Introduction to the Chapter Study Guides

READ THIS!!!

(please!)

Each chapter Study Guide tells you what you are expected to do to understand a chapter. The general organization is as follows:

Chapter goal: a general statement about what you will be learning
The Big Picture: how this fits in to the course
Reading Assignment: This is what you need to read in your textbook
Important concepts/terms in bold: an organized list of the most important terms/concepts in the chapter
Chapter objectives: Specific objectives of what you should learn from the chapter
Section by section statements: what you need to learn---what's important
Activities and assignments (if any) to be done
Additional help and explanation: anything else I think will be helpful to you. **This is important to read as it sometimes contains necessary information not in the text.**

Your book has a number of features to help you learn the material. **First** of all, you should look over the detailed table of contents for the chapter you are working on so that you can see the general subjects you will study. At the start of each chapter the authors list their learning objectives for the chapter. I do not always agree in detail with them, and I also feel you need more guidance than what the authors have written. Thus, the Study Guides include my statements of objectives to help you out. Be sure to study the *Summary of Key Concepts* at the end of each chapter.

How do you know what's important? The Study Guide gives, for each chapter, a list of "learning objectives; and for each section of your reading (something called *Section by Section*), statements of what you need to get from the reading. *If you know these, you will know the course material well.*

Please remember: Pima Community College says that students should be spending some 2 hours outside of class for every hour in class. (The University of Arizona says 2-3 hours out for every hour in class.) Because our class includes a lab that accounts for 3 hours per week of class time, you can reasonably expect to spend *an average of* 6-9 hours studying astronomy each week outside of class. A small percentage of the class may need to spend more time, as we are not all identical in our study habits or speed of learning.

Lastly, remember that while you may study with another student, all work you hand in must always be your own. Whenever you need to obtain data for an activity or assignment, the data you turn in and use must be your own unique data. Otherwise, you have committed academic misconduct. It's best to be sure there's never a even a doubt in the instructor's mind.

Chapter 1

Somewhere, something incredible is waiting to be known.

Learning is joyous.

Carl Sagan

The moment one gives close attention to anything, even a blade of grass, it becomes a mysterious, awesome, and indescribably magnificent world in itself.

Henry Miller

The most beautiful thing we can experience is the mysterious. It is the source of all true art and science. He to whom his emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed.

Albert Einstein

Science is a limitless voyage of joyful exploration.

Walt Whitman

Chapter 1 Goal: To begin to gain a feeling for what astronomy is about and a feeling for the sizes and distances of objects in the Universe.

The Big Picture: See either the end of the chapter or Mastering Astronomy Study Area Overview.

Assignment: Read Chapter 1 (be sure to look below at the "section by section" material so you know what I want you to learn). Afterwards, complete both the online homework and the separate online quiz.

Important concepts/terms in bold for chapter 1; I will attempt to group the words in meaningful ways to help you.

Big Bang
Observable universe
Supercluseters Local Supercluster
Galaxy clusters
Galaxy Milky Way Galaxy
Solar system
Light year Astronomical Unit (AU)
Orbit (revolution) Rotation
Ecliptic plane

Section by Section
Section 1.1
Describe our "cosmic address."
Describe in a very general way how we came to be.
Be able to define and use the terms listed under "Basic Astronomical Objects, Units, and Motions" on page 6.
Describe in a general way how we can talk about what the Universe was like the past.

Section 1.2

While this section is important, I want you to read it to obtain a general feeling for what it's talking about. A better understanding will come throughout the semester.

Look over the cosmic calendar on pages 14-15. This is for culture, not for testing.

Section1.3

Describe the basic motions of the earth and the periods of time over which they occur.

Describe what is meant by the *ecliptic plane* and what the angle 23½° is all about.

State the size of the astronomical unit in EITHER miles or kilometers.

Read the rest of the section to get a feeling for it; you will not be held responsible for the material at this time.

Section 1.4

Read this section for culture.

The "mathematical insights" contain important information. We will be doing some math in class itself that will help with the material in these boxes. Read them, work at them and try to understand them, and please do NOT go too crazy over them at this time!!

Mathematical Insight 1.1

Pay particular attention to the conversion of units in Step 2. Understanding this will make life significantly easier for you throughout the semester.

Mathematical Insight 1.2

The most important part of this one is the use of scientific notation, along with the continued examples of unit conversions.

Self-check on Scientific Notation

I want you to do a quick self-check of your knowledge of writing large and small numbers in scientific notation. If you do well, you will then check your knowledge of doing mathematical manipulations (add, subtract, multiply, divide) using scientific notation. If you do not do well, you'll then go to a web site for instruction.

Go to http://www.nyu.edu/pages/mathmol/textbook/scinot6.htm and complete 10 questions.

If you get 8 or more correct, then answer the following questions:

Solve each of the following questions (check the answers at the bottom of the page). Think with each one carefully; I tried to choose problems that could give you some difficulty if you don't really understand what's going on or if you're careless!

a. $(3 \times 10^{3}) \times (3 \times 10^{3})$
b. $(3 \times 10^{3}) \times (3 \times 10^{-8})$
c. $(9 \times 10^{5}) \div (3 \times 10^{3})$
d. $(6 \times 10^{3}) \div (3 \times 10^{-8})$
e. $(3 \times 10^{5}) + (5 \times 10^{7})$

f. $(7 \times 10^5) - (3 \times 10^7)$

If you got them all correct, congratulations!! Good job! You're done!

If you missed any, please look at one of these sites for instruction on doing such problems:
http://www.ieer.org/clssroom/scinote.html
http://members.aol.com/profchm/sci_not.html

^^

If you did not get at least 8 correct, then go to one of the following instructional sites for help (I'm giving you a number of sites since they are all different and present the material in different ways. I found these through www.google.com and a search for "scientific notation"):
http://www.ieer.org/clssroom/scinote.html
http://members.aol.com/profchm/sci_not.html
http://dbhs.wvusd.k12.ca.us/webdocs/SigFigs/Scientific-Notation.html
http://www.aaamath.com/dec71i-dec2sci.html
http://regentsprep.org/Regents/math/math-topic.cfm?TopicCode=scinot

Now, return to the original site
http://www.nyu.edu/pages/mathmol/textbook/scinot6.htm
and complete an additional 10 questions. If you still did not get 80% correct, try one of the other instructional sites and/or see me for some help.

If you now did get at least 8 correct, go to the section above for those who got 80% the first time.

If you're confused on anything, please come and see me soon.

Answers:
a. 9×10^6; b. 9×10^{-5}; c. 3×10^2; d. 2×10^{11}; e. 5.03×10^7; f. -2.93×10^7

Mathematical Insight 1.3
The ideas discussed here are important, so please read this carefully.

Mathematical Insight 1.4
Not needed at this time.

Chapter 2

The moon is gone
And the Pleiads set,
Midnight is nigh:
Time pass on
And pases; yet
Alone I lie.

Sappho (7th century B.C.E.)

When the Pleiades, the Hyades and the strength of Orion set, then be mindful of timely ploughing.... When the Pleiades, fleeing from the mighty strength of Orion, fall into the murky sea, the sailing season is over.

But when Orion and Sirius are come into mid-heaaven and the rosy-fingered dawn sees Arcturus, then ... cut off all the grape clusters and bring them home.

Hesiod (9th century B.C.E.)

Chapter Goal: To learn, understand, and make predictions about the changing appearance of the sky with place and time.

The Big Picture: In this chapter you lean about the sky as observed from various locations on Earth and at different times. You'll learn about daily, monthly, and yearly motions. You will learn how astronomers describe the sky in terms of the celestial sphere on which planets and star seem to be located.

Learning Objectives

When you have completed this chapter, you should be able to do the following:

- ✯ State what constellations are, both the traditional and modern definitions.
- ✯ State the two principal motions of Earth that cause change in the appearance of the sky during the day and during the year; explain how and why each of these motions produces change in the appearance of the sky.
- ✯ Describe why the appearance of the sky changes over the course of a night.
- ✯ Describe why the appearance of the sky changes from night to night.
- ✯ Describe the effect the observer's latitude has on what he or she will observe in the sky.
- ✯ Explain why the solar day is longer than the sidereal day.
- ✯ **Given two dates and the time at which some star rises on one of the dates, determine the approximate time the star will rise on the second date.**
- ✯ Describe what is meant by *precession* and its effect on the positions of stars.
- ✯ Explain how you can determine your latitude from the observed altitude of Polaris. (Figure 2-10 may help with this)
- ✯ Explain the terms *celestial sphere*, *celestial equator*, *ecliptic*, *meridian*, and *circumpolar stars*; be able to make a drawing of the celestial sphere and include these terms in the drawing.
- ✯ State the most important factor in determining seasonal variations on Earth, why they differ between the northern and southern hemisphere, and explain why that factor determines seasons.
- ✯ Explain Earth's tropics and circles and their significance.

Important concepts/terms in bold for chapters 2, and S1

Constellation

Celestial sphere

North (South) Celestial pole | Celestial equator | Ecliptic

Horizon | Zenith | Meridian

Direction | Altitude

Summer (winter) solstice | Spring (fall) equinox

Angular size | angular distance

Arcminutes | Arcseconds

Latitude | Longitude | Prime meridian

Zodiac

Reading assignment: Read chapter 2 and specified parts of chapter S1 (after chapter 3, on page 92).

FYI: the class periods are going to involve quite a few short activities following lecture over material not in this chapter. Thus, it's really important that you be there as there is no make-up.

Section by Section

Section 2.1

Describe the concept of the celestial sphere. Show your understanding by making a drawing of it and labeling its parts, including the **celestial equator**, **ecliptic**, **poles**. Describe and use the concepts of **horizon**, **zenith**, and **meridian**.

Explain how we can specify the location of an object in the local sky by **direction** and **altitude**.

Describe and use the concepts of **angular size** and **angular distance**.

Describe the units used to measure angles from large to small.

Describe why stars rise and set. Describe their motion in relation to the local sky.

Describe what **circumpolar stars** are.

Describe how the appearance of the sky depends on latitude and longitude, and the time of the year.

State the relationship between the altitude of the north celestial pole and the latitude of the observer.

Section 2.2

Explain in detail why we have seasons.

Explain the meaning of the **equinoxes** and the **solstices** in terms of both the celestial sphere and the local sky.

Describe **precession** in terms of what it means observationally. You do NOT need to explain its cause (although feel free to read it!).

Section 2.3

You do NOT need to read this; it is part of Astr 101 rather than 102!

Section 2.4

You do NOT need to read this; it is part of Astr 101 rather than 102!

Section S1.1 (pages 93-94; NOT 95)
Describe and explain the differences between the **solar day** and the **sidereal day**.
Describe the **sidereal year**.

You should read "How to tell the time of day" because it's something you should be aware of, but I will not hold you responsible for it. Same for "When and why do we have leap years?"

Describe and explain the differences between the **solar day** and the **sidereal day**.

Section S1.2 (This section has some really good information that I want you to know; yet, it has quite a bit more detail than you need. I'll give subsection by subsection details below). It is important for this material that you really study the figures in the book; if you don't it will hurt your understanding and make it significantly more difficult for you.

How do we locate objects on the celestial sphere?
Describe the parts of the celestial sphere.
Describe how we specify a place's location on the Earth.
Describe *in a general way* (in analogy to specifying locations on Earth) how we specify the location of an object on the celestial sphere.

How do stars move through the local sky?
Describe the sky and how it changes from different locations on Earth and at different times. (This subsection is important.)

How does the Sun move through the local sky?
Describe the sky and how it changes from different locations on Earth and at different times. (This subsection is important.)

Section S1.3
Not needed.

STUDY GUIDE FOR CHAPTER 3

Introduction

Science is not a democratic process
Unknown

Science is limited to explaining the natural world, using natural processes.
Unknown

Science is a very human form of knowledge. We are always at the brink of the known, we always feel forward for what is to be hoped. Every judgement in science stands on the edge of error, and is personal. Science is a tribute to what we can know although we are fallible.

Jacob Bronowski

Chapter 3 Goal: To learn what makes astronomy a science and what distinguishes science from pseudoscience.

The Big Picture: In his chapter you will learn about *science*—what science is and is not, and what is not science.

astrology
deduction (deductive reasoning)
induction (inductive reasoning)
theory hypothesis model
falsified
fact
Occam's razor (Law of Parsimony)
pseudoscience
paradigm
inference

Learning Objectives for chapter 3 (ALSO, see the Procedure below)
When you have completed this chapter, you should be able to do the following:

- ✯ Distinguish between a theory and a hypothesis.
- ✯ Describe what scientists mean by a model and its relationship to "truth."
- ✯ Explain the difference between an observational and an experimental science. List and explain the particular difficulties that face astronomers and describe several advantages that astronomy has over "earthbound" sciences.
- ✯ Describe why the great distances in astronomy are both a disadvantage and an advantage to its study.
- ✯ For the hypothetical "expedition to Earth" of this chapter, formulate and evaluate hypotheses that might be made by the alien scientists about life on Earth. Specify the kinds of observations that might be made when attempting to validate the hypotheses.
- ✯ Explain how the position of the alien scientists is similar to (and also different from) that of present-day astronomers.
- ✯ Compare and contrast the characteristics of pseudoscience and pseudoscientists presented in the chapter with those of science and scientists.
- ✯ Explain how theory and observation interact in the development of scientific ideas.
- ✯ Describe how you might go about determining whether some statement in a book, magazine, or the internet is to be given credence. Given such a statement, carry out such an analysis.
- ✯ Discuss the purpose and the basic workings of the “knowledge filter.”
- ✯ Describe what is meant when we say a hypothesis is “at risk.”
- ✯ Discuss the concept (meaning) behind the phrase “the game of science.”

Procedure

1. Read Chapter 3, Sections 3.4 and 3.5.
Your goal in reading this chapter is to get a good feeling for the process of science.

Important concepts/terms in bold for chapter 3
Theory Model
Hypothesis
Occam's Razor
Paradigm

2. Section by Section
Section 3.1-3.3 has lots of interesting history historical ideas that are useful for an improvements of you general historical and cultural knowledge. However, we will not cover it and I will not hold your responsible for it.

Section 3.2
Understand the general idea of a scientific **model**.

In the second subsection, all I want you to understand is the idea of a model and how it is used in science. I will not ask you to discuss any of the content as such.

The third subsection is strict for your cultural knowledge.

Section 3.3
This is an important section, but for astr 101. Lots of great ideas in here if you have the time and the interest. We may do some of it later one when we talk about binary stars, but it's not needed now.

Section 3.4
Make a general statement about what points the section is trying to get across.
Distinguish between a scientific **hypothesis** and a scientific **theory**.
Explain in what ways the scientific use of *theory* differs from the way non-scientists generally use it.

Section 3.5
You are to read this to understand why astrology is not a science, as astronomy is. (**NOTE: My lecture on this will important!!**)

Chapter 5

Up to the twentieth century, "reality" was everything humans could touch, smell, see, and hear. Since the initial publication of the chart of the electromagnetic spectrum ... humans have learned that what they can touch, smell, see, and hear is less than one-millionth of reality. Ninety-nine percent of all that is going to affect our tomorrows is being developed by humans using instruments and working in ranges of reality that are nonhumanly sensible.

R. Buckminster Fuller

When we step through the gateway of the atom, we are in a world which our senses cannot experience. There is a new architecture there, a way that things are put together which we cannot know; we only try to picture it by analogy, a new act of imagination. The architectural images come from the concrete world of our senses, because it is the only world that words describe. But all our ways of picturing the invisible are metaphors, likenesses that we snatch from the larger world of eye and ear and touch.

Jacob Bronowski

Chapter Goal: To learn about and understand the behavior and properties of light, and to learn about and understand how astronomers are able to break the light of stars into their component colors (spectrum) and from that information learn most of what we know about the universe beyond Earth.

The Big Picture: Astronomers learn about the Universe by collecting light. Thus, we need to understand light, which we begin to do here. In addition, light traveling through a prism is broken into its components. By a thorough study of the way starlight is divided into its colors, tremendous amounts of information about the universe are learned. **Note: This chapter is, over all, really important!!**

Important concepts/terms in bold for chapter 5 (NOTE: WORDS IN ITALICS ARE NOT IN THE BOOK BUT WILL BE DEFINED AND USED IN LECTURE)

electromagnetic radiation — electromagnetic spectrum
- frequency
  - *hertz*
- wavelength
  - *angstrom* — gamma-rays — X-rays
  - ultraviolet — infrared radiation
- *polarized light*
- *interference*
  - *constructive interference* — *destructive interference*
- *diffraction*
  - *diffraction grating* — *dispersion* — *spectrograph*
- *reflection* — *refraction*

photoelectric effect
- photon
- *wave theory of light* — *wave-particle duality*

Spectrum (spectra is plural)
- continuous spectrum
- absorption line spectrum
- emission line spectrum

Kirchhoff's laws
blackbody
- Blackbody curve
- Blackbody radiation
- Wien's law
- Stefan-Boltzmann law

atom
- nucleus
  - proton
  - neutron
  - atomic number
- isotope

energy-level diagram
- ground state
- excited state
- *hydrogen*
  - Lyman series
  - Balmer series
- ionization

Learning Objectives:

✯ State the speed of light.
✯ Describe and explain what is meant by the dual nature of light (as particles and as waves).
✯ Describe the types of radiation that make up the electromagnetic spectrum; list them in order of increasing/decreasing wavelength or frequency or energy.
✯ State what the spectrum of radiation from a dense object depends on.
✯ Describe the three temperature scales in common use. You do not need to know the formulae relating them.
✯ Define *blackbody* and describe, with a drawing, blackbody curves (spectra) for bodies of different temperature.
✯ State the concepts behind Wien's law and the Stefan-Boltzmann law and how they are used. Use them for simple problems.
✯ Describe what spectral lines are and how they are used to identify chemical substances.
✯ State Kirchhoff's laws and apply them to given physical situations (for example, as in Figure 5-14).
✯ Describe Rutherford's model of the atom.
✯ Describe the Balmer series, Lyman series, and Paschen series of the spectral lines of hydrogen using an energy-level diagram
✯ Explain the concept of the Doppler effect and use the equation to find how fast objects are moving or to find the amount of wavelength shift.

Reading assignment: Section by Section
NOTE: QUIZZES ARE BROKEN INTO PARTS: SECTIONS 5.1-5.3 AND 5.3 TO THE END.
Section 5.1:
Explain how we experience light.
Explain what we mean by a *spectrum* and the parts of it.
State what is meant by the concept of *power*.
Describe the ways in which light interacts with matter.
Explain why scientists say light has properties of particles (as well as properties of waves).
State the conceptual relationship between a photon's energy and its frequency or wavelength. Use the conceptual ideas to solve conceptual problems.

Section 5.2:

Describe the properties of light. (Note: lecture will expand upon this discussion.)

Describe the ways in which scientists describe (model) light.

Explain the ways in which waves are described (wavelength, frequency).

Explain how wavelength, frequency, and speed are related, and use it to compute the unknown quantity if two of them are given.

State the speed of light in either km/s or miles/hour.

Describe the properties of photons.

Explain what is meant by the *electromagnetic spectrum*.

All important. You want to know the various regions of the spectrum in order of wavelength, frequency, and energy.. You want to understand the conceptual relationship between wavelength, frequency and speed of light, and be able to use the mathematical relationship. (That is, study figure 5.7!)

Explain what evidence there is for the various models of light (mostly in lecture).

Section 5.3:

Describe the basic way scientists describe matter, including the components of which they are made.

Explain what is meant by *atomic mass* and *atomic (mass) number*.

Explain how a *molecule* differs from an *atom*.

You need NOT read from the start of section 5.3 through the end of the section on page 160 titled *Phase changes in water* (although it is something you really should know for your general knowledge).

Describe what is meant by the process of *ionization* and what an *ion* is.

You need NOT read the subsection on phases and pressure.

Explain how energy is stored in atoms.

Explain the concept of *energy-level diagrams* and be able to use such diagrams to answer a variety of questions. Explain transitions within the diagram.

Section 5.4 (A REALLY important section---one of the most important of the course!)

Describe each type of spectrum and explain how each is produced. (Study Figures 5.14 and 5.21 extra closely!)

State Kirchhoff's laws and apply them to various specified situations.

Use the energy-level diagram to explain the appearance of absorption and emission spectra.

Explain why a spectrum is a "chemical fingerprint."

Discuss the spectrum of hot dense objects including the relationship between temperature and maximum wavelength, and the relationship between temperature and energy output.

Explain the concept behind Wien's law. Make calculations with the formula. (Learn the concept; you do not need to memorize the formula.)

Explain the concept behind the Stefan-Boltzman law. Make calculations with the formula. (Learn the concept; you do not need to memorize the formula.)

Section 5.5:

Describe and explain the Doppler Effect—what it means and what determines the effect.

Apply the Doppler effect equation to the solution of problems (see box 5.3)

Extremely important. The information here (the Doppler effect) will be used in many places in the course. The math in this section is important.

Box 5.1: Most important is the **concept** behind the math—how the quantities vary with each other. Ideally, you should be able to do the arithmetic for these problems.

Box 5.2: : Most important is the **concept** behind the math—how the quantities vary with each other. Ideally, you should be able to do the arithmetic for these problems.

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Chapter 6

The best thing we're put here for's to see;
The strongest thing that's given us to see with's a telescope.
Someone in every town, seems to me, owes it to the town to keep one.

Robert Frost, The Star Splitter

Where the telescope ends the microscope begins. Which of the two has the grander view?

Victor Hugo

Chapter Goal: To learn about and understand something about the instruments astronomers use to gather light from the far reaches of the Universe.

The Big Picture: Once we understand light, then we have to collect it for analysis. Light collection is the job of a telescope. Telescopes are no longer only on Earth but also in space, and it's important for you to understand why it's important to be in space. Different types of telescopes are needed for different types of radiation. Finally, observatories are located where they are for a reason, and you need to understand those reasons.

Important concepts/terms in bold for chapter 6

telescopes
- reflector refractor
- light gathering power angular resolution magnification
- diffraction limit interferometry
- Focus Focal plane focal length

Detector
- Pixel CCD (Charged Coupled Device) spectral resolution

Spectrograph

light pollution

Learning Objectives

1. Describe difference between reflecting and refracting telescopes
2. Discuss the advantages and disadvantages of refracting telescopes and of reflecting telescopes.
3. Explain the difference between light-gathering power and resolution. Be able to calculate both given the needed quantities.
4. Explain what light pollution is and be able to describe the methods used to overcome it.
5. Explain what a charge-coupled device (CCD) is and why it's superior to photographic film.
6. Explain what a radio telescope is and the kind of information it provides.
7. Explain why we place telescopes in orbit.

Reading assignment: Read chapter 6. Read and understand the small boxes on common misconceptions.

Section by Section
Section 6.1
Describe how a lens produces an image.
Describe the appearance of an image formed by a lens at the focal plane.
Describe and explain the advantages a camera has over the human eye.
Describe the electronic detectors used by current-day astronomers.

Section 6.2
Describe the two most important properties of telescopes. (NOTE: Your book uses the term "light collecting area" to describe what is usually called the "light gathering power." I will be using that term, which I believe is a much better one to use. Explain why magnification is not so important.
Describe light gathering power mathematically, and work simple problems using the concept.
Explain why telescopes have limited resolving power.
Describe what telescope property determines light gathering power and what property determines resolving power.
Given the size of a telescope, determine the light gathering power and the resolving power.
Describe the types of telescopes and the advantages/disadvantages of each.
Describe the types of information astronomers obtain from using telescopes.

Section 6.3
Describe how the Earth's atmosphere limits what a telescope can do.
Describe what is meant by light pollution and the various ways used to combat it.
Explain why astronomers want telescopes in space rather than only on the Earth's surface.

Section 6.4
Explain why radio telescopes are so large.
Explain why infrared telescopes need to be cooled to very low temperatures.
What is *interferometry*? Why is it used?

Math Insight 6.1: Read and work to understand the examples and their solutions.

Math Insight 6.2: Read and work to understand the examples and their solutions. The concept used in this Insight is useful to understand.

Chapter 14

The Sun is a mass of incandescent gas
A gigantic nuclear furnace
Where hydrogen is built into helium
At a temperature of millions of degrees.

They might be Giants

Chapter Goal: To learn about and understand the concepts that make stars what they are—concepts that allow astronomers to understand stars' structure and evolution.

The Big Picture: This chapter begins the study of stellar evolution. In this chapter we lay the theoretical ground work for understanding how stars form, live, and die. We learn the source of their energy and the formation of the chemical elements in stars.

Important concepts/terms for chapter 14 (some will be given in lecture)

fusion
- proton-proton chain
- hydrogen burning
  - neutrino
  - antimatter

fission
hydrostatic equilibrium
- gas pressure
  - perfect (ideal) gas law
- radiation pressure

thermal equilibrium (in class)

energy transport
- radiation
- convection

stellar model
Russell-Vogt theorem (in class)

Learning Objectives from book and lecture:

1. Explain the significance of stellar contraction insofar as providing the Sun's energy. (p. 495)
2. Explain what we mean by nuclear fission and by nuclear fusion. (pp 499-501)
3. Explain why nuclear fusion is a viable source for the Sun's power, while fission is not. (p 499 + lecture)
4. State the *general* steps involved in the proton-proton chain. State explicitly the net result in terms of what goes in and what comes out. (p. 500)
5. State the general conditions of density and temperature required for fusion to take place and explain why each variable is important. Explain what would happen to the total amount of energy if the variables were altered. (p 499)

6. Describe what is meant by *antimatter* and what would result if antimatter and matter came into contact with one another. (p 500; see also page 476, the section on antimatter)
7. Describe what we mean by a neutrino. (pp 500, 505-507)
8. Explain the importance of the solar neutrino experiment for astronomy, and what are the current results are. (pp 506-507)
9. Explain what is meant by equilibrium. Include the forces in a typical star that maintain a state of equilibrium. Explain what happens to a star if it deviates only slightly from equilibrium (i.e. how does the solar thermostat work?).(pp 495-496, 502 and lecture)
10. Explain what is meant by a *stellar model* and explain how the study of a stellar model allows astronomers to understand the interior structure of a star. (p 505 + lecture)
11. Explain in a general way why the mass - luminosity relationship exists, and explain its implications for the lifetime of a star.
12. Describe the various physical concepts that enter into the discussion of a star's structure. (pp. 495-505)

Reading assignment: Section by Section

NOTE: This chapter has concepts that will be new to you. These concepts are necessary to understand the upcoming discussion of the structure and evolution of stars. Read slowly and carefully! Lecture will help clarify all this; you should be there!!

Section 14.1:
Explain the roles of gravitational contraction in the Sun's energy.
Explain why the Sun shines.
Explain the roles of gravity and pressure in keeping the sun in equilibrium.
Explain what is meant by the Sun's luminosity.
Explain the "burning" misconception for the Sun's energy.

Section 14.2:
Describe the nucleus and the parts the enter into nuclear fusion.
Describe the conditions under which nuclear fusion results.
Describe the proton-proton reaction in general terms.
State the result of the proton-proton reaction.
Explain the solar thermostat and how it works.
Describe the source of the Sun's internal pressure. (It's the first paragraph of Mathematical Insight 14.2)
Explain how energy gets out of the Sun.

Section 14.3: We will not cover this section!

Mathematical Insight 14.1: This is useful but I'll go over what I think is important in class. Some of it may be confusing!

Mathematical Insight 14.2: Read and try to understand the ideas; you should understand the concepts behind the Ideal Gas Law.

Chapter 15

. . . I wander'd off by myself,
in the mystical moist night air,
and from time to time,
Look'd up in perfect silence at the stars.
Walt Whitman

Look! at the Stars! look, look, up at the skies.
Oh look at all the fire folk sitting in the air.
Gerald Manley Hopkins

And thus we die,
Still searching, like poor old astronomers
Who totter off to bed and go to sleep
To dream of untriangulated stars.
Edwin Arlington Robinson

We are all in the gutter, but some of us are looking at the stars.
Oscar Wilde

Chapter Goal: To learn about, understand, and apply many of the ideas from Chapter 5 to stars in order to understand how we learn about the properties of individual stars. To learn about and understand the general properties of stars and how we can use this information to infer important information about individual stars. You will also learn about binary stars and what we can learn from them. We will also use some ideas from Chapter 4, which will be presented in class as needed.

The Big Picture: Stars are the building blocks of galaxies (which are the building blocks of the Universe). We thus begin with stars: their temperatures and other properties that we learn by applying the ideas of the previous chapter. We will learn how to obtain information about individual stars. We also look at large populations of stars to understand them as members of various types of groups.

Important concepts/terms in bold for chapter 15

spectral type (spectral class)
- Annie Cannon
- Cecilia Payne-Gaposchkin

radial velocity
parallax
- parsec

luminosity
inverse square law of light
- Apparent magnitude
- absolute magnitude

Hertzsprung-Russell (H-R) diagram
luminosity class
- main sequence
- white dwarf
- giant
- supergiant

binary star
- visual binary
- spectroscopic binary
- eclipsing binary

Learning Objectives:

1. Explain how astronomers use the parallax of stars to measure their distances.
2. Explain how to determine a star's luminosity from its brightness and distance.
3. Explain the difference between apparent magnitude and absolute magnitude.
4. Explain the relationship between a star's color and its surface temperature.
5. Explain how astronomers use the spectra of stars to reveal their chemical compositions and surface temperatures.
6. Know the sequence of spectral classes of stars.
7. Know the relationship among a star's luminosity, radius, and surface temperature.
8. Explain and draw a Hertzsprung-Russell (H-R) diagram and show the main groupings of stars that appear on it.
9. Explain how the details of a star's spectrum reveal what kind of star it is, its luminosity, and its distance. (This is done in lecture, not in the book)
10. Describe visual binary stars and explain how they provide information about stellar masses.
11. Describe the mass-luminosity relation for main-sequence stars. (In class, not in the book)
12. Describe and explain what visual binaries, spectroscopic binaries, and eclipsing binaries are.

Reading assignment: Section by Section
NOTE: This chapter is a really important one with many ideas that will be totally new to you. It also applies ideas from earlier chapters, in particular chapter 5. Please spend whatever time is needed to catch onto this chapter!! It's important for understanding what comes later, too. Be sure you are "reading" the diagrams involving graphs, as these are crucial in this chapter.

Section 15.1 (Lots of important stuff here!)
Describe the properties of stars discussed in this section.
What is meant by *apparent brightness* and by *luminosity*?
Explain the relation between brightness, luminosity, and distance (the inverse-square law).
Use the relation between brightness, luminosity, and distance.
Describe the concept of stellar parallax.
Use the formula relating stellar parallax and distance.
Explain what a *parsec* is.
State the approximate luminosity of the brightest and faintest stars in terms of the Sun's luminosity.
Discuss how the number of stars varies with luminosity. (To help with this, look at Mastering Astronomy, Study Area, Interactive Figure 15-4).
Describe the *magnitude system*.
(The concept of magnitudes is not too hard. We'll work in class to make the mathematics, given mostly in Mathematical Insight 15.3, work for you! Don't obsess too much over this but do work on it for the quiz.)
Describe star colors and how they are related to temperature.
Describe the spectral classification system.
What determines the spectral class (type) of a star?
State the stellar spectral classes and their approximate temperatures (an easy way to remember the temperatures will be given in class).
Describe the range of temperatures of stars.
Describe what is meant by a *binary star*?

State and describe the different types of binary stars.
State the type of information about stars can be found from the study of binary stars?
Describe the *mass-luminosity relation* and draw the graph of it.
(Look at and study Interactive Figure 15.7 and 15.8.)
State the range of masses of stars (in terms of solar masses.
Explain how the concepts of temperature, size, and luminosity are related. (Go back, if needed, to understand the Stefan-Boltzmann law.)

Section 15.2
Describe, and draw, and H-R diagram in detail. (You do not need to have the number on the axes correct except at the end points and where the Sun is.)
Place stars of different sizes on the H-R diagram.
Show on the H-R diagrams lines of constant radius.
Describe the different regions (luminosity classes) within the H-R diagram and the stars that fall within those regions.
Describe why the significance of the main sequence.
Describe how stars of different masses fall along the main sequence.
Explain why high-mass stars live shorter lives than low-mass stars.
State a star's most important characteristic, and explain why it is so important.
Explain what a variable star is.

Section 15.3
We will do this section in another chapter, so you need not read it now.

Mathematical Insight 15.1: The ideas here are very important. Let's work on this one---a good example is given and worked out.
Mathematical Insight 15.2: The ideas here are very important. Let's work on this one---a good example is given and worked out.
Mathematical Insight 15.3: This is pretty math intensive. I have some easy ways to present the basic ideas without math! But, if you can do the math, you'll be able to do that much more with the information.
Mathematical Insight 15.4: We will do some of the ideas here but this Insight is more detailed than I feel you need to worry about.
Mathematical Insight 15.5: We will do some of the ideas here but this Insight is more detailed than I feel you need to worry about.

Chapter 16

> We had the sky, up there, all speckled with stars, and we used to lay on our backs and look up at them, and discuss about whether they was made, or only just happened.
>
> Mark Twain, *Huckleberry Finn*

Chapter Goal: To learn about and understand how astronomers believe star formation occurs, and to describe the observational evidence that indicates such formation has occurred and is occurring.

The Big Picture: What are stars made from and how do they form?

Learning Objectives:

1. Describe the picture that astronomers have of the formation of stars. Include a description of the path that the protostar takes to the main sequence, and the conditions under which stars seem to form.
2. State the significance of the main sequence in terms of the results of stellar model calculations. (Mostly in lecture)
3. Describe the physical conditions (density, temperature, and masses) that exist in giant molecular clouds. Explain why these conditions are favorable for star formation.
4. Present the observational evidence that the variety of objects discussed in the chapter are indeed the precursors to stars. (Some in book; lots in class)
5. Explain how and why observations of one young star cluster differ from observations of a somewhat older cluster. (entirely in class)

Important concepts/terms for chapter 16

interstellar medium
interstellar reddening dark nebulae giant molecular clouds
protostar
Gravitational equilibrium
Ideal gas law thermal pressure degeneracy pressure radiation pressure
accretion
brown dwarf

The following will be discussed in class:

bipolar outflow	accretion disc	OB association
HII region	Bok globule	T Tauri star
Herbig-Haro object	reflection nebula	open cluster

Reading assignment: Section by Section

NOTE: There are two aspects to stellar evolution: the theory that predicts how stars evolve and the observations. We will present both in the following chapters. You want to understand the theoretical ideas and how the observations fit with them. Coming to class will, as always, be important because I have my own things on these topics I like to present and think you should know (which is a way of saying there are some things I'll present in class that could be on the exam over this material!!).

Section 16.1

Describe the various ways in which astronomers know about the presence of the interstellar medium. This includes your being able to describe molecular clouds, dust, and *interstellar reddening*.

Discuss where stars come from.

State the relative amounts of hydrogen, helium, and heavier elements in the interstellar medium.

Explain how stars form, and the interaction between gravity and pressure through the *ideal gas law*. Include fragmentation from a molecular cloud and isolated star formation.

Section 16.2

Discuss the stages of star formation.

Distinguish a protostar from a star.

Discuss the role of rotation, the role of accretion disk formation, protostellar winds, and jet formation.

Discuss the onset of nuclear burning and the formation of the main sequence.

Section 16.3

Describe star formation in terms of the evolutionary track on the H-R diagram. As a part of this, study Figure 16-17, which is quite important!

Discuss both the high and low limits on the mass of a star.

Describe what a brown dwarf is and why it forms.

Discuss the number of stars formed in relation to their mass.

Mathematical Insight 16.1: Optional, but some of you may find it interesting as long as you don't get hung-up on the math!!

Chapter 17

> The star shall fade away, the sun himself
> Grow din with age, and nature sunk in years
> Joseph Addison

Chapter Goal: To learn about and understand how stars evolve from after their formation through their mid-life until just before death.

The Big Picture: The evolution of the Sun is studied as a representative life cycle. We learn how stars like the Sun will end. We learn more about the synthesis of chemical elements in stars.

NOTE: I am splitting this chapter into parts, so pay attention below!

Important concepts/terms for chapter 17 (some will be given in lecture)

Main-sequence lifetime
Mass loss
hydrogen-burning shell
red giant
alpha particle
triple alpha process/reaction
Ideal gas
degenerate gas (degeneracy)
    helium flash
helium-burning shell
star clusters
    open cluster
    globular cluster
    main-sequence turn-off point
technetium

Learning Objectives

1. Explain why a star must inevitably leave the main sequence.
2. Explain how the length of time a star spends on the main sequence is affected by such things as the star's mass and luminosity. (Given in lecture!)
3. Describe the internal and visible changes that take place in a star after its main-sequence evolution. Your description should be in terms of the physical processes that are taking place. (Lecture will outline this better than your textbook does!)
4. Explain why the internal temperature of a star rises when its core nuclear fuel is exhausted. (Lecture will outline this better than your textbook does!)
5. Make a drawing to show what the evolutionary track of a 1-solar-mass star looks like on the Hertzsprung-Russell diagram. Relate the luminosity, surface temperature, radius of the star,

internal structure, and physical processes taking place in the star to its position along the evolutionary track. (Lecture will outline this better than your textbook does!)

6. Explain the unusual properties that distinguish a degenerate gas from a normal gas, and explain how these properties are responsible for the helium flash.
7. State the nuclear reactions in the triple alpha reaction, the physical conditions under which the reaction takes place, and when in the lifetime of a star the triple alpha reaction is important.
8. Describe the observational evidence for stellar evolution, and explain how the Hertzsprung-Russell diagram of a star cluster would be expected to evolve over time. (Lecture will outline this better than your textbook does!)
9. Describe, in a general sense, the advanced nuclear reactions that occur in stars in their advanced stages of life.
10. Discuss how the evolution of stars in binary star systems differs from that of single stars.

Reading assignment: Section by Section

NOTE #1: There are two aspects to stellar evolution: the theory that predicts how stars evolve and the observations. We will present both in the following chapters. You want to understand the theoretical ideas and how the observations fit with them.

Note #2: Lecture and/or chapter 18 from my book, which I put in Blackboard, is really important for this chapter. The approach I use is, I believe, much better because it explains more of what's happening and expresses that better (I think!) in terms of the interior structure of the star and what's happening in the H-R diagram. These will be important; that is, they will be on the test!

Section 17.1

Discuss why stars eventually become unbalanced.
Explain why the lifetime of a star depends on mass.
Explain how astronomers know about the evolution of stars.

Section 17.2

Discuss the life stages of low-mass stars, including WHY the various stages happen. This discussion includes the death of such stars. The discussion needs to include the evolutionary path on the H-R diagram (Figures 17.3, 17.6, 17.8). (The lecture presentation will present this is a clearer, more organized way!)
Describe helium burning.
Explain why the helium flash occurs.

Section 17.3

Discuss in what ways the lives of high mass stars differ from that of low mass stars.
Discuss the formation of elements through the processes of fusion.
The sub-subsection on iron (page 575) and the subsection on the "How does a Massive Star Die" on page 577-579 will be done in the next chapter rather than now.

Section 17.4

Discuss the role a star's mass plays in determining its evolution.
Discuss how the evolution of a star in a binary system is different from that of a single star.

Section 15.3 (This is NOT an error; you now do section 15.3!!)
Describe the different types of star clusters.
Describe how astronomers use the H-R diagram of star clusters to determine a cluster's age.

Section by Section from chapter 18 of my book. While I'm not assigning the reading, I believe you'll find it helpful in explaining what's going on. Also, the class presentations are along the lines used here, which is why I wrote the book the way I did!!

Section 18.1
Discuss the basic reason why stars evolve.
Explain the step-by-step process of solar evolution from the ZAMS through the end of helium burning. (e.g. explain why the core collapses when it does; explain why a hydrogen burning shell is formed; explain why the star expands to become a red giant; explain why a helium flash occurs.) Include appropriate drawings.
Relate each step of the evolutionary process to the corresponding changes occurring in the H-R diagram.
Include a labeled diagram of the internal structure of the star.
Outline the steps in helium burning.
Explain why the helium flash occurs when helium burning first occurs in a solar-type star, and why it's different from when hydrogen burning began.

Section 18.2
Explain how the mid-life evolution for stars less massive than the Sun differs from that of the Sun.

Section 18.3
Explain how the mid-life evolution for stars more massive than the Sun differs from that of the Sun. Include the physical changes in the star as well as the corresponding changes that occur in the H-R diagram. Include a labeled diagram of the internal structure of the star.

Section 18.4
State what happens to any star that crosses the *instability strip*.

Section 18.5
Describe at least two ways astronomers can study the loss of mass from stars.
Discuss how the existence of a gravitationally bound companion star can change the evolution of a star. That discussion should include a description of the Roche lobes and their effects (see Figure 18-16).

Section 18.6
Discuss observations that play a role in our understanding of the deaths of low mass stars. In other words, describe the types of objects that result when low mass stars die. Relate these observations to the H-R diagram.

Describe white dwarf stars by stating their physical characteristics (mass, size, density) and make-up, and the relationship between such a star's mass and radius (along with the consequences of that relationship).
Describe the source of energy in white dwarf stars.
State the contribution of S. Chandrasekhar to astronomy.

Section 18.7
Discuss how observations of star clusters provide information relevant to discussion of stellar evolution. Discuss how they are used to determine ages. Draw relevant diagrams.
Discuss how both open and globular clusters relate to stellar evolution discussions. Use both theory and observation in your discussion. Draw relevant diagrams.
Discuss what it is about star clusters that makes them particularly useful to discussions of stellar evolution. (This is actually part of chapter 17, but it's relevant here, too.)
Discuss spectroscopic observations that provide information relevant to stellar evolution discussions.

Chapter 18

I seem to have stood a long time and watched the stars pass.
They shall also perish I believe.
Here today, gone tomorrow, desperate wee galaxies
Scattering themselves and shining their substance away
Like a passionate thought. It is very well ordered.
Robinson Jeffers

Chapter Goal: To learn about and understand how stars of different masses die, what becomes of them, and how their death leads to the birth of new stars.

The Big Picture: Here we learn about the death of stars more massive than the Sun, and we learn about pulsars (neutron stars) and black holes.

Learning Objectives

1. Describe the ways Type I and Type II supernovae differ. Your description should be based on their observed properties and the models we have to explain them.
2. Explain how supernovae provide us with direct evidence for the synthesis of heavy elements within stars. Your explanation should name and describe three basic processes by which heavy elements are synthesized.
3. Discuss how stars of different masses die and what their end results are.

Important concepts/terms for chapter 18 (some will be given in lecture)

Supernova, supernova remnant
Type I Type II
Chandrasekhar limit
Core helium fusion
Mass-radius relation
Neutron capture
Planetary nebula
Red-giant branch
Supergiant
White dwarf

Reading assignment: Section by Section

NOTE #1: There are two aspects to stellar evolution: the theory that predicts how stars evolve and the observations. We will present both in the following chapters. You want to understand the theoretical ideas and how the observations fit with them.

Section 17.3

Read the sub-subsection on iron (page 575) and the subsection on the "How does a Massive Star Die" on page 577-579.

Discuss the formation of elements and the evidence for that formation.
Discuss how high mass stars produce a supernova explosion.
Discuss the possible remains from a supernova explosion.
Discuss the basic observations of supernovae.

Section 18.1

Discuss what a white dwarf is, how it comes about, and its properties (mass, size).
Discuss what can happen to a white dwarf in a binary system and the types of objects that can result.
Discuss the white dwarf mass limit (Chandrasekhar limit)
Explain how a white dwarf can be involved in the production of a supernova.
Distinguish between the "white dwarf supernova" and the "massive star supernova."

Section 18.2

Discuss what a neutron star is, how it comes about, and its properties (mass, size, gravity, structure).
Discuss pulsars, what they are, and their relation to neutron stars.
Discuss what can happen to a neutron star in a binary system and the types of objects that can result.

Section 18.3

Describe what a black hole is, how it comes about, and its properties (mass, size).
Describe the terms used in describing black holes (event horizon, Schwarzschild radius, singularity).
Explain why you would not want to fall into a black hole!
Explain why black holes do not suck!
Discuss the observational evidence for black holes. Explain how we can distinguish a black hole from a neutron star.
You may find the "special topic" on page 600 to be interesting and fun to read, but I will not hold you responsible for it.

Section 18.4

Describe what is meant by a *gamma-ray burst*.
Describe what is thought to cause a gamma-ray burst.

Section by Section from chapter 19 of my book. While I'm not assigning the reading, I believe you'll find it helpful in explaining what's going on. Understand that this chapter is not organized the same way Chapter 22 of your book is written, so there is not a one-to-one correspondence of material. The material here differs in some places from your book.

Section 19-1
Describe the observational event referred to as a nova.
Describe how the light from a nova might vary with time.
Describe how a shell of gas ejected by a nova explosion might appear within the spectrum.
State the part of the lifetime of a star in which a nova occurs.
Explain how we know that a nova explosion involves a small star.

Describe a nova in terms of what they all have in common.

Section 19.2
Describe the observational event referred to as a supernova.
Explain the difference in the ways Type I and Type II supernovae are formed.
Explain the mechanism for the formation of Type II supernovae. Include a schematic diagram of the interior structure.
Explain why supernovae explosions are necessary in the formation of heavy elements.

Section 19.3
Describe the physical characteristics (mass, size, density) of a neutron star.
What is *synchrotron radiation*? What causes it?
Describe the two properties of the radiation from a neutron star that helps distinguish it from a "normal" star such as the Sun.
Describe the observations distinguishing what astronomers call a *pulsar*.
State the contribution of Joyelyn Bell to astronomy.
State what a pulsar actually is.
Explain the model for what we see as a pulsar.
Explain what we can learn about pulsars that are a part of a binary system.

Section 19.4
Describe observations showing that mass bends light.
Upon what theory does the idea of a black hole depend?
Describe a black hole in terms of the concepts of *singularity* and *event horizon*.
State the contribution of Arthur Eddington to astronomy (its vastly more than what's described in this chapter; he was a superstar!)
Describe observations that astronomers make to infer the existence of black holes.

Section 19.5; FYI