

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. 3 for next time**

Course webpage -- <http://users.wfu.edu/natalie/f24phy711/>

PHY 711 Classical Mechanics and Mathematical Methods

MWF 10 AM-10:50 AM || OPL 103 || <https://www.wfu.edu/~natalie/f24phy711/>

Instructor: [Natalie Holzwarth](#) || Office: 300 OPL || e-mail: natalie@wfu.edu

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- [General information](#)
 - [Syllabus and homework assignments](#)
 - [Lecture Notes](#)
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Last modified: Wednesday, 21-Aug-2024 17:41:39 EDT

Course content –

Classical Mechanics and Mathematical Methods

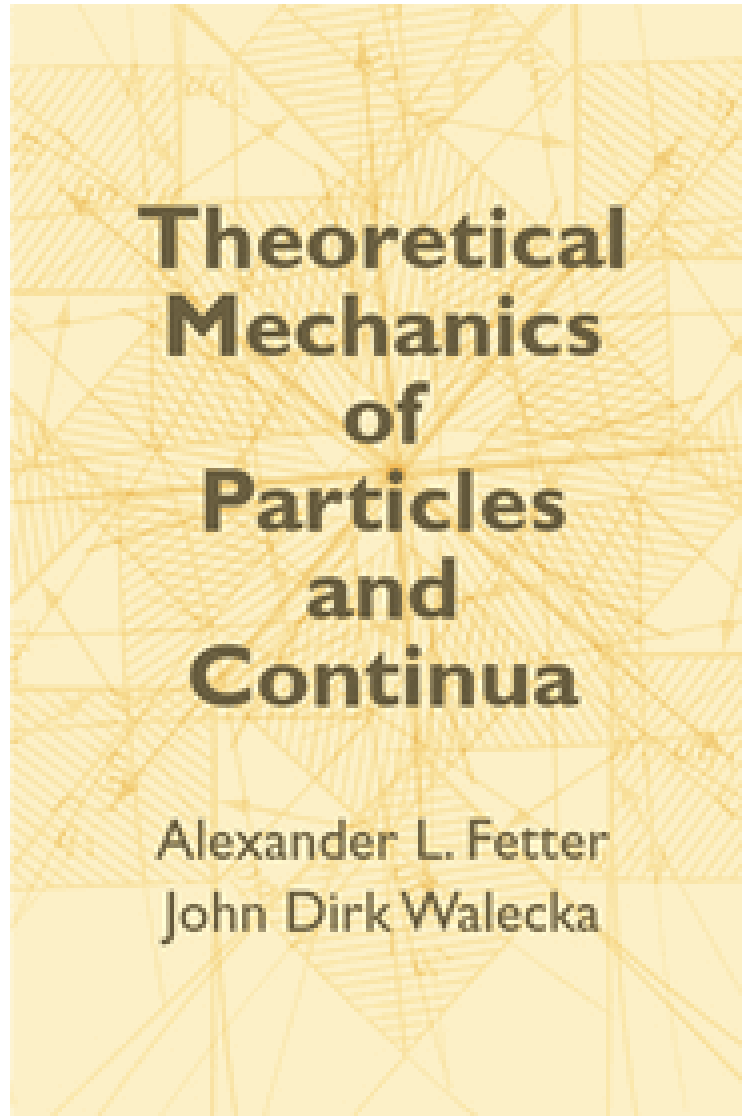
Comment – **Classical Mechanics is not Dead!**

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
- } **First**
- 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/f24phy711/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) -- **F&W** -- (now published by [Dover](#) and available at the bookstore).

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 class. The practice of formulating questions is one of the important tools of science. Note that there are no "silly" questions.
 - Homework sets. Typically there will be one homework problem associated with each class, due the following Monday.
 - 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.
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*The classroom is equipped with technology for zoom connections if needed. Student needing such accomodation should email [instructor](#) at least 10 minutes before class.

Course structure -- continuously adjusting --

<http://users.wfu.edu/natalie/f24phy711/info/>

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

Class participation	15%
<u>Problem sets</u> *	35%
<u>Project</u>	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. 26, 2024
- Take home mid term exam: Oct. 4-11, 2024 (tentative)
- Mid term grades due: Mon. Oct. 14, 2024
- Fall break: Oct. 17-20, 2024
- Thanksgiving Holiday: Nov. 27 - Dec. 1, 2024
- Last day of class: Fri. Dec. 6, 2024
- Take home final exam: Dec. 9-14, 2024
- Final grades due: Wed. Dec. 18, 2024

Course structure -- continuously adjusting --
<http://users.wfu.edu/natalie/f24phy711/homework/>

Course schedule

(Preliminary schedule -- subject to frequent adjustment.)

	Date	F&W	Topic	HW
1	Mon, 8/26/2024		Introduction and overview	#1
2	Wed, 8/28/2024	Chap. 3(17)	Calculus of variation	
3	Fri, 8/30/2024	Chap. 3(17)	Calculus of variation	
4	Mon, 9/02/2024	Chap. 3	Lagrangian equations of motion	
5	Wed, 9/04/2024	Chap. 3 & 6	Lagrangian equations of motion	
6	Fri, 9/06/2024	Chap. 3 & 6	Lagrangian equations of motion	
7	Mon, 9/09/2024	Chap. 3 & 6	Lagrangian to Hamiltonian formalism	
8	Wed, 9/11/2024	Chap. 3 & 6	Phase space	
9	Fri, 9/13/2024	Chap. 3 & 6	Canonical Transformations	

First assignment

PHY 711 – Assignment #1

Assigned: 08/26/2024 Due: 09/02/2024

1. Use maple or mathematica to evaluate the integral and plot $g(x)$

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

Note that $g(x)$ is a “special function”.

Course structure -- continuously adjusting --

<http://users.wfu.edu/natalie/f24phy711/info/project.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 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).

- Explain the details of a homework problem that was assigned or one you design, including the basic principles and the solution methods and results.
- Consider a scattering experiment in which you specify the spherically symmetric 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 center-of-mass or lab frames of reference.)
- Consider the Foucault 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 2024 Schedule
for N. A. W. Holzwarth**

	Monday	Tuesday	Wednesday	Thursday	Friday	
9:00-10:00	Lecture Preparation / Office Hours	Physics Research	Lecture Preparation / Office Hours	Physics Research	Lecture Preparation / Office Hours	
10:00-11:00	Classical Mechanics: PHY 711		Classical Mechanics: PHY 711		Classical Mechanics: PHY 711	
11:00-12:00	Office Hours		Office Hours		Condensed Matter Seminar	
12:00-4:00	Physics Research		Physics Research		Physics Department Colloquium	Physics Research
4:00-5:00						

Note: NAWH is happy to meet with you during office hours or at other times.



Note – Colloquium starts this week.

What is the best way to turn in homework?

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.

*Note that other software also can be used AS LONG AS you include annotated input/output of the results.

Example HOMEWORK for PHY 711

8/26/2024 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. (In this case we are using Maple)

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

$$\text{> } x^3 - x^2 = 7$$

$$x^3 - x^2 = 7 \tag{1}$$

Use graphics to help visualize the problem.

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

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

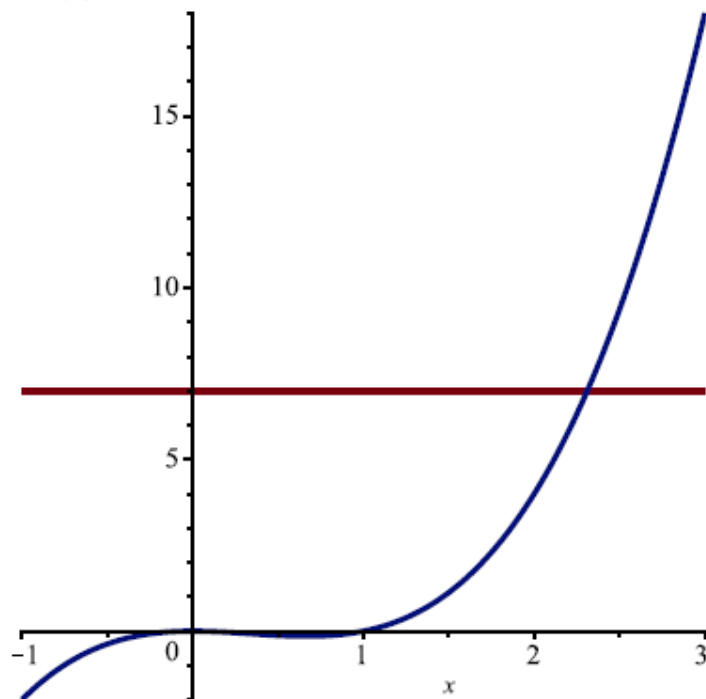
$$g := x \mapsto \int_0^x e^{-s^2} ds \tag{2}$$

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

Problem Set #0 continued

1.

```
> plot({x3 - x2, 7}, x=-1..3);
```



```
> fsolve(x3 - x2 = 7, x = 2.5)
```

2.310852163

(3)

2. We can use maple to evaluate the integral

```
> g := x → int(exp(-s2), s = 0 .. x)
```

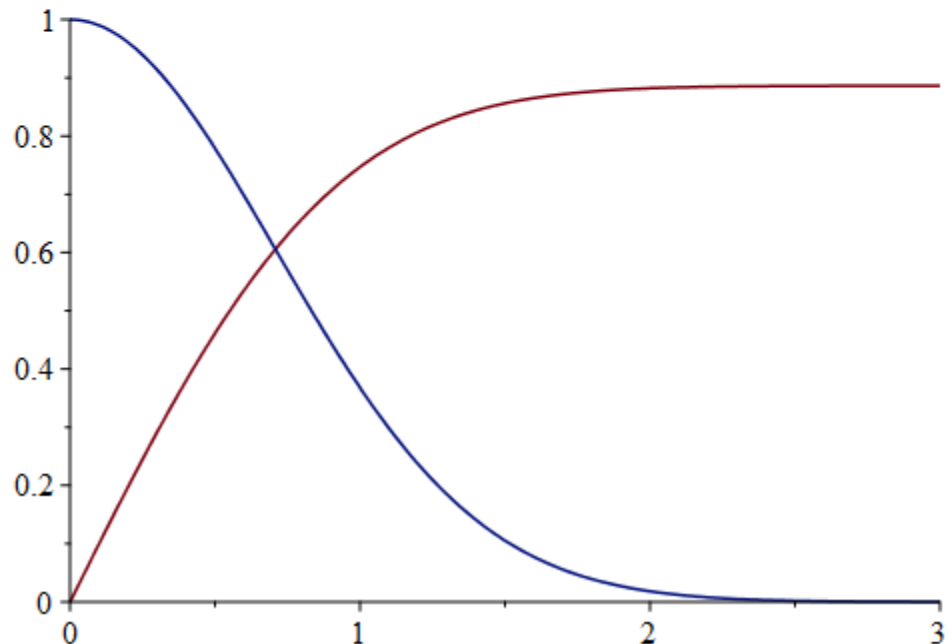
$$g := x \mapsto \int_0^x e^{-s^2} ds$$

```
> g(x)
```

special function

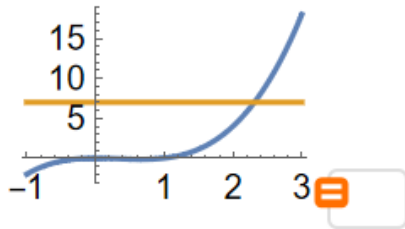
$$\frac{\sqrt{\pi} \operatorname{erf}(x)}{2}$$

```
plot({exp(-u2), g(u)}, u = 0 .. 3)
```



Results using Mathematica --

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



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

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

Additional help with mathematical software –

<https://www.physics.wfu.edu/resources/education-resources/>

WFU Physics

People

Events & News

Undergraduate

Graduate

Research

Resources

(Actually, web page needs updating which will hopefully happen soon.)

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/>



Maple



Mathematica



WFU VPN



Installation straightforward; takes a while ..

Please contact me or yipcw@wfu.edu if you have trouble.

Other possibilities –

<http://www.wolframalpha.com/>



Enter what you want to calculate or know about



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Physics

Society & Culture >

People

Arts & Media

Everyday Life >

Personal Health

Personal Finance

Advice for preparing for Wednesday's meeting –

1. Start reading Chapter 3(17) of F&W and other references on the calculus of variation. Annotated lecture notes will be available by 9 AM on August 27th.
2. While reading, formulate your questions and discussion points.
3. Email (natalie@wfu.edu) your discussion questions by 7 AM on August 28th.
4. Decide which algebraic manipulation software you prefer. As appropriate, install it on your computer and become familiar with it.

Brief assessment exercise.