SMU PHYSICS 1303: Introduction to Mechanics

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Dallas, TX, USA

SPRING, 2018

SMU | DEDMAN COLLEGE OF HUMANITIES & SCIENCES

Outline

Table of Contents

Introduction to the Course

Tell Me About Yourselves

Raise your hand if. . .

- You are interested in mechanical engineering
- You are interested in electrical engineering
- You are interested in computer science
- You are interested in physics
- You are interested in medicine
- You are interested in something other than the above topics
- you dislike ("hate") physics (don't be shy, I am not easily offended about my own career)

This may also be conducted in class using an interactive poll.

About Me

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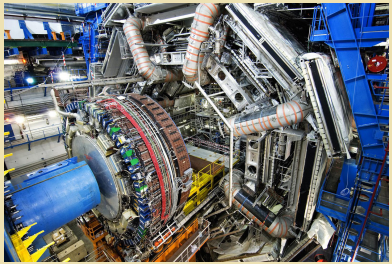

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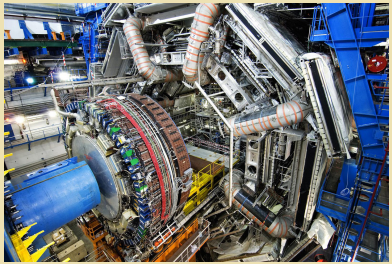

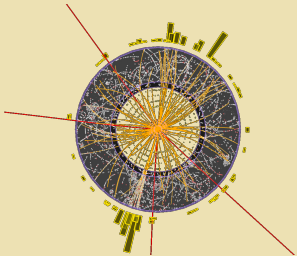

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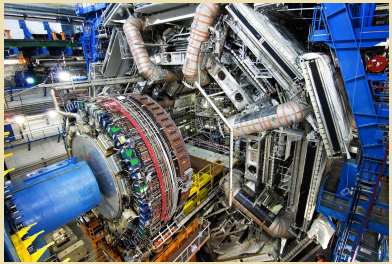
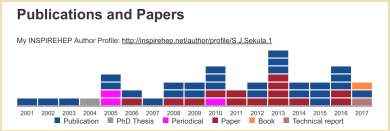
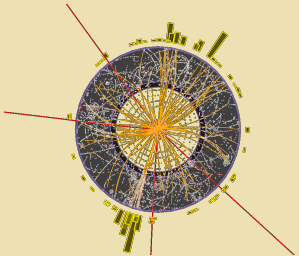



Publications and Papers
My INSPIREHEP Author Profile: http://inspirehep.net/author/profile/S.J.Sekula.1
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Publication
PhD Thesis
Periodical
Paper
Book
Technical report



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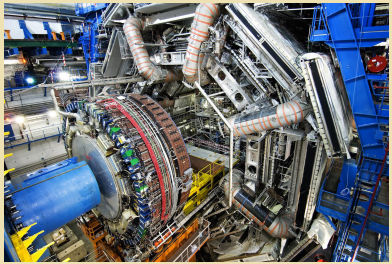

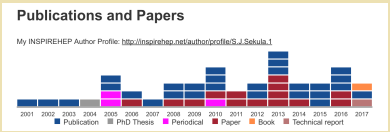
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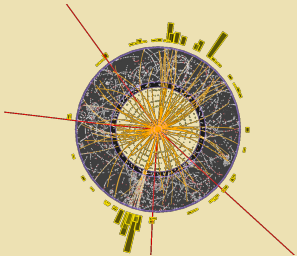

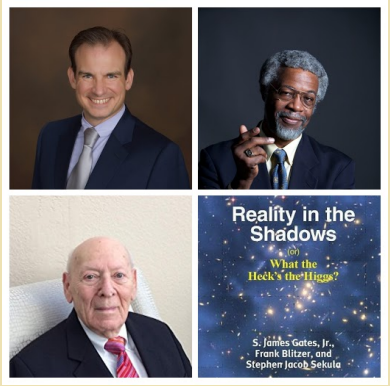
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(or)
What the Heck's the Higgs?
S. James Gates, Jr., Frank Blitzer, and Stephen Jacob Sekula

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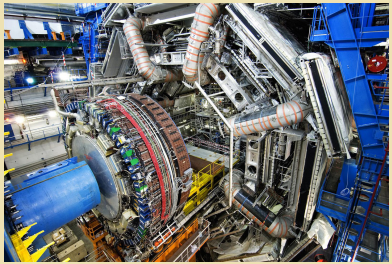

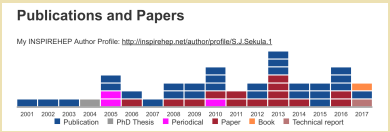
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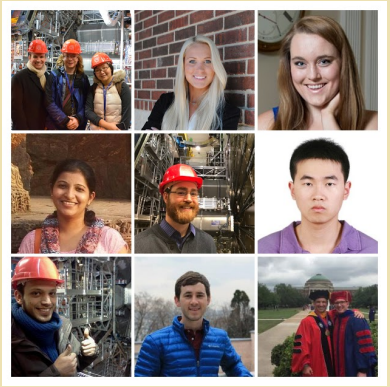

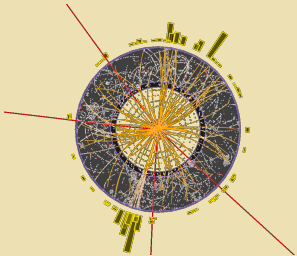

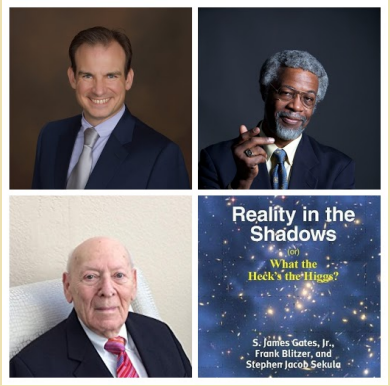
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Why Care About Mechanics?

BUILD **TRAVEL** **IMAGINE**

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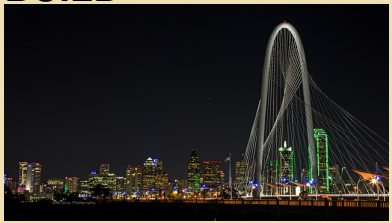

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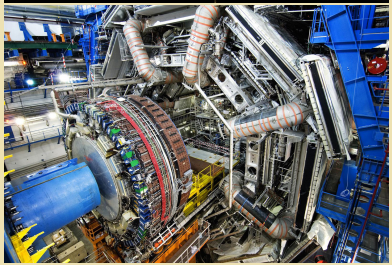

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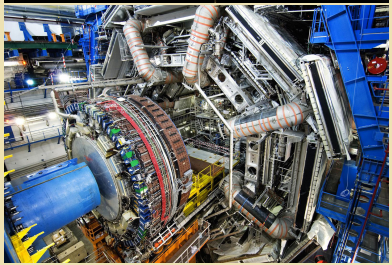

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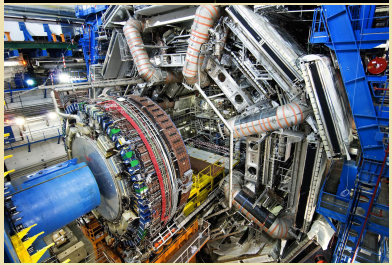

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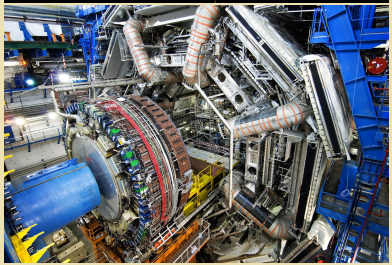

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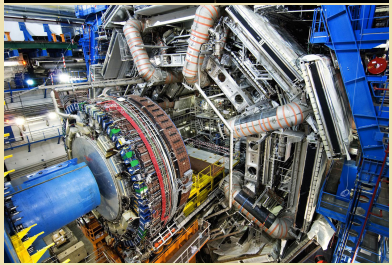

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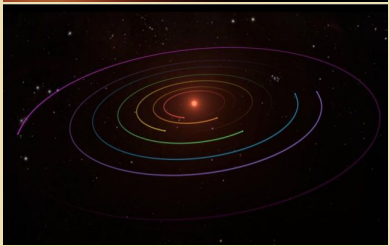
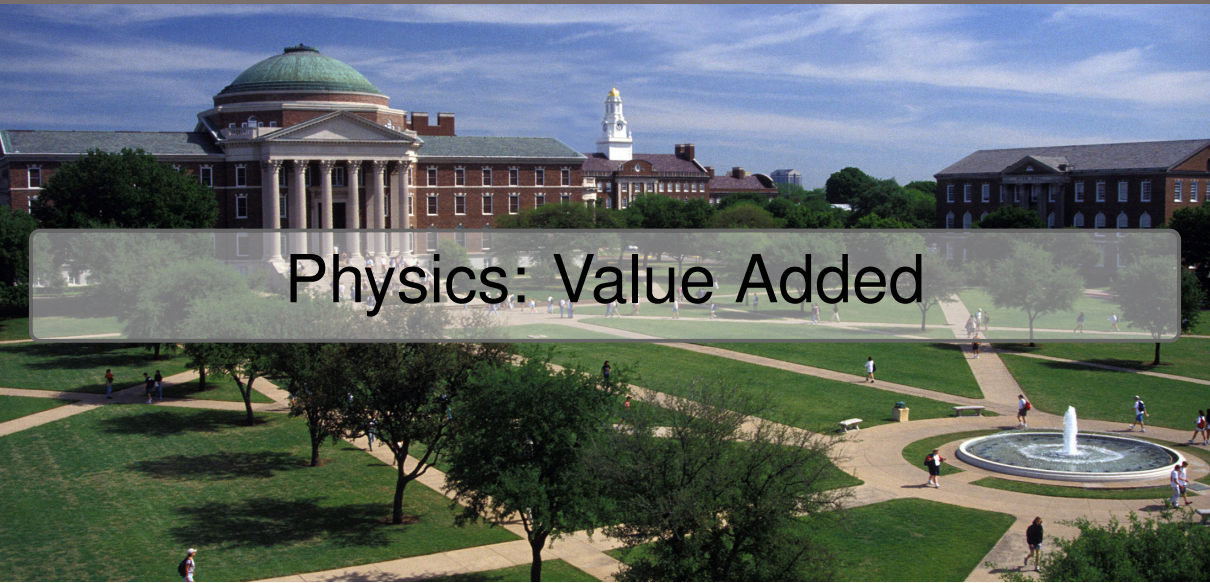
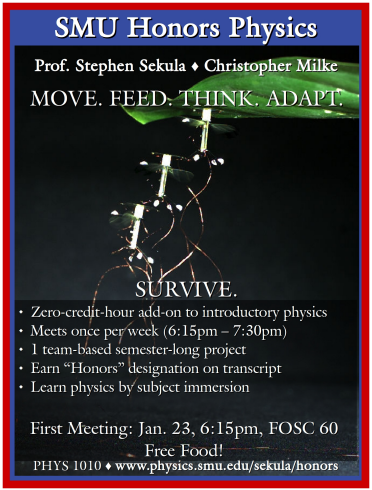




Physics: Value Added

Honors Physics - PHYS 1010



- Zero-credit-hour add-on to introductory physics
- Meets once per week (6:15pm — 7:30pm)
- 1 team-based semester-long project
- Earn Honors designation on transcript
- Learn physics by subject immersion

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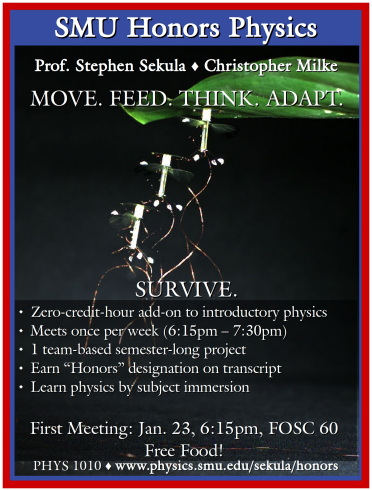

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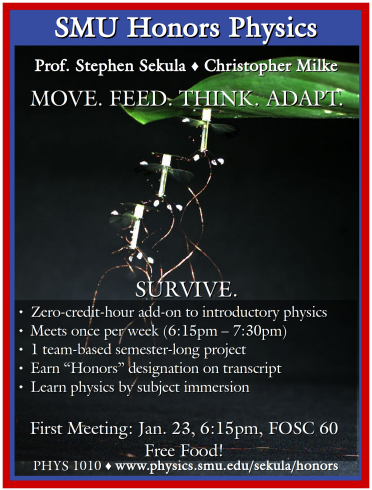

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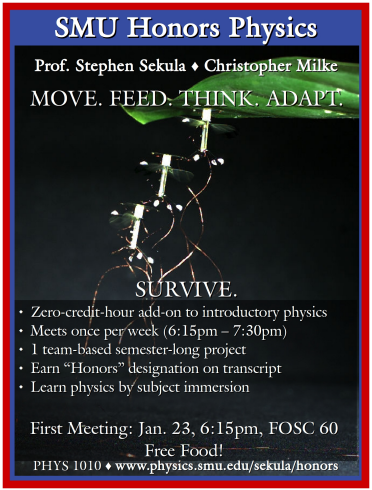

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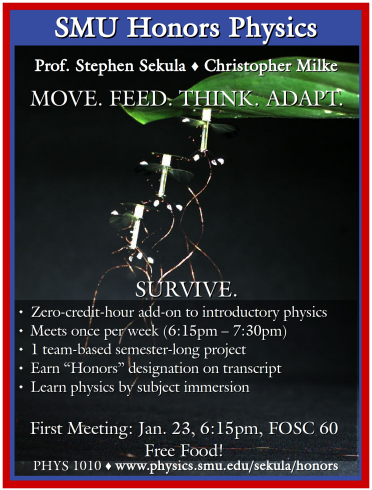

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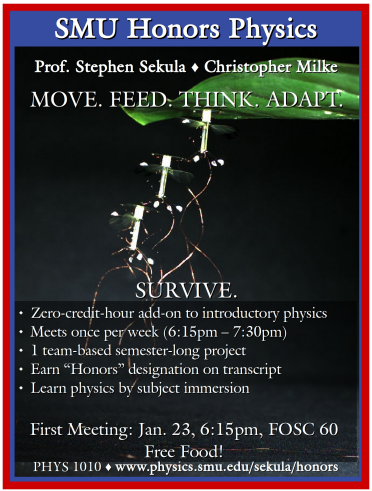

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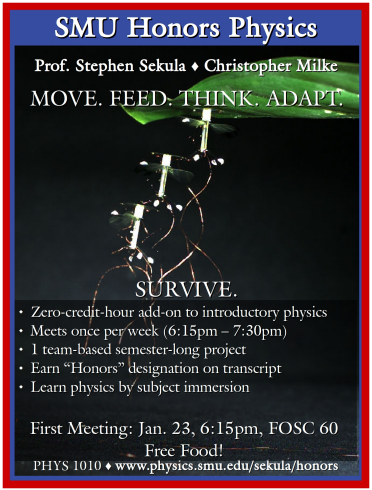
Taking the zero-credit-hour Honors Physics section and performing well in it would help distinguish you and your transcript while building leadership and collaboration skills.

Honors Physics - PHYS 1010



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Taking the zero-credit-hour Honors Physics section and performing well in it would help distinguish you and your transcript while building leadership and collaboration skills.
https://www.physics.smu.edu/sekula/honors/

What are the Goals (Learning Outcomes) of this Course?

University Curriculum Student Learning Outcomes

Pure and Applied Sciences Level 1 [PAS1] Student Learning Outcomes:

1. Students will be able to demonstrate basic facility with the methods and approaches of scientific inquiry and problem solving.
2. Students will be able to explain how the concepts and findings of science or technology in general, or of particular sciences or technologies, shape our world.

Quantitative Reasoning [QR] Student Learning Outcomes:

1. Students will be able to develop quantitative models as related to the course subject matter.
2. Students will be able to assess the strengths and limitations of quantitative models and methods.
3. Students will be able to apply symbolic systems of representation.
4. Students will be able to test hypotheses and make recommendations or predictions based on results.
5. Students will be able to communicate and represent quantitative information or results numerically, symbolically, aurally, visually, verbally, or in writing.

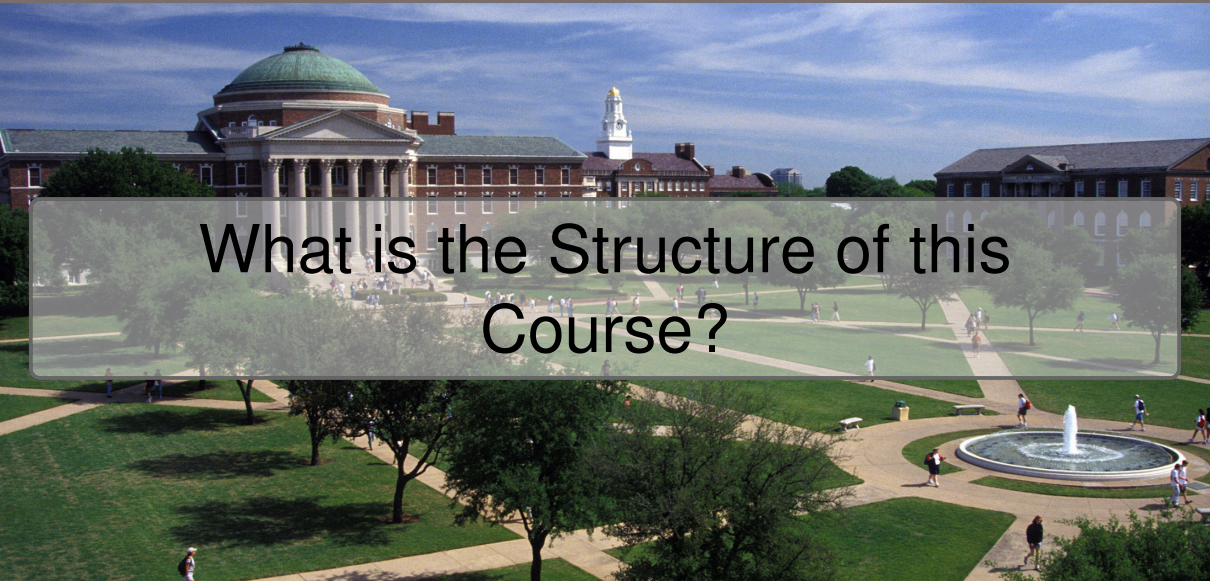
Goals of this Course

As described in the SMU Undergraduate Course Catalog:

> *For science and engineering majors. Covers vector kinematics, Newtonian mechanics, gravitation, rotational motion, special relativity, and structure of matter.*

The specific learning goals of this course are as follows. Upon successful completion of this course, students will be able to:

1. Describe matter in reference to space and time and its kinds of motion in space, explain the relationship between force and motion in space, describe the laws of nature that are known to explain motion, describe the relationship between energy and motion, as well as the kinds of energy available to matter, and to describe the force due to gravity;
2. Setup and solve quantitative problems in the areas described above, and thus be able to apply their understanding of space, time, motion, force, energy, and gravitation to areas other than physics, including the sub-fields of STEM (Science, Technology, Engineering, and Mathematics) and everyday life;
3. Demonstrate, through performance on homework, quizzes, in-class exercises and discussion, and exams, a clear understanding of the principles and application of the above concepts.



What is the Structure of this Course?

General Overview of Course Structure

- In-Class Periods
- Assigned Reading and Video Lectures
- Assigned Homework
- Exams (4 total)
- Help Sessions/Office Hours

In-Class Periods

- Regular
  - Tuesdays and Thursdays
  - 09:30-10:50, FOSC 123
- Style
  - Quizzes (every non-exam period, on assigned reading and lecture video material)
  - Demonstrations (some stuff is more fun in person)
  - Discussion
  - Problem Solving: how to setup and solve problems

Pre-Class: Reading and Lecture Videos

- Pace: about 1 chapter every 1-2 weeks
  - I expect you to spend 4 hours outside of class periods reading and watching video lectures, taking notes as you do those activities, and reading/reviewing/condensing your notes.
- Assessment: Reading and Video Lecture Quizzes
  - worth 10% of your final grade
  - check your pace and comprehension of weekly reading and lecture video material. To encourage to take notes on reading and lecture video, you may use 1 sheet (8.5x11) of notes to aid in the taking of the quiz.
  - in-class, at or near the beginning of each class. Used to check reading comprehension and attendance. Get here on time. If that is a problem, speak to me.
  - Two lowest reading quiz grades automatically dropped.
  - For an excused absence, quiz removed from final grade (counts neither for nor against you)

Student Response System

- What is a “student response system”?
  - Well, to be glib, it’s any system by which I can collect your responses to questions (paper would do just fine!)
  - But these days, it usually refers to an *electronic, real-time system for collecting student responses*
- For this class, we will use **PollEverywhere**
  - Go to PollEverywhere.com to register (free). **Use your SMU Email Address to register!** Then go to your settings on the site and register with me (use my SMU email address, written on the whiteboard)
  - To participate in active polls, go to my poll site: PollEv.com/drsekula. Feel free to use a web browser or the iOS or Android apps.
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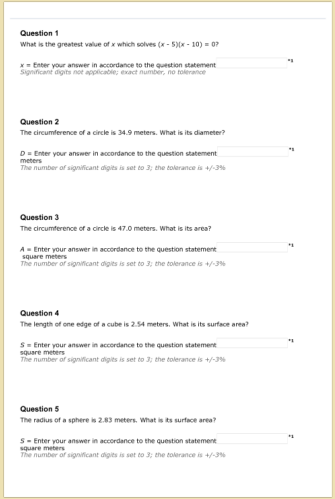
Homework

- Homework
  - worth 15% of your final grade
  - I expect you to spend 4 hours outside of class working on homework
  - Assigned weekly — a mix of WileyPLUS and custom problems I write. Due Thursdays by 9:30 am
  - WileyPLUS answers submitted online, but. . .
  - You must make good quality written solutions to each problem, because you will hand those in on Thursdays and one problem will be randomly graded. Half your homework grade (7.5%) comes from answers in WileyPLUS, while half (7.5%) comes from a full assessment of your methodology (clarity, structure, completeness, accuracy, etc.) to one problem.



Question 1

What is the greatest value of x which solves $(x - 5)(x - 10) = 0$?

x = Enter your answer in accordance to the question statement *1

Significant digits not applicable; exact number, no tolerance

Question 2

The circumference of a circle is 34.9 meters. What is its diameter?

D = Enter your answer in accordance to the question statement *1

meters

The number of significant digits is set to 3; the tolerance is +/-3%

Question 3

The circumference of a circle is 47.0 meters. What is its area?

A = Enter your answer in accordance to the question statement *1

square meters

The number of significant digits is set to 3; the tolerance is +/-3%

Question 4

The length of one edge of a cube is 2.54 meters. What is its surface area?

S = Enter your answer in accordance to the question statement *1

square meters

The number of significant digits is set to 3; the tolerance is +/-3%

Question 5

The radius of a sphere is 2.83 meters. What is its surface area?

S = Enter your answer in accordance to the question statement *1

square meters

The number of significant digits is set to 3; the tolerance is +/-3%

Homework

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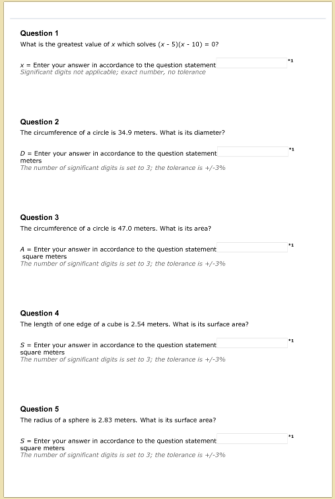

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Question 2

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Question 3

The circumference of a circle is 47.0 meters. What is its area?

A = Enter your answer in accordance to the question statement *1

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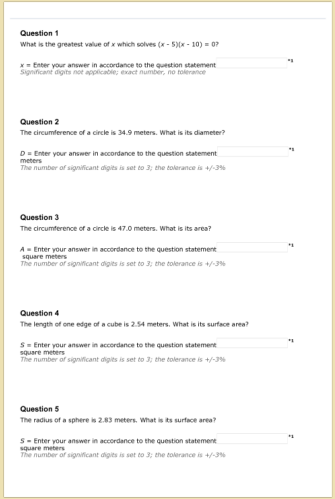

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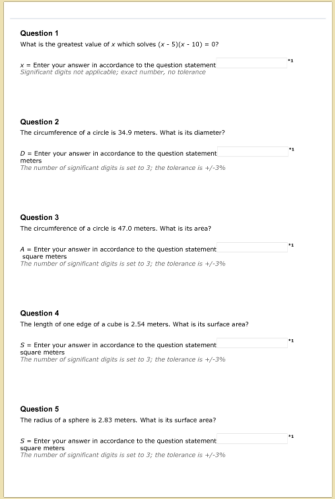

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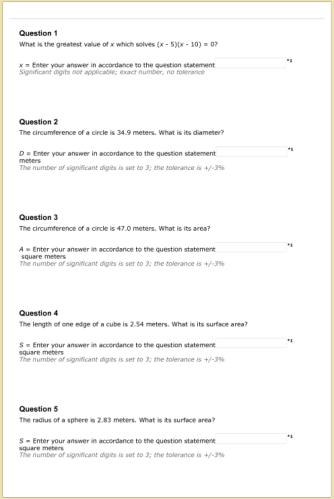

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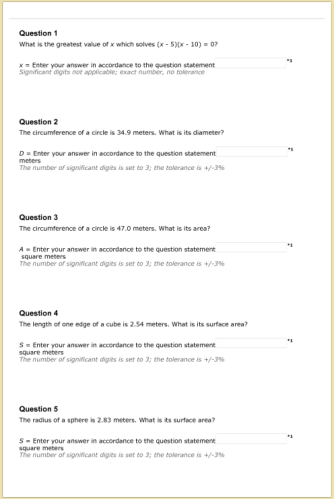

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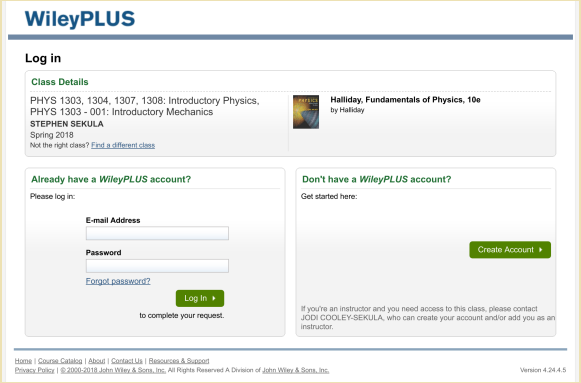
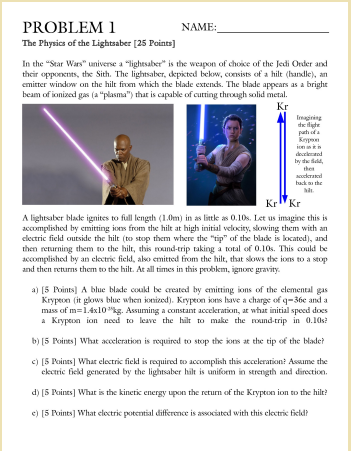
WileyPlus

- Course Link https://www.wileyplus.com/class/610493
  - Go register for my section! You need this to submit your answers to **Homework 0** (Assigned TODAY).
- WileyPlus will handle grading the correctness of your numerical answers, while the teaching assistant and I will assess your methodology and the quality of your solutions.



Exams

- 3 Monthly Exams (“Midterms”)
  - In-class, each covering a specific subset of topics
  - Each worth 15% of your final grade
- Final exam
  - Cumulative
  - Worth 30% of your grade
  - Goal is to assess your comprehensive learning from Exams 1-3 while checking your mastery of the last topics in the course



PROBLEM 1 NAME:_____

The Physics of the Lightsaber [25 Points]

In the “Star Wars” universe a “lightsaber” is the weapon of choice of the Jedi Order and their opponents, the Sith. The lightsaber, depicted below, consists of a hilt (handle), an emitter window on the hilt from which the blade extends. The blade appears as a bright beam of ionized gas (a “plasma”) that is capable of cutting through solid metal.

A lightsaber blade ignites to full length (1.0m) in as little as 0.10s. Let us imagine this is accomplished by emitting ions from the hilt at high initial velocity, slowing them with an electric field outside the hilt (to stop them where the “tip” of the blade is located), and then returning them to the hilt, this round-trip taking a total of 0.10s. This could be accomplished by an electric field, also emitted from the hilt, that slows the ions to a stop and then returns them to the hilt. At all times in this problem, ignore gravity.

a) [5 Points] A blue blade could be created by emitting ions of the elemental gas Krypton (it glows blue when ionized). Krypton ions have a charge of $q=3e$ and a mass of $m=1.4\times10^{-25}$kg. Assuming a constant acceleration, at what initial speed does a Krypton ion need to leave the hilt to make the round-trip in 0.10s?

b) [5 Points] What acceleration is required to stop the ions at the tip of the blade?

c) [5 Points] What electric field is required to accomplish this acceleration? Assume the electric field generated by the lightsaber hilt is uniform in strength and direction.

d) [5 Points] What is the kinetic energy upon the return of the Krypton ion to the hilt?

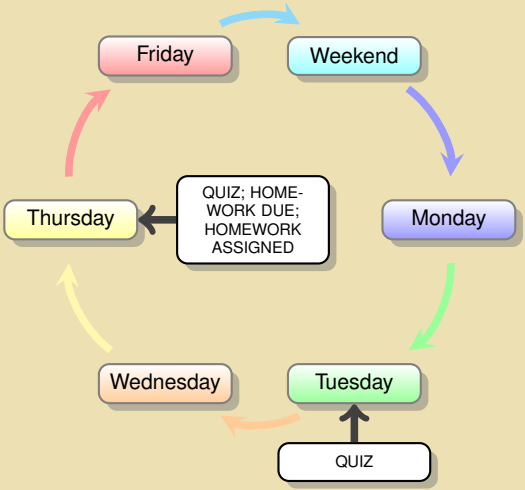
e) [5 Points] What electric potential difference is associated with this electric field?

Example multi-topic synthesis exam problem, from PHYS 1308

Don't Get Stuck... Get Help!

- Instructor office hours:
  - Tuesday, 1:00-2:30pm
  - Wednesday, 1:00-2:30pm
  - Hughes-Trigg Student Center, The Varsity
- TA-led help sessions:
  - See class website
- Learning Enhancement Center:
  - 202 Loyd Center (northwest corner of Ford Stadium, behind the Meadows Art Museum) http://www.smu.edu/Provost/ALEC/Contact
  - Physics tutors available
- Get a private tutor:
  - there are physics majors and minors who might be interested!

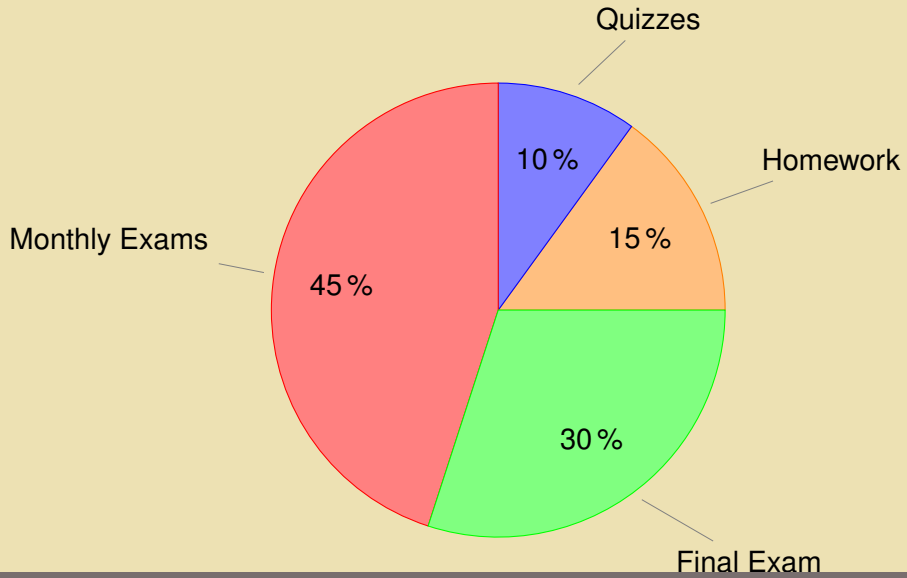
A Typical (Non-Exam) Week



- Thursday: Homework assigned
- Friday: Look through each and every problem assigned see which ones might cause you trouble
- Weekend: Really work the homework
- Monday: You should have tried to submit answers to the online system for your first attempts by the end of Monday. Come speak with me or the TAs about problems at office hours.
- Tuesday and Wednesday: Instructor and TA office Hours
- Homework due and new homework assigned

I expect you to put in 6-9 hours of your own time outside of class, roughly 4 on absorbing new ideas, principles, and material (reading, lecture videos) and 4 on beginning to exercise ideas in problem solving (homework).

Grade Composition



Resources

- Me
  - Office hours
  - Additional discussions must be arranged in writing (e-mail)
- Teaching Assistant
  - See website for their office hours
- The Web
  - Course website: https://www.physics.smu.edu/sekula/phys1303
- Communication
  - I will make official announcements in-class and over e-mail (please check at least once per day)

Teaching Assistants

Chris Milke

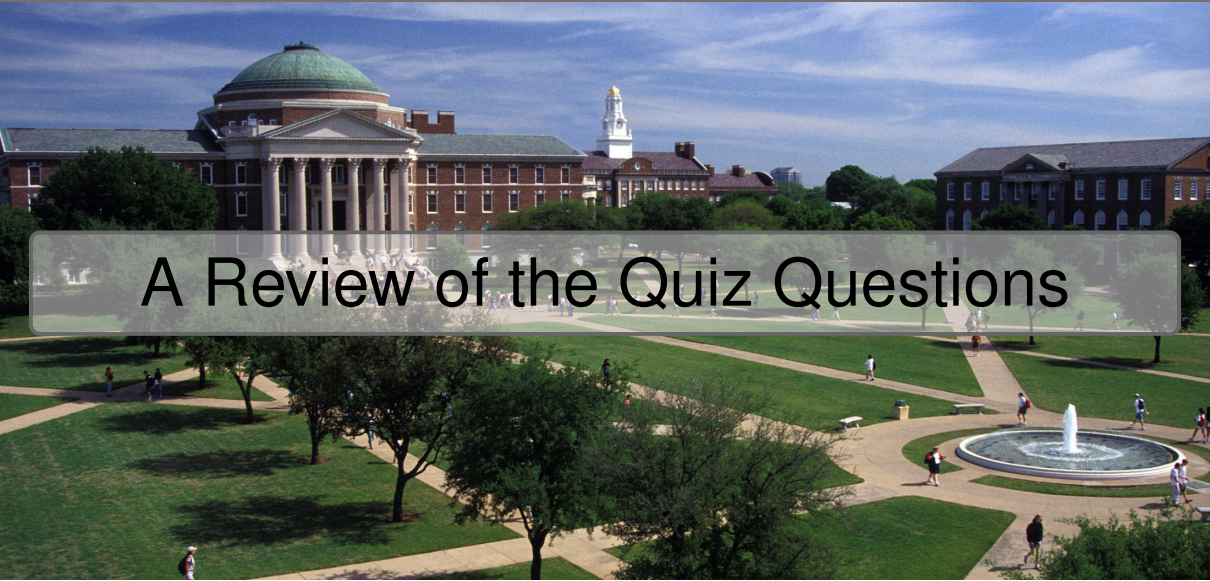
Christina McConville

The Big Picture

- I encourage you to work together outside of class. That said...
  - Cheating and plagiarism will NOT BE TOLERATED
  - Work handed in must be the unique product of your own effort, even if you collaborate with others
- Science has much in common with the humanities
  - The universe is a story that's been told and is still being told. In this class, we will begin to learn how to figure out what has been and is being said.
  - That we learn to seek a deeper understanding of the world around us and the larger cosmos, we will dig rigorously into many subjects
- Physics is exciting
  - It is the study of energy, matter, space, and time
  - It is a quest, paid for with the blood of experimental labor and expressed in the language of mathematics, for the ultimate knowledge of the origin, composition, and fate of the universe.

Quiz Time!

Use the PollEverywhere App or visit PollEv.com/drsekula



A Review of the Quiz Questions

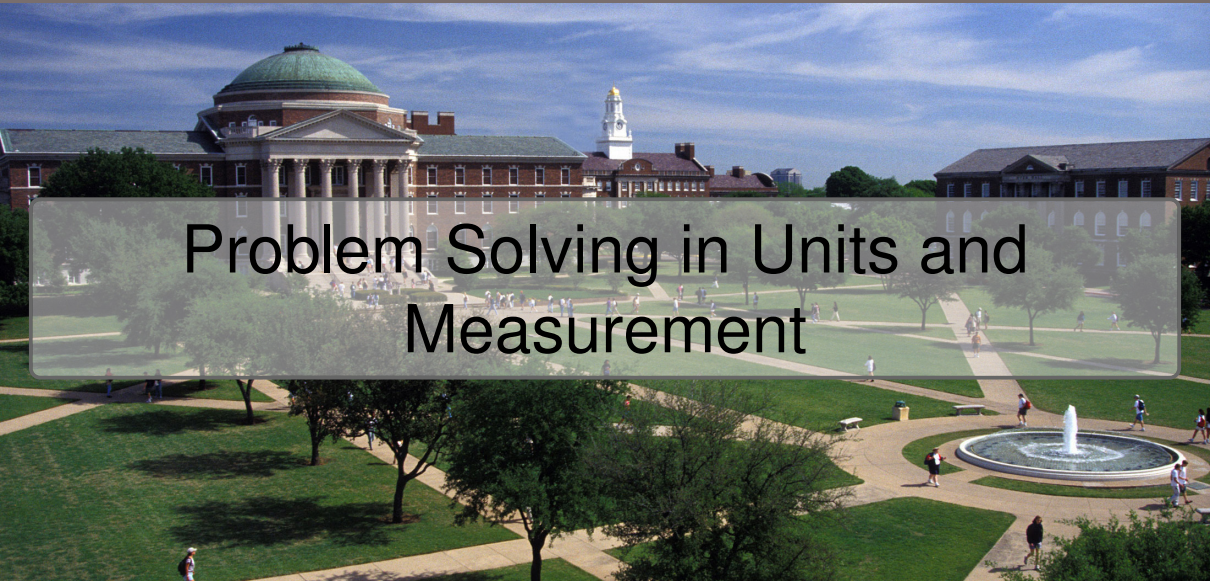
The Scientific Method

Creating Reliable Knowledge

- The Scientific Method has developed over centuries
- It incorporates philosophy and logic and math, but its defining feature is its requirement of evidence and testability of explanatory propositions
- It's simple to describe, but hard to do perfectly — so it must be repeated over and over again to establish a body of reliable knowledge
- When we discuss "Laws" in this class, the reliability is something that has been established through centuries of repeated application and testing. An idea is only a "good" one (in the scientific sense) if it withstands testing and generates new knowledge.

The Idealized Steps of the Scientific Method

- Observe a phenomenon and describe what you observe.
- Propose a testable, falsifiable explanation of the phenomenon
- Perform a test that assesses the explanatory mechanism
- If the test succeeds, all you can say is that the explanation is not yet falsified and you can make further predictions and tests. If it fails, the explanation was wrong and needs to be modified or discarded.

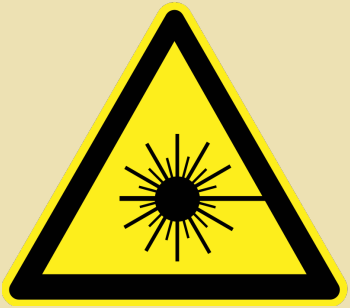


Problem Solving in Units and Measurement

Powers of Ten

How would you write the following number using scientific notation (powers of ten)?

$$299,800,000\,\mathrm{m/s}$$



"Laser Beam Warning Sign" by h0us3s, available from OpenClipArt.org

This may also be conducted in class using an interactive poll.

Unit Conversion: Miles to Kilometers

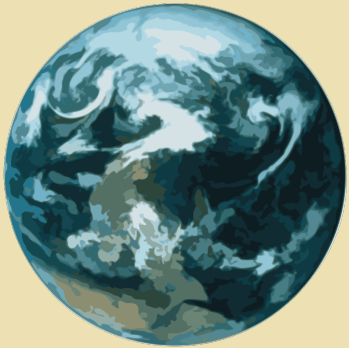
In the United States, the standard distance unit is the mile. There are 5280 feet to a mile, and 12 inches to a foot. If 1 inch = 2.54 cm, how many kilometers are there in a mile?

"Long Road in the Desert" by anarres, available from OpenClipArt.org

This may also be conducted in class using an interactive poll.

The Size of the Earth

The Earth is a nearly round planet, and can be modeled as a sphere with a radius of 3958.8 miles. How many kilometers is that?

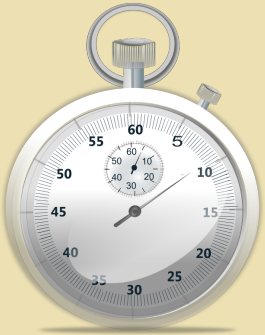


"earth" by orru, available from OpenClipArt.org

This may also be conducted in class using an interactive poll.

One Year in Seconds

It takes 365.25 days for the Earth to make one revolution around the sun (this is a “solar year”). If there are 24 hours in a day, 60 minutes in an hour, and 60 seconds in a minute, how many seconds are in a year?



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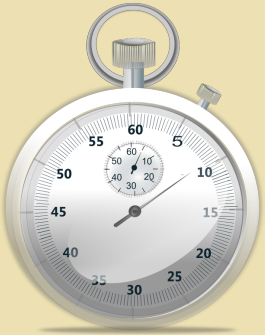
Fun fact: the number of seconds in a year is given approximately by $\pi \times 10^7$ s*, where* $\pi = 3.14159\ldots$*. This is accurate to 0.45%.*



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All the Atoms in the Cosmos

There are approximately 10^{80} atoms in the cosmos. If 76% of the atoms are Hydrogen (with mass $m_H = 1.67 \times 10^{-27}\,\mathrm{kg}$) and 24% are Helium (with mass $m_{He} = 6.65 \times 10^{-27}\,\mathrm{kg}$), what is the total mass of atomic matter in the universe?

"Helium (He) Block-Chemistry" by oldifluff, available from OpenClipArt.org

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Fun fact: many observations of the atomic content of the universe have been made, an indeed the universe's atomic matter is about 74% Hydrogen, 24% Helium, and 2% everything else.

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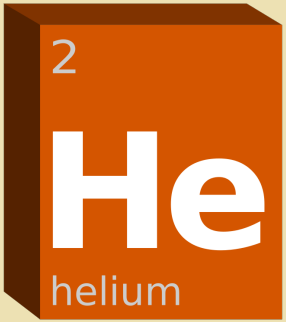
Fun fact: atomic matter only composes about 5% of the energy content of the universe. But that is a discussion for another day... and a place where some of you might make fundamental discoveries about the universe.



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A Star the Size of a City Center

A neutron star is the result of the death of a very heavy star, one with a core at least 1.5 times heavier than our own Sun's. If a typical neutron star is approximately a sphere with a diameter of 25 km, but a mass of $3.0 \times 10^{30} \mathrm{kg}$. What is the density of a typical neutron star? (BONUS: compare to the density of lead)

A neutron star compared in size to New York City (from Wikipedia)

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Fun fact: neutron stars are about the diameter of city centers but are so dense that a teaspoon of material from the star has a mass of about 2 trillion kilograms and would weigh about 2 billion tons on earth. A distant pair of colliding neutron stars was detected just last fall, beginning a new era in astronomy.

A neutron star compared in size to New York City (from Wikipedia)

This may also be conducted in class using an interactive poll.

Reminders

- Assigned Today
  - Read HRW Chapter 2.1 — 2.2 and watch lecture video on motion in one dimension [Due Thursday]
  - Homework 0: “mathematics calisthenics” to help you warm up some more [Due Thursday]
    - Numerical answers go in WileyPLUS
    - Bring your **written solutions** to class, making sure they comply with the policy on written materials (see website). Hand those in at the beginning of class.
- Summary of Today
  - You have been introduced to the course. Make sure to read the syllabus and policy on written assignments.
  - We have begun to play with numbers.

References I