DEPARTMENT OF PHYSICS AND ASTRONOMY
TRENT UNIVERSITY

PHYS-BIOL1060H: Physics for the Life Sciences
2020 WI
Peterborough

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Course Description:
This course is geared towards students who will continue studies in the life sciences, and any students interested in learning about the physical origins of biological processes, laboratory techniques, and everyday phenomena. Topics covered include physical properties of biomaterials such as elasticity and compressibility; physical limits on sizes and speeds in living systems; fluids: viscosity, surface tension, and how these affect the mobility of organisms; diffusion, thermal motion of molecules, sedimentation, heat flow, and energy.

Course Pre-requisites: None. 4U Mathematics is strongly recommended; 3U/4U physics a bonus.

Course Fees: $5 for printed course notes. These will be available for pickup in the first 3 lectures. Electronic copies will be freely available on blackboard.

Required Texts:

There is no required text. Weekly readings will be assigned from the course notes as well as occasional supplemental textbook passages uploaded to blackboard.

- Online class notes, available through Blackboard. These notes will represent the primary source for course materials and class organization.

Further reading: Williams *et al.*, “Physics for the Biological Sciences”, 5th edition, Nelson, 2011. This textbook was the course textbook for the past few years. It is a simple and clear textbook, recommended as a secondary text.

<u>Course Format</u>:

Type	Day	Time	Location
Lecture	WED	08:00-09:50	W101.2 (Wenjack)
Lecture	FRI	16:00-17:50	W101.2 (Wenjack)
Tutorial (note various rooms!)	W01: THU	15:00-15:50	GCS106
	W02: TUE	18:00-18:50	GCS103
	W03: MON	09:00-09:50	GCS108
	W04: THU	18:00-18:50	GCS103
	W05: MON	11:00-11:50	GCS106
	W06: TUE	19:00-19:50	GCS103
	W07: MON	10:00-10:50	GCS106

The hourlong tutorial/lab sessions will involve a mixture of TA-led problem solving sessions, bi-weekly quizzes, and class discussions.

<u>Learning Outcomes/Objectives/Goals/Expectations</u>: See end of document

<u>Course Evaluation</u>:

Problem Sets (WebWork)	10%	(~bi-Weekly)
Quizzes on problem sets:	20%	(~bi-weekly; in tutorial sessions, 5 in total)
Clicker participation:	10%	(~every class)
Tutorial attendance	5%	(gauged at end of term, based on entire term)
Pre-Lecture JIT quizzes:	5%	(before every class, administered on Blackboard)
Midterm Test:	15%	(week 8; Friday, March 6, 2020 in class)
Final Exam:	35%	(exam period; April 9-22, 2020)

By the class drop-date of March 6, 2016, it is expected that you will know approximately 25% of your final grade.

<u>Minimum exam achievement policy</u>: A cumulative average of at least 35% must be obtained on the midterm and final exam (weighted as above), otherwise a grade of no more than 45% (F) will be assigned irrespective of your earned course average

<u>Problem Sets</u>: There are five problem-sets to be completed throughout the term. Instructions for accessing the problem sets will be posted on Blackboard at least two weeks prior to when they are due. The problem sets consist of a variety of questions ranging from conceptual in nature to in-depth computational problems. These questions are designed to deepen your understanding of the concepts covered in class. The problem set questions will form the basis for the tutorial quizzes.

<u>Pre-lecture 'just in time' quizzes</u>: Prior to each lecture, you will need to complete a JIT quiz online through the Blackboard Learning System. The quiz will consist of 3–4 simple questions based directly on the required readings for that week. Your lowest 2 JIT quiz scores will be dropped. The last question on each quiz gives all students a free-form opportunity to flag difficult concepts or other material that they are struggling with. The following lecture will then be customized toward addressing the most common issues raised in the JIT quiz.

Missed Quizzes: Five bi-weekly quizzes are schedule during the term, and every student is expected to complete the quiz in the tutorial session (lab session) they have registered in. These 40-minute quizzes comprise two or three reworked questions from the prior problem set. Students may not, without prior authorization, write a quiz at an alternate time. At the end of the term, the best 4 scores among the 5 quizzes will be averaged and will stand for the quiz grade. This is to allow for one missed quiz for personal reasons. Regardless, a missed quiz—without prior authorization—will result in a quiz score of zero.

Clicker/PRD participation: It is anticipated that clickers (or other personal response device, PRD) will be used in lectures to “poll” the class on collective understanding and intuition. We will then use the results of such polls to guide subsequent in-class discussion. You are expected to participate in class with PRD voting. You receive full marks for any class in which you voted in at least 50% of the questions. Otherwise you receive zero. Your four lowest marks will be dropped before the final grade is calculated, to allow for weak batteries, equipment malfunction, etc. You may ONLY use your own PRD. As PRD records are used in this course to compute a portion of course grades, the **use of a personal response device other than your own is an academic offence**. In lecture or tutorial, possession of more than one PRD, or that of another student, WILL be interpreted as intent to commit an academic offence.

Tutorial Attendance: Tutorial sessions are listed as "labs" on the course schedule. These 50-minute sessions will be used to give a problem-set quiz and a mini-lecture in alternating weeks. Attendance is mandatory. If you cannot attend a tutorial session, you are expected to notify your tutorial leader as soon as possible. To allow for illness or unforeseen circumstances, two unexplained absences will be allowed without penalty.

Week-by-week schedule:

“PS” = Problem set

Week	Date (Mon–Fri)	Wednesday Class (08:00–09:50)	Tutorials	Friday Class (16:00–17:50)
1	Jan. 06–10	Course intro + Dimensional Analysis	None on first week	Dimensional Anal. Scaling and Proportionality
2	Jan. 13–17	Mechanics: Basic need-to-know for course	**-Math diagnostic Test in Tutorial-**	Gravity and Weight
3	Jan. 20–24	Bioengineering, elasticity	Mini-lecture and worked example	Biomaterial Engineering and elastic energy
4	Jan. 27–31	Geometric Scaling and allometry (Scaling I)	**Quiz on PS1**	Pressure: Basics and hydrostatic pressure
5	Feb. 03–07	Buoyancy	Mini-lecture and worked example	Surface tension
6	Feb. 10–14	Surface Tension & Capillairty	**Quiz on PS2**	Surface-tension and buoyancy: Interface life
Feb. 17–21 Reading Week—No classes				
7	Feb. 24 – 28	Viscosity and Hydrodynamics	Mini-lecture and worked example	Hydrodynamics and viscosity
8	Mar. 2 – Mar. 6	Life at low Reynolds #	**Quiz on PS3**	**Mid-term test**
9	Mar. 9–13	Kinetic theory and Temperature	Mini-lecture and worked example	Laws of diffusion
10	Mar. 16–20	Centrifugation & Biol. aspects of diffusion	**Quiz on PS4**	Barometric formula and sedimentation

11	Mar. 23–27	Heat and heat capacity	Mini-lecture and worked example	Thermal expansion, heat flow, insulation
12	Mar. 30. – Apr. 3	Heat Transfer Mechanisms & radiative heating	**Quiz on PS5**	Biothermal regulation
PHYS-BIOL 1060H Final Exam				

University Policies

Academic Integrity:

Academic dishonesty, which includes plagiarism and cheating, is an extremely serious academic offence and carries penalties varying from failure on an assignment to expulsion from the University. Definitions, penalties, and procedures for dealing with plagiarism and cheating are set out in Trent University's *Academic Integrity Policy*. You have a responsibility to educate yourself – unfamiliarity with the policy is not an excuse. You are strongly encouraged to visit Trent's Academic Integrity website to learn more: www.trentu.ca/academicintegrity.

Access to Instruction:

It is Trent University's intent to create an inclusive learning environment. If a student has a disability and documentation from a regulated health care practitioner and feels that he/she may need accommodations to succeed in a course, the student should contact the Student Accessibility Services Office (SAS) at the respective campus as soon as possible, (Peterborough, Blackburn Hall, Suite 132, 705-748-1281 or email sas@trentu.ca
For Trent University – Durham, Thornton Road, Room 111 contact 905-435-5102 ext. 5024 or email corinnphillips@trentu.ca Complete text can be found under Access to Instruction in the Academic Calendar.

STUDENT LEARNING GOALS

Very general course-wide objectives:

[You won't be directly tested on this, but these leaning objectives will represent a large part of how you will have to approach any exercise, concept, or problem in this course]

By the completion of the course, successful students should be able to…

1. Identify a wide array of theoretical and experimental consideration framed in a biological setting that strongly lie within the discipline of physics.
2. Identify the most relevant physics principles underlying a broad range of biological and biomedical phenomena.
3. Use simple heuristics (rough mental tricks) such as orders-of-magnitude, ratios, arithmetical estimates, dimensional analysis, and simplifications for rapid problem solving in biophysics and beyond.
4. Gauge the sensibility of generated answers based on renewed physical intuition, everyday experience, and common-sense.
5. Both view and work with physics/biophysics formulae as formal relationships between physical parameters and phenomena, rather than just as a proscriptive quantitative recipe for "solving" a given parameter.
6. Distinguish physical phenomena from similarly-named colloquial ideas; define, explain, and use the physics meaning of words that are common in everyday language, but which may mean something grossly (or subtly) different than it does scientifically.

Specific (testable) learning goals by topic:

By the completion of the course, successful students should be able to…

—Biomaterial Engineering—

1. Define (and if relevant, contrast) the scientific terms *stress*, *strain*, *elastic-regime*, *plastic-regime*, *Shear Modulus, Young's Modulus*, *tensile stress*, *shear stress*, *maximum* (or breaking) *stress* and *strain*.
2. Calculate Shear Modulus or Young's Modulus from stress and/or strain information in biomaterials; Compare strength of different biomaterials from their stress-strain behavior.
3. Calculate the tensile/compressive stress created by a mass under gravitational pull; i.e. use the concept of *weight* as a force that can create a *stress* in biomaterials.
4. Analyse a stress-strain curve in terms of: Maximum stress/strain, Young's Modulus, compressive strain, tensile strain, elastic and/or plastic range (regime), and energy stored in the strained biomaterial.
5. Relate stress and strain to stored elastic energy. Relate the quadratic relationship between stored elastic energy and level of stress/strain.

6. Work with a provided formula relating the stress (whether tensile, torsional, or otherwise) in a material system to other biomaterial engineering parameters to assess the strain behavior of said material system.

—Scaling and Size Effects—

7. Describe the relationship between the surface area, volume, and mass of an object that scales according to the "2/3 law" (or "allomerically")
8. Work with exponents in power-law relationships (such as the "2/3 law" or "1/4 law") to describe scaling relationships in a chain of parameters related by such laws.
9. Calculate relevant scaling laws by making basic approximations and assumptions about the geometry of scaling systems.
10. Discuss some physical limitations to the growth of various biological systems from a scalability point of view; Estimate which physical parameter places the most stringent upper bound on growth in various biophysical systems.

—Fluid Statics—

11. Demonstrate a working definition for the concepts of pressure: absolute pressure, gauge pressure; hydrostatic pressure; atmospheric pressure.
12. Describe the relationship between pressure and force.
13. Describe hydrostatic pressure in terms of depth in a fluid.
14. Describe changes in hydrostatic pressure in the circulatory system of various animals.
15. Demonstrate a working definition of density.
16. Demonstrate an understanding of Buoyancy.
17. Determine whether an object is net buoyant; compute and explain a submerged object's "apparent weight".
18. Calculate the buoyant force on an object given its density and the density of the surrounding fluid.
19. Work with various units of pressure such as atmospheres, mm Hg, psi, Pa, Bars, etc, given some conversion tables.
20. Describe "suction" forces in terms of pressure inside and outside key volumes; compute the maximum limit on suction forces in some simple geometries.
21. Demonstrate an understanding of surface tension both in terms of surface energy and in terms of forces on a line of action.
22. Describe the relationship between surface tension, pressure, and diameter of bubbles; and relate these ideas to the workings of lungs.

23. Calculate pressure differences between large and small bubbles, given surface tension and radius information.
24. Describe the concept of “wetting” and “wet-ability” or lack thereof.
25. Demonstrate an understanding of how capillary action works and calculate various physical parameters such as liquid column height in a tube with particular dimensions and material properties.
26. Describe what is meant by and what determines the “contact-angle” of a liquid/solid/gas interface.
27. Explain how some water-walkers and other interface-dwelling creatures exploit buoyancy, capillarity, surface tension, and wettability for locomotion.

—Fluid Dynamics—

28. Describe continuity of flow as a relationship between volume flow rate and cross-sectional area.
29. Describe continuity of flow as a mass-conservation concept.
30. Use fluid-flow continuity relations qualitatively and in conjunction with other fluid-flow principles such as Bernoulli’s law or Poiseuille’s law.
31. Describe the relationship between (ideal) fluid speed and local pressure (i.e. Bernoulli’s Law).
32. Estimate and Rank pressure at various points along an irregular pipe or other fluid-flow system.
33. Describe the effects of viscosity on the velocity profile of a fluid in a pipe or other fluid-flow system.
34. Qualitatively describe the relationship between viscosity, pressure, tube length, and tube diameter in a fluid-flow system; i.e. Poiseuille’s Law.
35. Quantitatively use Poiseuille’s Law to calculate fluid flow parameters.
36. Differentiate and describe Laminar, Bolus, and Turbulent flow.
37. Relate Reynold’s number to expected transition between laminar and turbulent flow.
38. Qualitatively describe some straightforward ramifications of turbulent flow on downstream pressure and velocity profile.
39. Qualitatively contrast locomotion for life living low Reynold’s number conditions from that of life living at high Reynold’s number. Identify which regime various organisms live under.
40. Qualitatively describe the effects of drag (Stoke’s Law) on a particle’s motion in the case of high and low Reynold’s numbers.

—Kinetic Theory of Gasses, Diffusion, Sedimentation—

41. Qualitatively describe sedimentation and link this phenomena to drag forces
42. Quantitatively calculate terminal speeds for sedimenting and centrifuging particles.
43. Link conceptually the Barometric Formula to the concept of sedimentation.
44. Link conceptually the average kinetic energy of particles with thermal energy $k_B T$.
45. Distinguish root-mean-square position and average position.
46. Describe biological applications/ramifications of diffusion.
47. Quantitatively describe the root-mean-square displacement in diffusion as a function of diffusion constant and time (in various dimensions)
48. Use Fick's laws to make qualitative predictions of diffusion rates and mass transport directions.

—Heat and Thermal Regulation—

49. Contrast between the concepts of "heat flow" and "temperature". Also describe the relationship between "heat flow" and "temperature"
50. Define the term "heat capacity" and use this concept in qualitative and quantitative descriptions of simple materials.
51. Define the concept of "latent heat" and describe how it is related to thermal energy and changes of phase.
52. Quantitatively use equations for thermal conductivity to describe heat flow across some area.
53. Use an expression for Newton's Law of Cooling for quantitative calculations of cooling rates.
54. Quantitatively use equations for thermal expansion in 1D, 2D, and 3D.
55. Qualitatively describe the process of thermal expansion and some physical ramifications of this phenomena.
56. Describe three mechanisms of heat flow: conduction, radiation, and convection.
57. Describe the relative importance of three mechanisms of heat flow (conduction, radiation, convection) in some key biological systems.
58. Qualitatively describe the relationship between the peak emission wavelength and temperature in a blackbody (Wien's law). Use this relationship quantitatively when provided.
59. Relate the intensity of emitted light and temperature of a "blackbody".