1.138J/2.062J/18.376J Wave Propagation.

Tue & Thu 9:30–11:00 in E25-117

Instructor. R. R. Rosales, 2-337, x3-2784, rrr@math.mit.edu. Off. hrs: TBA in web page.

TA. TBA. There may be none.

Relevant quotes and anecdotes.
Chinese proverbs: *He who asks a question is a fool for five minutes; he who does not remains a fool forever. The master leads you to the door, the rest is up to you.*
Ernest Rutherford's anecdote (1871-1937, famous New Zealand physicist). One student in his laboratory (in England) was extraordinarily hard-working. Having taken note of this, Rutherford asked him one evening, "Do you work in the mornings too?" The student (expecting commendation) proudly replied: "Yes!" Rutherford then looked puzzled, and asked in amazement: "But when do you think?"

Webpages. Two web pages: one public in the Math. site, and another in canvas [canvas: upload problem set answers, grading, announcements, piazza, recordings, etc.]. The **main page** is the public one, to which canvas is linked at various places. Please **check this webpage regularly.**
Main web page: https://math.mit.edu/classes/18.376/index.html
Important: *reload pages regularly, to make sure you are not looking at old cached versions.*

News Updates. ***Check the News Updates link in the math. web page frequently!*** Information concerning office hours, TA, etc., etc., will be posted there.
Announcements via the canvas page will also be sent.

Piazza. Please use piazza to send questions to the instructor or TA, so the answers are available to everyone. Use email only for private issues.

Video. The **lectures will be recorded,** and made available to the students through the canvas site (Panopto). This should not be an excuse to not attend the lectures; the recordings are made automatically and they are not professional level. They are offered as help, not substitute (and so you do not miss lectures if you have a problem, like being sick).
A few lectures may be virtual (via Zoom), either because it is better for the material covered, or because the lecturer is sick. They will also be recorded (then available through Zoom).

Course rules. Read the "policies" write-up in the course web-page.

Prerequisites. Basic theory of complex variables and a working knowledge of differential equations. Some familiarity with Fourier Transforms and Fourier series.

Textbook. The subject is based on the material presented in the lectures. There is no official textbook.

- Various course notes and related materiel are available through the course website. In particular, the comprehensive set of Lecture Notes prepared by Professor C. C. Mei [see OCW website]: https://ocw.mit.edu/courses/mechanical-engineering/2-062j-wave-propagation-spring-2017/lecture-notes/
- See the list of references below.

Exams. None. See **grading** below.

Problem sets. There will be 6 or 7 problems sets. Typically a new problem set will be handed every other week, and you will have at least a week to work on it. Answers will be posted after their due date.

Do them all, you need them to learn the material.
The uploaded (to canvas) **problem set answers must be typed via LaTeX, in pdf format** (a template will be provided in the web page). If your answers include pictures, please, be sensible; do not upload 20mb files to canvas (they slow down the canvas speed-grader massively).

Term paper. One. Should be **handed at least 10 days before the end of the lectures.** Start early. Can be on any topic relevant to the course (instructor pre-approval required). Does not have to be original research, but must be original work [e.g.: review the literature in some topic, and summarize the results in your own words, giving proper credit to the sources]. *The explanations must be clear, and accessible to an average student in this class.* You can use materiel from your own research, but **recycling** (e.g.: handing a piece of your thesis) **is not allowed.** Furthermore

- Must be typed (font size 11-14), and submitted electronically in **pdf format**.
- Length not exceed 15 pages. More if you have many figures, but use judgement here.

Failure to follow these guidelines may result in a paper being classified as "not acceptable".

Grading. Each problem set will contain a buried mini-quiz within it (1-3 problems). Only the quiz will be graded, but you need to do all the problems, since the quiz problems will not be identified. The course grade will be based on the cumulative quiz-grade, and a **binary-grade term paper:** If you hand in an acceptable term paper, then the grade is quiz-based, as explained before. Else the grade is F.

OUTLINE of the Course. Some topics may be covered in more/less detail than this suggests. Some topics may be skipped and others may be included. This is to give you an idea of the flavor of the course.

1. *Computers and numerical issues.* MatLab.
2. *Elementary concepts.* Exponential notation, frequency, wave number, phase, phase velocity, etc.
3. *Conservation laws and modeling in continuum physics.*
4. *Sample wave problems.* Taut string, elastic rod, shallow water waves, acoustic waves in a pipe, traffic flow, blood flow in arteries.
5. *One dimensional propagation.* Sinusoidal waves. Elastic strings. The wave equation: transient responses and characteristics. Dispersion: string in an elastic surrounding, rod on elastic foundation, flexural waves in a beam. Group velocity: dispersion of transient waves, method of stationary phase. Group velocity and energy transport. Scattering and radiation of harmonic waves, radiation conditions. Green's function.
6. *Two dimensional propagation in infinite space.* Plane waves, sound in homogeneous fluids. Nearly plane waves, geometrical optics/acoustics. Elastic solids: P and SV, SH waves. Rayleigh waves in a half space. Love waves in a layered medium. Reflection and refraction of sinusoidal sound from a plane interface. Reflection of a plane pulse. Mode conversion of elastic waves. Scattering of elastic waves, diffraction, parabolic approximation. Waves in an elastic layer. Radiation of waves from point sources, Green functions in 2-D and 3-D.

One, or more, of the topics below.

7. *Free-surface and internal gravity waves in fluids.* Surface waves linearized equations: dispersion relation, group velocity, phase velocity, scattering of sinusoidal waves by an obstacle. Transients due to impulsive forcing. Waves in a current, ship waves. Internal waves in a stratified fluid, dispersion relation, anisotropic wave propagation. Modes in a stratified fluid layer. Internal waves in a flow, Lee waves behind an obstacle.

8. *Waves in periodic media.* Bloch-Floquet theory. Stop bands, pass bands. Bragg resonance.

9. *Waves through laminated media.* Effective equation for thin and thick laminates.

10. *Nonlinear waves.* Traffic waves: shocks and traffic jams. Bores and hydraulic jumps: flood waves, bore from the breaking of a dam. Kinematic waves and characteristics. Conservation laws.

11. *Waves in a rotating fluid.* f and β plane approximations. Poincaré, Kelvin, and Rossby waves. The equatorial waveguide.

12. *Partially trapped waves* and leaky modes.

13. *Parametric resonances, Faraday waves, Floquet theory.*

Recommended/suggested books and textbooks.

1. Whitham, G. B. *Linear and nonlinear waves.* Wiley, 1999.
2. Lighthill, M. J. *Waves in fluids.* Cambridge U. P., 1978.
3. Courant and Friedrichs. *Supersonic Flows and Shock Waves.* Springer Verlag, 1977.
4. Drumheller, D. S. *Introduction to wave propagation in nonlinear fluids and solids.* Cambridge U. P., 1998.
5. Stoker, J. J. *Nonlinear vibrations in mechanical and electrical systems.* Wiley, 1992.
6. Stoker, J. J. *Water waves: The Mathematical Theory with Applications.* Wiley, 1992.

Other books (alphabetical)

7. Ablowitz M., and Segur. *Solitons and the Inverse Scattering Transform.* SIAM, 2000.
8. Achenbach, J. D. *Wave propagation in elastic solids.* North Holland, 1975.
9. Buckmaster, J. D. *The mathematics of combustion.* SIAM, Frontiers in Math. Series, 1985.
10. Buckmaster, J. D., and Ludford, G. S. S. *Theory of Laminar Flames.* Cambridge U. P., 1982.
11. Crawford, F. S. *Berkeley Physics Course, Vol. 3.* McGraw-Hill, 1968.
12. Cushman-Roisin, B. *Introduction to geophysical fluid dynamics.* Prentice Hall, 1994.
13. Drazin, P. G., and R. S. Johnson. *Solitons: An Introduction.* Cambridge U. Press, 1989.
14. Fickett, W., and Davis, W. C. *Detonation.* U. California Press, 1979.
15. Georgi, H. *The Physics of Waves.* Prentice-Hall, 1993.
16. Graff, K. S. *Wave motion in elastic solids.* Dover, 1975.
17. Hudson, J. A. *The excitation and propagation of elastic waves.* Cambridge U. P., 1980.
18. Kittel, C. *Introduction to Solid State Physics.* Wiley, 2004.
19. Kolsky, H. *Stress waves in solids.* Dover, 1963.
20. Leibovich, S. & Seebass, A. R., eds. *Nonlinear Waves.* Cornell U. P., 1974.
21. Lin, C. C., and Segal. *Mathematics applied to deterministic problems in the natural sciences.* SIAM, 1988.
22. Mei, C. C. *The Applied Dynamics of Ocean Surface Waves.* Wiley, 1983.
23. Miklowitz, J. *The theory of elastic waves and waveguides.* North Holland, 1978.
24. Tolstoy, I. *Wave Propagation.* McGraw-Hill, 1973.

PDE books

25. Carrier, G. F., and Pearson, C. E.. *Partial differential equations: theory and technique.* Academic Press, 1988, 2nd ed.
26. Debnath, L. *Nonlinear partial differential equations for scientists and engineers.* Birkhauser, 1997.
27. Kevorkian, J. *Partial differential equations: analytical solution techniques.* Springer, 2000, 2nd ed.