TRENT UNIVERSITY

DEPARTMENT OF PHYSICS AND ASTRONOMY
TRENT UNIVERSITY

PHYS-BIOL1060H: Physics for the Life Sciences
2015-16 WI
Peterborough

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Course Description:
This course is required for Biochemistry, Kinesiology, and Biology students. It is particularly geared towards students who will continue studies in the life sciences, and any students interested in learning about the physical origins of biological processes and laboratory techniques. 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; light, photons, and absorption/emission.

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

Course Fees: $5 for printed supplemental course notes. These will be available for pickup in the first 2 lectures. Electronic copies will be freely available on blackboard.

Required Texts:

There are two required reading sources for this course. Students are expected to read from both sources BEFORE EVERY LECTURE.

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

- Williams *et al.*, "Physics for the Biological Sciences", 5^{th} edition, Nelson, 2011. This required text will be used for broader subject readings, and a source for conceptual questions and problem set questions.

learningSystem/Blackboard: We will extensively use the online course management system (blackboard) for this course. For class notes, additional texts, and class resources: https://learn.trentu.ca/.

Course Format:

Type	Day	Time	Location
Lecture	MON	12:00-12:50	SC137
Lecture	THUR	10:00-11:50	SC137
Tutorial	W01: TUE	9:00-10:50	GCS106
	W02: TUE	11:00-12:50	GCS106
	W03: WED	14:00-15:50	GCS106
	W04: FRI	12:00-13:50	GCS106
	W05: FRI	10:00-11:50	GCS106

The two-hour tutorial/lab sessions will involve a mixture of problem solving sessions, quizzes, and class discussions.

Learning Outcomes/Objectives/Goals/Expectations: See end of document

Course Evaluation:

Quizzes on problem sets:	25%	(~bi-weekly; in tutorial sessions, 5 in total)
Clicker participation:	5%	(~every class)
Team participation	5%	(gauged at end of term, based on entire term)
Pre-Lecture JIT quizzes:	5%	(before every class, administered on Blackboard)
Term-Test:	20%	(week 7; Thursday, February 25, 2016)
Final Exam:	40%	(exam period; April 9-22, 2012)

By the class drop-date of March 3, 2016, it is expected that you will know approximately 30% of your final grade. This includes the results of a mid-term exam and 2 quizzes.

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. They 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.

Team participation: It is anticipated that the class will be divided into teams of 3-5 students. These teams will sit and work together in lectures, and will be expected to work together on the problem sets outside of class. At the end of the term, each student will submit a subjective "score" for each of their teammates. These scores will be tallied to give a mean participation score, as will be described in more detail during the term.

Clicker participation: It is anticipated that clickers will be used in lectures to "poll" the class on their collective understanding and intuition. We will then use the results of such polls to guide subsequent discussion. You are expected to participate in class with clicker 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. ONLY use your own clicker. As clicker records are used in this course to compute a portion of course grades, the **use of a clicker other than your own is an academic offence**. In lecture or tutorial, possession of more than one clicker, or that of another student, may be interpreted as intent to commit an academic offence.

Week-by-week schedule:

Week	Date (Mon–Fri)	Monday Class (12:00–12:50)	2-hour Tutorials	Thursday Class (10:00–11:50)
1	Jan. 04–08		None on first week	* Course introduction * Mechanics primer
1-2	Jan. 11–15	Gravity and weight	**-Math diagnostic Test in Tutorial-** working on PS1	***Team designations** *biomat. eng.: elasticity.
2-3	Jan. 18–22	Biomaterial engineering: elasticity, storage energy	working on PS1	Geometric scaling and allometry (scaling-I)
3-4	Jan. 25–29	Fluids: pressure, buoyancy	**Quiz on PS1**; working on PS2	Fluids: pressure, buoyancy
4-5	Feb. 01–05	Fluids: surface tension	working on PS2	Fluids: surface tension and capillarity: Interface life
5-6	Feb. 08–12	Fluids: hydrodynamics and viscosity #1	**Quiz on PS2**, working on PS3	Fluids: hydrodynamics and viscosity #2
Feb. 15–19 Reading Week				
6-7	Feb. 22 – 26	Life at low Reynolds number (scaling II)	working on PS3	**Mid-term test**
7-8	Feb. 29 – Mar. 4	Kinetic theory of gasses	**Quiz on PS3**, working on PS4	Laws of diffusion.
8-9	Mar. 7–11	Sedimentation and centrifugation	working on PS4	Biological applications in diffusion
9-10	Mar. 14–18	Heat and thermal energy	**Quiz on PS4**, working on PS5	Heat flow: conduction, convection, radiation.
10-11	Mar. 21–25	Temperature and thermo-regulation in biological systems	working on PS5	Light: waves and discrete nature of photons
11-12	Mar. 28. – Apr. 1	absorption and emission of photons	**Quiz on PS5, exam prep**	Quantized nature of vision
12	Apr. 4 –8	Review and debrief		
PHYS-BIOL 1060H Final Exam				

"PS" = Problem set

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".

—Light, Photons, Absorption and Emission—

60. Describe the photoelectric effect and its key interpretations.
61. Describe how the photoelectric effect experiment violates classical-physics concepts.
62. Use energy level diagrams to find the expected energy of emitted and/or absorbed photons.
63. Relate the energy of absorption to that of emission in a given fluorescing molecule.

64. Inter-convert photon energy and wavelength.
65. Use Beer's law (and the notion of an absorption coefficient) to estimate a sample's "absorbance" and "transmittance"
66. Qualitatively demonstrate the ramifications of the nonlinear relationship between path length and absorption inherent in beer's law.
67. Describe the gross physiology of the eye, including the retina, cornea, iris, crystal lens, fovea, optic nerve, blind spot, and pupil.
68. Describe how the discrete nature of photons and how they interact with rhodopsin is key to how the eye "sees".
69. Describe the role of cone cells for colour vision
70. Describe the role of rod cells for low-light-level vision
71. Describe how the retina can be "photobleached". Use the photobleaching equation to estimate photobleaching time constants or recovery percent.