

1051-716-20091 — FOURIER METHODS FOR IMAGING

website: <http://www.cis.rit.edu/class/simg716/>

Relevant Published Materials:

The list is meant to be fairly comprehensive and includes library call numbers. The comments are my own gauges of usefulness to this class and to imaging in general.

Text:

1. *Linear Mathematics with Applications to Imaging*, Roger L. Easton, Jr. (unpublished course notes)

Other (very useful) Textbooks

1. *Foundations of Image Science*, H.H. Barrett and K.D. Myers, Wiley-Interscience, 2004, ISBN 0-471-15300-1, Catalog number TK8315 .B37 2004.
2. *Linear Systems, Fourier Transforms, and Optics*, Jack D.Gaskill, Wiley, 1978, QC355.2.G37 (source of many homework problems)
3. *Two-Dimensional Imaging*, R.N. Bracewell, Prentice-Hall, 1995, TA1637.B73.

Mathematical Foundations of Linear Systems:

1. For review, Schaum's Outlines on Calculus, Linear Algebra, Vector Analysis, Matrices, Complex Variables; also Schaum's *Mathematical Handbook*
2. *Advanced Mathematical Methods for Engineering and Science Students*, G. Stephenson, P.M.Radmore, Cambridge, 1990 (§2 on special functions, §7 on Fourier transforms).
3. *Linear Algebra and its Applications* (3rd Edition), Gilbert Strang, Harcourt, Brace, Jovanovitch, 1988, (Chapters on orthogonal projections, eigenvectors, change of bases).
4. Any of several texts on mathematical physics, e.g., Kreysig, Arfken, Byron and Fuller, ...

Fourier Transforms in Mathematics:

1. *The Fourier Integral and Certain of its Applications*, N. Wiener, Dover Publications, 1958 (first published in 1933 -- *tediously mathematical*), QA404.W47.
2. *An Introduction to the Theory of Fourier's Series and Integrals*, H.S. Carslaw, Dover Publications, 1950 (first published in 1930 -- *also mathematical, but easier to read than Wiener*) QA404.C32
3. *A Handbook of Fourier Theorems*, D.C. Champeney, Cambridge, 1987, (*best of the three*) QA403.5.C47.

Fourier Transforms in Physics/Engineering:

1. *Fourier Series and Boundary-Value Problems*, R.V. Churchill, McGraw-Hill, 4th Edition, 1987, (*classic text with lots of physical applications*), QA404.C6.
2. *A First Course in Fourier Analysis*, D.M. Kammler, Prentice-Hall, 2000, (useful discussions of mathematical and computational aspects), QA403.5.K36.
3. *Fourier Transforms and their Physical Applications*, D.C. Champeney, Academic Press, 1973, (*excellent*), QA403.5.C46.
4. *Fourier methods for mathematicians, scientists, and engineers*, M. Cartwright, Ellis Horwood, 1990, (*paperback, introductory, lots of physical applications*), QA403.5.C37.
5. *The Fourier Transform and Its Applications* (Second Edition, Revised), R.N.Bracewell, McGraw-Hill, 1986, (*the standard reference on 1-D Fourier, good discussion of discrete transforms and applications*), QA403.5.B7
6. *Fourier Transforms, An Introduction for Engineers*, R.M. Gray and J.W. Goodman, Kluwer Academic Publishers, 1995, (*aimed at discrete transform, not as useful as I expected*), TK5102.9.G73.
7. *A student's guide to Fourier transforms*, J.F. James, Cambridge, 1995, QC20.7.F67J36, (*thin, cheap, useful*)
8. *The Fourier Integral and its Applications*, A. Papoulis, McGraw-Hill, 1962, (*old, pre-FFT, though good mix of mathematical theory and practical applications*), QA404.P32.
9. *Fourier Transforms*, I.N. Sneddon, Dover Publications, 1995 (first published in 1951), (*similar comments to Papoulis*), QA404.S53.

10. **Fourier Analysis**, T.W. Körner, Cambridge, 1988, (*potpourri of Fourier from nonconventional point of view -- historically driven*), QA403.5.K67.
11. **Exercises for Fourier Analysis**, T.W. Körner, Cambridge, 1993, (*see comment above*), QA403.5.K66.
12. **Integral Transforms in Science and Engineering**, K.B. Wolf, Plenum, 1979, (*mathematical reference*), QA432.W64.
13. **Probability, Statistical Optics, and Data Testing**, 2nd Ed. B.R. Frieden, Springer-Verlag, 1991 (particularly §4 on Fourier methods – *excellent discussion of applications of statistical principles to many types of imaging problems, not just optics*), QA273.F89.
14. **Statistical Optics**, J.W. Goodman, Wiley, 1985, (*applications of Fourier theory to statistics, particularly in optics*), QC355.2.G66.
15. **Who is Fourier? A Mathematical Adventure**, Transnational College of LEX, Language Research Foundation, 1995. (\$25 paperback translated from Japanese, very introductory, lots of pictorial examples. usefulness limited by lack of index).
16. **The Hartley Transform**, R.N. Bracewell, Oxford, 1986, (*special case of Fourier transform that is real valued for real-valued inputs, a favorite of the author*) QA403.5.B73.

Discrete Fourier Transforms:

1. **The FFT, Fundamentals and Concepts**, R.W. Ramirez, Prentice-Hall, 1985, (*graphical introduction to discrete Fourier transform*).QA403.5.R36.
2. **The Fast Fourier Transform and its Applications**, E.O. Brigham, Prentice-Hall, 1988, (*excellent*), QA403.B75.
3. **Fast Fourier Transforms**, J.S. Walker, 2nd Edition, CRC Press, 1996, (*w/ DOS software*), QA403.W33.
4. **Multidimensional Digital Signal Processing**, D.E. Dudgeon and R.M. Mersereau, Prentice-Hall, 1984 (§1-§2), (*written for EEs, but good discussion of 2-D discrete transform*, TK5102.5.D83).
5. **Digital Image Processing**, K.R. Castleman, Prentice-Hall, 1996 (§1-2,§9-16), (*excellent for lots of imaging problems, demonstrates relationship of linear systems to optical systems*), TA1632.C37.

Linear Systems and Optical Imaging:

1. **Introduction to Fourier Optics**, J.W. Goodman, (2nd Edition), McGraw-Hill, 1996, (*updated classic, the BEST book on applications of Fourier transforms in optical imaging*), QC355.G65.
2. **Fourier Optics, An Introduction** (2nd Edition), E.G. Steward, Wiley, 1987, (*useful introduction, lower level than Goodman*), QC454.F7S83.
3. **Introduction to the Optical Transfer Function**, C.S. Williams and O.A. Becklund, Wiley, 1989, (*specialized topic of linear systems in optics*), QC367.W55.
4. **Systems and Transforms with Applications in Optics**, A. Papoulis, McGraw-Hill, 1968, (*another classic, showing its age a bit*), QC383.P23.
5. **Applications of Optical Fourier Transforms**, H. Stark, ed., Academic Press, 1982, (*as implied, discussions of specific applications*), TA1632.A68.
6. **Quantitative Coherent Imaging: Theory, Methods, and Some Applications**, J.M.Blackledge, Academic Press, 1989, (*nice description of subject, unusual notation/spellings*), QC476.C6.B553
7. **The New Physical Optics Notebook**, Reynolds, DeVelis, Parrent, and Thompson, SPIE Press, 1989, (*applications of linear systems to optics/holography*), QC395.2.N48.
8. **Fourier Series and Optical Transform Techniques in Contemporary Optics**, Raymond Wilson, John Wiley & Sons, Inc, 1995. QC454.F7 W55 (ISBN 0-471-30357-7)

Image Recovery:

1. **Image Restoration and Reconstruction**, R.H.T.Bates and M.J.McDonnell, Oxford University Press, 1986, (*application of linear systems to imaging*), TA1632.B36.
2. **Image Recovery, Theory and Application**, (H.Stark, ed.), Academic Press, 1987, (*similar to Bates but more applications, multiple authors, fragmented*), TA1632.I4824.

Useful References from Magazines and Journals:

1. "The Fourier Transform", R.N. Bracewell, in *Scientific American* June 1989, pp.86-95.
2. "Numerical Transforms", R.N. Bracewell, in *Science*, v.248 11 May 1990, pp.697-704.
3. "Fourier Analysis Using a Spreadsheet", R.A. Dory and J.H. Harris, in *Computers in Physics* Nov.-Dec. 1988, pp. 83-86.
4. "A Plain Man's (*sic*) Guide to the FFT", P. Kraniuskas, in *IEEE Signal Processing Magazine*, v.11, April 1994, pp. 24-35.
5. "Tom, Dick, and Mary Discover the DFT", J.R. Deller, Jr., in *IEEE Signal Processing Magazine*, v. 11 April 1994, pp. 36-50.
6. "SIGNALS, Interactive Software for One-Dimensional Signal Processing, R.L. Easton, Jr., in *Computer Applications in Engineering Education*, v.1 December 1993, pp.489-501.
7. "Fast Fourier Transforms For Fun and Profit", W.M. Gentleman and G. Sande, in *Proceedings - Fall Joint Computer Conference*, 1966, pp.563-578.

Other books containing useful discussions of imaging subjects:

1. *Principles of Digital Image Synthesis*, Andrew Glassner, Morgan-Kauffman, 1995 (two volumes), (*very nice discussion of broad range of imaging topics, relevant material in §4-5,§8-10*), T385.G585.
2. *Image Reconstruction in Radiology*, J. Anthony Parker, CRC Press, 1990, (*of much more general application than the title indicates; written for medical students and radiologists, does not require a "high" level of mathematical knowledge, useful intuitive discussions of imaging principles*) RC78.7.D53 P36.
3. *Radiological Imaging*, H.H. Barrett and W.Swindell, Academic Press, 1981, (*terrific book, also much more general than indicated by its title*), RC78.B337, (§2, §4 on Linear Systems, §3 on Random Processes, §7 on Computed Tomography)

Computing Resources:

Many computational software packages are available that would be helpful when learning the material in this class. CIS has selected **IDL**[™] from ITT Visual Information Solutions (<http://www.itvis.com/>) as its "standard" package. It is installed on the *UNIX* workstations in the Center, and also is available for purchase from CIS. Other packages exist, including **Mathematica**[™] (available on RIT VAX), **MathCad**[™], **Matlab**[™], and **Scientific Workplace**[™]. All these packages allow computations involving most aspects of matrix algebra and complex analysis to be evaluated quickly and (more or less) painlessly. They also have graphing routines which may assist in visualizing concepts. In my opinion, most of the packages have a fairly steep learning curve – you can't do much that is useful "out of the box." The programs also have their respective advantages and disadvantages, *e.g.*, my opinion is that the interfaces to **Mathematica**[™] and **MathCAD**[™] are not very intuitive, which means that new users have to travel the learning curve. Conversely, experienced users are rewarded by quicker answers.

Two free programs are available for illustrating the concepts of linear systems. My old DOS program, "**Signals**" for 1-D functions runs in DOS and in Windows (at least) through XP. By using the "DOSBox" utility (an x86 emulator available from <http://www.dosbox.com/>), it can be run in new editions of Microsoft Windows and on Apple OS X. **Signals** was written with the intent of being easy to use (though you must decide for yourself whether it succeeds). It is available *gratis* and may be downloaded from the CIS website at:

<http://www.cis.rit.edu/resources/software/index.html>

A user manual also is available online at:

http://www.cis.rit.edu/resources/software/sig_manual/index.html

SignalShow

The new Java counterpart of **Signals**, called **SignalShow**, illustrates both 1-D and 2-D cases. The beta releases for the three primary computing platforms (Windows, Macintosh OSX, and Linux) are available online at <http://www.signalshow.com/>. This site includes links to help videos that are posted on YouTube. You may find this program very helpful in your quest to visualize the concepts in this course, as well as in 1051-718 "Digital Imaging Mathematics," and in 1051-733 "Optics for Imaging."