PHYS 2P20 - Introductory Mechanics
Course outline
Instructor: E. Sternin

About this course

Official Brock Calendar entry for this course:

> **PHYS 2P20 - Introductory Mechanics**
> Mechanics of particles and systems of particles by the Newtonian method; conservation of linear momentum, angular momentum and energy; elementary dynamics of rigid bodies; oscillators; motion under central forces; selected applications.
>
> **Course Format:** Lectures, problem sessions, 3 hours per week; lab, tutorial, 3 hours per week.
> **Prerequisite(s):** PHYS 1P21 or PHYS 1P91 or PHYS 1P95 (recommended); PHYS 1P22 or PHYS 1P92 or PHYS 1P96 (recommended); MATH 1P01 and MATH 1P02, or MATH 1P05 and MATH 1P06 (recommended), or MATH 1P07 and MATH 1P08
> **Course Notes:** Materials fee required. This course may be offered in multiple modes of delivery. The method of delivery will be listed on the academic timetable, in the applicable term.

What do I need to bring into the course?

» This course is a core course of the Physics program, and requires Y1 Physics and Math courses as prerequisites.

Course Goals

» to develop a more comprehensive understanding of Newton's laws of motion and their origin in and application to real physical systems;
» to discover the underlying conservation laws and the manner in which physical systems evolve with time;
» to gain experience in the use of advanced mathematical tools (e.g. advanced algebra and trigonometry, analytic geometry, differential and integral calculus, differential equations);
» to develop experimental data analysis, error estimation, and numerical modelling skills;
» to enhance scientific writing skills.

Textbook

» *An Introduction to Mechanics*, second edition, by Daniel Kleppner and Robert Kolenkow. Cambridge University Press, 2013.

Topics to be covered

This is an approximate list, based on previous experience. As the course progresses, some of topics may be removed and some others may get added.

» **Vectors, a review of concepts**
  » algebra of vectors
  » multiplication of two vectors: dot- and cross-products
  » base vectors, orthonormality
  » derivatives of vectors

» **Kinematics in 2D and 3D**
  » elementary kinematics
  » **Ex:** uniform circular motion
  » solving kinematic equations
  » 2D motion in polar coordinates
  » approximation methods: Taylor series and related expansions

» **Newton's Laws**
  » Newton's Laws
  » inertial and non-inertial frames
  » procedure for applying Newton's Laws to complex systems
  » examples; constraints; non-physical solutions
  » linear restoring force
  » momentum, impulse

» work and kinetic energy

» **Harmonic oscillator**
» potential energy, damping, formal solutions to the DE
» classification of solutions, under- over- and critically-damped cases
» quality factor Q
» forced (driven) HO, resonance
» **Ex:** analogy with LCR circuits

» **Kinematics in 3D**
» work and energy in 3D, potentials, conservative forces
» momentum of a system of particles
» center-of-mass, extended bodies, c.o.m. coordinates
» rocket motion
» momentum transport
» collisions between masses
» collisions and the c.o.m. coordinates

» **Rotational motion and angular momentum**
» angular momentum of a particle
» importance of the 3rd dimension: a conical pendulum
» conservation of angular momentum
» **Ex:** Kepler's 2nd law
» **Ex:** Bohr's atom, quantization of angular momentum
» **Ex:** torque on a conical pendulum
» angular momentum associated with a fixed axis' rotation
» moment of inertia
» parallel axis theorem
» solving problems involving torques
» the physical pendulum, center of gyration
» motions with both translation and rotation
» modified work-energy theorem
» generalization of rotational motion; infinitesimal rotations
» stability of rotating objects; a gyroscope
» generalization of angular momentum; tensor of inertia

Grading and the grading scheme

Component	% of the final mark	Notes
Homework	20%	Problem sets, every week. Late submissions have a sinking cap of 15%/day.
Midterm test	10%	An in-class test, date TBA. Only a calculator and one letter-size (one-sided) self-prepared formula sheet allowed; no complete solutions.
Final exam	35%	Minimum passing grade 50%, marks given for correct answers. Only a calculator and one letter-size (one-sided) self-prepared formula sheet allowed; no complete solutions.
Labs	35%	Completion of all labs and submission of all lab reports is required to obtain a grade in the course. Late submissions will not be accepted.

Expectations and responsibilities

Here is a summary of our expectations of you, which are your responsibilities. You are expected to:

» attend each scheduled lecture and laboratory session;
» do your work honestly and maintain academic integrity (see a separate section below for details);
» complete each test, using only the materials that have been authorized for use, such as a non-graphics calculator and writing instruments;
» attend labs having **prepared in advance** by reading relevant parts of the lab manual, and having completed the prelab problems.

And most important of all, you must take responsibility for your own learning. The lectures are there to guide you and assist you, but only you can actually do the hard work of learning the course material. To get the most out of the course, work on it a little bit every day. Daily work is key for placing your learning in long-term memory, where it will be readily available to help you to advance your knowledge in subsequent years - and acing the final exam, of course. Cramming on the night before may place the material in your short-term memory and you might even do fine on a weekly test, where the amount of new material is relatively small, but this approach will fail miserably on the final exam.

Your instructor will provide weekly textbook chapter references; read through those section. The best way is to read them twice: once before the lectures, just to orient yourself in the material, to identify those parts that seem like they might need extra time and attention. Make a note of the questions that arise in your mind. The lecture

should answer some of them, and if it does not, raise your hand and ask! Asking questions is a sign of active learning, not a sign of weakness. It is likely that many others have the same question. After the lecture, read the textbook again, with a pen and paper in hand, repeating all derivations on your own, trying every solved example before looking at the solution, then solving every follow-up questions at the end of the section. Sometimes, the answers to questions are available; use those to check up on the skills you are developing. But most of the time, the answers are not known, and you must learn to develop enough confidence in your skills to solve those. Both are integral to the learning process.

Use your time effectively. Study smart, instead of hard. Ask questions in class. Your instructor has an open-door policy, so outside of a few restricted hours, you are always welcome to come and ask a question one-on-one. Do not wait until you have a "worthy" pageful of questions - that's too long to let them fester unanswered. It is better to come three times with one or two questions than once with a list accumulated over the past several weeks, when things get too desperate.

Weekly Homework

Please, note that while some of the chapter-end problems will be assigned explicitly, the students are encouraged and expected to review and attempt the majority of the chapter-end problems in the book for the readings assigned on a weekly basis.

All Textbook references are to *An Introduction to Mechanics*, second edition, by Daniel Kleppner and Robert Kolenkow. Cambridge University Press, 2013.

Before coming to class: review your Year 1 notes

» PHYS 1P21/1P91 and PHYS 1P22/1P92, or equivalent
» PPLATO also contains useful review links
» PHYS 1P97

In particular, refresh your `python` skills. In every lab you will need to record, graph, and analyze the data. A self-check: can you read a data file, plot it, fit a curve to it and determine parameters of the fit and their errors? For example, consider this set of measurements of load voltage V, in Volts, and load current I, in mA, in a circuit. Plot power ($P = V \times I$) delivered to the load as a function of load resistance ($R = V/I$), find the maximum, and determine at which R value it occurs.

The first lab session will teach you how to do the above. A simple-to-learn yet powerful software `eXtrema` will be introduced that will enable you to quickly accomplish the above task. In the lab, you may use `eXtrema`, `python`, or any other software you know, but the lab instructor(s) may not be able to offer much help with packages they may not know.

Week 1. Vectors. Components of motion. Polar coordinates.
- K&K2, Ch.1.1-1.6,1.11
- Assignment 1, due 2025-09-19.

Week 2. Integration of kinematic equations.
- K&K2, Ch.1.7-1.10

Week 3. Newton's Laws.
- K&K2, Ch.2
- K&K2, Ch.3.4-3.6.
- Assignment 2, due 2025-10-03.

Week 4. Momentum, work, energy
- K&K2, Ch.3.7
- K&K2, Ch.4.1;4.6.
- K&K2, Ch.5.1-5.3.1; 5.6-5.7; 6.1-6.3.

Week 5. A simple harmonic oscillator
- K&K2, Ch.11
- Assignment 3, due 2025-10-21.

Week 6. Work, energy and momentum in 3D
- K&K2, the rest of Ch.4-5.
- Assignment 4, due 2025-11-04.

Week 7. Reading week

Week 8. Midterm. Conservation of energy
- In-class midterm (on all of the material up to this point)
- Center-of-mass; reduced mass.

Week 8. Conservation of momentum. Collisions.
- K&K2, Ch.6.
- Assignment 5, due 2025-11-18.

Week 9. Angular momentum.
- K&K2, Ch.7.

Week 10. Angular momentum, cont'd. Rigid body motion.
- K&K2, Ch.7.
- Assignment 6, due 2025-12-02.

Week 11. Non-intertial systems. Fictitious forces.

- K&K2, Ch.8.

Costs

See the Campus Store for textbook costs, if any.
There are no ancillary fees for this course.

Academic Integrity

Academic misconduct is a serious offence. The principle of academic integrity, particularly of doing one's own work, documenting properly (including use of quotation marks, appropriate paraphrasing and referencing/ citation), collaborating appropriately, and avoiding misrepresentation, is a core principle in university study. Students should consult "Academic Misconduct" section in the Undergraduate Calendar to view a fuller description of prohibited actions, and the procedures and penalties. The University takes academic misconduct extremely seriously and will follow its strict procedures to the letter in all cases.

A helpful website explains Brock's Academic Integrity Policy. Please consult it, as all students are expected to know and abide by its provisions.

Courses may use `turnitin.com`, a phrase-matching software, to verify originality of your submitted lab reports and written assignments. If you object to uploading your assignmentsr to `turnitin.com` for any reason, please notify the instructor to discuss alternative submissions.

Be aware that it is the policy of the Department of Physics that any academic misconduct including (but not limited to) possessing, using or accessing unauthorized material in any form (including online) during final exams or assessments will *automatically* result in zero grade for the exam. Since most courses require a minimum passing grade on the final exam to complete the course, this will likely lead to a failure in the course.

FMS Penalties for Academic Misconduct

Unless otherwise specified, the Department of Physics follows the following minimum penalty guidelines for cases of academic misconduct in the Faculty of Mathematics and Science (FMS). Please be aware that the Associate Dean, Undergraduate Programs, may assign different penalties than those listed here, depending on the details of individual cases. Also note that cheating on exams carries significantly higher penalties.

First offence:
: Zero grade on the assignment, additional penalty of 100% of the weight of the assignment to be subtracted from the final grade, mandatory completion of the AZLS Academic Integrity workshop

Second offence:
: Zero grade on assignment, additional penalty of 100% of the weight of the assignment to be subtracted from the final grade, 4-month suspension

Third or additional offence:
: Zero grade in the course, 1-year suspension, permanent removal from major program.

FMS Penalties for Misconduct in Final Exams

First Offense:
: Zero grade in the course.

Second Offense:
: Zero grade in the course, 4 month suspension.

Third Offense:
: Zero grade in the course, 1 year suspension, permanent removal from major program

Fourth Offense:
: Permanent Suspension, debarment.

FMS Academic Policies

Intellectual Property Notice

All slides, presentations, handouts, tests, exams, and other course materials created by the instructor in this course are the intellectual property of the instructor. A student who publicly posts or sells an instructor's work, without the instructor's express consent, may be charged with misconduct under Brock's Academic Integrity Policy and/or Code of Conduct, and may also face adverse legal consequences for infringement of intellectual property rights.

Use of Generative AI (GenAI)

In the age of GenAI (*e.g.*, ChatGPT), our expectation of you remains the same as it ever was: original academic work, following the instructions of the assignment determined by the instructor for this course for requirements, expectations, and parameters for completion and submission of your work for grading. Therefore, the use of GenAI tools and GenAI-generated content is not allowed (unless explicitly requested/instructed) as a resource or source for answers and discussion in submitted work. Unauthorized use of GenAI will be treated as an academic misconduct.

You probably won't find much use of GenAI in this course anyway, even when writing something like a lab report. Why? GenAI doesn't know what you did in the lab. GenAI may know a lot about the overall idea you were studying, but not how you demonstrated it. In your lab reports, your answers and discussion need to relate to what you did and the data you took.

Important dates

Please be aware of all the important dates, such as the first/last days of classes, snow days and reading week, as well as the deadline for withdrawal without academic penalty. For the current academic term, this information can be found here.

Relationship between attendance and grades

Unless the instructor announces otherwise, students are expected to attend all lectures, discussion groups, seminars, laboratory periods and examinations of the courses in which they are registered and must submit all assignments in order to pass this course.

Accommodations

The University is committed to fostering an inclusive and supportive environment for all students and will adhere to the Human Rights principles that ensure respect for dignity, individualized accommodation, inclusion and full participation. The University provides a wide range of resources to assist students, as follows:

a. If you require academic accommodation because of a disability or an ongoing health or mental health condition, please contact Student Accessibility Services at askSAS@brocku.ca or 905 688 5550 ext. 3240.
b. **Medical Self-Declaration Forms** (brief absence up to 72 hours)

   In the case of a short-term medical circumstance, if a student wishes to seek an academic consideration, please use the Medical Self-Declaration Form. The request is to be made in good faith by the student requesting the academic consideration due to a short-term condition that impacts their academic activities (e.g., participation in academic classes, delay in assignments, etc.). The period of this short-term medical condition for academic consideration must fall within a 72-hour (3 day) period. The form must be submitted to the instructor either during your brief absence or if you are too unwell, within 24 hours of the end of your 3 day brief absence.

   Medical Verification Form (extended duration)

   In cases where a student requests academic consideration due to a medical circumstance that exceeds 72 hours (three days) and will impact their academic activities (e.g., participation in academic classes, delay in assignments, etc.), or in the case of a final exam deferral, the medical verification form must be signed by the student and the health professional as per process set out in the Faculty Handbook III:9.4.1.
c. If you are experiencing mental health concerns, contact the Student Wellness and Accessibility Centre. Good2Talk is a service specifically for post-secondary students, available 24/7, 365 days a year, and provides anonymous assistance. Follow the above link or call 1-866-925-5454. For information on wellness, coping and resiliency, visit: Brock University (Mental Health).
d. If you require academic accommodation on religious grounds, you should make a formal, written request to your instructor(s) for alternative dates and/or means of satisfying requirements. Such requests should be made during the first two weeks of any given academic term, or as soon as possible after a need for accommodation is known to exist.
e. If you have been affected by sexual violence, the Human Rights & Equity Office offers support, information, reasonable accommodations, and resources through the Sexual Violence Support & Education Coordinator. For information on sexual violence, visit Brock's Sexual Assault and Harassment Policy or contact the Sexual Violence Support & Response Coordinator at humanrights@brocku.ca or 905 688 5550 ext. 4387.
f. If you have experienced discrimination or harassment on any of the above grounds, including racial, gender or other forms of discrimination, contact the Human Rights and Equity Office at humanrights@brocku.ca.

For a full description of academic policies in the Faculty of Mathematics and Science, consult brocku.ca/mathematics-science/