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"Current Comments"

Characteristics of Highly Cited Publications in the Engineering Sciences

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In order to study the literature of the engineering sciences, a subset of the journals covered by the *Science Citation Index®* (*SCI®*) was selected and examined in an unpublished ISI® study. The subset was chosen by including all journals classified by ISI or NSF as belonging to some area of engineering or applied science. The information from the 382 journals finally selected was extracted from the 1973 *SCI* data-base. All references contained in these journals were included.

Figure 1 lists those journals that collectively account for 50% of the references cited. As expected from Bradford's law of scattering, only 10% of the source journals account for 50% of the citations. While there is a high concentration of applied physics in this list, there are journals represented from most of the engineering science areas.

In this study, we eliminated all items cited less than four times, removing 97.9% of the unique items cited. Only the top 2.1% were considered. A complete listing of items cited ten or more times would show a definite preponderance of books at the top of the list, with journal articles becoming more prevalent towards the end. Figure 2 lists the top 25 books.

This characteristic is significantly different from results obtained in the studies of the chemical literature and other pure science areas. In studies of other disciplines, journal articles are usually more highly cited than books. Most of the books referred to in the engineering sciences are standard texts or handbooks used by engineers in their fieldwork. In the engineering sciences, this finding suggests that there exists a strong link between engineering scientists and practicing engineers, both of whom regard the text or handbook as an indispensable authority for basic knowledge of the field.

The information in these texts tends to be a few years older than more recently published journal articles. The vast majority of the authors of journal articles are engineering scientists, whose overall citation pattern seems to be to cite some standard textbook about five years old and a few journal articles about two years old.

The highly cited engineering literature was sorted by journal to obtain a list of journals that accounted for the most highly cited items. Figure 3 lists journals that published twenty or more articles cited four or more times. These 39 journals account for about 45% of the highly cited items. At the

Figure 1. Journals ranked by number source item pairs extracted for each journal. **A** = Journal title (abbreviation). **B** = Citation records. **C** = Cumulative records. **D** = Cumulative percent of total records.

A	B	C	D
1. J. Appl. Phys.	16,274	16,274	4.7
2. Phys. Stat. Sol. A.	11,396	27,670	8.0
3. Solid St. Comm.	9,252	36,922	10.6
4. Nucl. Instrum.	8,384	45,306	13.1
5. Proc. IEEE	8,198	53,504	15.4
6. J. Water Poll. Contr. Fed.	6,565	60,069	17.3
7. Applied Optics	6,246	66,315	19.1
8. J. Acoust. Soc. Amer.	5,496	71,811	20.7
9. AIAA Journal	5,431	77,242	22.3
10. Appl. Phys. Letters	4,838	82,080	23.7
11. J. Materials Sci.	4,795	86,875	25.1
12. Planetary & Space Sci.	4,433	91,308	26.3
13. J. Catalysis	4,002	95,310	27.5
14. J. Fluid Mechanics	3,865	99,175	28.6
15. AICHE Journal	3,793	102,968	29.7
16. J. Sci. Indust. Res.	3,686	106,654	30.8
17. Int. J. Heat Mass Transf.	3,683	110,337	31.8
18. Chem. Eng. Sci.	3,602	113,939	32.9
19. IEEE Tr. Nuclear Sci.	3,567	117,506	33.9
20. Rev. Sci. Instrum.	3,433	120,939	34.9
21. Chemie-Ing.-Technik	3,423	124,362	35.9
22. IEEE J. Quantum Electr.	3,259	127,621	36.8
23. J. Amer. Ceramic Soc.	3,177	130,798	37.8
24. Soil Sci. Soc. Amer. Proc.	3,114	133,912	38.6
25. J. Sound Vibration	3,079	136,991	39.4
26. J. Vacuum Sci. Technol.	2,992	139,983	40.4
27. Water Resources Res.	2,827	142,810	41.2
28. Automation Rem. Contr. USSR	2,808	145,618	42.0
29. Thermal Eng.	2,777	148,395	42.8
30. Electr. Comm. Japan	2,702	151,097	43.6
31. Tr. Amer. Soc. Agr. Eng.	2,669	153,766	44.4
32. IEEE Tr. Power App. Syst.	2,666	156,432	45.2
33. Nuclear Sci. Eng.	2,589	159,021	45.9
34. Water Research	2,563	161,584	46.6
35. Telecomm. Radio Eng.	2,552	164,136	47.4
36. Solid St. Electr.	2,484	166,620	48.1
37. Proc. IEE	2,465	169,085	48.8
38. J. Appl. Mechanics	2,462	171,547	49.5
39. IEEE Tr. Electr. Dev.	2,461	174,008	50.2

top of the list are the expected high prestige journals in basic and applied physical and chemical sciences. Very notable are two journals sponsored by industrial organizations, the *IBM Journal of Research and Development* and the *Bell System Technical Journal.*

The top 27 journal articles (those with citation rates of at least 18 for the 1973 subset) were considered in detail, and Figure 4 lists these articles in rank order by the number of citations in the full 1973 *SCI.* These articles represent very important contributions to the engineering sciences.

Figure 2. The 25 Books Most Frequently Cited in Engineering Sciences in 1973. **A** = rank. **B** = times cited. **C** = bibliographic data.

A	B	C
1.	113	**Abramowitz M & Stegun I A (eds.).** *Handbook of mathematical functions with formulas, graphs and mathematical tables.* New York: Dover Publications, Inc., 1964.
2.	82	**Carslaw H S & Jaeger J C.** *Conduction of heat in solids.* 2nd ed. Cambridge: University Press, 1959.
3.	60	**Sze M.** *Physics of semiconductor devices.* New York: John Wiley & Son, 1969.
4.	55	**Hansen M.** *Constitution of binary alloys.* 2nd ed. New York: McGraw-Hill, Inc., 1958.
5.	48	**Bird R B, Stewart W E & Lightfoot E N.** *Transport Phenomena.* New York: John Wiley & Son, Inc., 1960.
6.	46	**Schlichting H & Kestin J.** *Boundary layer theory.* 6th ed. New York: McGraw-Hill, 1968.
7.	45	**Gold B & Rader C M.** *Digital processing of signals.* New York: McGraw-Hill, 1969.
8.	45	**Paupoulis A.** *Probability, random variables and stochastic processes.* New York: McGraw-Hill, 1965.
9.	38	**Gallager R G.** *Information theory and reliable communication.* New York: John Wiley & Son, 1968.
10.	37	**Morse P M & Feshbach H.** *Methods of theoretical physics.* 2 pts. (Illus.) New York: McGraw-Hill, 1953.
11.	36	**Zienkiewicz O C & Cheung I K.** *Finite element method in engineering science.* 2nd. ed., New York: McGraw-Hill, 1971.
12.	36	**Lucky R W, Salz J & Weldon E J Jr.** *Principles of data communication.* New York: McGraw-Hill, 1968.
13.	35	**Peterson W W & Weldon E J Jr.** *Error correcting codes.* 2nd ed. Cambridge: MIT Press, 1971.
14.	34	**Stratton J A.** *Electromagnetic theory.* New York: McGraw-Hill, 1941.
15.	34	**Hinze J O.** *Turbulence.* New York: McGraw-Hill, 1959
16.	33	**Wilkinson J H.** *Algebraic eigenvalue problem.* Cambridge: Oxford University Press, 1965.
17.	33	**Bryson A E & Ho Y C.** *Applied optimal control: optimization estimation & control.* Waltham: Xerox College Publishing, 1969.
18.	33	**Hill R.** *Mathematical theory of plasticity.* Cambridge: Oxford University Press, 1950.
19.	33	**Van Dyke M.** *Perturbation methods in fluid mechanics.* New York: Academic Press, 1964.
20.	33	**Doob J L.** *Stochastic processes.* New York: John Wiley & Son, 1953.
21.	32	**Pontryagin L S, Boltyanskii V G, Gamkrelidze R V & Mishchenko E F.** *Mathematical theory of optimal processes.* New York: John Wiley & Son, 1962.
22.	32	**Athans M & Falb P.** *Optimal controls.* New York: McGraw-Hill, 1966.
23.	31	**Morse P M & Ingard K U.** *Theoretical acoustics.* New York: McGraw-Hill, 1968.
24.	31	**Timoshenko S P & Goodier J N.** *Theory of elasticity.* 3rd ed. Engineering Societies Monographs Ser. New York: McGraw-Hill, 1970.
25.	30	**Satterfield C N.** *Mass transfer in heterogeneous catalysis.* rev. ed. (Orig. Title: *Role of Diffusion in Catalysis*) Cambridge: MIT Press, 1969.

Figure 3. Journals Cited Four or More Times by Engineering Sciences 1973. A = rank. B = number of highly cited items. C = journal title (abbreviation). A number in parentheses after a journal title (abbreviation) indicates the rank of the journal among the top 50 journals most frequently cited by engineering journals in 1969.

A	B	C	A	B	C
1.	304	J. Appl. Phys. (5)	21.	42	AIAA Journal (16)
2.	250	Appl. Phys. Letters (22)	22.	41	Phys. Stat. Sol.
3.	232	Physical Review (14)	23.	38	Nucl. Instrum.
4.	199	IBM J. Res. Developm.	24.	37	J. Opt. Soc. Amer.
5.	135	Proc. IEEE (1)	25.	35	Philosophical Mag.
6.	113	Bell Syst. Techn. J. (9)	26.	34	Rev. Sci. Instrum.
7.	98	J. Fluid Mechanics (12)	27.	34	IEEE J. Quantum Electr.
8.	76	J. Acoust. Soc. Amer. (36)	28.	32	IEEE Tr. Inform. Theory (25)
9.	74	AICHE Journal (13)	29.	32	J. Amer. Ceramic Soc.
10.	72	J. Chem. Physics (20)	30.	30	Water Research
11.	72	Electr. Letters (44)	31.	29	Proc.IEEE (15)
12.	70	Proc. Royal Soc. London (26)	32.	28	J. Appl. Mechanics
13.	68	Appl. Optics	33.	25	Industr. Eng. Chem. (2)
14.	68	Phys. Rev. Letters (47)	34.	25	J. Noncryst. Solids
15.	65	Solid St. Electr. (39)	35.	23	J. Sound Vibration
16.	61	IEEE Tr. Microwave (24)	36.	22	J. Electrochem. Soc. (23)
17.	58	IEEE Tr. Electr. Dev. (31)	37.	21	Planetary & Space Sci. (40)
18.	53	J. Catalysis (42)	38.	21	Rev. Mod. Phys.
19.	49	IEEE Tr. Autom. Control	39.	20	Int. J. Heat Mass Transf.
20.	45	Chem. Eng. Sci. (18)			

It is significant that an article on mathematical computation should head the list. While 94 citations in one year would place it on any highly cited list, Cooley's article stands out even more when compared to other papers in the same field. Clustering papers in citation studies avoids invidious comparisons. In any case, the importance of math to engineering progress is plainly evident from this particular study of engineering literature.

Two of the more interesting articles among this list of the top 27 are the items by Mie and Fenstermacher. Mie's article, the oldest in this list was published in 1908. It concerns optical scattering, and is cited by diverse journals in the areas of optics, photographic science, ceramics, air pollution, and telecommunications. Fenstermacher's 1972 article is the most recently published, and deals with carbon dioxide lasers.

A detailed account of all 27 papers would be a veritable encyclopedia of engineering progress. It should be quite apparent that physics is inseparable from engineering since so many of the highly cited articles are from journals not included in the original list. Indeed, the *Physical Review* and other basic physics journals were deliberately omitted from the *input* journals.

The most obvious feature of the list is the preeminence of the *Bell System Technical Journal* (6 out of 27). As a consequence, a substantial number of AT&T researchers appear on the list. This small sample verifies that the most important area of the engineering sciences during the last twenty years has been communications--the movement of information, whether by analog or digital techniques.

During this period, chemical, civil, mechanical, and other areas of engin-

Figure 4. Journal Articles Most Highly Cited by the Engineering Subset, ranked in order of Total 1973 Citations in the *SCI*. **A** = rank. **B** = times cited. **C** = bibliographic data.

A	B	C
1.	94	**Cooley J W.** An algorithm for the machine calculation of complex Fourier series. *Math. Comput.* **19**:297, 1965.
2.	86	**Fletcher R.** A rapidly convergent descent method for minimization. *Computer Journal* **6**:13, 1963.
3.	74	**Marquardt D W.** An algorithm for least squares estimation of non-linear parameters. *SIAM J. Appl. Math.* **11**:431, 1963.
4.	58	**Van der Pauw L J.** A method of measuring specific resistivity and Hall effect disks of arbitrary shape. *Philips Research Reports* **13**:1, 1958.
5.	53	**Mie G.** Beitrage zur Optik trüber Medien, speziell kolloidaler Metallösungen (On optical characteristics of turbid media, with special reference to colloid metallic solutions) *Ann Phys* **25**:377-445, 1908.
6.	53	**Shockley W.** Statistics of the recombinations of holes and electronics. *Phys. Rev.* **87**:835, 1952.
7.	45	**Heilmeier G H et al.** Dynamic scattering; a new electro-optic effect in certain classes of nematic liquid crystal. *Proc. IEEE* **56**:1162, 1968.
8.	39	**Josephson B D.** Possible new effects in superconductive tunnelling. *Phys. Letters* **1**:251, 1962.
9.	39	**Ovshinsky S R.** Reversible electrical phenomena in disordered structures. *Phys. Rev. Letters* **21**:1450, 1968.
10.	35	**Taylor R L & Bitterman S.** Survey of vibrational relaxation data to processes important in the CO_2-N_2 laser system. *Rev. Mod. Phys.* **41**:26, 1969.
11.	34	**Fenstermacher C A et al.** Electron-beam controlled electrical discharge as a method of pumping large volumes of CO_2 laser media at high pressure. *Appl. Phys. Letters* **20**: 56, 1972.
12.	34	**Nicollian E H.** The Si-SiO_2 interface, electrical properties as determined by the metal-insulator silicon conductance technique. *Bell Syst. Tech. J.* **46**:1055, 1967.
13.	33	**Tien P K.** Light waves in thin films and integrated optics. *Applied Optics* **10**:2395, 1971.
14.	32	**Rice S O.** Mathematical analysis of random noise. *Bell Syst. Tech. J.* **23**:282, 1944.
15.	32	**Rice S O.** Mathematical analysis of random noise. *Bell Syst. Tech. J.* **24**:46, 1945.
16.	31	**Smith W R et al.** Analysis of interdigital surface wave transducers by use of an equivalent circuit mode. *IEEE Tr. Microwave Theory* **MT17**:856, 1969.
17.	28	**Ruch J G & Fawcett W.** Temperature dependence of the transport properties of gallium arsenide determined by a Monte-Carlo method. *J. Appl. Phys.* **41**:3843, 1970.
18.	28	**Tancrell R H & Holland M G.** Acoustic surface wave filters. *Proc. IEEE* **59**:393, 1971.
19.	28	**White R M.** Surface elastic waves. *Proc. IEEE* **58**:1238, 1970.

20. 27 **Scharfetter D L.** Large signal analysis of a silicon Read diode oscillator. *IEEE Tr. Electr. Dev.* **ED16**:64, 1969.

21. 25 **Read W T.** A proposed high frequency negative resistance diode. *Bell Syst. Tech. J.* **37**:401, 1958.

22. 24 **Adler R.** A study of locking phenomena in oscillators. *Proc. IRE* **34**:351, 1946.

23. 24 **Kalman R E & Bucy R S.** New results in linear filtering and prediction theory. *Tr. ASME* **D-83**:95, 1961.

24. 24 **Lighthill M J.** On sound generated aerodynamically. *Proc. Royal Soc. A.* **21**:564, 1952.

25. 23 **Hayashi I. et al.** GaAs-$Al_xGa_{1-x}A_s$ double heterostructure injection lasers. *J. Appl. Physics.* **42**:1929, 1971.

26. 23 **Marcuse D.** Mode conversion caused by surface imperfections of a dielectric slab wave guide. *Bell Syst. Tech. J.* **48**:3187, 1969.

27. 20 **Kurokawa K.** Some basic characteristics of broadband negative resistance oscillator circuits. *Bell Syst. Tech. J.* **48**:1937, 1969.

eering have played a less important role. Examining Figure 4, the reader may also note the rather low number (6) of papers produced in academic environments. This helps to strengthen the hypothesis that the industrial research laboratory is of prime importance for basic research in the electrical, electronic, solid state, and communications fields. On the other hand our data also shows that significant advances in chemical, civil, and mechanical engineering were achieved in government and university environments.

Some readers may wish to compare the list in Figure 1 with a similar list we published last year[1] based on our 1969 *SCI* files. There are some dramatic changes in the composition of these lists. And the ranks of certain journals have changed. Consider that *Industrial & Engineering Chemistry* ranked second in our 1969 study but does not show up at all in Figure 1. It does show up in Figure 3 as having published many classic papers in the past. On the other hand the *Journal of the Acoustical Society* has changed in rank from 36 to 8th. If for any reason you do not have access to this earlier paper please let us know.

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1. **Garfield E.** Journal citation studies. 21. Engineering journals. *Current Contents®* No. 27, 7 July 1975, p. 5-10.