Course Pack Contents

Rough Sketch of the Week

TIME PERIOD 1330 – 1545 Monday through Friday.

CLASSROOM PREPARATION Chairs in circular arrangement; later adjust to form five groups. Post physics and astronomy posters on wall.

GENERAL STRUCTURE

Monday	Discussion: What this course is about; questions addressed by astronomy Explain research projects; students select topics Discussion: The scale of things Spectroscopy lab and discussion
Tuesday	Student selected discussion; distribute example written reports Research time in science library Collect project proposals
Wednesday	Solar observation lab and discussion Research time in science library
Thursday	Photoelasticity lab and discussion Research time in science library
Friday	Poster session and feedback Final words: Careers in science; emerging projects in astronomy; faster than the speed of light? Students complete instructor evaluations

Research/Design Project Guide

Background One of the objectives of scientific inquiry is to answer specific questions that we have about the world around us. Similarly, the main objective of engineering is to design a process, device, or system that solves a specific problem or fulfills a particular need. You and your teammate(s) will select a question or problem that interests you and report on what work has been (and is being) done to address your question or problem. If it is something that has already been conclusively addressed (i.e., how to measure the speed of light), please describe to the best of your ability the method used to answer the question or devise the solution, and the steps taken to arrive at that method. If on the other hand it is a question or problem that is currently being addressed (i.e., theory of quantum gravity), please describe the ongoing efforts and, if you wish, note any contributions you would like to make.

The projects will be comprised of three main parts: a project proposal, a written report, and a poster. Please use a computer to print your proposal and written report. If no-one on your team has access to a computer and/or printer, please contact one of the instructors as soon as possible.

Project Proposal Your team will select a general topic (or "topic phrase") on Monday, but will refine the focus of your project by submitting a project proposal at the end of class on Tuesday. On Page 5 is a guide designed to help you draft your project proposal.

Written Report On Friday, your team will submit a written report with two main parts:

> *Technical Paper* Your technical paper will discuss in detail the answer or solution to your question or problem—or, if there is not yet a conclusive answer or solution, will discuss relevant ongoing efforts to address it. On Page 7 is a guide designed to help you write your technical paper.
>
> *Project Narrative* Your project narrative will be a written description of the process that your team went through while writing your technical paper and preparing your poster. Its purpose is to help your team think about and understand your individual involvement in the research process and your team's operation as a group. On Page 8 is a guide designed to help you write your project narrative.

Poster Finally, your team will share your findings with the class by preparing a poster. All of the posters will be displayed during class on Friday in a poster session, during which instructors and students will provide feedback on the posters. Teams should prepare to the best of their ability to answer any questions that instructors or students might have. On Page 9 is a guide designed to help you create your poster.

A Few Project Ideas Below, listed in categories, are a few topic phrases that might lead to interesting projects. Note that most of these are so broad that entire volumes have been written about them. This is good from a reference point of view, but also means that you must be very specific when writing your project proposals.

Our Solar System

- Composition
- Formation
- Sunspots, prominences, and the solar furnace

- The solar wind and the heliopause
- Atmospheres of the gas giants
- Near-Earth objects
- Quaoar and other orbital oddities
- Pluto, Charon, and the fuzzy boundaries of planethood
- The Kuiper Belt and the Oort Cloud
- Life on the Jovian moons?
- Past, present, and/or future missions of exploration
- Planned and/or possible commercial space endeavors
- "Mining the sky"
- Getting from here to there in the solar system
- Kepler's Law and orbital mechanics

Life in the Universe

- SETI
- The Drake Equation
- Voyager's message in a bottle and imagining a message from an extraterrestrial intelligence

Beyond the Heliopause

- The stellar life cycle
- Extrasolar planets
- The Milky Way galaxy, our neighborhood of galaxies, and the structure of the universe

Astrophysical Exotics

- Chandrasekhar's limit and the stellar endgame: novae, supernovae, white dwarfs, neutron stars, and black holes
- Black holes in detail
- Pulsars, quasars, cosmic rays, and other faraway things

Cosmology

- The cosmological speed limit and special relativity
- What is gravity?
- The cosmic microwave background
- Defining a universe: fundamental physical constants and what the universe would be like if they were different
- Dark matter, dark energy, the magically reappearing cosmological constant, and other accomplices in our inexplicably accelerating universe
- The singularity dilemma and theories of quantum gravity
- Topology: the shape of the universe
- Elementary particles
- What is light?

Tools and Techniques of Astronomy and Cosmology

- How to find an extrasolar planet
- How to find a black hole
- Looking back in time: measuring the cosmic microwave background
- How do we know the universe is expanding?

Project Proposal Guide

Your project proposal is the document that tells your readers

- What your project objective is
- Why you want to do it (i.e., why you feel it is important)
- How you will accomplish your project objective
- How you will present your findings to others

Professional scientists write proposals in order to obtain funding from agencies like the National Science Foundation. While writing your proposal, think carefully about *why* you are investigating a particular topic, and what someone interested in funding your project might think. If you are not convinced that your topic is important, this does not mean you should lie; rather, it means that you may wish to consider modifying your topic or selecting an entirely new one.

Your proposal should be written in paragraph form and should have approximately the following sections, in approximately the following order. You may label each section if you like, but keep in mind that if you cannot tell one section from another without labeling them you may wish to make some revisions. Finally, your proposal should probably not be longer than two pages.

TITLE Your title should describe what your project *is* or *does*—not just what it is about—as specifically as possible while remaining concise. Your title may be a question if you feel it is appropriate. Note that while "Black Holes" is not a very informative title, "What Are Black Holes?" is moderately helpful and "An Overview of Modern Theories of Black Hole Physics" tells us exactly what we are getting into. If you are feeling particularly poetic, feel free to add a creative part to your title—i.e., "Singularity Sky: An Overview of Modern Theories of Black Hole Physics." You can probably be more creative, though, and not copy your title from a science fiction novel like the above example.

PURPOSE OF YOUR PROJECT What is the purpose of your project? Answer this question as specifically, simply, and concisely as you can. This should consist mainly of the specific question that you are trying to answer (i.e., "What are black holes?") or problem you are trying to solve (i.e., "How to accurately measure the speed of light").

CONTEXT Briefly discuss the broader context of your project. Why is your project important? Is answering your question the stepping stone to a theory of quantum gravity? Is there a social or practical need that your design fulfills? Be broad, but make the link to your project very clear.

PRIOR KNOWLEDGE Briefly summarize whatever previous knowledge the team members have about the topic.

METHODS Briefly describe how you plan to accomplish your objective. Be as specific as possible; if you have particular books, web sites, people, or other resources in mind that you think will help you in your work, list them (please use a standard citation format for listing books and web sites). Also discuss any difficulties or challenges you think you may encounter during the course of your project. This could be anything from "We have heard that understanding relativity is hard" to "Nobody on the team has a computer." Discuss possible methods for overcoming each potential difficulty.

DISPLAY OF FINDINGS Briefly discuss how you plan to display your findings; what figures or tables do you plan to include in your technical paper? In your poster? What do you plan to discuss in the text of your technical paper?

OTHER THOUGHTS Please note any other thoughts or concerns that your team might have about the project. Again, please be as specific as possible. (This section is, of course, optional.)

FIG. 1. Please refrain from using heavy explosives to power your project.

Technical Paper Guide

Your technical paper is the heart of your project, and should be as complete and accurate as you can make it—but remember to be concise. Do not include useless or irrelevant information. There is no length limit or requirement for the technical paper: it should be as long as you need it to be in order to accomplish the objective that you described in your proposal, but no longer.

TITLE Your title should be the same as your proposal title. You knew that already.

INTRODUCTION Your introduction should serve to orient your reader. In approximately the following order (and in paragraph form), answer the following questions:

- What is your project objective?
- What broader context does your project fit into?
- Why is your project important?
- How did you achieve your project objective?

Note that if you did a good job writing the "Context" and "Methods" sections of your proposal, you should be able to use those (with some editing!) as a starting point for your introduction. Additionally, explain any related phenomena, processes, or physical principles that your reader needs to understand before they can understand your project.

FINDINGS Present the answer to your question or the solution to your problem. Do this in as much detail as you are able. If, for example, complicated mathematics is needed to fully understand the answer or solution, you will not be required to understand or discuss the mathematics, but you should provide a thorough and clear discussion of the physical concepts involved. ("Complicated mathematics" in this case means "calculus". Even if you have not yet taken an algebra course, you can work with your teammates, classmates, and instructors to develop an understanding of more or less any non-calculus mathematics that is pertinent to your project—and you should do your best to include it in your findings along with an explanation.) Use figures, tables, and equations where you feel they are appropriate and help convey information to the reader.

If you would like to make an original contribution—a new design for solving a problem, for example—this is the place to do it. Please ensure that these are thoroughly explained.

POTENTIAL AREAS FOR FUTURE RESEARCH AND/OR OTHER APPLICATIONS Unless this is already addressed in your findings, briefly discuss (1) potential areas for future research—i.e., things we still don't know about—and (2) potentially useful or interesting uses for the principles, processes, phenomena, or technology discussed in your findings.

CONCLUSION In no more than three or four sentences, restate your major findings and discuss the most interesting or promising (to you) area for future research or application of your findings.

REFERENCES List the references you used. For websites and books, use a standard citation format.

Project Narrative Guide

Your project narrative is designed to help you think about your individual involvement in the research/design process and your team's functioning as a group. Broadly, it should tell the story of your team as you completed the project and offer each team member's reflections on the process. It should be written in paragraph form and not be longer than two pages.

THE STORY Tell the story of the project. This should comprise about half of your project narrative.

ANALYSIS Each team member should compose a reflection (in paragraph) on the project process. Use the following questions as a starting point, but do not simply list answers to them.

- What did you learn about the science? about working in groups?
- What were the most notable difficulties that you faced as an individual? as a team? How did you overcome them?
- What were the team's strengths as a group? the team's weaknesses?
- What perspectives, skills, or knowledge did each team member bring to the group that was unique?
- What would you do differently if you could repeat the project?

Poster Guide

Science and engineering poster sessions provide you with an opportunity to discuss your work with your colleagues and other participants in an informal setting. The objectives of your poster should be to:

- Visually stimulate an interest in your project.
- Present enough information for viewers to understand the significance and methods of your work.
- Stimulate conversations and networking among participants.

ORGANIZATION Your poster should include the following textual items. Text from your proposal or technical paper should do the trick, with a little editing. Textual items should be mainly in paragraph form, but feel free to use bulleted lists or tables if you feel that they will help convey information more effectively.

- Title
- Purpose
- Introduction: context, project importance, related information, and methods
- Findings
- Potential areas for future research and/or other applications

DESIGN NOTES Perhaps the most useful thing to keep in mind while creating your poster in the objective behind it: remember that you are trying to stimulate interest, not provide complete details.

Avoid clutter. Your poster does not need to completely explain your findings down to the finest detail. It should serve to convey enough information that your reader (1) is interested in your work and (2) understands why your work is important. Once you have achieved that, they will either speak with you directly or proceed to your written report. Keep this in mind, and select only the most important material. Minimize purely decorative material.

Create a logical flow. Your poster should have a clear sense of direction, which should match the logical flow of information (i.e., introduction, then purpose, then findings, and so on). Your poster should generally flow from left to right. Use lines, frames, contrasting colors, or arrows to call attention to important points.

Keep it clean. Select a clean, simple font and use it consistently. The smallest letters should be 18 point and easy to read. Do not use all capital letters, especially in the text blocks.

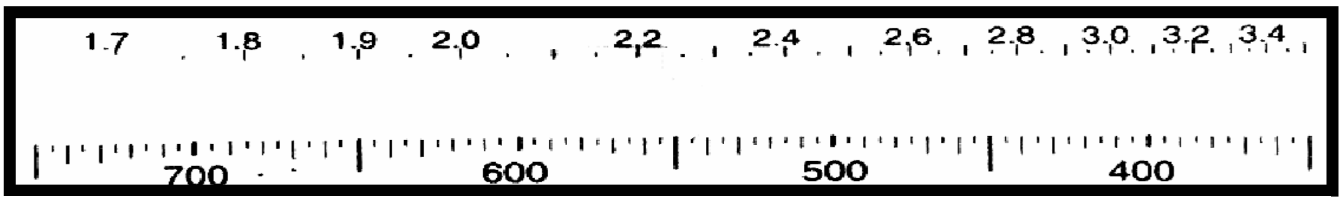
Colors. Use colors to accent important information, but do not overuse them: generally, no more than four colors are called for (with the exception of color figures).

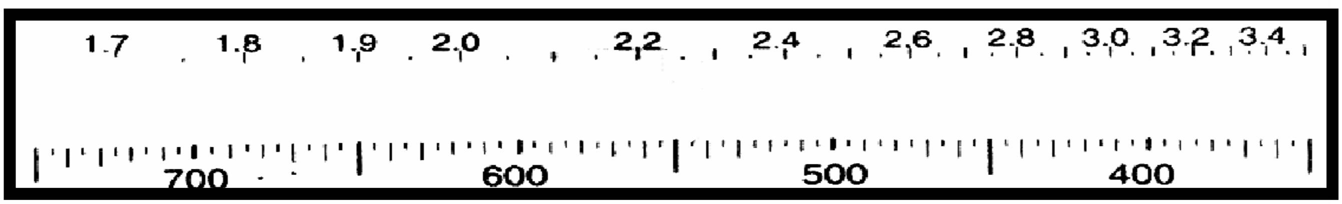
Adapted from “Poster Tips” by Charles Lea, Sea Education Association.

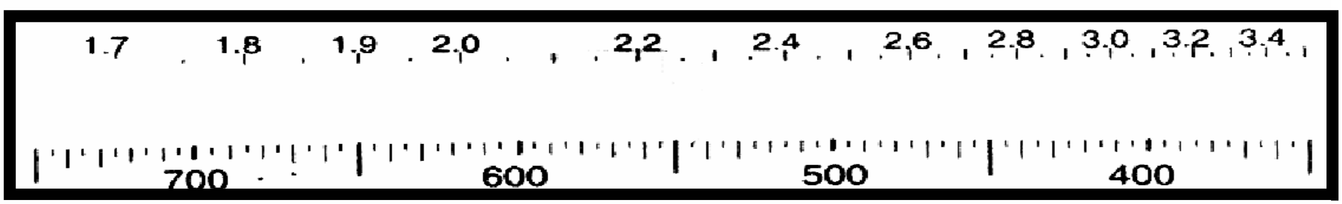
Spectroscopy Lab and Datasheet

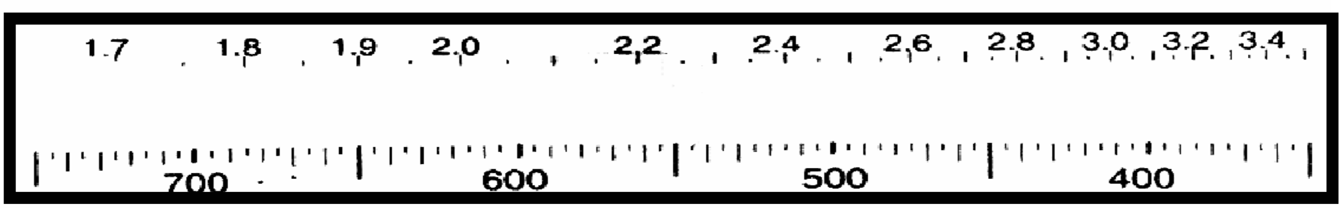
This afternoon you will earn your credentials as a cosmic detective. Four unknown substances have been gathered in gaseous form and placed in tubes. When a voltage is placed across the tubes, the gases *fluoresce* or give off light. Using only a reference sheet and a simple tool called a spectroscope, your task is to identify each substance.

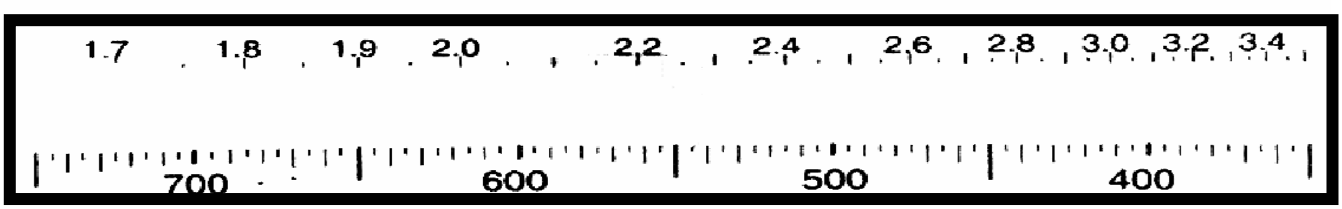
You may find the markings below to be of use in your quest. The reference sheets begin on Page 11.







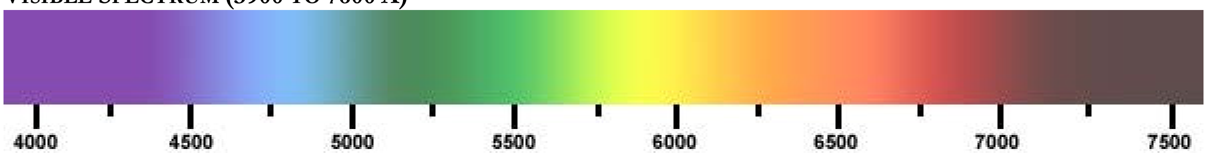




Emission Spectra Reference Sheet

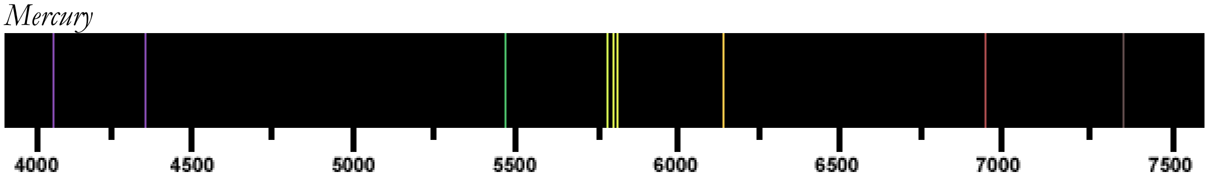
NOTE 1 Å ("Angstrom") = 1 x 10^{-10} m = 0.1 nm.

VISIBLE SPECTRUM (3900 TO 7600 Å)

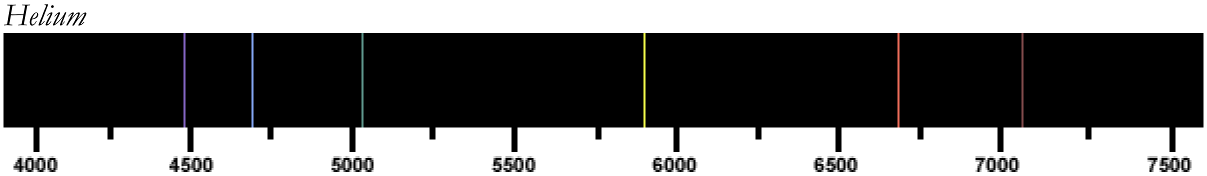


EMISSION (BRIGHT LINE) SPECTRA

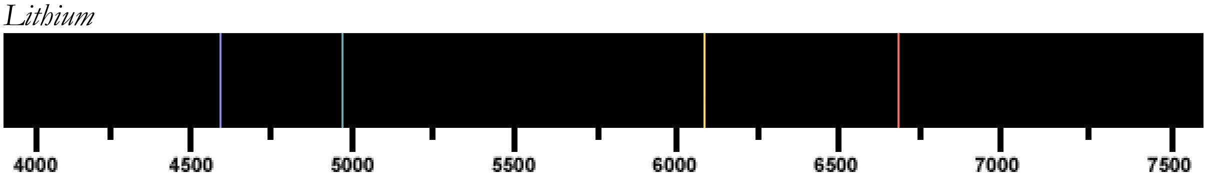
Mercury



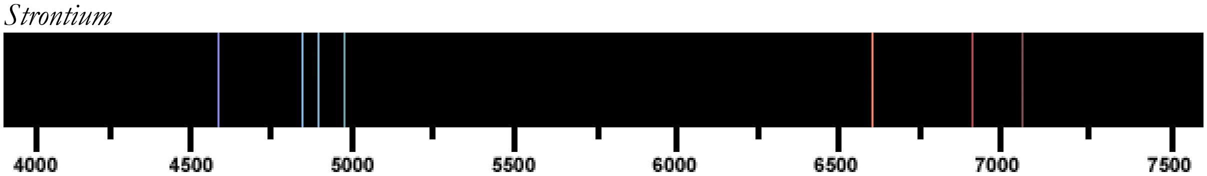
Helium



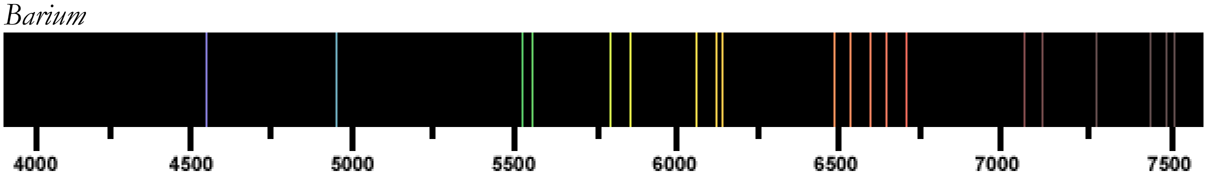
Lithium



Strontium

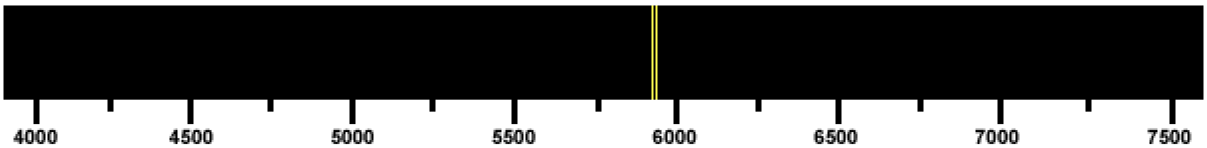


Barium

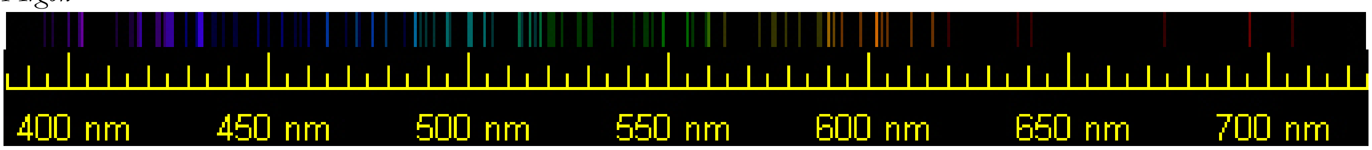


Hydrogen

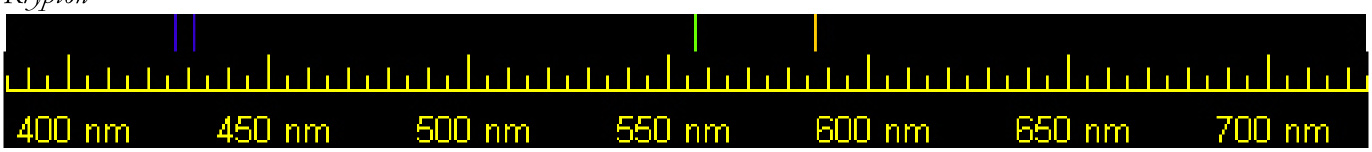
Sodium



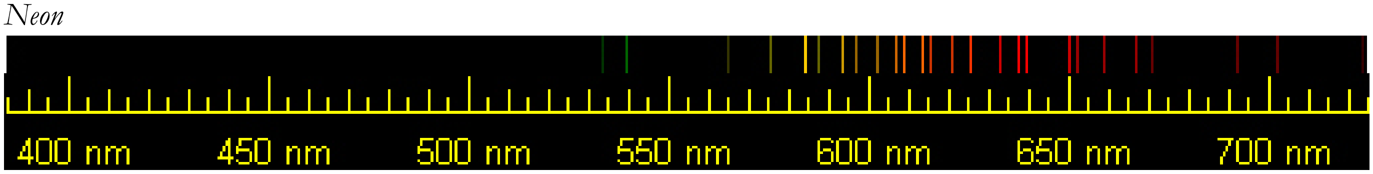
Argon



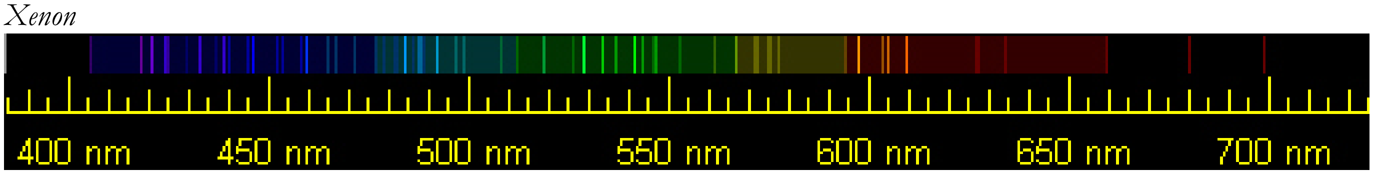
Krypton



Neon

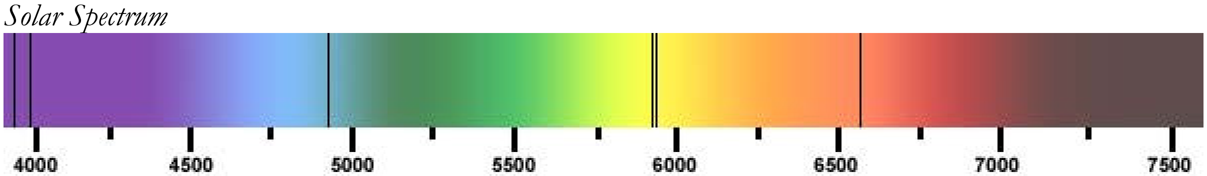


Xenon

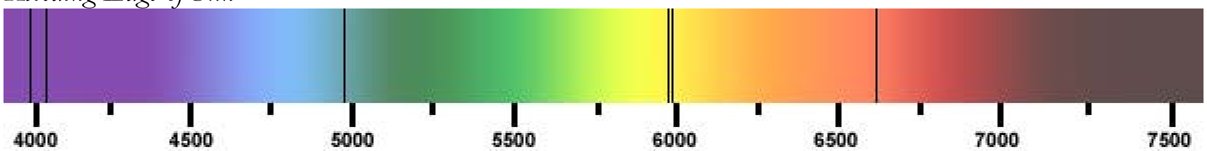


ABSORPTION SPECTRA

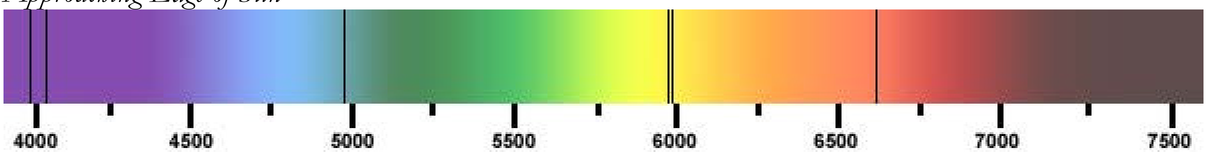
Solar Spectrum



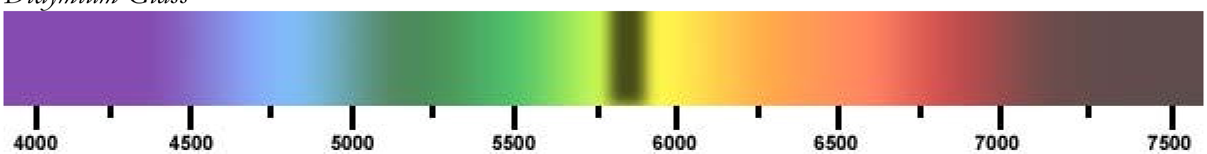
Receding Edge of Sun



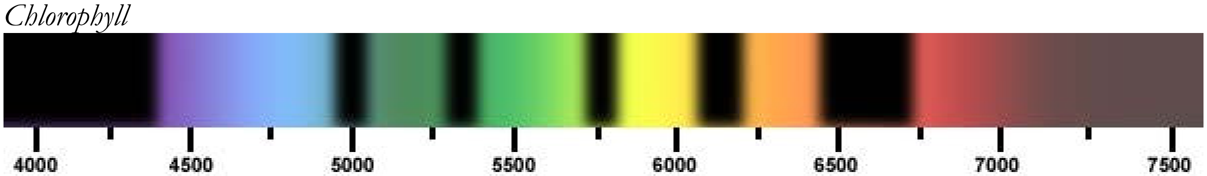
Approaching Edge of Sun



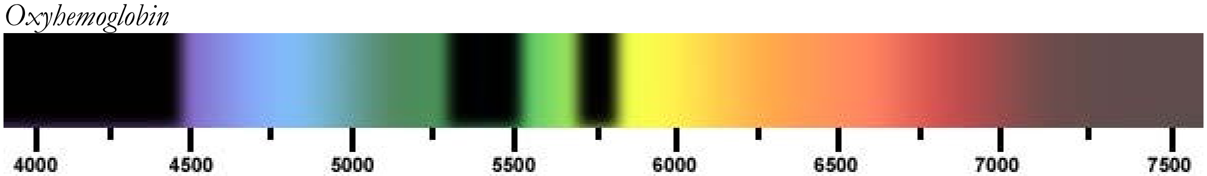
Didymium Glass



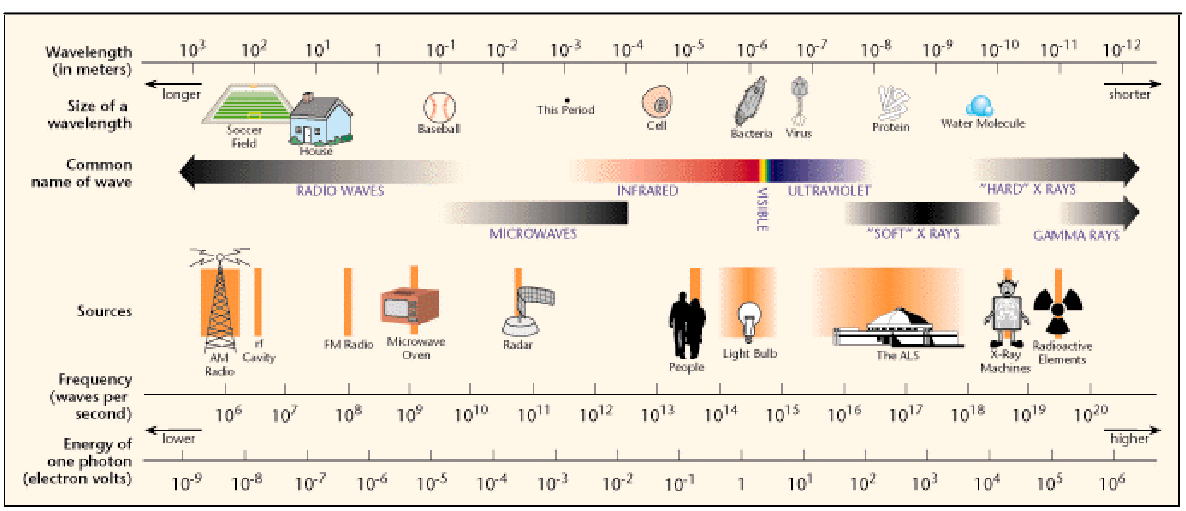
Chlorophyll



Oxyhemoglobin

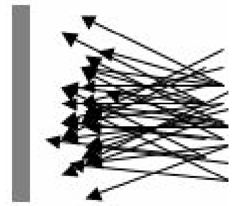


ELECTROMAGNETIC SPECTRUM REFERENCE



Discussion Reference: Spectroscopy

ANATOMY OF A SPECTROSCOPE The spectroscope is a simple yet very useful device containing a diffraction grating, a scale, and a lens. In the spectroscopes we used, light enters from a clear slit in the transparency. The thin beam of light travels the length of the housing until it reaches a lens, which collimates the beam (focuses it to infinity; see Fig. 2). The diffraction grating is located just after the lens, and you place your eye up close to the grating as you look through it. The grating disperses the different wavelengths (colors) of light, because the diffraction angle is a function of wavelength. The resulting rainbow image appears to be located at optical infinity, superimposed on the scales (Fig. 3). The markings on the scales are actually transparent too, so that rear illumination allows you to see them clearly.


(a)

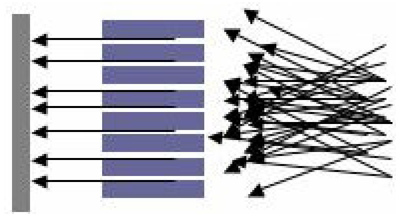

(b)

FIG. 2. (a) Without a collimator. (b) With a collimator. After passing through the collimator, the rays of light appear to be coming from a source infinitely far away from the observer.

WAVE NATURE OF LIGHT When we look at the behavior of light interacting with the various components of our spectroscope, we think of it as behaving like a *wave*; that is, we are able to diffract it (with the diffraction grating), refract it and collimate it (with the lens), and identify materials based on the colors—that is, the *wavelengths* of light—that we observe. These are all things that we could not do to the light if it were simply a beam of discrete particles or packets.

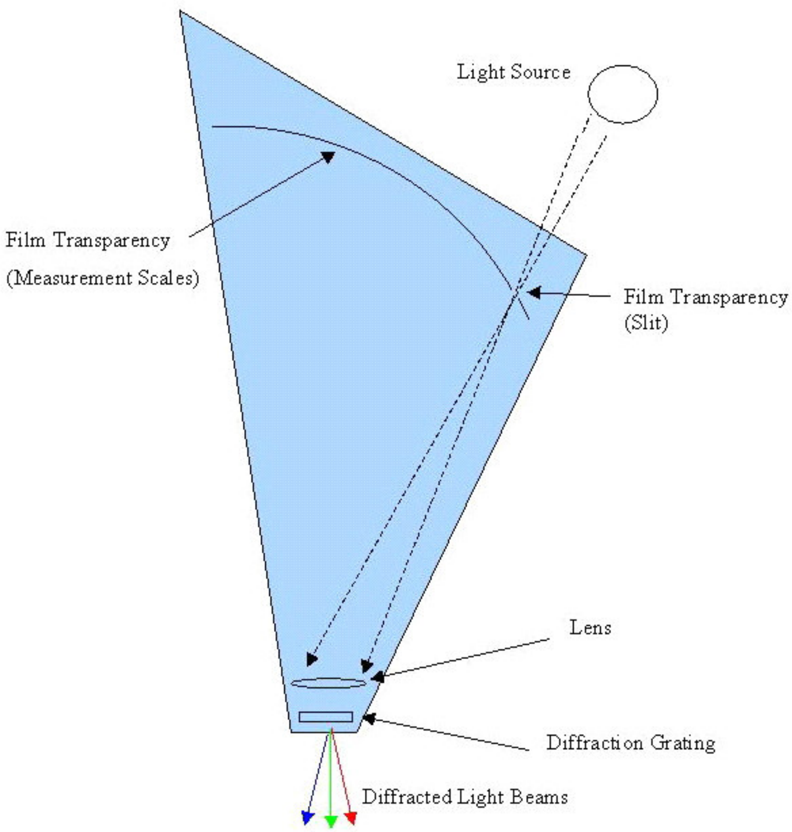


FIG. 3. Path of light rays through the spectroscope and to the observer.

EMISSION SPECTRA Why do different substances have different emission spectra, and why do they so precisely correspond to different wavelengths of light? The long answer to this question lies in the atomic structure of the elements, but the short answer is that the elements react differently to different wavelengths because packets or particles of light—called *photons*—of a given wavelength carry a certain amount of energy that depends only on the wavelength. But we agreed that our spectroscopes would only work if light behaved like a wave and *not* like a beam of tiny particles. What is going on here? What *is* light?

The mystery deepens...

Solar Observation Lab

Today we will look through a simple telescope at the sun. Of course, we will use *filters* to reduce the amount of light that reaches our eyes when we do so; if we were to look at the sun directly without using a filter of some sort, our retinae (the parts of our eyes that tell our brains about the amount of light that is reaching our eyes) would start to look like a couple of fried eggs and we would quickly become blind.

Use the space below to make drawings or take notes of any interesting observations you make (i.e., sunspots or prominences) or thoughts you might have.

Discussion Reference: The Sun

The big burning ball of gas that holds nine major planets in orbit is similar to many stars in the universe. The Sun makes up 99.86 percent of the solar system's mass and provides the energy that both sustains and endangers us. Scientists have lately begun calling its tremendous outpouring of energy "space weather."

MASSIVE ENERGY The Sun can be divided into three main layers: a core, a radiative zone, and a convective zone. The Sun's energy comes from thermonuclear reactions (converting hydrogen to helium) in the core, where the temperature is 15 to 25 million degrees. The energy radiates through the middle layer, then bubbles and boils to the surface in a process called convection. Charged particles, called the solar wind, stream out at a million miles an hour.

SUNSPOTS Magnetic fields within the sun slow down the radiation of heat in some areas, causing sunspots, which are cool areas and appear as dark patches. Sunspot activity peaks every 11 years. During this so-called solar maximum, the sun will bombard Earth's atmosphere with extra doses of solar radiation. The peak in 1989 caused power blackouts, knocked satellites out of orbit and disrupted radio communications.

Scientists also say a small ice age from 1645 to 1715 corresponded to a time of reduced solar activity, and current rises in temperatures might be related to increased solar activity.

SOLAR FLARES The Sun frequently spews out plumes of energy, essentially bursts of solar wind. These solar flares contain Gamma rays and X-rays, plus energized particles (protons and electrons). Energy equal to a billion megatons of TNT is released in a matter of minutes. Flare activity picks up as sunspots increase.

EFFECT ON EARTH The Sun's charged high-speed particles push and shape Earth's magnetic field into a teardrop shape. The magnetic field protects Earth from most of the harmful solar radiation, but extreme flares can disable satellites and disrupt communication signals. The charged particles also excite oxygen and nitrogen in the atmosphere, creating the aurora borealis, or northern lights. More solar radiation during the upcoming solar maximum means an increase in the aurora.

CORONAL MASS EJECTIONS Similar to a solar flare, a coronal mass ejection is a bubble of gas and charged particles ejected over several hours. It can occur with or without solar flares, and can also threaten Earth's atmosphere.

NOTA BENE If you stood on the Sun, its gravity would make you feel 38 times more heavy than you do on Earth. But it's kind of hot, so please don't try it.

From http://www.space.com/scienceastronomy/solarsystem/sun-ez.html.

Photoelasticity Demonstration

Place a transparent plastic object in between two polarizing filters (called a "plane polariscope"). The colors that appear will highlight the stresses in the object being examined.

FIG. 4. Equipment for the photoelasticity demonstration.

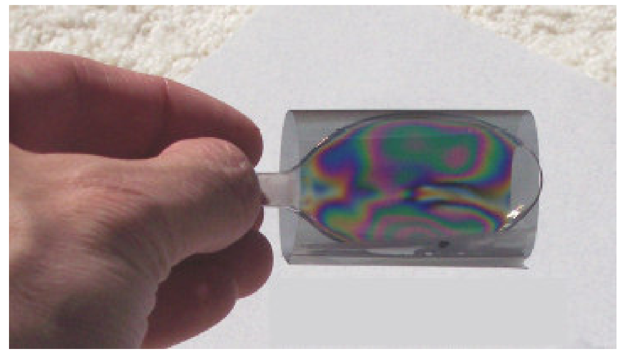


FIG. 5. Photoelasticity patterns observed through a plane polarizer.

Use the space below to draw the pattern you observe, or to make any other observations or notes that seem interesting.

Discussion Reference: Polarization

Natural sunlight and most forms of artificial illumination transmit light waves whose electric field vectors vibrate equally in all planes perpendicular to the direction of propagation. When their electric field vectors are restricted to a single plane by filtration, however, then the light is polarized with respect to the direction of propagation.

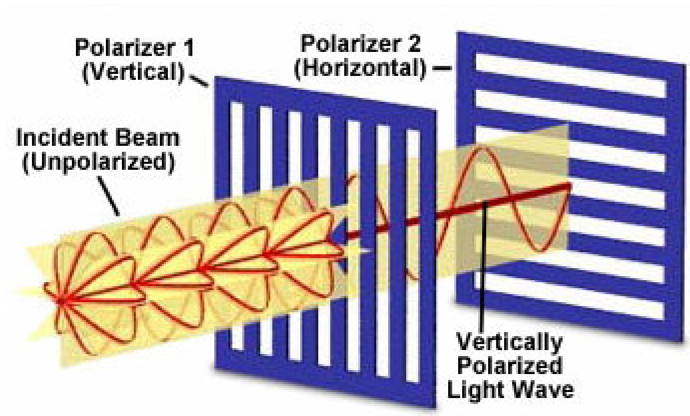


FIG. 6. Unpolarized light passing through crossed polarizers.

In Fig. 6, the electric field vectors of the incident light are vibrating perpendicular to the direction of propagation in an equal distribution of all planes before encountering the first polarizer, a filter containing long-chain polymer molecules that are oriented in a single direction. Only the incident light that is vibrating parallel to the polarization direction is allowed to continue propagating unimpeded. Therefore, since Polarizer 1 is oriented vertically, it only permits the vertical waves in the incident beam to pass. However, the waves that pass through Polarizer 1 are subsequently blocked by Polarizer 2 because it is oriented horizontally and absorbs all of the waves that reach it due to their vertical orientation. The act of using two polarizers oriented at right angles with respect to each other is commonly termed crossed polarization and is fundamental to the practice of polarized light microscopy.

From http://micro.magnet.fsu.edu/optics/lightandcolor/polarization.html.

Course Evaluation

Please complete this course evaluation thoroughly and honestly; this course exists for you, the students, and your feedback is the most important way for us as instructors to improve our courses and our teaching. We thank you for your honest input.

Session _____
Student Name (optional) ____________________

Please indicate agreement or disagreement with statements 1 through 11 by selecting a number from 1 to 10, where 10 means "I strongly agree" and 1 means "I strongly disagree".

1. I had fun in this course. _____
2. I learned a lot in this course. _____
3. The hands-on activities contributed significantly to my learning. _____
4. The discussions contributed significantly to my learning. _____
5. The handouts contributed significantly to my learning. _____
6. The research project contributed significantly to my learning. _____
7. The hands-on activities were relevant and interesting. _____
8. The discussions were relevant and interesting. _____
9. The handouts were relevant and interesting. _____
10. The research project was relevant and interesting. _____
11. Having more than one instructor improved the course experience. _____

Please answer the following questions.

10. What do you think were the best parts of the course?

11. What would you change about the course or do differently if you were an instructor?

12. Do you feel that the course helped you gain an understanding of what astronomy is and what it means to "do" science? If so, was there any activity or event in particular that you felt stood out? If not, how do you think we could do a better job at conveying those ideas?

13. Would you take an astronomy course (not necessarily this one) again in the future, if you could?

14. Would you recommend this course to your friends?

Please make any additional comments or suggestions on the back of this sheet or on a separate piece of paper.

Instructor Evaluation

Please complete this instructor evaluation thoroughly and honestly; this course exists for you, the students, and your feedback is the most important way for us as instructors to improve our courses and our teaching. We thank you for your honest input.

Session _____
Student Name (optional) ____________________
Instructor Name ____________________

Please indicate agreement or disagreement with statements 1 through 8 by selecting a number from 1 to 10, where 10 means "I strongly agree" and 1 means "I strongly disagree".

1. The instructor knew the material well. _____
2. The instructor explained the material well. _____
3. The instructor was approachable and helpful rather than intimidating. _____
4. The instructor ensured that all students were involved in the learning process, including hands-on activities and discussions. _____
5. The instructor was a pleasant person to be in the classroom with. _____
6. The instructor was genuinely interested in engaging both the students and the material. _____
7. The instructor contributed significantly to my understanding of the material. _____
8. The instructor contributed significantly to my understanding of what it means to "do" science. _____

Please answer the following questions.

9. What did the instructor do best?

10. What advice would you give the instructor to improve his/her teaching?

11. Would you take another course with this instructor?

12. Would you recommend this instructor to a friend?

Please make any additional comments or suggestions on the back of this sheet or on a separate piece of paper.

Instructor Evaluation

Please complete this instructor evaluation thoroughly and honestly; this course exists for you, the students, and your feedback is the most important way for us as instructors to improve our courses and our teaching. We thank you for your honest input.

Session _____
Student Name (optional) ____________________
Instructor Name ____________________

Please indicate agreement or disagreement with statements 1 through 8 by selecting a number from 1 to 10, where 10 means "I strongly agree" and 1 means "I strongly disagree".

1. The instructor knew the material well. _____
2. The instructor explained the material well. _____
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5. The instructor was a pleasant person to be in the classroom with. _____
6. The instructor was genuinely interested in engaging both the students and the material. _____
7. The instructor contributed significantly to my understanding of the material. _____
8. The instructor contributed significantly to my understanding of what it means to "do" science. _____

Please answer the following questions.

9. What did the instructor do best?

10. What advice would you give the instructor to improve his/her teaching?

11. Would you take another course with this instructor?

12. Would you recommend this instructor to a friend?

Please make any additional comments or suggestions on the back of this sheet or on a separate piece of paper.

Instructor Evaluation

Please complete this instructor evaluation thoroughly and honestly; this course exists for you, the students, and your feedback is the most important way for us as instructors to improve our courses and our teaching. We thank you for your honest input.

Session _____
Student Name (optional) ____________________
Instructor Name ____________________

Please indicate agreement or disagreement with statements 1 through 8 by selecting a number from 1 to 10, where 10 means "I strongly agree" and 1 means "I strongly disagree".

1. The instructor knew the material well. _____
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5. The instructor was a pleasant person to be in the classroom with. _____
6. The instructor was genuinely interested in engaging both the students and the material. _____
7. The instructor contributed significantly to my understanding of the material. _____
8. The instructor contributed significantly to my understanding of what it means to "do" science. _____

Please answer the following questions.

9. What did the instructor do best?

10. What advice would you give the instructor to improve his/her teaching?

11. Would you take another course with this instructor?

12. Would you recommend this instructor to a friend?

Please make any additional comments or suggestions on the back of this sheet or on a separate piece of paper.

Course Materials List (for One Week)

For this materials list we assume that the class has 20 students.

Research/Design Project Materials and Equipment

- Access to a science library with physics and astronomy texts
- Access to a computer lab with at least 15 computers with internet access and at least one color printer
- 100 sheets of construction paper or copy paper of various colors
- 10 foam poster boards, approximately 36” x 30”
- Colored pencils and/or markers
- 10 pairs of scissors
- 4 standard rolls of stationery tape
- 5 to 10 calculators

Spectroscopy Lab Equipment

- 4 gas-filled tubes with holders
- 4 spectroscopes

Solar Observation Lab Equipment

- About 3 telescopes with solar filters

Photoelasticity Demonstration

- 20 “Magic Stripes” Theme Packs