**42709**
Special Topics: Biofluid Mechanics
TF 05:00PM 06:20PM WEH 5316

Instructor: Kerem Pekkan

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| office: | Pittsburgh Technology Center (PTC) Building 4317 (see the new PTC shuttle hours: http://www.cmu.edu/police/escort.htm) |
| office phone: | 412-268-3027 |
| office hours: | Thursday 10:30am-12:00pm |


Text Used: Each module has its own reading material which is compiled from multiple sources (including one-two current selected journal paper per lecture). These will be assigned from the blackboard course website. (A bibliography of recommended books on biofluids is provided below students encouraged to read one of these books during the class)

Prerequisites: Familiarity with basic fluid mechanics and introductory matlab programming. (Students who have not taken any Fluid Dynamics class should contact me so that I can provide additional material for them to familiarize and speed them up early in the class.)

Objectives:
The purpose of this course is (1) to equip students with the fluid dynamics tools in order to design and perform research in physiological and biofluid mechanics. (2) Review and understand emerging biomimetic approaches, emphasizing the quantitative understanding and fundamental engineering concepts. Computational and experimental techniques (CFD, flow visualization, PIV, LDV, POD, confocal microscopy) will be studied with hands on research projects based on student's interest.

Upon completing this course, the students should:

- understand the governing physics of fluid mechanics as applied to the biological problems
- be familiar with the current state of the art computational modeling tools (CFD) and experimental methodologies (PIV). Students should be competently applying one of these techniques to their course project.
- learn to conduct biofluids research on an interesting problem and apply engineering fundamentals to contribute its solution
- learn the fundamentals of interdisciplinary (biology/engineer) work (collaboration/research)

A biomechanical engineering perspective will be followed throughout the course; more applications from general Bio-Fluid Mechanics topics but Cardiovascular Fluid Dynamics will be also reviewed.

Laboratory: Laboratory work can be either experimental, field-work or computational. Experimental demonstrations will be conducted at the instructor's lab at the PTC (3rd floor 3210-3212-3215).

Fall 2008: (always tentative, topics can be changed based on student interest)

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| August 26: | Introduction (challenges, applications) |
| August 29: | Principles of biomimetic fluid dynamics |
| September 2: | Kinematics of fluid flow and flow topology (flow visualization) |
| September 5: | Governing equations and review of fundamental fluid dynamics (Suggested projects by Instructor) |
| September 9: | Unsteady Flow – 1 |
| September 12: | Unsteady Flow – 2 (Deadline for student initiated project proposals) |
| September 16: | Computational Fluid Dynamics – 1 (grid generation) |
| September 19: | Computational Fluid Dynamics – 2 (solvers) |
| September 23: | Computational Fluid Dynamics – 3 (verification and validation) |
| September 26: | Non-dimensional numbers in Biofluids. Flow-dependency principle, Energetics |
| September 30: | Ideas on biological optimization, Growth and remodeling, allometry, Principles of comparative biomechanics |
| October 3: | Vortex Dynamics in Nature (Vortex Methods, Matlab code) – 1 |
| October 7: | Vortex Dynamics in Nature (Vortex Methods, Matlab code) – 2 |
| October 10: | Creeping Flow and micro-biological fluid dynamics. Bioreactors |
| October 14: | Project status review meeting (Conceptual Test - 1) |
| October 17: | **Mid Semester Break** |
| October 21: | Cardiovascular fluid dynamics – 1 (LV Filling – 1) |
| October 24: | Cardiovascular fluid dynamics – 2 (venous flows) |
| October 28: | **Invited Guest Lecture:** TBD |
| October 31: | **Invited Guest Lecture:** TBD |
| November 4: | Experimental techniques, Particle Image Velocimetry |
| November 7: | micro PIV, Confocal and two-photon microscopic velocimetry. Analysis of flow field data |
| November 11: | Valves in Nature |
| November 14: | Topics in Flow Control |
| November 18: | Review Optimization Techniques |
| November 21: | Cardiovascular fluid dynamics – 3 (diseases) |
| November 25: | Aquatic propulsion and definitions of efficiency (Steady unsteady modes) Accompanied by a Field visit to the Pittsburgh Aquarium |
| November 28: | **Thanksgiving Day** |

December 2: Introduction to constructal theory
December 5: Schools and analysis of collective motion of organisms

December 12: Take home final no class (Conceptual Test - 2)
December 18: **Final Grades Due**

Grading:

There will be two short exams with conceptual questions in take home-format (Mid-semester and Final) (20%)

Class participation (20%)

Instructive small scale projects in Matlab (n=1 or 2) (20%)

A short presentation and critique of a paper selected from literature (15 min by two lead people + 20 min interactive class discussion and critical evaluation) 2 x per semester per student (20%)

Larger scale project (Either CFD or Experimental) (There will be suggested project topics, but students are welcome to propose their own projects related to their research, a formal 2-page short proposal needed from each student, Background, Specific Aim, Research Design, Expected Results, Obstacles ) (20%) Funds are available for these projects but needs to be professionally justified and planed by the student.

Peer-reviewed journals of interest:

Journal of Fluid Mechanics, Experimental Biology, Journal of Biomechanics, Annals of Biomedical Engineering, ASME Journal of Biomechanical Engineering, IEEE Transactions, Bioinspiration & Biomimetics, Journal of Biomimetics

Annual conferences: (CD's available for check-out from Kerem Pekkan's office)

American Physical Society Division of Fluid Dynamics (DFD) Meeting
ASME Summer Bioengineering Meeting
Biomedical Engineering Society (BMES) Meeting
European Society of Bioengineering (ESB) Meeting

Recommended Text-books:

1. Biomechanics: Circulation, Y. C. Fung, Springer, 1996
2. Biofluid Mechanics: The Human Circulation, K B. Chandran, A P. Yoganathan, CRC Press, 2006
3. Mathematical Biofluiddynamics, James Lighthill, SIAM, 1987
4. Aerodynamics of Low Reynolds Number Flyers. W Shyy, Y Lian, Cambridge University Press, 2007
5. Biofluid Dynamics: Principles and Selected Applications, C. Kleinstreuer, CRC Press, 2006

Note: If you wish to request an accommodation due to a documented disability, please inform Dr. Kerem Pekkan and contact: Disability Resources, 102 Whitfield Hall 412.268.2013, lpowell@andrew.cmu.edu, as soon as possible. For ongoing documented classroom accommodations one week's notice is required. Accommodations for finals require three weeks notice.