2	\$506.9	119	1,121
Pennsylvania State University–University Park	61	3.8	3.8	755	34.8%	3.3	2.8%	\$118.1	\$329.8	191	1,628
23. Harvard University (MA)	57	3.5	3.7	740	12.8%	5.2	13.6%	\$35.2	\$596.6	29	345
University of Minnesota–Twin Cities	57	3.7	3.8	771	36.3%	3.6	5.7%	\$71.7	\$349.6	143	1,620
University of Washington	57	3.7	3.6	736	34.3%	4.0	5.7%	\$91.6	\$497.8	107	1,440
26. Johns Hopkins University (Whiting) (MD)	56	3.9	3.9	759	20.4%	4.1	3.0%	\$54.3	\$408.6	66	2,604
Ohio State University	56	3.6	3.6	758	27.8%	2.8	2.4%	\$108.4	\$438.8	136	1,211
University of Florida	56	3.5	3.4	757	43.3%	4.4	2.4%	\$107.8	\$387.6	181	2,224

“Ivys”



2007 US News Graduate Schools of Engineering rankings

2006 Ranking of World Universities*

World Rank	Institution	Region	Regional Rank	Country	National Rank	Score on Alumni	Score on Award	Score on HiCi	Score on N&S	Score on SCI	Score on Size	Total Score
1	Harvard Univ	Americas	1	USA	1	100	100	100	100	100	73.6	100
2	Univ Cambridge	Europe	1	UK	1	96.3	91.5	53.8	59.5	67.1	66.5	72.6
3	Stanford Univ	Americas	2	USA	2	39.7	70.7	88.4	70	71.4	65.3	72.5
4	Univ California - Berkeley	Americas	3	USA	3	70.6	74.5	70.5	72.2	71.9	53.1	72.1
5	Massachusetts Inst Tech (MIT)	Americas	4	USA	4	72.9	80.6	66.6	66.4	62.2	53.6	69.7
6	California Inst Tech	Americas	5	USA	5	57.1	69.1	59.1	64.5	50.1	100	66
7	Columbia Univ	Americas	6	USA	6	78.2	59.4	56	53.6	69.8	45.8	61.8
8	Princeton Univ	Americas	7	USA	7	61.1	75.3	59.6	43.5	47.3	58	58.6
8	Univ Chicago	Americas	7	USA	7	72.9	80.2	49.9	43.7	54.1	41.8	58.6
10	Univ Oxford	Europe	2	UK	2	62	57.9	48	54.3	66	46	57.6
11	Yale Univ	Americas	9	USA	9	50.3	43.6	59.1	56.6	63	49.3	55.9
12	Cornell Univ	Americas	10	USA	10	44.9	51.3	56	48.4	65.2	40.1	54.1
13	Univ California - San Diego	Americas	11	USA	11	17.1	34	59.6	54.8	65.6	47.1	50.5
14	Univ California - Los Angeles	Americas	12	USA	12	26.4	32.1	57.6	47.5	77.3	34.9	50.4
15	Univ Pennsylvania	Americas	13	USA	13	34.2	34.4	57	41.7	73.6	40	50.1
16	Univ Wisconsin - Madison	Americas	14	USA	14	41.5	35.5	53.3	45.1	68.3	29.3	48.8
17	Univ Washington - Seattle	Americas	15	USA	15	27.7	31.8	53.3	47.6	75.5	27.8	48.5
18	Univ California - San Francisco	Americas	16	USA	16	0	36.8	55.5	54.8	61.1	48.2	47.7
19	Tokyo Univ	Asia/Pac	1	Japan	1	34.8	14.1	41.4	51.5	85.5	35.2	46.7
20	Johns Hopkins Univ	Americas	17	USA	17	49.5	27.8	40.7	52.2	68.8	25.3	46.6
21	Univ Michigan - Ann Arbor	Americas	18	USA	18	41.5	0	61.5	41.6	76.9	31.2	44.5
22	Kyoto Univ	Asia/Pac	2	Japan	2	38.3	33.4	36.9	36.2	72.4	31.7	43.9
23	Imperial Coll London	Europe	3	UK	3	20.1	37.4	40	39.7	64.2	40.2	43.4
24	Univ Toronto	Americas	19	Canada	1	27.1	19.3	38.5	36.5	78.3	44.8	42.8
25	Univ Illinois - Urbana Champaign	Americas	20	USA	19	40.1	36.6	45.5	33.6	57.7	26.3	42.5



* Compiled by Shanghai Jiao Tong University

2006 Ranking of World Engineering Schools*

World Rank in ENG	ARWU 2006 Rank	Institution*	Country	Score on Fund	Score on HiCi	Score on PUB	Score on TOP	Total Score
1	5	Massachusetts Inst Tech (MIT)	USA	100	100	71	91	100
2	3	Stanford Univ	USA	78	98	58	90	89.6
3	25	Univ Illinois - Urbana Champaign	USA	91	68	66	82	84.9
3	21	Univ Michigan - Ann Arbor	USA	87	64	61	95	84.9
5	4	Univ California - Berkeley	USA	74	71	69	86	83.2
6	42	Pennsylvania State Univ - Univ Park	USA	74	71	63	84	80.8
7	102-150	Georgia Inst Tech	USA	97	29	73	91	80.4
8	39	Univ Texas - Austin	USA	68	76	60	86	80
9	13	Univ California - San Diego	USA	80	67	52	83	78
10	73	Purdue Univ - West Lafayette	USA	95	48	59	79	77.9
11	35	Univ California - Santa Barbara	USA	53	82	47	97	76.9
12	47	Univ Southern California	USA	83	58	46	87	75.4
13	37	Univ Maryland - Coll Park	USA	78	58	57	78	75.1
14	56	Carnegie Mellon Univ	USA	76	55	56	83	74.3
15	12	Cornell Univ	USA	72	58	47	92	74.2
16	2	Univ Cambridge	UK		53	61	85	73.2
17	76	Tohoku Univ	Japan		48	76	74	73.1
18	6	California Inst Tech	USA	43	75	46	96	71.8
19	24	Univ Toronto	Canada	55	60	62	82	71.6
20	33	Northwestern Univ	USA	51	68	44	95	71.2
21	16	Univ Wisconsin - Madison	USA	69	51	52	81	70
22	102-150	North Carolina State Univ - Raleigh	USA	63	53	50	86	69.4
22	17	Univ Washington - Seattle	USA	61	55	48	87	69.4
24	8	Princeton Univ	USA	49	65	41	95	69.2
25	22	Kyoto Univ	Japan		36	74	77	69



* Compiled by Shanghai Jiao Tong University

A Few Top EE Grad Schools (US)

1. MIT
2. Stanford
3. UC Berkeley
4. Illinois
5. Michigan
6. Georgia Tech
7. Caltech
8. Cornell
9. UT Austin
10. Carnegie Mellon
11. Purdue

For MEMS, strength in
Mechanical Engineering,
Materials Science,
Chemical Engineering,
and Bioengineering are
also *very important*

There are at least another 12
U.S. schools where you
could earn a Ph.D. in
MEMS and have your
initial career trajectory
more or less the same ...



***USN&WR EE Grad
School Rankings***

Beyond the Rankings

- The Ivys
 - Harvard (big push in engineering), Princeton, Penn, Columbia, Yale, Duke ... especially for an academic career but industry has heard of these schools, too
- Look at the up-and-coming campuses in the top state university systems:
 - UT Dallas and UT Arlington: pushing nano
 - UC San Diego, Santa Barbara, Irvine, and Santa Cruz
 - University of Florida: new fab early 2008
- Look at schools in high-tech areas with strong industry ties
 - Arizona State in Tempe (Phoenix)
 - Univ. of Washington



How Can You Distinguish Yourself?

1. Your undergrad degree ... and work experience
2. US undergrad education and background (even without residency *or* citizenship) is a *major plus*
3. Internships, undergrad research opportunities
 - National labs, research universities, companies
 - Letters from these places are important!
4. Projects: these lead to content-rich letters of recommendation, *which are critically important*
5. Family background: engineering? farming? college/university education?
6. Work experience: 1-2 years after B.S. is not unusual for engineering applicants



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To Be an Engineering Professor

- Getting hired: the postdoc (or industrial equivalent) as a preliminary step is becoming a the norm in the MEMS/nano fields
- The tenure track: (slightly) less stressful in engineering vs. sciences; depends on the school
- Fund raising: more challenging since early 2000's
 - NSF engineering research budget is 1/3 of what it was when I started at CMU in 1985 (real dollars)
 - DoD funding: feast or famine ... and long-term decline
 - Industry funding: near-term development orientation is an issue, but can be very productive



What Do Professors Do?

- Come up with new research directions
- Raise money to support these ideas
- Come up with curriculum innovations (courses, books, web-based instruction, ...)
- Lead shared research facilities (e.g., the SNF)
- Do “outside stuff”
 - Present papers, give talks (about 10/year)
 - Consulting, expert witness in patents, ...
 - Government service (examples from my own experience and other Berkeley and Stanford faculty)
 - Start new companies
- Teach (!)



The Pluses

- Flexibility to pursue new ideas by yourself or through collaboration within your university or with other schools or companies
- No boss! Dept. Chairs and Deans have some, but usually quite limited authority over professors, especially after tenure
- Interacting with new classes of undergraduates, new generations of graduate students, postdocs, and staff (technical and administrative)
- The long-term ties to your own Ph.D. alumni



The Academic Family



**Frank J. Zendejas, Ph.D. “hooding” at
College of Engineering commencement, UC Berkeley, May 2006**

**Dr. Zendejas joined the large-area photovoltaic technology group at Sandia
National Labs in Livermore, Calif.**

I first met Frank in 1998 as a summer intern in my group from CSU-Fresno

