UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

Department of Physics & Astronomy
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REVISED COURSE OUTLINE FOR REMOTE LEARNING

To account for the necessary transition to remote learning from March 13 onward, adjustments have been made to assessment deadlines and requirements so that all coursework tasks are in line with the necessary and evolving health precautions for all involved (students and staff). If you are unable to meet the deadlines or requirements specified, please connect with your course instructor to work out alternative dates/assessments.

1. **Course:** PHYS 501, Relativity - Winter 2020

   Lecture 01: MWF 15:00 - 15:50 - Remote Learning (check with your instructor or coordinator for details)

Instructor	Email	Phone	Office	Hours
Dr. Sean Stotyn	sean.stotyn@ucalgary.ca	403 210-7594	SA 101B	Tuesdays and Wednesdays 11:30 AM – 12:30 PM

   This course on a modern approach to Einstein's theory of Special Relativity will begin with Lorentz transformations in classical mechanics and relativistic energy and momentum. These will be applied to relativistic kinematics and relativistic electrodynamics. Throughout the course, a geometrical interpretation will be developed via space-time diagrams and causal structure. Moving beyond the restrictive formulation in terms of inertial frames, four-vectors and tensors will be introduced, leading finally to an introduction to General Relativity and the Schwarzschild black hole.

   Course Site:

   D2L: PHYS 501 L01-(Winter 2020)-Relativity

   Note: Students must use their U of C account for all course correspondence.

2. **Requisites:**

   See section 3.5.C in the Faculty of Science section of the online Calendar.

   Prerequisite(s):
   Physics 455; and Mathematics 375 or 376; and Mathematics 367 or 377.

3. **Grading:**

   The University policy on grading and related matters is described in F.1 and F.2 of the online University Calendar. In determining the overall grade in the course the following weights will be used:

Component(s)	Weighting %	Date
Assignments (x7)	28	
Worksheets (x8)	9	
Pre-worksheet Quizzes (x8)	9	
Midterms (x2)	24	Feb 14, Mar 23
Final Exam	30	Take-home (released Wednesday April 15 and due the following Wednesday, April 22)

   Each piece of work (reports, assignments, quizzes, midterm exam(s) or final examination) submitted by the student will be assigned a grade. The student's grade for each component listed above will be combined with the indicated weights to produce an overall percentage for the course, which will be used to determine the course letter grade.

   The conversion between a percentage grade and letter grade is as follows.

	A+	A	A-	B+	B	B-	C+	C	C-	D+	D
Minimum % Required	95 %	90 %	85 %	80%	75%	70 %	65 %	60%	55%	53 %	50 %

There will be two in-class midterms in this course:

1. Midterm 1 will take place on **Friday Feb 14** and will cover material up to and including Friday Feb 7
2. Midterm 2 will be a take-home exam released on **Monday March 23** and handed in on **Wednesday March 25**. It will cover material up to and including Wednesday Mar 11

As your term work items (assignments, worksheets, pre-worksheet quizzes, and exams) accumulate, the marks for students will be posted on D2L. The marks that appear on this website are the marks that will be used to determine each student's overall course grade. Check your marks frequently; missing or incorrectly posted term work marks should be reported to the course instructor as soon as they are noticed. You should be prepared to produce the original work to verify the requested correction.

4. **Missed Components Of Term Work:**

The University has suspended requirements for students to provide evidence for reasons for absences so please do not attend medical clinics for medical notes or Commissioners for Oaths for statutory declarations. Please let your instructor know immediately if you are ill and cannot meet the deadlines specified.

Missed assignments:

Please contact the course instructor if you have a legitimate reason for missing a deadline for an assignment. Sleeping in, forgetting about the deadline etc. is not considered a legitimate reason.

Missed activities:

If a student misses an activity (either in class or on D2L), they should contact the course instructor. If the instructor feels that an accommodation is warranted, then one will be provided.

Missed midterm:

Students who miss a midterm due to ill health or other valid reasons must contact the course instructor and by no later than 11:59 pm the day after the exam. The instructor will get back to the student with a suitable accommodation.

5. **Scheduled Out-of-Class Activities:**

There are no scheduled out of class activities for this course.

6. **Course Materials:**

Required Textbook(s):

James B. Hartle, *Gravity: An Introduction to Einstein's General Relativity*. Addison Wesley.

Assignments:

There will be 7 homework assignments (including Assignment 0, which is a short problem set on the course incomes) that will be due roughly every two weeks. Each one will be composed of a handful of challenging questions designed to expand the skills we develop in lecture. Solutions should be written on one side of a page, and multiple-page homework assignments must be stapled.

Expectations: It is encouraged that students work together on homework assignments in order to get a richer understanding of the material. However, the work turned in must be the student's and not a duplicate of someone else's. All written work must be neat, organized, and legible; any portions not following this will not be graded.

Worksheets:

These are to be completed in class and handed in at the beginning of the following lecture. Their purpose is to increase student engagement and have the students better construct the knowledge being learned in a structured manner. This is a type of formative assessment and is therefore crucial to learning the material in greater depth. Grading of the worksheets will be based on both correctness and the process used to find the answer.

Expectations: It is essential that students work collaboratively during these in-class worksheets and it is expected that all steps be appropriately reasoned through so that somebody else can easily follow the thought process. All written work must be neat, organized, and legible.

Pre-worksheet quizzes:

Students will be expected to come to the worksheet classes prepared and so will be assigned a short video to

watch on the content of that week's worksheet, on which there will be a pre-worksheet quiz comprised of a handful of multiple choice questions. These quizzes will be on D2L under Assessments>Quizzes and they will be made available to students on Tuesdays at 5:00 pm and they will be due on Thursdays at 11:59 pm.

Midterm 2 and Final Exam Details:

Midterm 2 will be a take-home midterm that will be released at 9:00 AM on Monday March 23 and is to be submitted by 5:00 PM on Wednesday March 25.

The final exam will be a cumulative take-home final that will be released at 9:00 AM on Wednesday April 15 and is to be submitted by 5:00 PM on Wednesday April 22.

In both exams, students are not permitted to communicate with each other about the exam questions and must submit their own work.

Course Schedule:

The following is a rough outline of the topics covered, the readings that are expected, and important due dates:

Date	Chapter sections	Topics covered	Due Dates
Jan. 13	2.3, 2.5, 2.6	Introduction to course, non-Euclidean geometries, coordinate invariance	
Jan. 15	4.1–4.2	Invariance of EM waves, Lorentz transformations, postulates of relativity	
Jan. 17	4.3	Space-time, space-time diagrams, light cones, causality	Assignment 0
Jan. 20	4.4–4.5	Proper time, Lorentz boosts, simultaneity of events	
Jan. 22	4.5–4.6	Length contraction, relativistic addition of velocities	
Jan. 24	N/A	Worksheet 1	
Jan. 27	5.1	4-vectors, the metric tensor, scalar products, Lorentz symmetry	
Jan. 29	5.2	4-velocity, observer basis vectors, local measurements	Assignment 1
Jan. 31	N/A	Worksheet 2	
Feb. 3	5.5, 5.6	Null worldliness, wave 4-vector, observer-dependence + Doppler shift	
Feb. 5	5.6	4-potential, transformation of electromagnetic fields	
Feb. 7	N/A	Worksheet 3	
Feb. 10	3.5, 5.4, 5.5	Variational principle for time-like and null particles, geodesics	
Feb. 12	5.3	4-acceleration, 4-force, 4-momentum, relativistic energy-momentum	Assignment 2
Feb. 14	N/A	**MIDTERM 1 IN CLASS**	Midterm 1
Feb. 17-21	N/A	**READING BREAK: NO CLASSES SCHEDULED**	
Feb. 24	6.2–6.4	Equivalence principle, gravitational time dilation	
Feb. 26	6.5, 6.6	Gravitational weak field, Newtonian gravity in curved space-time terms	
Feb. 28	N/A	Worksheet 4	
Mar. 2	7.1–7.3, 7.5	Coordinates, metric, summation convention, light cones, worldlines	
Mar. 4	7.6, 7.8, 20.1, 20.2	Space-time volumes, dual vectors, inverse metric	Assignment 3
Mar. 6	N/A	Worksheet 5	
Mar. 9	20.4, 8.1	Parallel transport of vectors, covariant derivative, Christoffel symbols	
Mar. 11	8.2, 8.3	Symmetries, Killing vectors, time-like and null geodesics	
Mar. 13	N/A	N/A	
Mar. 16	N/A	Worksheet 6	
Mar. 18	9.1, 9.2	Schwarzschild geometry, gravitational red/blue shift, FRW metric	
Mar. 20	9.3	Time-like orbits, conserved quantities, effective potential	Assignment 4
Mar. 23	9.3	Stable time-like circular orbits, ISCO	Midterm 2 released
Mar. 25	9.4	Null orbits, photon sphere, impact parameter, null effective potential	Midterm 2 due
Mar. 27	N/A	Worksheet 7	
Mar. 30	12.1	Schwarzschild black hole, Eddington-Finkelstein coordinates	
Apr. 1	12.3	Kruskal-Szekeres extension, Penrose diagram	
Apr. 3	N/A	Worksheet 8	Assignment 5
Apr. 6	12.3	More on the Kruskal-Szekeres extension	
Apr. 8	12.2	Gravitational collapse to a black hole	

Apr. 10	N/A	**GOOD FRIDAY: UNIVERSITY CLOSED**	
Apr. 13	N/A	**EASTER MONDAY: NON-INSTRUCTION DAY**	
Apr. 15	N/A	Review	Assignment 6

7. **Examination Policy:**

All examinations in the course will be open-book, open-resource. Students are free to consult their course notes, textbook, internet sources, etc. However, communication with others (including those outside the class) during any of the exams is strictly forbidden.

Students should also read the Calendar, Section G, on Examinations.

8. **Approved Mandatory And Optional Course Supplemental Fees:**

There are no mandatory or optional course supplemental fees for this course.

9. **Writing Across The Curriculum Statement:**

For all components of the course, in any written work, the quality of the student's writing (language, spelling, grammar, presentation etc.) can be a factor in the evaluation of the work. See also Section E.2 of the University Calendar.

10. **Human Studies Statement:**

Students will not participate as subjects or researchers in human studies.

See also Section E.5 of the University Calendar.

11. **Reappraisal Of Grades:**

A student wishing a reappraisal, should first attempt to review the graded work with the Course coordinator/instructor or department offering the course. Students with sufficient academic grounds may request a reappraisal. Non-academic grounds are not relevant for grade reappraisals. Students should be aware that the grade being reappraised may be raised, lowered or remain the same. See Section I.3 of the University Calendar.

   a. **Term Work:** The student should present their rationale as effectively and as fully as possible to the Course coordinator/instructor within **ten business days** of either being notified about the mark, or of the item's return to the class. If the student is not satisfied with the outcome, the student shall submit the Reappraisal of Graded Term work form to the department in which the course is offered within 2 business days of receiving the decision from the instructor. The Department will arrange for a reappraisal of the work within the next ten business days. The reappraisal will only be considered if the student provides a detailed rationale that outlines where and for what reason an error is suspected. See sections I.1 and I.2 of the University Calendar

   b. **Final Exam:** The student shall submit the request to Enrolment Services. See Section I.3 of the University Calendar.

12. **Other Important Information For Students:**

   a. **Mental Health** The University of Calgary recognizes the pivotal role that student mental health plays in physical health, social connectedness and academic success, and aspires to create a caring and supportive campus community where individuals can freely talk about mental health and receive supports when needed. We encourage you to explore the mental health resources available throughout the university community, such as counselling, self-help resources, peer support or skills-building available through the SU Wellness Centre (Room 370, MacEwan Student Centre, Mental Health Services Website) and the Campus Mental Health Strategy website (Mental Health).

   b. **SU Wellness Center:** The Students Union Wellness Centre provides health and wellness support for students including information and counselling on physical health, mental health and nutrition. For more information, see www.ucalgary.ca/wellnesscentre or call 403-210-9355.

   c. **Sexual Violence:** The University of Calgary is committed to fostering a safe, productive learning environment. The Sexual Violence Policy (https://www.ucalgary.ca/policies/files/policies/sexual-violence-policy.pdf) is a fundamental element in creating and sustaining a safer campus environment for all community members. We understand that sexual violence can undermine students' academic success and we encourage students who have experienced some form of sexual misconduct to talk to someone about their experience, so they can get the support they need. The Sexual Violence Support Advocate, Carla Bertsch, can provide confidential support and information regarding sexual violence to all members of the university community. Carla can be reached by email (svsa@ucalgary.ca) or phone at 403-220-2208 .

   d. **Misconduct:** Academic misconduct (cheating, plagiarism, or any other form) is a very serious offence that

will be dealt with rigorously in all cases. A single offence may lead to disciplinary probation or suspension or expulsion. The Faculty of Science follows a zero tolerance policy regarding dishonesty. Please read the sections of the University Calendar under [Section K](). Student Misconduct to inform yourself of definitions, processes and penalties. Examples of academic misconduct may include: submitting or presenting work as if it were the student's own work when it is not; submitting or presenting work in one course which has also been submitted in another course without the instructor's permission; collaborating in whole or in part without prior agreement of the instructor; borrowing experimental values from others without the instructor's approval; falsification/ fabrication of experimental values in a report. **These are only examples**.

e. **Assembly Points:** In case of emergency during class time, be sure to FAMILIARIZE YOURSELF with the information on [assembly points]().

f. **Academic Accommodation Policy:** Students needing an accommodation because of a disability or medical condition should contact Student Accessibility Services in accordance with the procedure for accommodations for students with disabilities available at [procedure-for-accommodations-for-students-with-disabilities.pdf]().

Students needing an accommodation in relation to their coursework or to fulfill requirements for a graduate degree, based on a protected ground other than disability, should communicate this need, preferably in writing, to the Associate Head of the Department of Physics & Astronomy, Dr. David Feder by email phas.ahugrd@ucalgary.ca or phone 403-220-8127. Religious accommodation requests relating to class, test or exam scheduling or absences must be submitted no later than **14 days** prior to the date in question. See [Section E.4]() of the University Calendar.

g. **Safewalk:** Campus Security will escort individuals day or night (See the [Campus Safewalk]() website). Call [403-220-5333]() for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

h. **Freedom of Information and Privacy:** This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). Students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page. For more information, see [Legal Services]() website.

i. **Student Union Information:** [VP Academic](), Phone: [403-220-3911]() Email: [suvpaca@ucalgary.ca](). SU Faculty Rep., Phone: [403-220-3913]() Email: [sciencerep@su.ucalgary.ca](). [Student Ombudsman](), Email: [ombuds@ucalgary.ca]().

j. **Internet and Electronic Device Information:** Unless instructed otherwise, cell phones should be turned off during class. All communication with other individuals via laptop, tablet, smart phone or other device is prohibited during class unless specifically permitted by the instructor. Students that violate this policy may be asked to leave the classroom. Repeated violations may result in a charge of misconduct.

k. **Surveys:** At the University of Calgary, feedback through the Universal Student Ratings of Instruction ([USRI]()) survey and the Faculty of Science Teaching Feedback form provides valuable information to help with evaluating instruction, enhancing learning and teaching, and selecting courses. Your responses make a difference - please participate in these surveys.

l. **Copyright of Course Materials:** All course materials (including those posted on the course D2L site, a course website, or used in any teaching activity such as (but not limited to) examinations, quizzes, assignments, laboratory manuals, lecture slides or lecture materials and other course notes) are protected by law. These materials are for the sole use of students registered in this course and must not be redistributed. Sharing these materials with anyone else would be a breach of the terms and conditions governing student access to D2L, as well as a violation of the copyright in these materials, and may be pursued as a case of student academic or [non-academic misconduct](), in addition to any other remedies available at law.

Course Learning Incomes

Coming into the course, students should be able to:

1. Construct the laws of Newtonian physics in inertial frames in cartesian, cylindrical, and spherical coordinates.
2. Utilize available symmetry to make a given problem tractable.
3. Perform basic vector calculus (Green's theorem, Stokes' theorem, etc.) using unit vector notation.
4. Express electrodynamics in terms of fields that exert forces on charged particles.
5. Use the Euler-Lagrange equations to find equations of motion (this will also be reviewed in the course).

Course Outcomes:

- Describe the Lorentz transformation laws of space-time and apply them to resolve apparent paradoxes.
- Describe how energy and momentum of null and time-like particles transform between inertial frames.
- Use the symmetries of space-time to construct the 4-velocity of a generic time-like observer, and the wave 4-vector of a null particle.
- Interpret and draw conclusions about causal structure from space-time diagrams.
- Identify the key properties of black holes, including event horizons, singularities, and (un)stable orbits.

Electronically Approved - Mar 18 2020 15:33

Department Approval

Electronically Approved - Mar 18 2020 17:11

Associate Dean's Approval for alternate final examination arrangements or remote learning