PHYS 1420 (F19)
Physics with Applications to Life Sciences

2019.09.04

Relevant reading:
Kesten & Tauck ch. 1.1-1.6 + Polya
Question
How might we “see” brain? How it “functions”?
Question
How do we make a 3-D image of really small things (e.g., molecular structure)?

Franklin & Gosling (1953)

→ How did Watson and Crick actually figure out a “double helix” for DNA?

Watson & Crick (1953)
Caveat
Even “simple” questions can be hard... e.g., How many mountain peaks are there in this image?
e.g., How many mountain peaks are there in this image?
Etymology

- What does “physics” even mean?

(from wikipedia)

“The **Physics** (from Ancient Greek: φυσική (ἐπιστήμη) *phusikē* (epistémē) ‘knowledge of nature’, from φύσις *phúsis* "nature")

... is the natural science that involves the study of matter and its motion and behavior through space and time, along with related concepts such as energy and force. One of the most fundamental scientific disciplines, the main goal of physics is to understand how the universe behaves.”

(from Merriam-Webster)

“A science that deals with matter and energy and their interactions”

(Kahn Academy)

“To be honest, it’s really difficult to define exactly what physics is. For one, physics keeps changing as we progress and make new discoveries.”

(our working PHYS 1420 definition) → Problem solving
PHYS 1420 Logistics

York University
PHYS 1420: Physics with Applications to Life Sciences
(6 credits; two-semester course)
Fall 2019 Syllabus

Time & Location
Lecture: MWF 12:30-1:30 (ACE 102)
Tutorial: T 1:30-2:30 (ACE 102)
Labs: Scheduled individually via course registration

Instructor: Christopher Bergevin
Email: cberge [at] yorku.ca
Office: Petrie 240
Office Hours: T 2:30(ish)-4:00 and/or by appointment (email to set up)

TAs/Graders:
- TBD (TBD@yorku.ca)

Graders:
- TBD (TBD@yorku.ca)

Course Website – http://www.yorku.ca/cberge/1420F2019.html

Prerequisites: A survey of physics in which many fundamental concepts are emphasized through applications to the life sciences. Topics include kinematics, dynamics, momentum and energy for linear and rotational motion; elementary kinetic theory and thermodynamics; static and current electricity; waves and physical and geometrical optics; elements of modern physics. This is a calculus-based course recommended for students unlikely to take 2000-level Physics courses. Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 4.00; MHF4U Advanced Functions and MCV4U Calculus and Vectors, or 12U Advanced Functions and Introductory Calculus, or OAC Algebra and OAC Calculus, or SC/MATH 1505 6.00, or SC/MATH 1520 3.00. Course Credit Exclusions: SC/PHYS 1010 6.00; SC/PHYS 1410 6.00; SC/PHYS 1800 3.00 and SC/PHYS 1801 3.00; SC/ISCI 1310 6.0.

Two-semester Sequence: Note that PHYS 1420 is a two-semester course. C. Bergevin will be teaching the Fall 2019 (F19) term, while Prof. Cody Storry will be teaching the Winter 2020 term. This syllabus applies to the full term. For F19, we are aiming to cover chapters 1–9 & 11–13 of the text. Not all material in these chapters will be covered, and there will be material covered in class not explicitly covered from the textbook.

Learning Objectives: By the end of the course (F19), students should be able to

- Understand the foundations of the areas of physics with application in life sciences. More specifically, topics include: kinematics (1-D and 2-D); momentum; work and energy for linear and rotational motion; fluid statics and dynamics; diffusion; oscillations; waves.
PHYS 1420 Logistics

Physics with Applications to Life Sciences
(PHYS 1420)

York University
Fall 2019 - Course Website

Basic Information

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- **Location & Time:** MWF 12:30-1:30 (ACE 102) **AND** Tutorial T 1:30-2:30 (ACE 102)

- **Course Syllabus** (includes course logistics): [here](https://www.yorku.ca/cberge/1420F2019.html) (pdf; tentative draft prior to 2019.09.04)

- **Instructor:** Christopher Bergevin
  - Office: Petrie 240
  - **Email:** cberge [AT] yorku.ca
  - **Office Hours:** T 2:30ish-4:00 and/or by appointment
  - **Phone:** 416-736-2100 ext.33730

- **TAs:** See syllabus

- **Text**: *University Physics for the Physical and Life Sciences vols. 1 & 2* by Kesten PR and Tauck DL (W H Freeman & Co, 2012). You will also need a copy of the lab manual, available only from the university bookstore. Lastly, you will need the Sapling Online Homework license, which comes packaged w/ the hard copy of the course text as sold by the bookstore. You will not need a "clicker" for F19.

Updates and useful bits

Important Dates (2019)

First Day of Class .................................................. Sept. 4
Add Deadline ................................................................. Sept. 17
Fall Reading Week ......................................................... Oct. 14–18 (no classes)
*Midterm Exam* ............................................................... Oct. 21
Drop Deadline ................................................................. Nov. 8
Last Day of Class ............................................................. Dec. 2
*Final Exam* ................................................................. TBD
1. Learn the basics of 1st year physics and some applications to the life sciences

→ "Physics" is generally equated w/ a branch of critical inquiry trying to track down the "universal rules" that govern how the universe works

2. Develop/refine "quantitative problem solving" skills

→ Ultimately an issue of "attitude" such that you feel comfortable tacking the unknown (as these sorts of skills are invaluable and will open doors for you downstream). by and large, this involves refining/developing your mathematical-based reasoning skills
Areas such as biophysics are two-way streets in that such can be simultaneously viewed as both "physics-applied-to-biology" and "biology-motivating/informing-physics". So physics & biology can be seen as naturally going together hand-in-hand.

By and large, we follow a well-established curricular path, covering: Newtonian mechanics, concept of energy, circular motion, oscillations, etc....

... BUT also weave in some novel directions (e.g., diffusion)

A handful of associated mathematical topics naturally fall out of this (to varying degrees of depth): vectors, calculus (i.e., how things "change"), polar coordinates, geometry, sinusoids, etc....
PHYS 1420 Logistics

- Course website:  http://www.yorku.ca/cberge/PHYS1420F19.html

- Read the book & come to class (get a scratch pad and notebook)

- Do the HW (both written & online) → purpose is to practice problem-solving & develop confidence!

- Come to tutorials and engage w/ one another

- All the above will help you get properly prepared for the tests

→ Let’s take a step back for a moment and look at some of the broader “themes” that we aim to (interdisciplinarily) weave into the course.....
**Etymology**

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... is the natural science that involves the study of matter and its motion and behavior through space and time, along with related concepts such as energy and force. One of the most fundamental scientific disciplines, the main goal of physics is to understand how the universe behaves.”

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“To be honest, it’s really difficult to define exactly what physics is. For one, physics keeps changing as we progress and make new discoveries.”

(our working PHYS 1420 definition) ➔ **Problem solving**
Determine the “rule” that is different between the two sides (each of six)

e.g., http://www.foundalis.com/res/bps/bpidx.htm
“Puzzles” – Bongard problems
“Puzzles” – Bongard problems
How To Solve It

A New Aspect of Mathematical Method

G. POLYA
Stanford University

A man lives on the tenth floor of a building. Every day he takes the elevator to go down to the ground floor to go to work or to go shopping. When he returns he takes the elevator to the seventh floor and walks up the stairs to reach his apartment on the tenth floor. Why does he do this?

e.g., “classical mechanics”

von Baeyer
Theme: What is Life?

One response to the question, What is Life? is simply, Look Around!

-Frank M. Harold

→ Quick tangent into hurricanes, uncertainty, and “fake news”...
The National Hurricane Center publishes graphics like this one so the public can plan ahead for tropical storms and hurricanes. However, many people who see these maps read them wrong.

Studies show that some people misinterpret the map as indicating the hurricane getting bigger over time. Others think it shows areas under threat. Research by Hurakan, a University of Miami team I’m a part of, suggests 40 percent of people wouldn’t feel threatened if they lived just outside of the cone.
How to interpret the National Hurricane Center's map, then? The cone actually represents a range of possible positions and paths for the storm's center.
To create the cone, the N.H.C. surrounds each estimated position of the storm center with circles of increasing size. These circles represent uncertainty.
Finally, a curve connects the circles. The result is what is popularly known as the “cone of uncertainty.”

Aside: Fake news?

Aug. 29, 2019

https://www.clickorlando.com/weather/hurricane/updates-track-computer-models-satellite-for-hurricane-dorian
Aside: Fake news?

Aug. 29, 2019

https://www.clickorlando.com/weather/hurricane/updates-track-computer-models-satellite-for-hurricane-dorian

See also:

→ Weather modeling & prediction is highly challenging!

Sept. 1, 2019

Life (like weather) is stochastic

The National Hurricane Center says cones will contain the path of the storm center only 60 to 70 percent of the time. In other words, one out of three times we experience a storm like this, its center will be outside the boundaries of the cone.

Female hurricanes are deadlier than male hurricanes

Do people judge hurricane risks in the context of gender-based expectations? We use more than six decades of death rates from US hurricanes to show that feminine-named hurricanes cause significantly more deaths than do masculine-named hurricanes. Laboratory experiments indicate that this is because hurricane names lead to gender-based expectations about severity and this, in turn, guides respondents’ preparedness to take protective action. This finding indicates an unfortunate and unintended consequence of the gendered naming of hurricanes, with important implications for policymakers, media practitioners, and the general public concerning hurricane communication and preparedness.

gender stereotypes | implicit bias | risk perception | natural hazard communication | bounded rationality

Note: [https://en.wikipedia.org/wiki/Dorian_(name)]

Dorian is a unisex given name of Greek origin. In Greek, the meaning of the name Dorian is of Doris, a district of Greece; or of Doros, a legendary Greek hero. Doros was the son of Helen of Sparta (who was the daughter of Zeus and Leda). Doros was the founder of the Dorian tribe, and the most likely origin of Doros' name was the Greek word "doron", meaning 'gift'.
Islands of venomous fire ant colonies spotted floating in rising floodwaters in Houston

→ How do they “know” (how) to do this?!

Theme: Notion of “information” (plus the idea of emergence from complex systems)

Theme: Bridging “micro” and “macro”-scopic scales
How many neurons are there in the human brain? Synapses?

Human brain contains \( \sim 10^{11} \) (100 billion) neurons!
(with 100 trillion+ connections in between)
Aside: Neurons

Neurons ("fibers")
= Information highway

Key Point: Electrical properties of cells are important

Figure 1.22

Weiss (1996)
Aside: Cell membranes

- Membrane primarily consists of a “lipid bilayer” (to separate inside from outside)

- All sorts of “stuff” embedded inside, to allow for “communication” across membrane

Figure 1.22

Figure 2.19
(crazy idea) **Model the cell membrane as an electric circuit**

**Hodgkin Huxley model**

1963 Nobel Prize
**Theme (REVISTED):** Bridging “micro” and “macro”-scopic scales

**Note:** Take BPHS 4080 (Cellular Electrodynamics) if you really want to delve into this properly...

**Theme: Neuroscience and the brain**
Biophysics @ York

redefine THE POSSIBLE.
Note: Studying how stuff “moves” across a cell membrane is the same basic thing as the more general “how does stuff move?”

→ We’ll start delving into that next week via “mechanics” and easier sorts of “stuff” to study
Aside: Microscopic basis for diffusion

Brownian motion $\Rightarrow$ ‘Random Walker’ (1-D)

Ensemble of Random Walkers
$t = 0$

$\rightarrow$ Diffusion (for which Brownian motion is the \textit{microscopic} basis)
% NOTE: the loop is set up in such a way to average x2ave across walkers

for r=1:N
    x=0; % initialize position for r'th walker
    position(r,1)=0;
    % loop to go through M steps for r'th walker
    for nn=1:M:
        % conditional determines whether step is to the left or right
        if (rand<bias), x=x+1;
        else x=x-1; end;
        x2ave(nn)=x2ave(nn)+x^2; % store squared displacement (handles averaging across r)
        position(r,nn+1)=x; % store displacement for each walker and step
    end;
end;
x2ave = x2ave/N; % Divide by number of walkers

% plot MSD
figure(1);
plot([1:1:M], x2ave, 'k'); hold on;
title(['MSD for 1-D random walk (average from ',num2str(N),' walkers)']);
xlabel('Step number'); ylabel('Mean-Squared Distance (x^2)');

% plot a subset of individual traces
figure(2); clf; hold on; grid on;
for nn=1:K
    shade = 1-(nn-1)/K;
    plot(position(nn,:), 'Color', [1 1 1]-shade);
end
x2ave = x2ave/N; % Divide by number of walkers
figure(3);
plot([0 M],[1 1]*sqrt(x2ave(end)),'g--','LineWidth',2) % include MSD bounds at step M
plot([-1 -1]*sqrt(x2ave(end)),'g--','LineWidth',2)
plot(M,sqrt(mean(position(:,end)).^2),'ro'); % reality check (another way to compute final MSD)
disp(['Final mean (non-squared) distance = ',num2str(mean(position(:,end)))]);
On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat (Brownian motion)

(sid-)Theme: Computational approaches (i.e., programming)
Your brain/community is “programmed” to solve problems...

... so how might you “program” a computer to solve these problems?
Mathematics of Vision Workshop

October 17-18, 2019
Fields Institute, Toronto, ON Canada

Invited Speakers

• Stephanie Palmer (U. of Chicago)
• Alexandre Pouget (U. of Geneva)
• Odelia Schwartz (U. of Miami)
• Tatyana Sharpee (UCSD, Salk Inst.)
• Lai-Sang Young (NYU)
• Richard Zemel (U. of Toronto & Vector Inst.)

Biophysics
Lennart Nilsson

Website ⇒ http://www.fields.utoronto.ca/activities/19-20/vision
Pre-registration ⇒ https://forms.gle/k9NA82w9gTCBn67V7
Questions? ⇒ MOVfields2019@gmail.com