

# Physics 6101 Classical Mechanics

Fall Semester 2024

Version 1.2

Last Updated on August 14th 2024

## Goal

Comprehensive understanding of formal Classical Dynamics in Lagrange and Hamiltonian formalisms towards an introduction to modern physics such as General Relativity and Quantum Mechanics.

## Instructor

**Dr. Shun Saito**

Office: Physics 106

Office hours: 1:45-3:45pm on Thursday or by email appointment

Email: [saitos@mst.edu](mailto:saitos@mst.edu)

## Meeting time and location

Tuesday and Thursday, 12:30pm-1:45pm@Physics 127

All announcements and resources will be available **on One Canvas**.

## Textbook

Required:

1) **Goldstein, Poole, and Safko, “Classical Mechanics (3rd edition)”**

Be aware that there are MANY typos: Check out [the author’s website](#).

2) **Helliwell & Shakian, “Modern Classical Mechanics”**

Supplements:

3) Wells, “Lagrangian Dynamics”

4) Landau & Lifshitz, “Mechanics”

5) Marion & Thornton, “Classical Dynamics of Particles and Systems”

6) Soper, “Classical Field Theory”

## Class Structure

On Tuesday, a class will consist of a simple blackboard lecture. On Thursday, the last 30-minute portion of each class will be devoted to solving **Practice Problems**. The Practice Problem set will be basic questions which will help students solve Homework Problems. The answer keys to Practice Problems will be available with the Homework Problem set on Thursday, and students are NOT required to turn in their work on Practice Problems. Students are encouraged to work on Homework Problems after each Thursday class when the official office hours are set.

## Grading

A  $\cong$  535, B  $\cong$  475, C  $\cong$  415 for 600 total points whose break down is following:

Homework	200
Exam I	120
Exam II	120
Final Exam	160
<hr/>	
Total	600

## Homework

Problem sets will be due every week (except for the first week and post-exam weeks) in class (namely 12:30pm) on **Tuesday**. Homework will be collected electrically in a form of **PDF file on Canvas**. Each homework will be graded on Canvas with **maximum of 20 points**, and returned by the next class. **Any late submission is subject to a 2-point subtraction**. The minimum two scores out of 12 submissions will be dropped.

## Exam

There will be two mid-term exams scheduled during a regular class in addition to a final exam. The first two in-class exams will cover the materials specified in "Schedule", and will be graded with maximum of 120 points. The final exam is officially scheduled during 7:30-9:30am on Tuesday, 12/12 (but will likely to happen before the final week), and will cover the first two exams and the few more chapters covered after Exam II.

## **Course attendance policy**

Students are required to attend all classes. Please do not arrive late to class or leave early unless you have been previously excused by the instructor. Of course, if you are taken ill during class, or in case of an emergency, feel free to leave. However, as soon as you feel better, or the emergency is over, let the instructor know the reason why you left. The instructor will not solicit details of the occurrence, or any personal or private information. Students with inadequate attendance may be dropped. Any student who has inadequate attendance, as evidenced by 5 (five) confirmed absences or by missing a total of 5 (five) graded assignments of any kind (exams and homework) are subject to being dropped if a subsequent class or assignment is missed. The University requires that all students have their course attendance verified at least once during the first two weeks of the semester. If your attendance is not verified, then you will be dropped from the course and any financial aid will be adjusted accordingly.

In case you are/may be exposed to COVID-19, please follow [the university guideline](#). Please notify the instructor as soon as you expect to be absent in a class due to sickness. If it involves multiple students particularly for COVID-19, the instructor will flexibly deal with an individual case.

## **Statement about Copyright, FERPA, and Use of Video**

It is vitally important that our classroom environment promote the respectful exchange of ideas. This entails being sensitive to the views and beliefs expressed during discussions, whether in class or online. Please obtain instructor permission before recording any class activity. It is a violation of University of Missouri policy to distribute such recordings without authorization and the permission of all who are recorded. More information is provided [online](#).

## **Accessibility and Accommodations**

It is the university's goal that learning experiences be as accessible as possible. Student Accessibility and Testing provides services and accommodations that facilitate full participation in Missouri S&T's learning experience for students with disabilities. If you anticipate or experience physical, academic, and/or digital barriers due to a disability, please contact Student Accessibility and Testing at (573) 341-6655, email [dss@mst.edu](mailto:dss@mst.edu), or visit <https://saat.mst.edu/> for information.

## **Student Honor Code and Academic Integrity**

- All students are expected to follow the [Honor Code](#).
- [Student Academic Regulations](#) describes the student standard of conduct relative to the University of Missouri System's Collected Rules and Regulations section 200.010, and offers descriptions of academic dishonesty including cheating, plagiarism, sabotage, and **unauthorized use of artificially generated content**, any of which will be reported to the Vice Provost for Undergraduate Education.
- Other resources for students regarding academic integrity can be found [online](#).

## **Student Well-Being**

Your well-being is important, and it contributes to your success in this course. At S&T, we provide resources to support your mental, physical, and social well-being. Any of us can experience challenges that make learning difficult. If you are struggling, take advantage of the following resources offered by the university:

### **Student Well-Being**

Student Well-Being provides counseling services, health promotion initiatives, and prevention programs to empower the S&T community to thrive and enhance personal, academic, and professional success. Department office hours are Monday-Friday, 8 a.m. – 5:00 p.m. On the website, you can find information related to confidential individual and group counseling, wellness consultations and trainings, resources for many health and wellness topics, and help for mental health crisis situations. For the 988 Suicide and Crisis Lifeline, call or text 988, or visit [missouri988.org](https://missouri988.org). For the National Suicide Prevention Lifeline, call or text 988, or visit [missouri988.org](https://missouri988.org).

### **Health and Well-Being Canvas Course**

The Health and Well-Being Canvas Course features trainings, presentations, and other health and well-being resources for students. The course is free for all students, is non-credit, and students can enroll at any point in the semester.

[Student Support and Community Standards](#) is your “Google Maps” for support. During your time at S&T, you or a friend may need help navigating their student experience, facing a barrier, or experiencing a challenge. You are not alone!

Student Support has a dedicated team and numerous resources such as [UCARE](#) and the [student emergency fund](#) to help you navigate the S&T experience and support your success. This includes support to address barriers related to academic, personal, emotional,

medical, financial, or any other needs. All students can learn and grow from challenges or setbacks, they are stepping stones to success and we are here to help.

## **Nondiscrimination, Equity, and Title IX**

Missouri S&T is committed to the safety and well-being of our campus community, and to creating an environment free from discrimination and harassment.

The University prohibits discrimination and harassment on the basis of race, color, national origin, ancestry, religion, sex, pregnancy, sexual orientation, gender identity, gender expression, age, disability, protected veteran status, and any other status protected by applicable state or federal law. As used in this policy, the word “sex” is also inclusive of the term “gender.”

Additionally, US Federal Law Title IX states that no member of the university community shall, on the basis of sex, be excluded from participation in, or be denied benefits of, or be subjected to discrimination under any education program or activity. Sexual harassment violations of this law include quid pro quo, hostile environment, sexual assault, dating/ domestic violence, and stalking. The U.S. Department of Education has stated the prohibition on discrimination on the basis of sex includes sexual orientation and gender identity.

Students who are experiencing pregnancy or pregnancy-related conditions, including the birthing parent and non-birthing parent, have rights protected under Title IX. Students should contact the Office of Equity and Title IX to learn more about their rights and pregnancy-related assistance/accommodations provided by the University to ensure equitable access to University educational programs and activities.

In accordance with the University of Missouri’s Collected Rules and Regulations, all faculty and staff are required to report any information concerning discrimination disclosed through communication including, but not limited to, direct conversation, email, social media, classroom papers and homework exercises to the Equity Officer/Title IX Coordinator.

For more information regarding support for those that have been impacted or to report an incident of discrimination or harassment as defined by [Chapter 600](#) of the University’s Collected Rules and Regulations, visit the Office of Equity and Title IX or visit their website at [equity.mst.edu](http://equity.mst.edu).

## **Office of Equity and Title IX**

Equity Officer and Title IX Coordinator: Dr. Paul Hirtz

Phone: (573) 341-7734

Location: 900 Innovation Drive, Suite 500

E-mail: [equity@mst.edu](mailto:equity@mst.edu)

## **Classroom Egress Maps**

For all in-person instruction, faculty should explain where the classroom emergency exits are located. Classroom egress maps are posted at <http://designconstruction.mst.edu/floorplan/>.

## **University Libraries**

The Curtis Laws Wilson Library is the place to gather on campus, offering group meeting spaces, quiet study carrels and reservable conference rooms. The library provides students and faculty with physical and electronic books, journals, articles and databases as well as recreational reading, games and DVDs. We also have technology to check out, from laptops to chargers to calculators and everything in-between. Librarians create library and course guides to help navigate searching for resources. Talk to us one-on-one via chat, email, phone or in person for any assistance regarding library services or finding peer-reviewed, credible research materials for study and research needs. Find out more information and connect with the library here: [library.mst.edu](http://library.mst.edu).

## **Writing and Communication Center**

The Writing and Communication Center's mission is to assist all students in their efforts to become better writers, communicators, and critical thinkers. The Center's peer consultants and coaches provide free individualized one-on-one and small-group conversations to offer meaningful feedback and guidance to students across all disciplines. More information can be found on our website, through email: [writing@mst.edu](mailto:writing@mst.edu) or stop by Curtis Laws Wilson Library 314-315.

## **Student Success Center**

The Student Success Center (SSC) supports student development through peer Academic Mentoring focusing primarily on STEM courses, peer-to-peer soft skill coaching which can also act as an accountability buddy, and campus programming – all while providing free coffee and hot beverages! All undergraduate students are encouraged to utilize the SSC's free services to get timely support and to enhance their S&T Miner Experience. Contact us at [success@mst.edu](mailto:success@mst.edu) OR 573-341-7590. To see the course offerings and times for SSC Academic Mentoring, visit <https://studentsuccess.mst.edu/academicmentoring/>.

## **S&T Tutoring Opportunities**

The Student Success Center (SSC) helps you with your studies in three ways:

- **LEAD Drop-in:** Our LEAD Drop-in service provides convenient access to experienced peer learning assistants for a multitude of courses across campus. No appointments necessary. Simply check our tutoring schedule to discover when support for your specific course is available: <https://ssc.mst.edu/leaddrop-in/>
- **LEAD Group Sessions:** Our LEAD Group sessions offer after-hours group tutoring, facilitated by our dedicated peer learning assistants in partnership with faculty members. Explore the LEAD Group schedule to see if your course is featured and join us at the next session: <https://ssc.mst.edu/leadgroup/>
- **Knack Tutoring:** If your schedule clashes with our LEAD offerings, or if your course isn't covered, Knack is your solution. Request a tutor for either a virtual meeting or an in-person session on campus, ensuring you get the help you need, when you need it. To sign up for your FREE Knack account, visit: <https://ssc.mst.edu/knacktutoring/>

## **Student Veterans Resource Center**

The Student Veterans Resource Center (SVRC) is the nexus of resources and support for student veterans at S&T. The SVRC provides student veterans with a “safe space” and a familiar atmosphere. The center's Veteran Consuls provide one-on-one consultations to guide students to various resources on campus, while its advisor provides students with VA health and benefits resources. Visit the SVRC at Harris Hall, Suite G10, and contact us at [svrc@mst.edu](mailto:svrc@mst.edu).

## **Changes to syllabus**

If a revision of the syllabus becomes necessary during the semester, it will be discussed in a class. Any changes to the syllabus will be posted on Canvas.

## **Statement of agreement**

Please carefully review and print for your records this syllabus. By taking this class, you confirm you have read and understood this document and are agreeable to the policies and provisions set forth therein.

## Schedule

Number	Date	Contents	Homework due
1	Tue, 8/20	<b>Overview, 1.1, 1.2</b>	
2	Thu, 8/22	<b>1.2, 1.3</b>	
3	Tue, 8/27	<b>1.4, 1.5</b>	HW#1
4	Thu, 8/29	<b>1.6</b>	
5	Tue, 9/3	<b>2.1, 2.2, 2.3</b>	HW#2
6	Thu, 9/5	<b>2.4</b>	
7	Tue, 9/10	<b>2.6, 2.7, 3.1</b>	HW#3
8	Thu, 9/12	<b>3.2, 3.3, 3.5</b>	
9	Tue, 9/17	<b>3.4, 3.6</b>	HW#4
10	Thu, 9/19	<b>3.7, 3.8, 3.9</b>	
11	Tue, 9/24	<b>Practice Problems for Exam I</b>	HW#5
	Wed, 9/25	Special Office hours for Exam I	
<b>E1</b>	Thu, 9/26	<b>1st Exam [Chap. 1, 2, 3]</b>	
12	Tue, 10/1	[Prerecorded] <b>3.10, 3.11</b>	
13	Thu, 10/3	[Prerecorded] <b>HS 9.1, 9.2, 9.3</b>	
14	Tue, 10/8	[Prerecorded] <b>HS 9.4, 9.5</b>	HW#6
	Thu, 10/10	No lecture (Fall Break)	
15	Tue, 10/15	<b>HS 12.1-12.4</b>	HW#7
16	Thu, 10/17	<b>HS 12.7-12.10</b>	
17	Tue, 10/22	<b>HS 12.11-12.12</b>	HW#8
18	Thu, 10/24	<b>HS 12.13</b>	
19	Tue, 10/29	<b>Practice Problems for Exam II</b>	HW#9
	Wed, 10/23	Special Office hours for Exam II	
<b>E2</b>	Thu, 10/31	<b>2nd Exam [Chap. 3, HS9, HS12]</b>	
20	Tue, 11/5	<b>8.1</b>	
21	Thu, 11/7	<b>8.2, 9.1</b>	
22	Tue, 11/12	<b>9.2, 9.5</b>	HW#10

<b>Number</b>	<b>Date</b>	<b>Contents</b>	<b>Homework due</b>
23	Thu, 11/14	<b>9.3, 9.4</b>	
24	Tue, 11/19	<b>7.1, 7.2</b>	HW#11
25	Thu, 11/21	<b>7.3, 7.4</b>	
	Tue, 11/26	No lecture (Thanksgiving Break)	
	Thu, 11/28	No lecture (Thanksgiving Break)	
26	Tue, 12/3	TBD for adjustment	HW#12
	Wed, 12/4	Special Office hours for Final Exam	
<b>FE</b>	Thu, 12/5	<b>Final Exam</b>	

# Why Classical/Analytic Mechanics even at a graduate level?

Shun Saito  
August 2022

*“Scientists do not research the nature because it is useful. They do research because it is joy, and it is joy because the nature is beautiful. If the nature is not beautiful, it is not worth while spending tremendous efforts to understand it and even finding the meaning of our lives.”*  
-Henri Poincaré: Science et méthode (1908)

If you think that your goal in learning Classical Mechanics is to be able to solve Newtonian equations given a situation (for instance to pass the Qualifying Exam), you don't even need to take this course seriously (I know this is a required course in the physics graduate program). I encourage highly you to completely change your motivation.

It is not wrong to say analytic mechanics is a reformulation of the Newtonian dynamics. At the level of physics, this course will not add anything complexly new beyond the Newtonian physics which you learned when you were a freshman/sophomore. You may be a physics major who has already learned basics of analytic mechanics during your undergraduate program. In any cases I guess it is natural for you to ask “why we need to learn the Classical Mechanics again and what is the point to even learn a formal aspect of it?”

Usual answers to these questions I often encounter include:

- Analytic mechanics is an introduction to a paradigm shift to modern physics including Quantum Mechanics (and Quantum Field Theory) and General Relativity.
- Newton's laws are not derived from any principles. Analytic mechanics provides a principle to derive Newtonian dynamics. Similarly, it provides a guiding principle to formulate a new theory in Physics.

I completely agree with these answers and statements, but argue that they are not satisfactory and just consequentialism from the modern people's point of view. Looking back the physics history, we know Lagrange and Hamilton developed their formulation in 18th and 19th century, respectively, long before the foundation of QM and GR. Imagine why Lagrange and Hamilton did so. I believe a short answer lies essentially in the excellent quote by Henri Poincaré. This is the reason why I accepted to teach this course, and I am hoping that this is the motivation to drive your hard work and joy in this course.