PHY 711 Classical Mechanics and Mathematical Methods
10-10:50 AM MWF Olin 103

Welcome & overview

1. Class structure & announcements
2. Introduction to algebraic manipulation software – Maple and Mathematica

- Start reading Chap. 1 for next time

Course webpage -- http://users.wfu.edu/natalie/f21phy711/

PHY 711 Classical Mechanics and Mathematical Methods

MWF 10 AM-10:50 AM	**OPL 103**	**http://www.wfu.edu/~natalie/f21phy711/**

Instructor: Natalie Holzwarth	**Office:**300 OPL	**e-mail:**natalie@wfu.edu

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- General information
- Syllabus and homework assignments
- Lecture Notes

Last modfied: Wednesday, 11-Aug-2021 13:07:24 EDT

Course content –

Classical Mechanics and Mathematical Methods

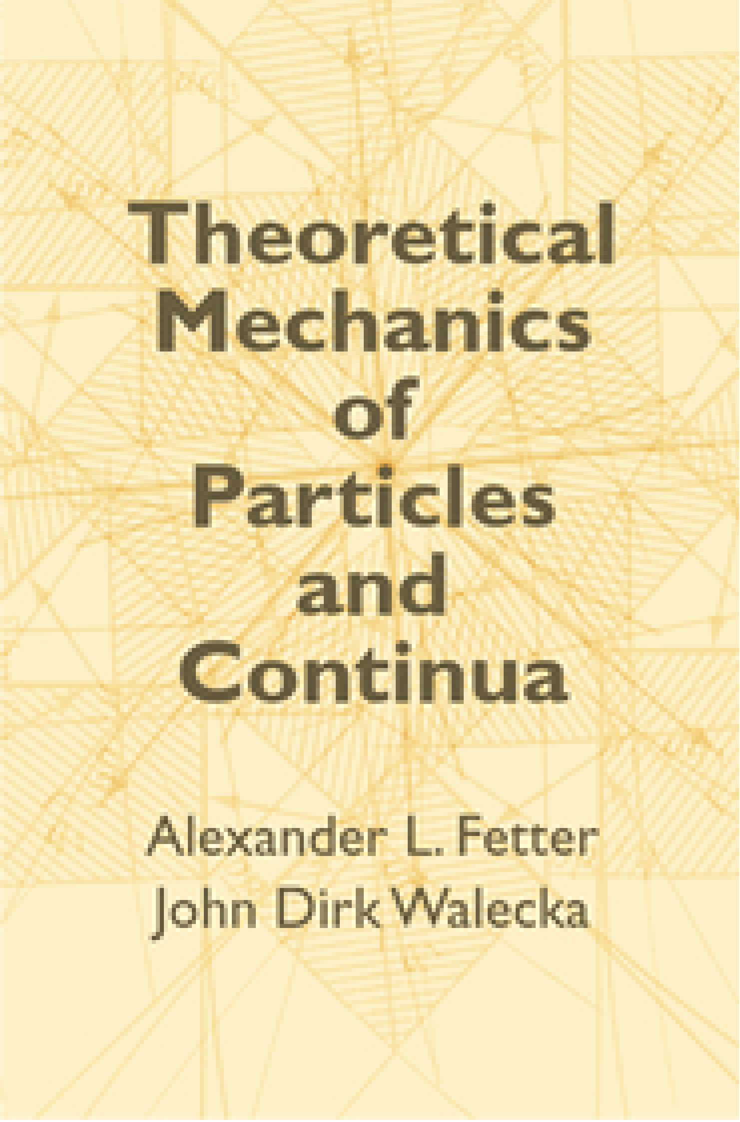
Comment – **Classical Mechanics is not Dead!**

While the topic of classical mechanics was well established by 1920 and much earlier, it forms the foundation of modern investigations, and its extensions can be found in many current research areas.

Examples:

1. Scattering theory/experiment – detailed interactions between a few particles
2. Rocket science/astrophysics
3. Limiting results of quantum mechanics
4. Atomistic simulations of materials – “molecular dynamics”
5. Mechanics of continua

Textbook:



SIGNIFICANT NAMES IN MECHANICS AND MATHEMATICAL PHYSICS'

Isaac Newton (1642–1727)
Daniel Bernoulli (1700–1782)
Leonhard Euler (1707–1783)
Jean Le Rond d'Alembert (1717–1783)
Joseph Louis Lagrange (1736–1813)
Pierre Simon de Laplace (1749–1827)
Adrien Marie Legendre (1752–1833)
Jean Baptiste Joseph Fourier (1768–1830)
Karl Friedrich Gauss (1777–1855)
Siméon-Denis Poisson (1781–1840)
Friedrich Wilhelm Bessel (1784–1846)
Augustin-Louis Cauchy (1789–1857)
George Green (1793–1841)
Carl Gustav Jacob Jacobi (1804–1851)
William Rowan Hamilton (1805–1865)
Joseph Liouville (1809–1882)
George Gabriel Stokes (1819–1903)
Hermann Ludwig Ferdinand Helmholtz (1821–1894)
Gustav Robert Kirchhoff (1824–1887)
William Thomson (Lord Kelvin) (1824–1907)
Georg Friedrich Bernhard Riemann (1826–1866)
John William Strutt (Lord Rayleigh) (1842–1919)

Topics

Classical Mechanics

- Scattering theory
- Accelerated reference frames
- Calculus of variation
- Lagrangian formalism
- Hamiltonian formalism
- Oscillations about equilibrium
- Wave equations
- Rigid rotation; moments of inertia
- Physics of fluids
- Sound waves in fluids and solids
- Surface waves
- Heat conduction
- Viscous fluids
- Elastic continua

Math Methods

- Use of Maple and/or Mathematica
- Solutions methods for differential equations
- Green's function methods
- Special functions
- Matrix properties; eigenvalues and eigenvectors
- Fourier transforms
- Laplace transforms
- Contour integration

Course structure -- continuously adjusting -- http://users.wfu.edu/natalie/f21phy711/info/

General Information

This course is a one semester survey of Classical Mechanics and Mathematical Methods at the graduate level, using the textbook: **Theoretical Mechanics of Particles and Continua** by Alexander L. Fetter and John Dirk Walecka (McGraw-Hill, 1980) (now published by Dover) -- **F&W**.

Having endured the difficulties brought by the pandemic during the past year, we are all looking forward to moving to the "normal" classroom interactions, mindful of the need for careful monitoring of the health situation and using tools such as zoom when necessary or convenient. The course will consist of the following components:

- In person meetings MWF 10-10:50 AM in Olin 103. Starting with the second meeting, the sessions will focus on discussion of the material, particularly answering your prepared and spontaneous questions.
- Asynchronous review of annotated lecture notes and corresponding textbook sections. Starting with Lecture 2, the annotated lecture notes will be available one day before the corresponding synchronous online discussion. For each class meeting, students will be expected to submit (by email) at least one question for class discussion at least 3 hours before the synchronous online meeting.
- Homework sets. Typically there will be one homework problem associated with each synchronous meeting.
- There will be two take-home exams, one at mid-term and the other during finals week.
- There will be one project on a chosen topic related to mechanics and/or mathematical methods.
- There will be weekly one-on-one meetings of each student with the instructor to discuss the course material, homework, and/or projects. These may be face-to-face or online as appropriate.

Course structure -- continuously adjusting -- http://users.wfu.edu/natalie/f21phy711/info/

It is likely that your grade for the course will depend upon the following factors:

Class participation	15%
Problem sets*	35%
Project	15%
Exams	35%

*In general, there will a new assignment after each lecture, so that for optimal learning, it would be best to complete each assignment before the next scheduled lecture. According to the honor system, all work submitted for grading purposes should represent the student's own best efforts.

Projected course dates --

Dates of note:

- Classes begin: Mon. Aug. 23, 2021
- Fall break: Fri. Oct. 8, 2021
- Take home mid term exam: Oct. 11-15, 2021
- Mid term grades due: Mon. Oct. 18, 2021
- Thanksgiving Holiday: Nov. 24-26, 2021
- Last day of class: Fri. Dec. 3, 2021
- Take home final exam: Dec. 6-10, 2021
- Final grades due: Wed. Dec. 15, 2021

Course structure -- continuously adjusting --
http://users.wfu.edu/natalie/f21phy711/homework/

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Instructor: Natalie Holzwarth	**Office:**300 OPL	**e-mail:**natalie@wfu.edu

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Course schedule

(Preliminary schedule -- subject to frequent adjustment.)

	Date	F&W Reading	Topic	Assignment	Due
1	Mon, 8/23/2021	Chap. 1	Introduction	#1	8/27/2021
2	Wed, 8/25/2021	Chap. 1	Scattering theory	#2	8/30/2021
3	Fri, 8/27/2021	Chap. 1	Scattering theory		
4	Mon, 8/30/2021	Chap. 1	Scattering theory		
5	Wed, 9/01/2021	Chap. 1	Scattering theory		
6	Fri, 9/03/2021	Chap. 2	Non-inertial coordinate systems		

First assignment

PHY 711 – Assignment #1

08/23/2021

1. Use maple or mathematica to evaluate and plot the integral

$$g(x) = \int_0^{\pi} \cos(x\cos(t))dt.$$

Note that the result is a “special function”.

Course structure -- continuously adjusting --
http://users.wfu.edu/natalie/f21phy711/info/computational.html

Project

The purpose of this assignment is to provide an opportunity for you to study a topic of your choice in greater depth. The general guideline for your choice of project is that it should have something to do with classical mechanics, and there should be some degree of of analytic or numerical computation associated with the project. The completed project will include a short write-up and a presentation to the class. You may design your own project or use one of the following list (which will be updated throughout the term).

- Consider a scattering experiment in which you specify the spherically symetric interaction potential V(r). Write a computer program (using your favorite language) to evaluate the scattering cross section for your system. (Depending on your choice, you may wish to present your results either in the the center-of-mass or lab frames of reference.)
- Consider the Foucoult Pendulum. Analyze the equations of motion including both the horizontal and vertical motions. You can either solve the equations exactly or use perturbation theory. Compare the effects of the vertical motion to the effects of air friction.
- Consider a model system of 2 or more interacting particles with appropriate initial conditions, using numerical methods to find out how the system evolves in time and space. For few particles and special initial conditions this approach can be used to explore orbital mechanics. For many particles and random initial conditions, this approach can be used to explore statistical mechanics via molecular dynamics simulations.
- Examine the normal modes of vibration for a model system with 3 or more masses in 2 or 3 dimensions.
- Analyze the soliton equations beyond what was covered in class.

Fall 2021 Schedule
for N. A. W. Holzwarth

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00-10:00	Lecture Preparation		Lecture Preparation		Lecture Preparation
10:00-11:00	Classical Mechanics PHY711	Physics Research	Classical Mechanics PHY711	Physics Research	Classical Mechanics PHY711
11:00-12:00	Office Hours		Office Hours		Office Hours
12:00-4:00					
4:00-5:00	Physics Research		Physics Research	Physics Colloquium	Physics Research

Note – Colloquium starts next week.

Additional schedule items

- Weekly Condensed Matter (Theory) PHY 363/663 seminari -- 1 hr
- Weekly one-on-one PHY 711 meetings -- 0.5 hr

What is the best way to turn in homework?

1. 1. On paper including maple or mathematica results
2. Email your annotated maple or mathematica output converted to pdf form.
3. Email scan or photo of written work.

Example HOMEWORK for PHY 711
8/23/2021 Natalie Holzwarth

Problem Set 0

The purpose of this problem set is to become familiar with the use of Maple, Mathematica, or Wolfram Alpha as a tool for analyzing mathematically complex problems. Choose one of the tools to visualize and solve the following problems.

1. Numerically find the values of x which satisfy the following equation.

```
> x^3-x^2=7
```

$$x^3 - x^2 = 7 \quad (1)$$

Use graphics to help visualize the problem.

2. Find the following integral as a function of x.

```
> g := x→int(exp(-s^2), s=0..x)
```

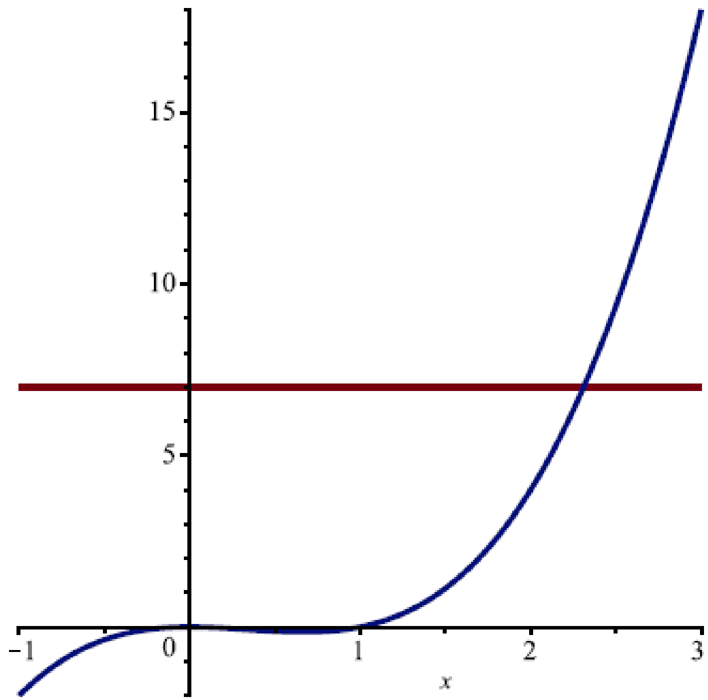
$$g := x \mapsto \int_0^x e^{-s^2} \, ds \quad (2)$$

Use graphics to help you visualize the integrand and the intregral.

Problem Set #0 continued

1.

> $plot(\{x^3 - x^2, 7\}, x = -1..3);$



> $fsolve(x^3 - x^2 = 7, x = 2.5)$

$$2.310852163 \quad \mathbf{(3)}$$

2. We can use maple to evaluate the integral

> $g := x \rightarrow int(\exp(-s^2), s = 0..x)$

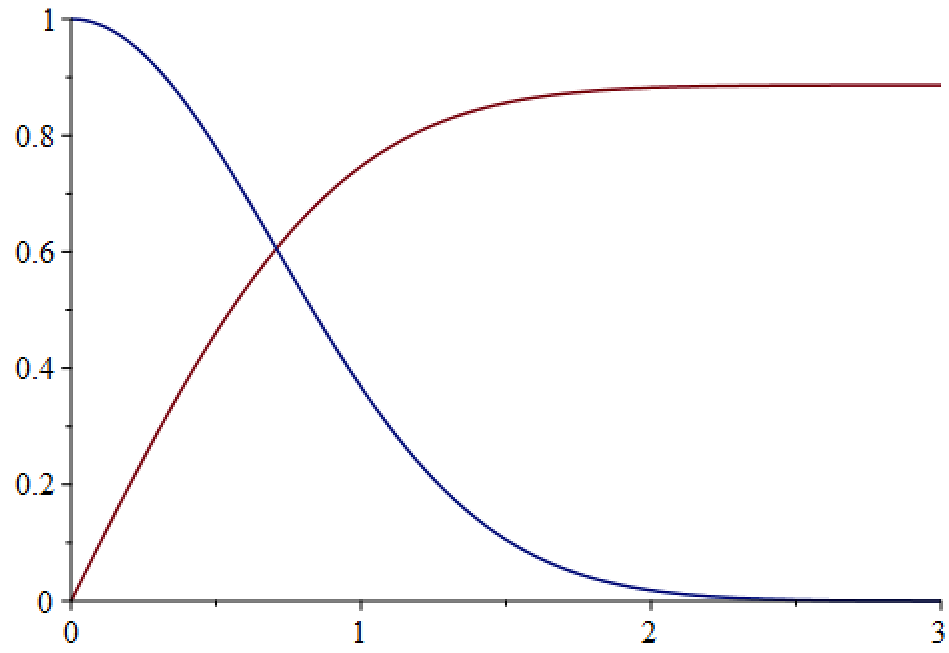
$$g := x \mapsto \int_0^x e^{-s^2}\, ds$$

> $g(x)$

$$\frac{\sqrt{\pi}\ \mathrm{erf}(x)}{2}$$

special function

$plot(\{\exp(-u^2), g(u)\}, u = 0..3)$



Results using Mathematica --

In[ ]:= Solve[x^3 - x^2 == 7, x]

Out[ ]= $\left\{\left\{\left\{\left\{x \to \frac{1}{3}\left(1+\left(\frac{191}{2}-\frac{3\sqrt{4053}}{2}\right)^{1/3}+\left(\frac{1}{2}\left(191+3\sqrt{4053}\right)\right)^{1/3}\right)\right\},\right.\right.\right.$

$\left\{x \to \frac{1}{3}-\frac{1}{6}\left(1+i\sqrt{3}\right)\left(\frac{191}{2}-\frac{3\sqrt{4053}}{2}\right)^{1/3}-\frac{1}{6}\left(1-i\sqrt{3}\right)\left(\frac{1}{2}\left(191+3\sqrt{4053}\right)\right)^{1/3}\right\},$

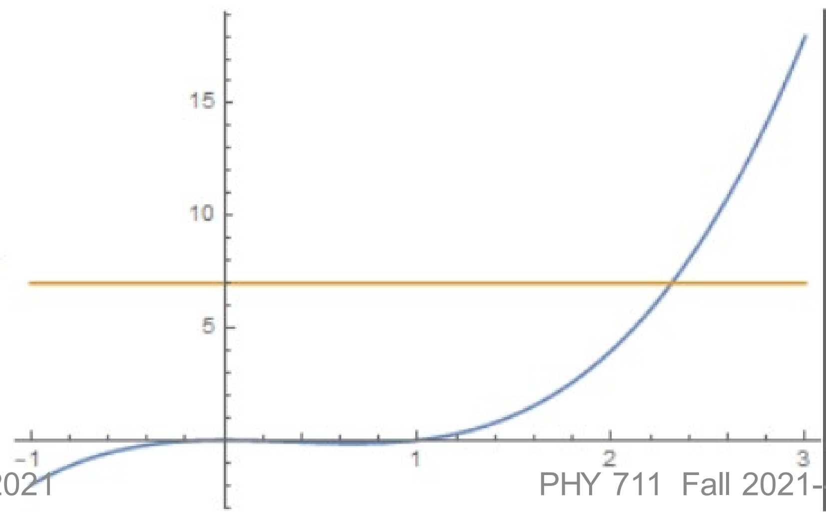
$\left.\left.\left.\left\{x \to \frac{1}{3}-\frac{1}{6}\left(1-i\sqrt{3}\right)\left(\frac{191}{2}-\frac{3\sqrt{4053}}{2}\right)^{1/3}-\frac{1}{6}\left(1+i\sqrt{3}\right)\left(\frac{1}{2}\left(191+3\sqrt{4053}\right)\right)^{1/3}\right\}\right\}\right\}, \{\square\}\right\}$

In[ ]:= NSolve[x^3 - x^2 == 7, x]

Out[ ]= {{{{x → -0.655426 - 1.61233 i}, {x → -0.655426 + 1.61233 i}, {x → 2.31085}}}, {□}}

In[ ]:= Plot[{x^3 - x^2, 7}, {x, -1, 3}]

Out[ ]=



Additional help with mathematical software – https://www.physics.wfu.edu/resources/education-resources/

WFU Physics   People   Events & News   Undergraduate   Graduate   Research   Resources

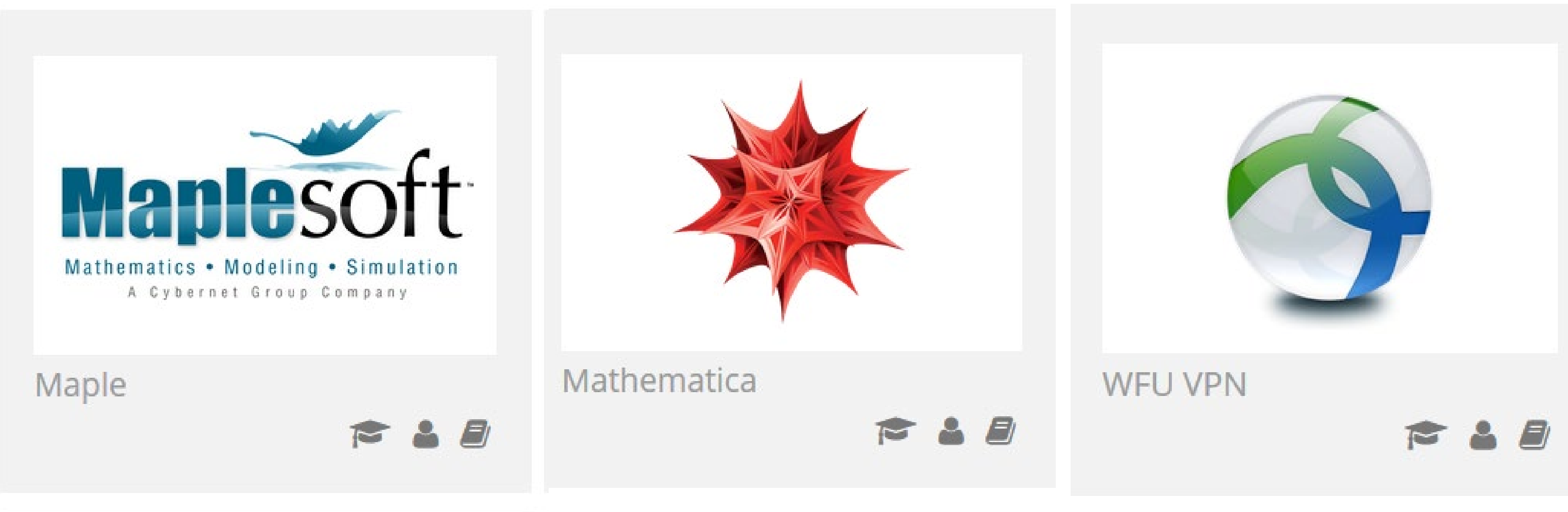
GUIDE TO MATHEMATICAL SOFTWARE AT WFU

While our ancestors used slide rules and calculators, 21st century Physicists have the opportunity to use a variety of powerful software tools for problem solving, analysis, and visualization. The Wake Forest Community has many of these tools available from the web page available for PC and MAC formats. The licensing is handled on campus through the campus network or through VPN off campus. The following software packages are used in several physics courses at various levels and more generally by scientists and engineers throughout the world. All of these tools require some effort to realize their capabilities. The links below provide some instructions and examples on how to use each tool.

- Matlab — for numerical analysis and visualization
- Mathematica — for analytical analysis and visualization
- Maple — for analytical analysis and visualization
- Excel, Google Sheets & Numbers — for spreadsheet analysis and plotting

Comment on software useful for this course

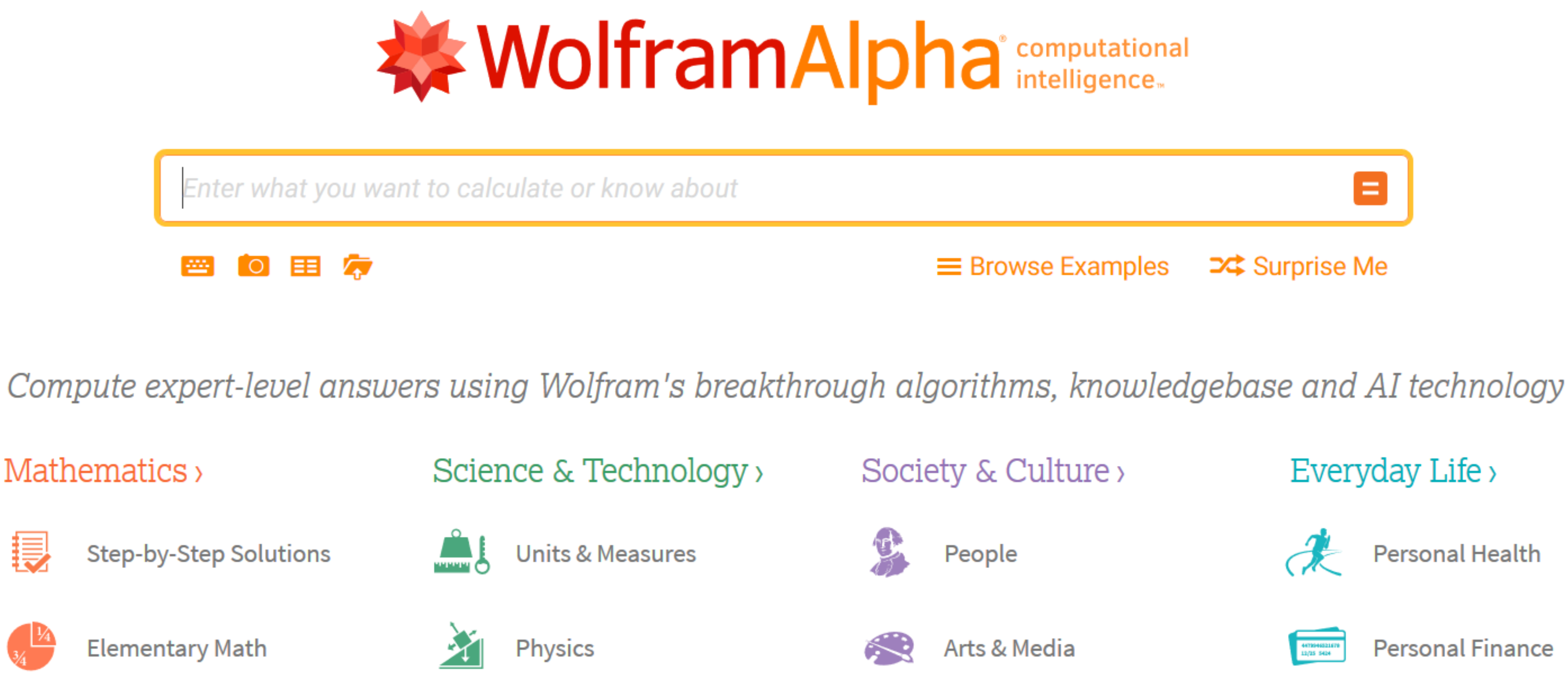
https://software.wfu.edu/



Installation straightforward; takes a while ..
Please contact me or yipcw@wfu.edu if you have trouble.

Other possibilities –

http://www.wolframalpha.com/



Advice for preparing for Wednesday's meeting –

1. Start reading Chapter 1 of F&W. The annotated lecture notes will be available by 9 AM (Winston-Salem time) on August 24th. While reading, formulate your questions and discussion points.
2. Email (natalie@wfu.edu) your discussion questions by 7 AM on August 25th.
3. Decide which algebraic manipulation software you prefer. As appropriate, install it on your computer and become familiar with it.
4. Email (natalie@wfu.edu) with your preferences for weekly (or more) one-on-one meetings. Face to face or zoom meetings are possible as appropriate.

Brief assessment exercise.