Physics 101H

General Physics 1 – Honors

Lecture 18 – 10/5/22

Drag and computational physics

Study groups!

Feel free to join if your interested in making study groups and working through problems together!

Summary

Topics

Today: Computational physics

- Air resistance (again)
- Python and Google Colab
- Modelling air resistance

This week:

- Energy conservation [chapter 8]
- Momentum and collisions [chapter 9]

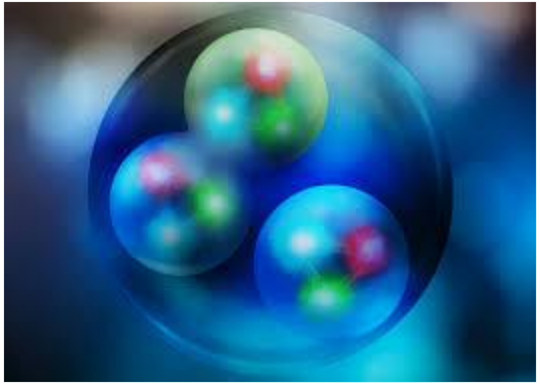
Air resistance

Recall linear and quadratic models of air resistance [see Sec. 6.4 of the textbook, too!]

Not all differential equations can be solved analytically!

Some (especially nonlinear differential equations) must be solved numerically

Example: the strong nuclear force



Python

Python [see www.python.org] is a widely-used free scripting language

- Web development
- Mathematical applications and data analysis
- General-use system scripts

Excellent introduction and tutorials at
https://www.w3schools.com/python/default.asp

Commonly used with Jupyter notebooks [see https://jupyter.org/]

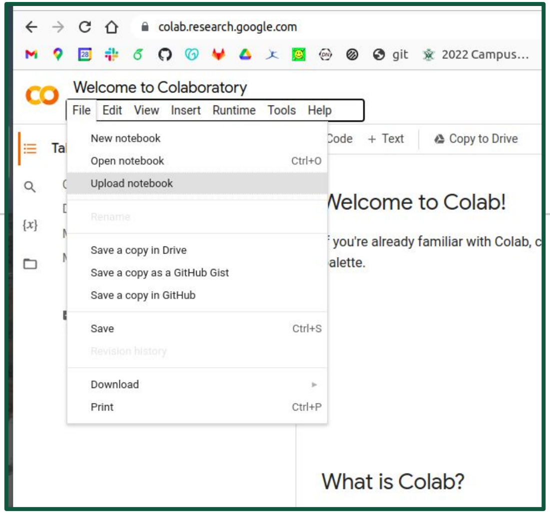
- Interactive environment
- Runs in a browser

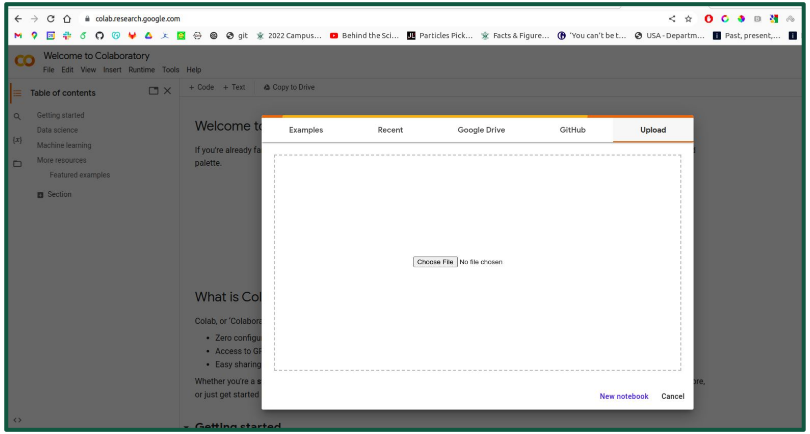
Easy to install (typically already installed on many systems), but there's no need!

Run in Google Colab [see https://colab.research.google.com/]

Colab

1. Open your browser
2. Navigate to https://colab.research.google.com/
3. Upload notebook to work on it
   a. Appears as a splash screen, or
   b. Navigate to “File > Upload notebook”
4. Execute cells by pressing the “play” button or hitting “Shift-Enter”
5. Enter “playground mode” if you want to make changes that won’t be saved





Air resistance in Colab

Python programs have a typical structure

1. Load modules (external routines that provide more functionality)

   [You can basically ignore this part for now]

2. Set up ("**declare**") **variables**

   [Generally important to pick useful names for things]

3. Manipulate variables by **calling functions**, modules or other routines

   [In other words, do stuff and calculate things]

4. Display results in some helpful format or form

   [Basically – make and display plots]

Problem Set in Colab

For Problem Set 4

1. Navigate to https://colab.research.google.com/drive/1vVPZrTE2ir5Qkc_BBW41iuAjpOh0qjDh?usp=sharing
2. Make a copy and save it to your own Google Drive
3. Use your own copy to make changes until you are happy with your answers
4. Upload a pdf of your notebook as your submission to Blackboard (you can also make it accessible to anyone with a link and then share the link as your submission on Blackboard – however a pdf is easier). To do this, go to “File > Print > Save as PDF”

Summary

Topics

Today: Drag & computational physics

- Google colab
- Solving ODEs numerically

Tomorrow: Energy conservation [chap. 8]

- Types of energy
- Energy transfer
- Energy conservation
- Power

Friday: Momentum & Collisions

- Momentum
- Conservation of momentum
- Elastic & inelastic collisions

Announcements

This week: **Problem Set 4 posted**

PHYSICS 101 - HONORS

Lecture 18 10/5/22

Air resistance (slide 4)

Recall our: ← Lecture 13 9/26/22

linear model — $\bar{R} = -b\bar{v}$ ⇒ $mg - bv = ma$ ← "1st order ODE in v"

$$v = \frac{mg}{b}\left(1 + Ae^{-bt/m}\right)$$

Recall we solved this via

$$\int \frac{dv}{v - \frac{mg}{b}} = -\frac{b}{m}\int dt$$

$$v(t=0) = 0 \Rightarrow v(t) = \frac{mg}{b}\left(1 - e^{-bt/m}\right)$$

quadratic model — $\bar{R} = -\frac{D}{2}\rho A v^2 \hat{v}$ ⇒

$$m\frac{dv}{dt} = mg - \frac{D\rho A v^2}{2}$$

or

$$\frac{d^2x}{dt^2} = g - \frac{D\rho A}{2m}v^2$$ ← "2nd order ODE in x"

$$= g - \frac{D\rho A}{2m}\left(\frac{dx}{dt}\right)^2$$

$$\int \frac{dv}{g - kv^2} = \int dt$$

↑ $$\int \frac{dv}{g - kv^2} = -\frac{1}{\sqrt{gk}}\,\text{arctanh}\left(\sqrt{\frac{k}{g}}\,v\right)$$

$$\ddot{x} = g - \frac{D\rho A}{2m}\dot{x}^2$$

This can be rewritten as two 1st order ODEs, using new variables $u = x$ and $w = \dot{x}$

$$\Rightarrow \quad \dot{u} = w$$
$$\dot{w} = g - kw^2 \quad \Leftarrow \quad k \equiv \frac{D\rho A}{2m}$$

These are easier to solve numerically