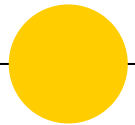
Physics 101H

General Physics 1 – Honors



Lecture 2 – 8/31/23

Problem-solving strategies

Welcome!

I am Prof. Monahan

Pronouns: **he/him/his**

Email: **cjmonahan@wm.edu**

Office: **Small Hall 326C**

Am I in the right room?

This course: for students who **intend to major in physics or physical sciences**

I assume you have a strong preparation in mathematics

- Comfortable with **calculus**

PHYSICS 101 (not this course!) does not assume knowledge of calculus

- Held at the same time
- Uses the same textbook
- Add/Drop deadline is **11:59 pm** on **Monday September 11**

DO NOT MISS THIS DEADLINE

Undergraduate research: info sessions

Friday, September 8th 11am-12pm
Monday, September 11th 3:30-4:30 pm
Thursday, September 14th 3:30-4:30 pm
Wednesday, September 27th 2-3 pm
Tuesday, October 5th 11 am - 12 pm

Take place in Blow Hall 201 or the Sadler Center (James Room) - check the website.

"Undergraduate research can be done in any major and lead to some amazing opportunities - but how do you get started? At this info session, learn more about what undergraduate research entails, how to find a faculty mentor, and what funding opportunities exist. By the end of this info session, you should be ready to take your first steps into the world of research! Open to all majors and class years. Snacks provided!"

Some resources

Writing Resources Center (located on the first floor of Swem)
Offers free, one-on-one sessions with trained consultants, who offer individual assistance with writing, presentation, and other communication assignments across disciplines and at any stage, from generating ideas to polishing a final product. You can make an appointment on the website for online or in-person sessions. Find out about the Writing Resources Center here.

TutorZone (located on the ground floor of Swem)
Supports you through one-on-one tutoring to learn skills for success in particular courses, practice problem-solving skills, and reviewing course material. You can make an appointment on the website. Find out about the TutorZone here.

Society of Physics Students (located in Small Hall)
Dedicated physics tutoring from other physics students.

Problem sets

Problem Set 0 has been posted on **Blackboard**

Due by the **start of class** (i.e. 10:59 am) on **Wednesday 6 September**

Remember

- I will **drop the lowest grade** on your weekly Problem Sets (not including Problem Set 0)

Problem sets

Handwritten problems:

- Partial credit **is** available
- Graded by a graduate student grader

Hints:

- You will lose points if your solution is illegible or a mess
- Pen or pencil acceptable
- If you use a pen, cross through entire lines with a single line

MAKING SURE YOUR WORK IS LEGIBLE IS *YOUR* RESPONSIBILITY

Problem sets

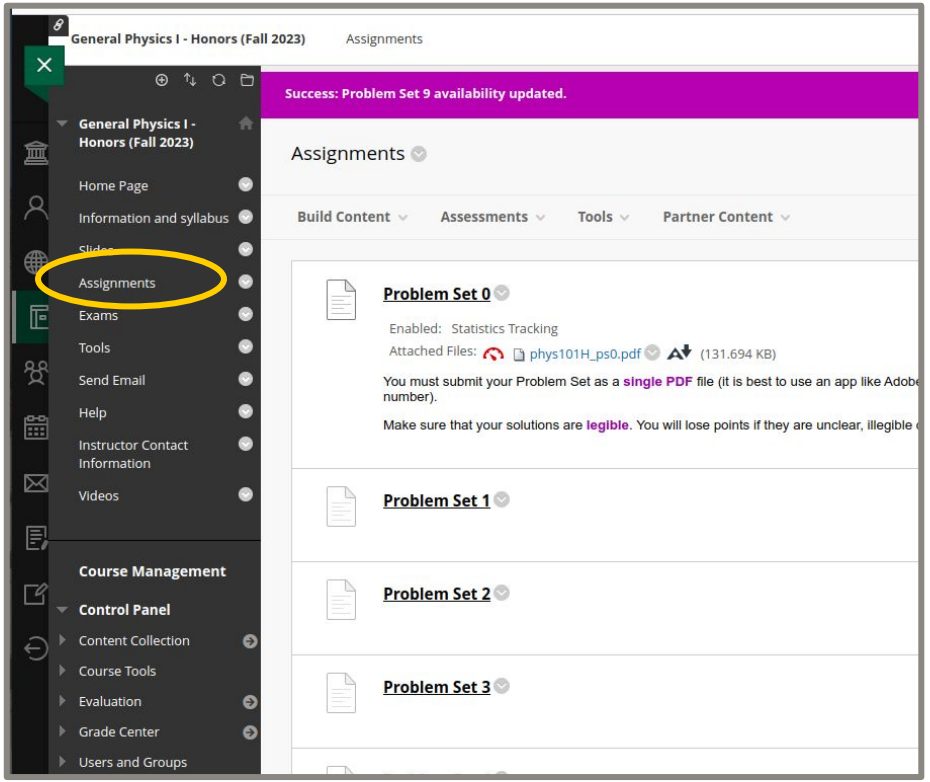
Submitting handwritten problem sets:

- Produce a **single PDF** of your written notes
  - If you have a scanner, then that is the best option
  - Photos will work – use an app like Adobe Scan to make them legible
- Name your **single PDF file** `lastname_hwXX.pdf`
  - Replace "`lastname`" with your last name
  - Replace "`XX`" with the problem set number
- Submit your **single PDF file called** `lastname_hwXX.pdf` to **Blackboard**
  - Go to the appropriate assignment in Blackboard
  - Drag and drop your pdf file to the Attach Files section
  - Hit submit

Problem sets

Submitting problem sets:

- Produce a **single PDF**
- Name your **single PDF file** `lastname_hwXX.pdf`
- Submit your **single PDF file** `lastname_hwXX.pdf` to **Blackboard**



Office hours

Questions? Come to **office hours**! Take place in **Small Hall 326C** (my office)

- **Thursday 2:00–3:00 pm** and **Friday 3–3:30 pm**
- I will also be in my office Monday 10–10:30 am

Office hours provide an opportunity to

- Discuss physics in more detail
- Get to know you a bit better

YOU DO NOT NEED TO MAKE AN APPOINTMENT

Summary

Topics

Yesterday: Course introduction

- Course details
- Grading and homework
- Logistics and timetable

Today: Problem solving [chapter 1]

- Basic strategies
- Setting up and solving problems
- Troubleshooting

What problem solving strategies do you use?

PHYSICS IS A SKILL

AND YOU CAN GET BETTER AT IT BY PRACTISING!

Tips and tricks

These tips and tricks may help with many problems, but are not a checklist you have to memorise and apply to every single problem

- Stuck on a problem? Don't worry! It is OK not to know the answer!
- Revisit these notes – see if one helps unstick you
- Use these ideas to check your answer
- Keep practising problems and you will internalise many of these
- Not all strategies are necessary for all problems, but practise using them on simpler problems to reinforce their application when things get tougher (for example, in research)

Basic strategies: I

- Solve problems **symbolically**
  - Change all numbers to symbols
  - Solve equations for the unknown
  - Plug in numbers **at the end**
- Draw a **picture**
  - Really. Draw a big picture with labels.
- Check **units, dimensions and orders of magnitude**
  - May help determine the form of the solution
  - Can help you identify algebra mistakes

Example 2.1: Consider a mass on a string of length 1 m, swinging through a small angular amplitude under only the force of gravity. Find an expression for the period of the swing using dimensional analysis.

Example 2.2 [an estimation problem]: How many people in the world are using their cell phones in any given minute?

Basic strategies: II

- Check **limiting and special cases**
- Check the **Taylor series expansion**

Useful Taylor Series

$$\frac{1}{1+x} = \sum_{n=0}^{\infty} x^n \qquad = 1 - x + x^2 - x^3 + \dots$$

$$\ln(1+x) = \sum_{n=1}^{\infty} (-1)^{n-1} \frac{x^n}{n} \qquad = x - \frac{x^2}{2} + \frac{x^3}{3} + \dots$$

$$e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} \qquad = 1 + x + \frac{x^2}{2} + \frac{x^3}{6} + \dots$$

$$\sin x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!} = x - \frac{x^3}{6} + \frac{x^5}{120} + \dots$$

$$\cos x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n}}{(2n)!} \qquad = 1 - \frac{x^2}{2} + \frac{x^4}{24} + \dots$$

$$\arctan x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{2n+1} \qquad = x - \frac{x^3}{3} + \frac{x^5}{5} + \dots$$

$$(1+x)^m = \sum_{n=0}^{\infty} \binom{m}{n} x^n \qquad = 1 + mx + \frac{m(m+1)}{2} x^2 + \dots$$

Specific strategies: set up

- Read the problem carefully
- Identify:
  - What you know
  - What you are trying to solve for
  - Extraneous information
- Identify:
  - Initial and final states
  - Constraints
- Choose a reference frame (choose wisely)
- Draw a big picture with labels
- Try to stay organised

Specific strategies: solving

*Not really (I hope!), but it is a good way to remember to draw big pictures and write out your solution attempts in full.

- Try to think in terms of physical statements, not equations
  - Identify the physical principles involved
  - Convert physical statements into equations
  - Make sure the number of equations = number of unknowns
- Draw a big picture with labels
- Try to stay organised
  - Don't be afraid to use plenty of paper

REMEMBER: PHYSICISTS HATE TREES*

Specific strategies: troubleshooting

- Check the units of your numerical answer
- Check the size of your numerical answer is reasonable
- Reduce the problem to a simpler problem
  - Break it up into steps
  - Try to identify similar problems that you know how to solve
- Re-read the problem
- Check your maths, especially the minus signs
- Call on your intuition

Practice in pairs

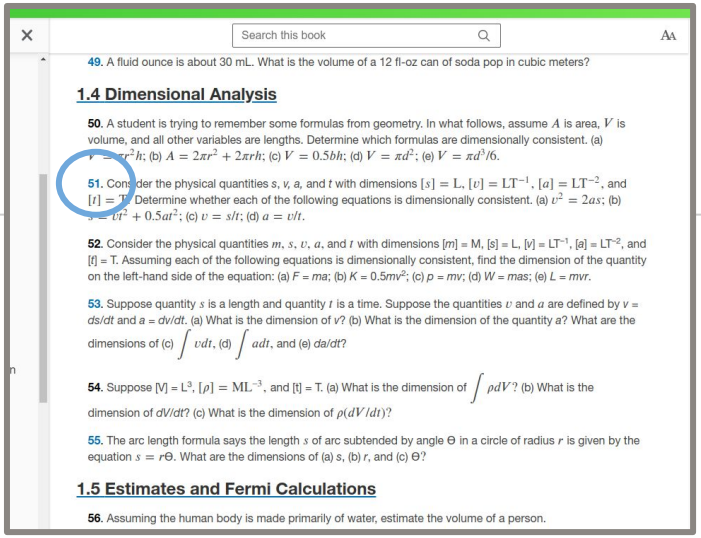
*Explaining your attempts and/or your solutions helps you clarify your own understanding, as well as helping others learn. You may also learn new tips and techniques from your peers.

Instructions: Discuss the following question with a neighbour. Your answers will not be graded; your discussion is for your own learning*.

Question 2.1: The Schwarzschild radius R_S defines the ***event horizon*** of a black hole of mass m. The Schwarzschild radius depends on the speed of light c, and the gravitation constant G (with units $m^3/(kg\ s^2)$). Which of the following quantities is R_S proportional to?

(a) $G/(m\ c^2)$ (b) $G\ m/c^2$ (c) $G\ m/c^3$ (d) $c^2/(G\ m)$ (e) $c^3/(G\ m)$

Want more practice?



Check out the following problems in the textbook

- Conceptual questions: 9, 11, 13
- Problems: 14+15, 18, 19, 29, 31, 41, 51, 61, 65, 83

For each topic, I will try to suggest good ungraded practice problems

Note that answers are provided for questions with blue numbers (odd numbered)

Click on the number to be taken to the answer.

But make sure you at least **try** the problem first!

Summary

Topics

Today: Problem solving [chapter 1]

- Basic strategies
- Setting up and solving problems
- Troubleshooting

Tomorrow: Yet more introduction

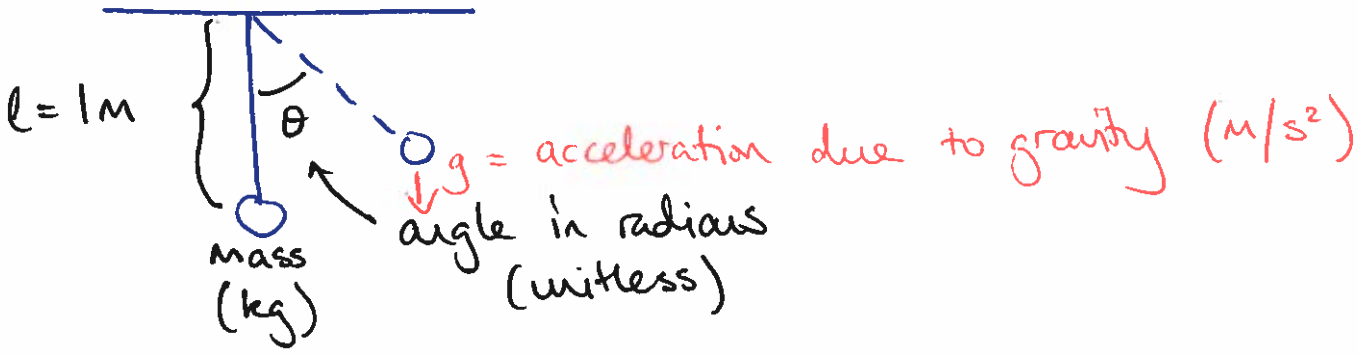
- Mechanics

PHYSICS 101 - HONORS

Lecture 2 8/31/23

Pendulum example (slide 16)

Step 1 - draw a picture



Step 2 - identify what we need to solve for

=> period (a time, in units of seconds)

Step 3 - try combining units

$$[t] = [\ell]^a \, [\text{mass}]^b \, [g]^c$$

$$\Rightarrow s^1 = M^a \cdot kg^b \cdot (M/s^2)^c$$

=> equate units on each side

equating seconds : $1 = -2c \Rightarrow c = -1/2$

equating kg : $0 = b \Rightarrow b = 0$

equating metres : $0 = a + c$, $0 = a - 1/2 \Rightarrow a = 1/2$

So $$\boxed{T \propto \sqrt{\frac{\ell}{g}} = f(\theta)\sqrt{\frac{\ell}{g}}}$$

Estimation problem (slide 17)

Order of magnitude estimate:

$\sim \frac{1}{2}$ people in the world have cell phones

Approximately 7 billion or 7×10^9 people in the world

$\Rightarrow \sim 4 \times 10^9$ have phones

Order of magnitude estimate:

~ 4 hours per day of cellphone usage ← average person in the US uses 5.4 hours!

$\Rightarrow \sim \frac{4}{24} = \frac{1}{6}$ of the minutes in the day

Putting this together, we have

$\sim 4 \times 10^9 \cdot \frac{1}{6} = \sim \frac{2}{3} \times 10^9$ people $= 0.667 \times 10^9$ people

This is approximately $\boxed{7 \times 10^8 \text{ people}}$

Taylor series

$f'(0) = \left.\frac{df}{dx}\right|_{x=0}$

$f''(0) = \left.\frac{d^2f}{dx^2}\right|_{x=0}$

Defined as

$$f(x) = f(0) + f'(0)\cdot x + \frac{f''(0)}{2!}\cdot x^2 + \frac{f'''(0)}{3!}\cdot x^3 + \dots$$

expansion in powers of x

$f(0)$: this is a Taylor series of $f(x)$ around $x=0$ (can be generalised)

$n! = n\cdot(n-1)\cdot \dots \cdot 2\cdot 1$

$\dots$ continues

- If x is small the first few terms are a good approximation (because $x^4 \ll x^3 \ll x^2 \ll 1$)
- In summation notation

$$f(x) = \sum_{n=0}^{\infty} \frac{f^{(n)}(0)}{n!}\cdot x^n$$

Schwarzschild radius

The answer is **b**

We want a radius $\Rightarrow$ units are [length] = m

We have three dimensionful quantities (mass, speed, G)

$\Rightarrow$ [length] = [mass]^a [speed]^b [G]^c

$m' = kg^a\cdot(m/s)^b\cdot(m^3/kg\,s^2)^c$

Now we need to equate units on each side

Equating m $\Rightarrow$ $1 = b + 3c$ ①

Equating kg $\Rightarrow$ $0 = a + (-c)$ ②

Equating s $\Rightarrow$ $0 = (-b) + (-2c)$ ③

③ tells us that $b = -2c$

Plugging this into ① tells us that $1 = -2c + 3c = c$

② tells us that $c = a$

Taken together $\Rightarrow$ $c = 1$, $b = -2c = -2$, $a = c = 1$ $\Rightarrow R_s \propto M G/c^2$

In fact $R_s = \frac{2GM}{c^2}$