Revamping Introductory Physics for Life Sciences

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Background

Course: Physics for Pre-health
Enrollment: 6 sections of 110 students each (660 students)
Classroom: 15 round tables of 9 students at each table
Lecture format:

- Traditional until Spring 2022
- Active Learning since Fall 2022

ALM outcomes:

- Increased student participation and engagement
- Better course performance and student evaluations

Project – Summer 2024:

- Making it more relevant – striking the balance between physics concepts and biological applications

4 UTAs per section
1 GTA per instructor

Instructional Challenges

Students' perception:

- Physics is more challenging and demanding
- Emphasis on critical thinking over memorization
- Apply acquired knowledge in real-world contexts

Bridging the gap – Physics and Biology

Main motivation:

- Desire to excel in standardized entrance exams for health profession
- Prioritize achieving high grades over gaining a good understanding of the concepts and applications.

Aim of the Project

1. ***Address the disconnect between physics topics and biological applications*** by providing the students with a platform to identify the connection and freely discuss their views on where they can find it applicable.
2. ***Address student's passive mindset and approach to learning physics*** by cultivating a sense of belonging and promoting student responsibility to contribute to learning the material collaboratively via active participation and engaging in extensive field related discussions for better understanding.

Specific Activities

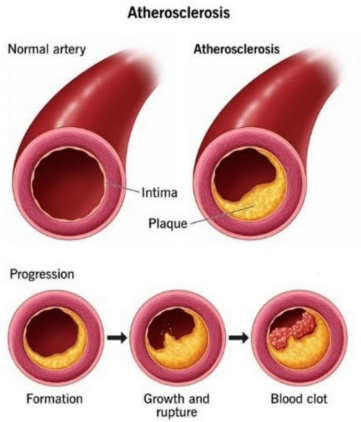
1. Modifying lecture worksheets to enhance student learning.

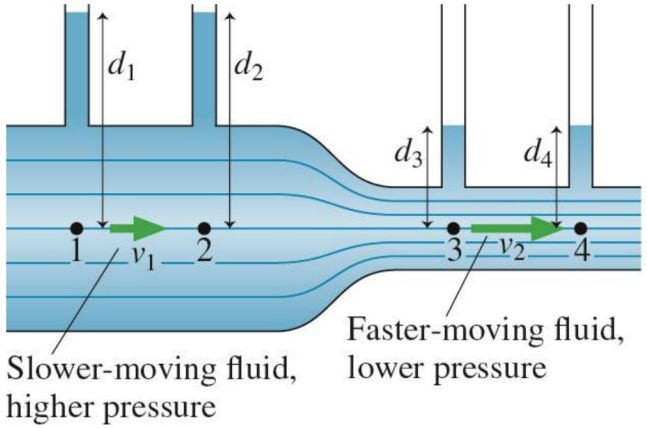
2. Crafting a pool of multiple-choice questions aimed at assessing student understanding.

Lecture Worksheets (30)

2022-2024: Typically, a 4-page worksheet on concept discussion, equations, problems and conceptual questions

Modification: Adding a section highlighting the biological application and one corresponding problem illustrating the application





Constricted blood flow in arteries and the condition of ATHEROSCLEROSIS.

The blood speed in a normal segment of a horizontal artery is typically 0.11 m/s. An abnormal segment of the artery is narrowed down by an arteriosclerotic plaque to one-fourth the normal cross-sectional area. Applying Bernoulli's principle, as the area decreases, velocity of blood increases leading to a lower blood pressure.

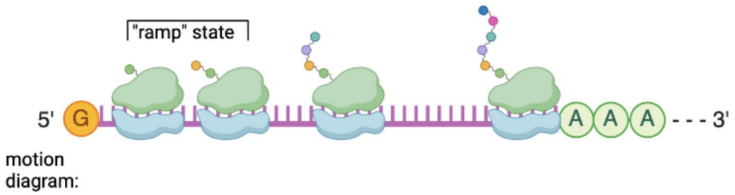
Physics concept: BERNOULLI'S PRINCIPLE

This principle relates the velocity at which a fluid flows to fluid pressure. According to this principle, as the velocity of the fluid increases, the fluid pressure decreases and vice-versa.

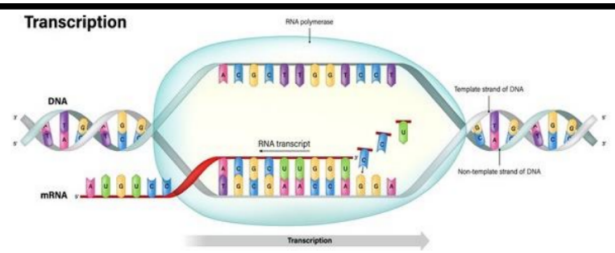
Samples

Motion Diagram – Application:

Once a full ribosomal unit forms over a strand of mRNA, a tRNA will attach at a corresponding codon sequence on the mRNA strand. Once the tRNA finds a start codon (AUG), it will begin translating the codon sequences into corresponding amino acid chains. Multiple tRNA's will utilize a ribosome, or ribosomal RNA (rRNA) as a site to attach and detach from the mRNA strand. With each attachment and detachment of tRNA, the rRNA will gradually move across the mRNA until finding a stop codon. A recent study has found that translation speed varies across the codon sequence; when the tRNA is translating the first 30-50 codons, the rRNA is predicted to move slowly, as if it is experiencing a "ramp". Then, over time, the rRNA will gradually accelerate, accumulating a larger and larger amino acid chain until it reaches the 3' end.



Application: A strand of messenger RNA (mRNA), which contains the information to synthesize one protein, is transcribed from DNA by the enzyme RNA polymerase. Molecular biology experiments show that an RNA polymerase molecule moves along a DNA molecule at the rate of roughly ***60 nt/s***, where nt stands for *nucleotide*, the "letters" of the DNA code. X-ray crystallography studies have found that nucleotides are strung along DNA at ***3.0 nt/nm***.

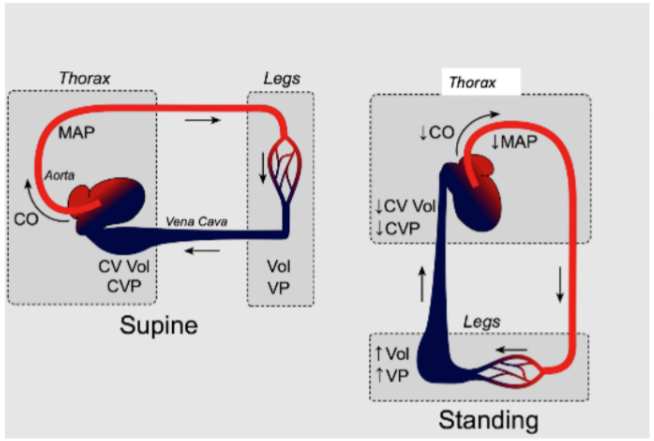


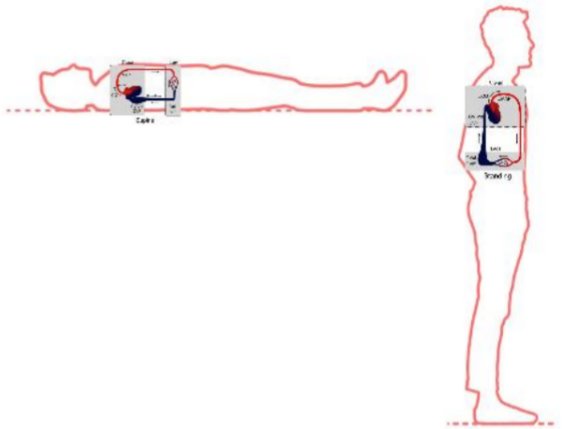
a. ***What is the speed with which RNA polymerase moves along DNA?***
b. ***How long does it take to transcribe the mRNA molecule needed to synthesize a typical protein with 300 amino acids?***

[A major point of this example is that simple calculations can provide insights into cellular processes. Here we find that DNA transcription is pretty slow, with each gene able to generate only about four mRNA molecules per minute. (Several different genes on a single DNA molecule can be doing this simultaneously.) Combined with additional information about the overall rate of protein synthesis, this example reveals that each cell must have a large number of ribosomes, the organelles that carry out protein synthesis from the mRNA transcripts, to compensate for the slow transcription rate.]

Samples

Application: The variations in blood flow can cause incredible variations in medical conditions with patients. Normally, there are significant barriers and mechanisms that ensure that blood flow remains normal, but there are certain conditions and simply some random circumstances that can cause blood flow to become abnormal. Gravity is an incredibly strong force, and when certain mechanisms such as baroreceptors do not respond to the change in position, it can cause blood to pool at the lower levels of the cardiovascular system. When working with blood, while it does not exactly mimic ***free fall*** due to the liquid state it inhabits, this study works well to understand free fall and gravity in the medical sense and how these different conditions can vary.





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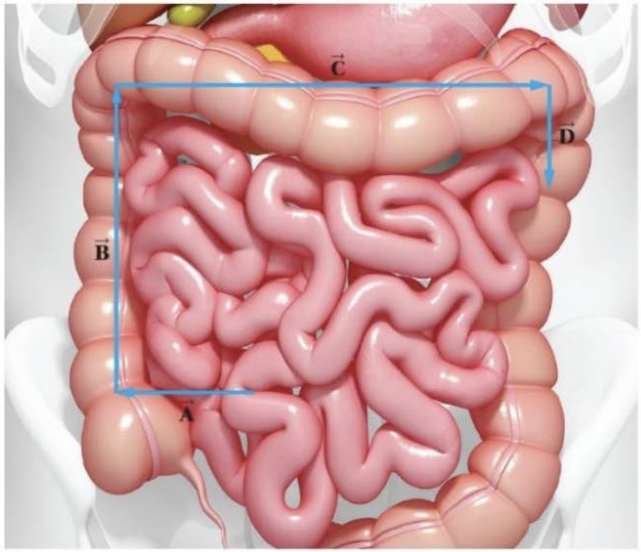
Samples

Problem 5: A food particle from your breakfast takes a circuitous path through your digestive system. Suppose its motion over a period of time can be represented by the four displacement vectors depicted in the figure. Let the vectors have magnitudes ***A = 8 cm, B = 16 cm, C = 23 cm and D = 5.6 cm.***

a. ***What is the total displacement of the food particle? Express it in terms of magnitude and direction.***
b. ***If the average speed of the particle is 0.010 mm/s, what is its average velocity over the time interval of the four displacements?***



Weekly Quizzes

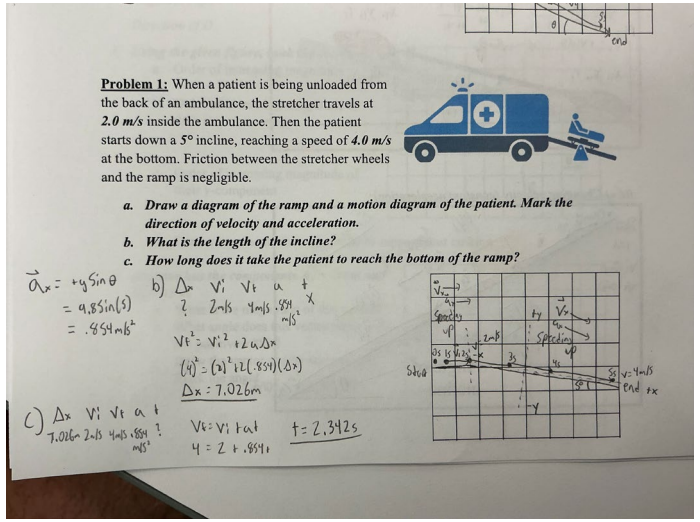
Weekly conceptual quiz on Canvas

- 10 multiple choice questions, with a total of 10 quizzes conducted throughout the semester.
- On-going work: Creating a question bank comprising 7-10 questions for each of the 15 chapters covered in this course.
- Weekly assessment to evaluate student understanding.

Anticipated Impacts

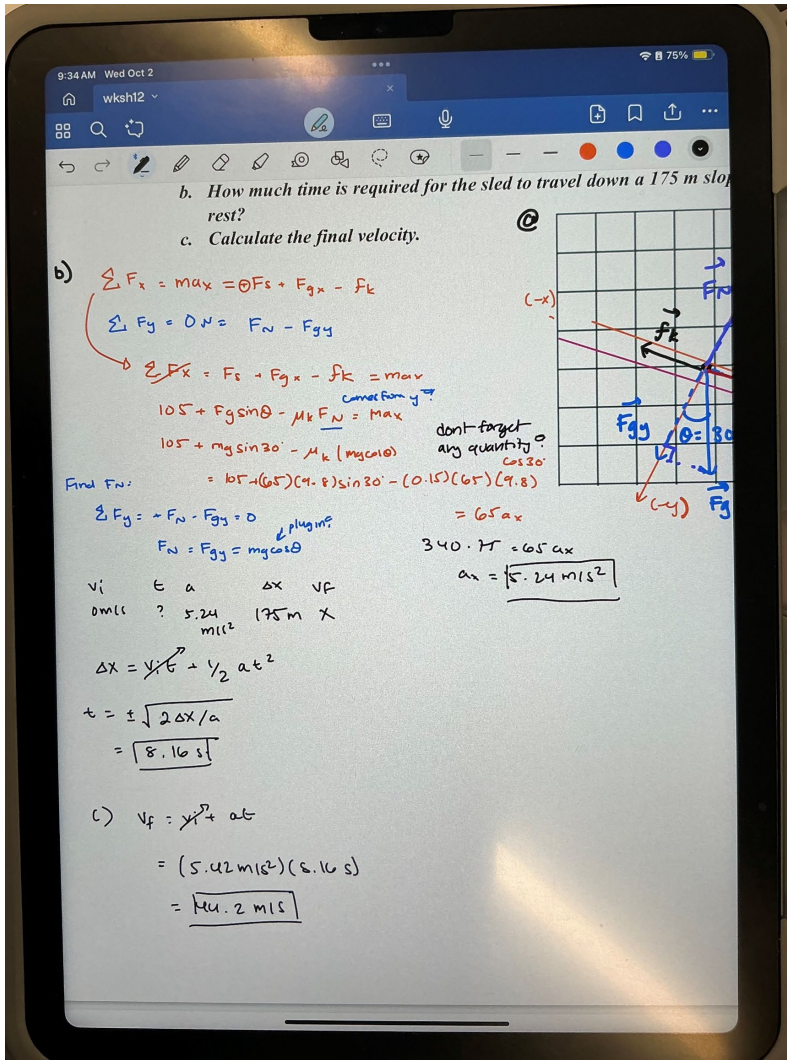
- ✓ Improved student participation during lecture
- ✓ Learning by sharing the acquired knowledge
- ✓ Increased sense of belonging in the course
- ✓ Better academic performance

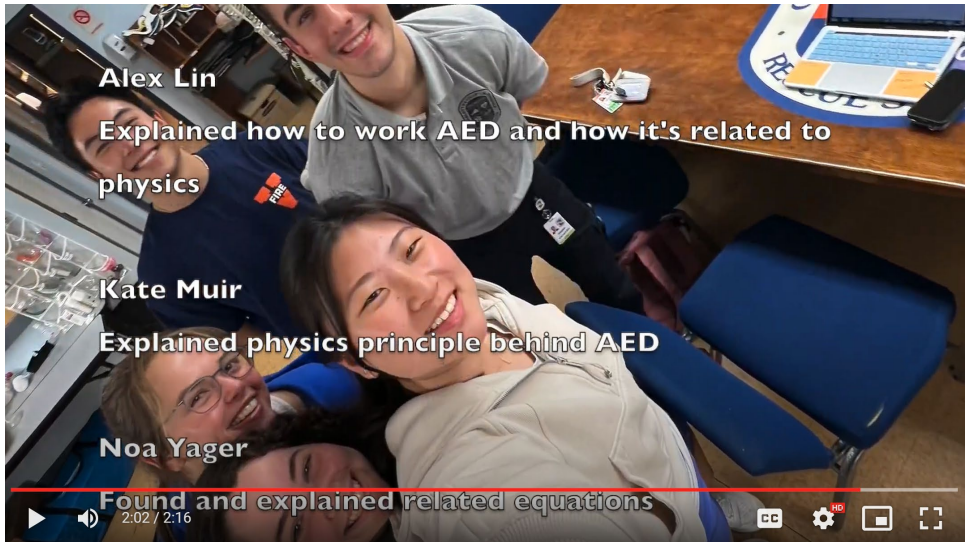
Anticipated Impacts

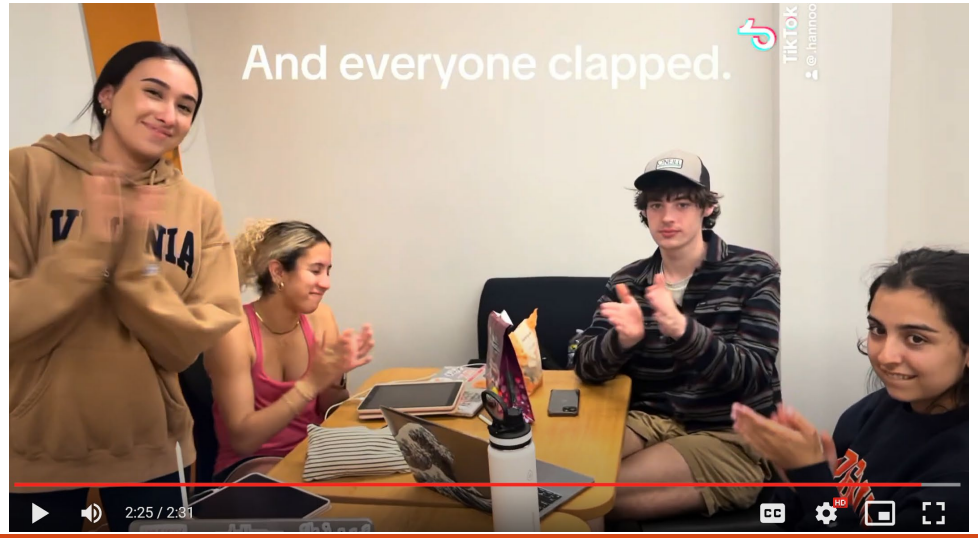


Problem 1: When a patient is being unloaded from the back of an ambulance, the stretcher travels at ***2.0 m/s*** inside the ambulance. Then the patient starts down a ***5°*** incline, reaching a speed of ***4.0 m/s*** at the bottom. Friction between the stretcher wheels and the ramp is negligible.

a. ***Draw a diagram of the ramp and a motion diagram of the patient. Mark the direction of velocity and acceleration.***
b. ***What is the length of the incline?***
c. ***How long does it take the patient to reach the bottom of the ramp?***

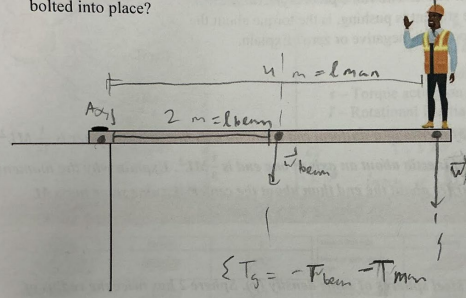






Problem 3: A ***4.00 m*** long, ***500 kg*** steel beam extends horizontally from the point where it has been bolted to the framework of a new building under construction. A ***70.0 kg*** construction worker stands at the far end of the beam.

a. What is the magnitude of the gravitational torque about the point where the beam is bolted into place?



Evaluate Impact

Weekly summary report: In the redesigned 4-page worksheet, the last page is dedicated to conceptual questions. Students collaborate during class time to answer these questions. Since the class meets three times a week, the last page from each day's worksheet is submitted as a weekly summary report over the weekend on Gradescope for assessment.

Weekly quizzes: For this course, there will be a total of 10 quizzes. Quizzes will primarily focus on conceptual understanding and qualitative analysis, occasionally incorporating calculations. They will be based on the materials covered in class each week. Quizzes will be assigned on Canvas to assess student progress.

Survey: A mid-semester survey and an end-of-semester survey will be administered to collect feedback from students regarding the impact of the new materials in generating interest in the subject and the effectiveness of weekly assessment tools in evaluating their progress.

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