UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

Department of Physics & Astronomy
Science B 605
403 220-5385
phasoffice@ucalgary.ca

COURSE OUTLINE

1. **Course:** PHYS 501, Special Relativity - Winter 2019

   Lecture 01: MWF 15:00 - 15:50 in MS 319

Instructor	Email	Phone	Office	Hours
Dr. Sean Stotyn	sean.stotyn@ucalgary.ca	403 210-7594	SA 101B	TBA

   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 2019)-Special 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 325 and 457; and one of Mathematics 353 or 377 or Applied Mathematics 309.

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 (x6)	30	Bi-weekly
Activities	10	N/A
Midterms (x2)	30	Feb 15, Mar 22
Final Exam	30	TBA

   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 %

   This course has a registrar scheduled final exam.

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

1. Midterm 1 will take place on **Friday Feb 15** and will cover material up to and including Friday Feb 8
2. Midterm 2 will take place on **Friday Mar 22** and will cover material up to and including Friday Mar 15

As your term work items (assignments, activities, 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:**

In the event that a student misses the midterm or any course work due to illness, supporting documentation, such as a medical note or a statutory declaration will be required (see Section N.1; for more information regarding the use of statuary declaration/medical notes, see FAQ). Absences must be reported within 48 hrs.

The regulations of the Faculty of Science pertaining to this matter are found in the Faculty of Science area of the Calendar in Section 3.6. It is the student's responsibility to familiarize themselves with these regulations. See also Section E.3 of the University Calendar.

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, will most often be granted an accommodation provided that the alleged problems are supported in writing by a person in a position of authority (physician, counsellor, etc.). The student must contact the course instructor and provide the necessary documentation preferably the day of the exam, but no later than 11:59 pm the day after the exam. Once the claim is substantiated, 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 6 homework assignments 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 you work with fellow students on homework assignments in order to get a richer understanding of the material. However, the work you turn in must be yours 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.

Activities:

In order to help students to better understand and learn course material there will be additional activities. Participation will earn students 10% toward their overall course grade: in-class worksheets (5%) and pre-worksheet quizzes (5%)

Worksheets: these are to be completed in class and handed in at the end of lecture. Their purpose is to increase

student engagement and have you better construct the knowledge being learned in a structured manner. This is a formative assessment and will be treated as such; in particular, emphasis will not be on whether you have the correct answer, but rather the process you used to find it. It is essential that you work with fellow students during these in-class worksheets and it is expected that all steps be appropriately reasoned through so that somebody else can easily follow your 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 Wednesdays at 5:00 pm and they will be due on Thursdays at 11:59 pm.

Course Schedule:

The following is a rough outline of what topics we'll be covering, the reading that you'll be expected to do, about how long I expect to take on those topics, and important due dates:

Date	Chapter sections	Topics covered	Due Dates
Jan. 11	2.1–2.6	Non-Euclidean geometries, Coordinates, line element, coordinate invariance	
Jan. 14	4.1–4.2	Michelson-Morley experiment, Lorentz transformations, inertial frames	
Jan. 16	4.3	Space-time, space-time diagrams, light cones, causality	
Jan. 18	N/A	Worksheet 1	
Jan. 21	4.4–4.5	Proper time, Lorentz boosts, simultaneity, particle decay	
Jan. 23	4.5–4.6	Length contraction, relativistic addition of velocities	Assignment 1
Jan. 25	N/A	Worksheet 2	
Jan. 28	5.1	4-vectors, the metric tensor, scalar products of 4-vectors, Lorentz symmetry	
Jan. 30	5.2	Space-like, time-like, null curves, 4-velocity, accelerated worldlines	
Feb. 1	N/A	Worksheet 3	
Feb. 4	5.5, 5.6	Wave 4-vector, observer-dependence, Doppler shift, relativistic beaming	
Feb. 6	5.6	Particle collisions/decays, centre of momentum frame	Assignment 2
Feb. 8	N/A	Worksheet 4	
Feb. 11	3.5, 5.4, 5.5	Variational principle for time-like and null particles, geodesics	
Feb. 13	5.3	4-acceleration, 4-force, 4-momentum, relativistic energy-momentum	
Feb. 15	N/A	MIDTERM 1 IN CLASS	Midterm 1
Feb. 18-22	N/A	READING BREAK: NO CLASSES SCHEDULED	
Feb. 25	6.2–6.4	Accelerated rocket ship, gravitational time dilation, GPS satellites	
Feb. 27	6.5, 6.6	Gravitational weak field, Newtonian gravity in curved space-time terms	Assignment 3
Mar. 1	N/A	Worksheet 5	
Mar. 4	7.1–7.3, 7.5	Coordinates, metric, summation convention, light cones, worldlines	
Mar. 6	7.6, 7.8, 20.1, 20.2	Space-time volumes, vectors, dual vectors, inverse metric	
Mar. 8	N/A	Worksheet 6	
Mar. 11	8.1	Geodesic equation, variational principle, Christoffel symbols	
Mar. 13	8.2, 8.3	Symmetries, Killing vectors, time-like and null geodesics	Assignment 4
Mar. 15	N/A	Worksheet 7	
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	
Mar. 22	N/A	MIDTERM 2 IN CLASS	Midterm 2
Mar. 25	9.4	Null orbits, gravitational lensing	
Mar. 27	12.1	Schwarzschild black hole, Eddington-Finkelstein coordinates	Assignment 5
Mar. 29	N/A	Worksheet 8	
Apr. 1	12.3	Kruskal-Szekeres extension, Penrose diagram	
Apr. 3	12.3	More on the Kruskal-Szekeres extension	
Apr. 5	N/A	Worksheet 9	
Apr. 8	12.2	Gravitational collapse to a black hole	
Apr. 10	15.1–15.5	Properties of a rotating black hole	Assignment 6
Apr. 12	N/A	Review	

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 **15 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 immediately submit the Reappraisal of Graded Term work form to the department in which the course is offered. The department will arrange for a re-assessment of the work if, and only if, the student has sufficient academic grounds. 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: suvpaca@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.

Department Approval:	Electronically Approved	Date: 2019-01-08 17:19