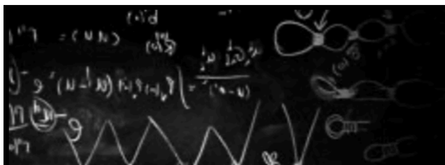
Course: ASTR 403 A01 - INTRO: ASTROPHYSICAL PROCESSES

Instructor: Babul, Arif **Credits:** 1.5

CRN: 10198 **Term:** 202609



Astronomy 403

Updated: August 2026

Home Information Expectations Topics Grading-Scheme Links About the instructor

IMPORTANT

I STRONGLY RECOMMEND THAT YOU MAKE SURE YOU ARE SEEING THE LATEST VERSION OF THE WEBSITE EACH TIME YOU ACCESS IT.
Please click HERE for must-read instructions on how to guarantee that and about optimal devices and browsers for viewing this website.

Welcome to the "AST403" course webpage!

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This course will offer a combined quantitative-qualitative introduction to important radiative processes and associated concepts that one often encounters in astrophysical settings.

Radiative processes can be thought of as our windows into the universe. The radiation observed and an understanding of the mechanisms that give rise to this observed radiation allows us to determine conditions present in regions as diverse as the interstellar and intergalactic medium, and to probe processes underlying galaxy formation to active galactic nuclei.

This course will touch upon topics like thermal and non-thermal radiation, radiative transfer, Bremsstrahlung, Compton scattering, etc. Given the time constraints, the course will necessarily skim over some of the concepts and focus on the most important ideas. On the other hand, if time allows, I will try to touch on HI observations given its growing importance for cosmology.

The emphasis will be on introducing the basic processes and exploring how they are used in astrophysics.

Important: You will need a username and password to access the lecture notes and other protected course content. This information will be given to you in class.

University of Victoria course copyright Statement:

ASTR 303 course GenAI policy

In this course, you are limitedly allowed but NOT ENCOURAGED to use Generative AI such as ChatGPT, Claude, etc.

By "limitedly" I mean that you are expected to work out the assigned questions (including those to be handed in for grading) by yourself in the first instance.

If you are finding it difficult to get started, you are welcome to **glance** at the final answer at the back of the book and then, reverse engineer to find the logic and the steps required to solve the problem. I strongly encourage you to do the reverse-engineering on your own. I will be grading you on how you solve the problem so show me all the steps explicitly. Do not just write down the final answer from the back of the book as that will be assigned an automatic zero. Even a simple answer needs an explanation.

Please note that some of the numbers in the back of the book are incorrect. Make sure you agree with the answer and at the end of the day, can derive it without assist.

You are also welcome to discuss the questions with your classmates. Use this to get an handle on how to solve the problem but then, go solve it yourself and write the the steps explicitly, as highlighted above, **in your own words and writing style.** If your solution is a duplicate of someone else's, both problem sets will be assigned a zero.

As a last resort, you are allowed to get guidance from GenAI. I recommend using it to get hints or maybe the first couple of steps, and then complete the problem yourself. In any case, your problem set cannot be a copy of something produced by GenAI. At the very least, you are expected to rewrite the answer in your own words and style. And, it must show each step with no leaps.

This is what I mean by limited use.

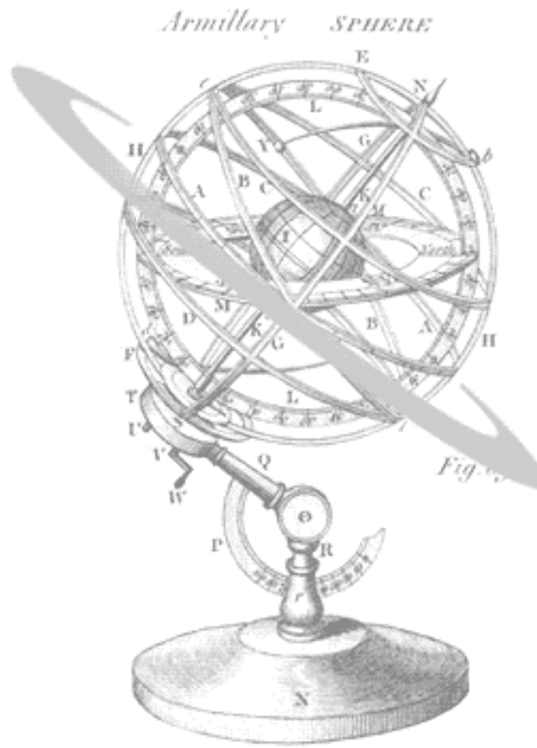
Do note that GenAI is prone to making errors. Errors in submitted problem sets will be attributed to you. You are responsible for making sure that the answer is correct.

Also, GenAI may use information or methods that are not covered in the text book. I reserve the right to ask you to come and see me, and explain what you did and why.

Finally and most importantly, my midterms and final exams are paper and pencil/pen-orientated. You will only have a "cheat sheet" and a non-programmable calculator. At least one and possibly more of the questions will be taken verbatim from the questions I draw your attention to - not only the ones you will hand in for grading but all the questions listed on the Topics page.

The same is true of problems I work out in class. I strongly encourage you to go through the problems and work them through on your own. These problems also tend to show up on midterms and finals, either verbatim or with slight changes intended to distinguish between memorizing and understanding.

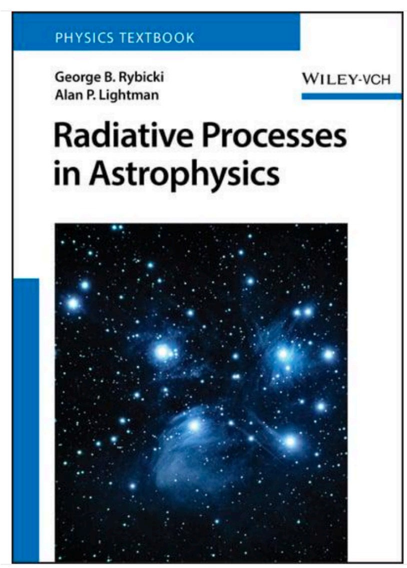
If you have follow this advice and work through the problems yourself, understand the questions, and learn how to solve them without assist, you will do fine.



Information

Instructor:	Professor Arif Babul
Lecture Schedule:	*Tuesday, Wednesday & Friday, 12:30-1:20pm* *In-Person Lectures* *Synchronous Online Lectures*
Lecture Format:	**Unless otherwise announced:** *FIRST WEEK OF SEPTEMBER: Wednesday and Friday lectures (**in-person**)* *REST OF SEPTEMBER: Tuesday, Wednesday (**in-person**); Friday (**online**)* ****** NOTE: NO CLASS on Wed. Sept. 30th*** *ALL OF OCTOBER: Tuesday, Wednesday (**in-person**); Friday (**online**)* ****** NOTE: NO CLASSES the week of Oct 12th*** *ALL OF NOVEMBER: Tuesday, Wednesday (**in-person**); Friday (**online**)* ****** NOTE: NO CLASSES the week of Nov 9th*** *FIRST WEEK OF DEC: Tuesday, Wednesday and Friday (**in-person**)*

Required Text



Radiative Processes in Astrophysics
by Rybicki & Lightman.

Please make sure that you purchase the 2nd Edition, which has blue and white cover.

According to UVic Bookstore, the hardcopy is out of print though some second-hand sellers likely still have it. I have also placed an electronic copy on reserve. This copy can be accessed **HERE** or via Course Tools tab in Brightspace for 202509 ASTR 403.

You may also want to check **HERE** or **HERE**.

Course readings and the problem set questions will be assigned from this textbook.

The publishers describe this book as a "clear, straightforward, and fundamental introduction is designed to present-from a physicist's point of view-radiation processes and their applications to astrophysical phenomena and space science. It covers such topics as radiative transfer theory, relativistic covariance and kinematics, bremsstrahlung radiation, synchrotron radiation, Compton scattering, some plasma effects, and radiative transitions in atoms. Discussion begins with first principles, physically motivating and deriving all results rather than merely presenting finished formulae. However, a reasonably good physics background (introductory quantum mechanics, intermediate electromagnetic theory, special relativity, and some statistical mechanics) is required. Much of this prerequisite material is provided by brief reviews, making the book a self-contained reference for workers in the field as well as the ideal text for senior or first-year graduate students of astronomy, astrophysics, and related physics courses. Radiative Processes in Astrophysics also contains about 75 problems, with solutions, illustrating applications of the material and methods for calculating results. This important and integral section emphasizes physical intuition by presenting important results that are used throughout the main text; it is here that most of the practical astrophysical applications become apparent."

My take: I agree with most of what is written here. This is one of the few books from my student days that I still go back to every so often. I learnt radiative processes and radiation transfer theory by reading this book and working through the problems. However, I personally think that the book would definitely benefit from more problems applying the concepts and theory to more realistic astrophysics problems.

There are two additional things to note:

(1) There are errors in this second edition. A list of some of these can be found here: ERRATA

2) We will work exclusively in astronomical cgs units. In other words, we will use cgs units to do the calculations and then for a handful of units (e.g. solar masses, solar luminosities, etc.), we will convert to these if the question requires. Here is a convenient reference:

CONSTANT	SYMBOL	VALUE IN GAUSSIAN CGS UNITS		
		Coefficient		Units
Speed of light	c	3.00×10^{10}	20	cm / s
Elementary unit charge	e	4.80×10^{-10}	2	statcoulomb or esu
Electron mass	m_e	9.13×10^{-28}		g
Proton mass	m_p	1.67×10^{-24}		g
Boltzmann constant	k_B	1.38×10^{-16}		erg / K
Gravitational constant	G	6.67×10^{-8}		$cm^3 / g / s^2$
Planck constant	h	6.62×10^{-27}		erg s
Thompson cross-section	σ_T	6.65×10^{-25}		cm^2
Stefan-Boltzmann constant	σ	5.67×10^{-5}		$erg / cm^2 / K^4 / s$

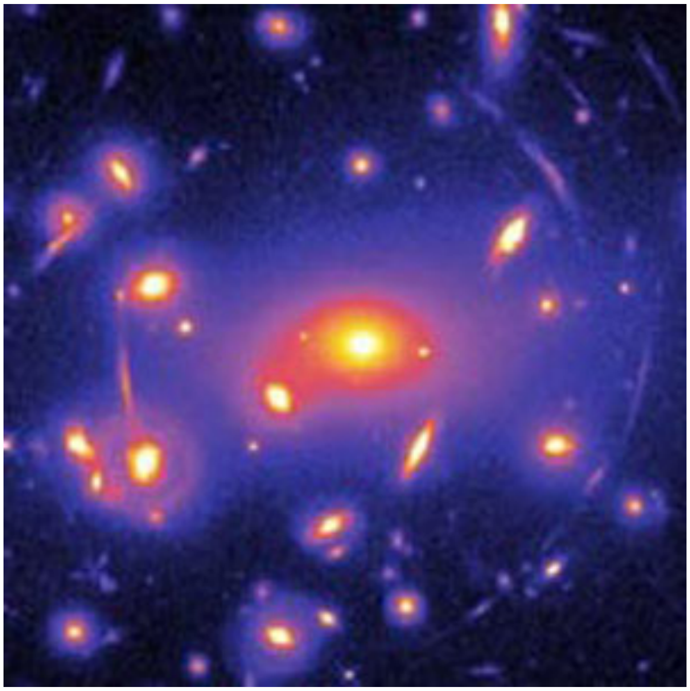
In Astrophysics, it often convenient to use: $G \approx 4.302 \times 10^{-3}\ \mathrm{pc}\, M_\odot^{-1}\, (\mathrm{km/s})^2$.

Quantity	Symbol	Value in Gaussian-CGS units		
		Coefficient		Units
Astronomical Unit	AU	1.5×10^{13}		cm
Parsec	pc	3.1×10^{18}		cm
Light-year	ly	0.95×10^{18}		cm
Angstrom	Å	10^{-8}		cm
Solar Radius	$R_\odot$	7.0×10^{10}		cm
Neutron Star Radius		$\sim 10^6$		cm (~10 km)
Solar Mass	$M_\odot$	2.0×10^{33}		g
Solar Luminosity	$L_\odot$	3.9×10^{33}		erg / s
Electron Volt	eV	1.6×10^{-12}		erg
1 eV is equivalent to $\sim 1.1 \times 10^7$ K (temperature)				

Course Expectations

In teaching ASTR 403: Introduction to Astrophysical Processes, I will expect that students are familiar with calculus-based electromagnetic theory and calculus-based classical mechanics, including familiarity with computing the mass profile M(r) given a density profile (and vice versa), the relationship between rotation (or circular) velocity and mass, for any general spherically symmetric mass profile M(r), etc. If you need to refresh your memory, please see:

(a) The text associated with Eq. 13.3 of Frank Shu's "The Physical Universe"
(b) Work thru Problem 13.5 of Shu,
(c) Review section 2.3 and 2.4 of Carroll and Ostlie's "An Introduction to Modern Astrophysics"



I will also assume a background in basic quantum mechanics, and special relativity. This is necessary if I am to cover the required material in the allocated time. If you need a memory jog, I would recommend reviewing your course notes for prior classes in these subjects. You may also want to peruse the book "The Physical Universe" by Frank shu for some basic review.

The general expectation for this course is that the students will read the assigned chapters from the course textbook (all this is specified in the section titled "Topics") and familiarize themselves with the material presented there.

I will highlight some of the questions at the end of the chapter and specify a subset to be handed in. I strongly recommend that you solve ALL the highlighted questions **as seriously and as rigorously as you would if you were handing them in.**

One or more of these questions will appear verbatim on the midterm and the final. See also Course AI Policy for IMPORTANT additional details.

All this information, including the problem set due dates, is specified in the section titled "Topics".

INSTRUCTIONS FOR SUBMITTING PROBLEM SETS

The problem sets must be handed by 5pm on the specified date. I will only accept problem sets emailed to me at babul@uvic.ca in PDF format.

IMPORTANT:

- Rename your PDF as follows: **LASTNAME_FIRSTNAME_A403_PSX** where X=1,2,3...
- Compress your PDF if it is too big to be emailed.
- Draft email with subject: "**YOUR NAME ASTR 403 PROB SET X**" where X=1,2,3...
- Attach your PDF and email to **babul@uvic.ca**
- Send by 5pm on the due date unless you have received explicit permission.

I strongly recommend getting an app that will allow you to take a picture of your pages and automatically convert these in PDF pages.

Late problem sets will not be accepted without prior approval or official documentation. If you are going to be away, I would recommend planning ahead and handing in the problem set ahead of the due date. Handing in a partially completed problem set is better than not turning one in at all.

EXPECTATIONS REGARDING THE PROBLEM SETS

I do not have an issue with students discussing the highlighted/assigned questions with - and learning from - each other. However, I expect that each person will then go back and work through the problems independently and write out their own solutions. Plagerism will result in a score of "0". I should also note that the answers to the problems are given at the back of the textbook. If you are stuck, you are welcome to glance at the final answer and see if that offers a direction.

As for the use of GenAI/LLMs etc., please see Course AI Policy.

The bottom line is that I strongly recommend that you work through the questionsdiscussed in the class as well as those listed on the Topics page by yourself so that you are prepared for the midterm/final.

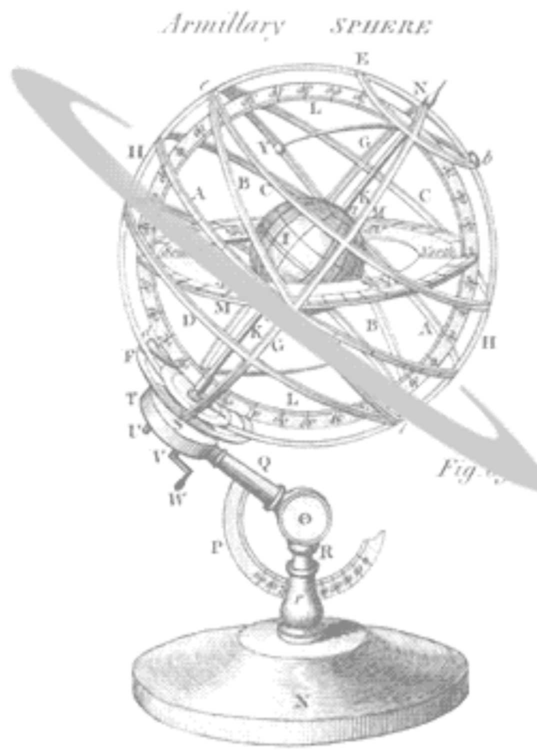
Importantly, I expect that the solutions submitted for grading will be detailed (much more detailed than the terse explanation at the back of the book) and show full reasoning in a step-by-step manner. Please explain your reasoning, highlight (and if necessary) justify any assumptions you need to make, etc. Do not assume that anything is obvious: explain and clarify. Full marks will only be given if the solutions are explicit and allow me to see how you have thought things through.

Even a question with a one-sentence answer requires an explanation. Tell me "why" - in your own words - even if it seems obvious.

The lectures WILL NOT reproduce the text. The text is very well written and the concepts are very well explained. I expect you will read carefully and thoroughly the assigned sections as per the course schedule. Sometimes, you may find that you need to look up an idea or an explanation to get a different

perspective. I encourage you to do that. There is an abundance of relevant material on the web. The book does have a weakness. It does not do enough problems and that is where I will focus my attention. I will use the lectures to show how the processes and concepts discussed in the book are used in an astrophysical setting through supplementary and much more realistic problems.

Please see the webpage titled "Grading Scheme" for more details

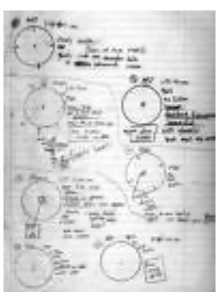


Topics, Readings, Lecture Notes and Assignments

Week of 2026-09-07 (Monday); first class on 2026-09-09

Introduction and Overview to the Course

Readings: Think Physics (Watch the video)
Back of the Envelope Calculations
R&L: Sections 1.1 to 1.3 inclusive

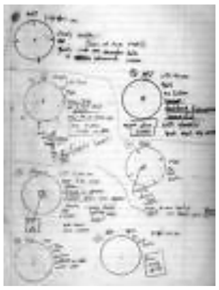


Class Schedule: Wednesday and Friday lectures in-person

Lecture Notes: Lecture notes for the semester are posted here. Please do not download them all at once. I will be fine-tuning these over the course of the semester. Download these as needed.

Course Syllabus (course info covered on preceeding these webpages)

WEEK0 Week 1 Think Physics notes (see above)



PART_1A, PART_1B, PART_1C : These cover lecture material up to and including Bremstrahlung

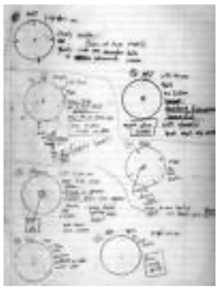
PART_2A, PART_2B, PART_2C : These cover the balance of the lecture material.

IMPORTANT NOTE: Lecture notes 2A, 2B
and/or 2c may be revised over the course of the semester. I will let you know.
-- Arif Babul (Sept 1, 2026)

Please note that the lecture material DOES NOT replace textbook material. It is intended to augment the latter. Please ensure that you read the assigned sections of the textbook and make notes as appropriate.

A: Week of 2026-09-14
Fundamentals of Radiative Transfer

Readings: R&L 1.4 to 1.7 inclusive



Class Schedule: Tuesday and Wednesday lectures in-person; Friday via zoom (synchronous)

Problems: Recommended to work through and understand: 1.1, 1.3, 1.4, 1.5, 1.7, 1.8, 1.9

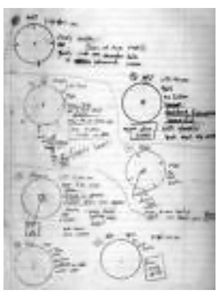
HAND-IN FOR MARKING: 1.4 ONLY
DUE DATE: by 5pm (always) on 2026-09-22

NOTE: Please follow these instructions precisely when submitting your assignments.

B: Week of 2026-09-21
Radiation Fields

Readings: R&L 2.1 to 2.6 inclusive (in 2.4 focus on polarization!)

While you don't need to know about stokes parameters, you should know know how to write down the wave equation for plane polarized waves (in a specified direction) as well as left and right circularly polarized waves.



Class Schedule: Tuesday and Wednesday lectures in-person; Friday via zoom (synchronous)

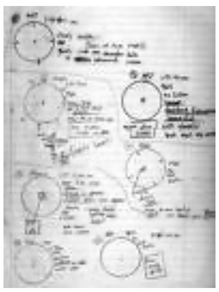
Problems: Recommended to work through and understand: 2.1, 2.2, 2.3

HAND-IN FOR MARKING: 2.2
DUE DATE: 2026-10-01

C: Week of 2026-09-28

Moving Charges (Non-Relativistic)

Readings: R&L 3.1 to 3.5 inclusive



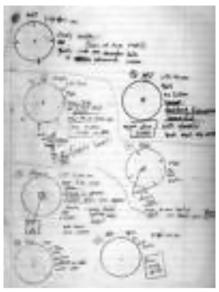
Class Schedule: Tuesday lecture in-person; Wednesday (**no class**); Friday via zoom (synchronous)

Problems: Recommended to work through and understand: 3.1, 3.2, 3.3, 3.5, 3.6, 3.7

HAND-IN FOR MARKING: 3.1
DUE DATE: 2026-10-09

D: Week of 2026-10-05
Bremsstrahlung (Non-Relativistic)

Readings: 5.1 to 5.3 inclusive



Class Schedule: Tuesday and Wednesday lectures in-person; Friday via zoom (synchronous)

Problems: Recommended to work through and understand: 5.1, 5.2

HAND-IN FOR MARKING: 5.2 ONLY
DUE DATE: 2026-10-16

E: Week of 2026-10-12

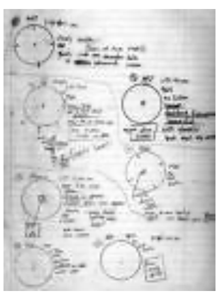
No Classes This Week (2026)

F: Week of 2026-10-19

Finish Bremsstrahlung and Start Relativistic Motion (2026)

Readings: Catch-up week for Chapters 1-3; and 5 Midterm will cover these four chapters

Readings: Start on R&L 4.1 and 4.5 to 4.9 inclusive (4.2-4.4 is optional)



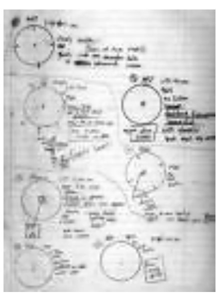
Class Schedule: Tuesday and Wednesday lectures in-person; Friday via zoom (synchronous)

MIDTERM ON TUESDAY 2026-10-27

G: Week of 2026-10-26
Relativistic Motion

Readings: R&L 4.1 and 4.5 to 4.9 inclusive
(4.2-4.4 is optional)

In this class, we will not use tensors or four-vectors. We will make do with algebraic expressions for the transformations -- but you should know the conversation laws and how E and B fields transform.



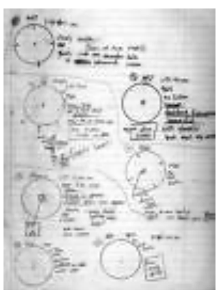
Class Schedule: **In-person Midterm on Tuesday 2026-10-27**
Tuesday and Wednesday lectures in-person; Friday via zoom (synchronous)

Problems: Recommended to work through and understand: 4.1, 4.2, 4.4, 4.7, 4.10, 4.11, 4.12, 4.13

HAND-IN FOR MARKING: 4.1 ONLY
DUE DATE: 2026-11-04

H: Week of 2026-11-02
Synchrotron Radiation

Readings: R&L 6.1 to 6.4 inclusive; and 6.6



Class Schedule: Tuesday and Wednesday lectures in-person; Friday via zoom (synchronous)

Problems: Recommended to work through and understand: 6.1, 6.2, 6.3, 6.4

HAND-IN FOR MARKING: 6.1 ONLY
DUE DATE: 2026-11-13

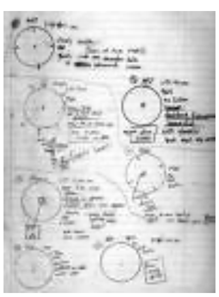
I: Week of 2026-11-09

READING BREAK (NOV 9TH TO 11TH); NO CLASS ON FRIDAY

J: Week of 2026-11-16

Compton Scattering A

Readings: R&L 7.1 to 7.4 inclusive See last week & next week



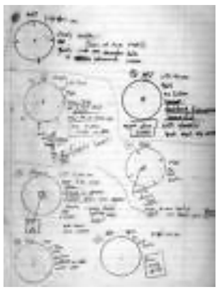
Class Schedule: Tuesday and Wednesday lectures in-person; Friday (TBD)

Problems: See entry for next week

K: Week of 2026-11-23

Compton Scattering B

Readings: R&L 7.6 to 7.7 inclusive



Class Schedule: Tuesday and Wednesday lectures in-person; Friday (TBD)

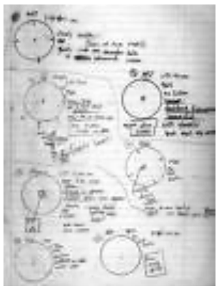
Problems: Recommended to work through and understand: 7.1, 7.2, 7.3

HAND-IN FOR MARKING: 7.1 ONLY
DUE DATE: 2026-11-27

L: Week of 2026-11-30

LAST WEEK: CATCH-UP OR MAYBE 21cm RADIATION -- TO BE DECIDED

Readings: Class notes

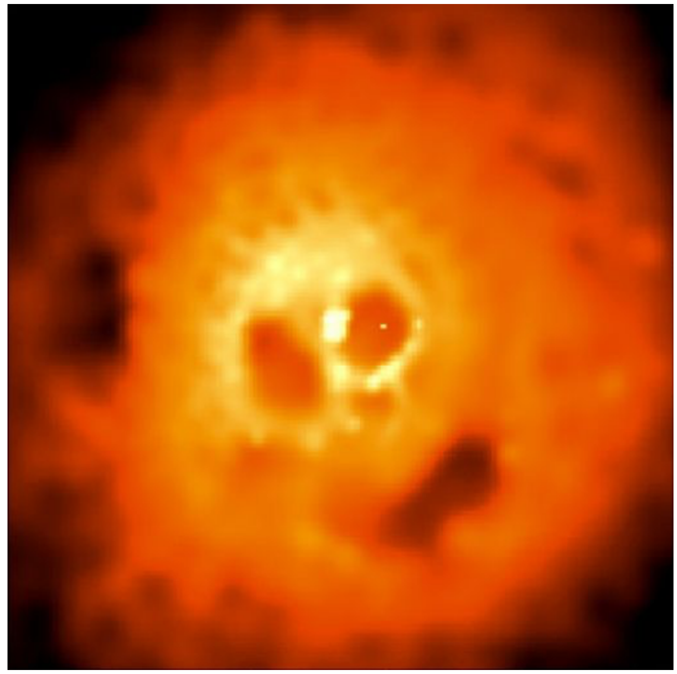


Class Schedule: Tuesday, Wednesday and Friday lectures in-person

Problems:

HAND-IN FOR MARKING:
DUE DATE:

Course Grading Scheme



Problem Sets (see below):	10%
Midterm Test (see below):	40%
Final Exam (see below)	50%

UVIC Grading Scheme and Percent-to-Letter Grade Conversion
(will open in new window)

*Problems Sets

See **EXPECTATIONS section** for detailed instructions for completing and submitting the problem sets.

*Midterm and Final Exam Schedule

The midterm exam is usually scheduled in mid-october. It will be an in-class, in-person event unless otherwise announced. You will find the exact date in **TOPICS section** .

The date of the final exam will be announced by the UNIVERSITY closer to the end of term. Please check the final exam schedule when available.

Questions on the midterm and the final will be a mix of questions similar to those in your textbook and those worked out in class. Each year, between 1-3 questions on each of the midterm and final are either verbatim versions of the problems worked out in class or those recommended to you to work on, or nearly the same with a minor twist.

"Cheat Sheet" policy: For both the midterm and the exam, you are allowed to bring cheat sheet (unless informed otherwise). It cannot be bigger than a 8.5" X 11" sheet of paper. You may write on both sides but it most definitely should be handwritten and in your own handwriting.

Calculator Restrictions on Midterms and Final Tests: According to recently adopted Department of Physics and Astronomy policy, in cases where the use of a calculator is allowed on a test or an exam (as in this course), the standard, and only, calculator that may be used is the Sharp EL-510R or Sharp EL-510RNB. For updates to allowed models (and departmental policy), please see FAQ page on department webpage for current undergraduate students. Allowed calculators are available for purchase from the Bookstore (for example) for about $10, plus taxes.