Astronomy 110

Mr. MacDonald

Room 522

Astronomy 120
Course Information

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Expectations

- This is an academic, fast pace, course that requires consistent and constant effort for success.
- Excellent attendance, being on-time, and a strong work ethic is essential.
- It is your responsibility to ensure you have all notes and handouts.
- You must also make your own notes from handouts and from lecture discussions.
- The underlying theme of this course is scientific and critical thinking.

Evaluation

- Tests: 45% (includes a midterm)
- Quizzes: 25% (includes assignments, projects)
- Exam: 30% (no exemptions)

Required Supplies

- Pens, Pencils, etc.
- 3-Ring Binder
- Scientific Calculator

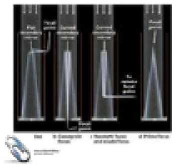
Text ($125)

Comins, Neil F., & Kaufmann III, William J., *Discovering the Universe 8e.* W. H. Freeman and Company. New York, 2008.

Astronomy 120 Course Outline

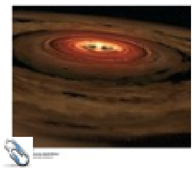
Part I - Understanding Astronomy

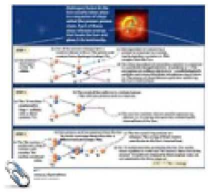
- Discovering the Night Sky
- Gravitation and the Motion of the Planets
- Light and Telescopes
- Atomic Physics and Spectra

Part II - Understanding the Solar System

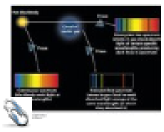
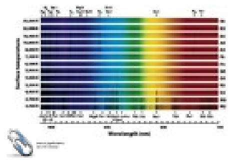
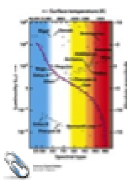
- Formation of Solar Systems
- Earth and Moon
- The Other Terrestrial Planets
- The Outer Planets
- Vagabonds of the Solar System
- The Sun



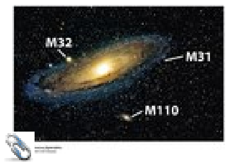
Part III - Understanding Stars

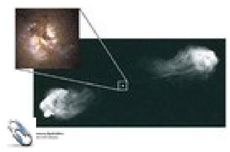
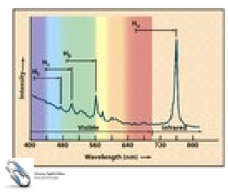
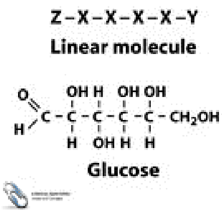
- Characterizing Stars
- Lives of Stars: Birth Through Middle Age
- The Deaths of Stars
- Black Holes: Matters of Gravity


Part IV - Understanding the Universe

- The Milky Way Galaxy
- Galaxies
- Quasars and Other Active Galaxies
- Cosmology
- Astrobiology



Discovering the Night Sky

Chapter Outline

1-1 Astronomical distances are, well, astronomical
1-2 Constellations make locating stars easy
1-3 The celestial sphere aids in navigating the sky
1-4 Earth's rotation creates the day-night cycle and its revolution defines a year
1-5 The seasons result from the tilt of the Earth's rotation axis combined with its revolution around the Sun
1-6 Clock times based on the Sun's location created scheduling nightmares
1-7 Calendars based on equal-length years also created scheduling problems
1-8 Precession is a slow, circular motion of the Earth's axis of rotation
1-9 The phases of the Moon originally inspired the concept of the month
1-10 Eclipses occur only when the Moon crosses the ecliptic during the new or full phase
1-11 Three types of lunar eclipses occur
1-12 Three types of solar eclipses also occur
1-13 Frontiers yet to be discovered

In this chapter students will discover

- How astronomers organize the night sky to help them locate objects in it
- That the Earth's spin on its axis causes day and night
- How the tilt of the Earth's axis of rotation and the Earth's motion around the Sun combine to create the seasons
- That the Moon's orbit around the Earth creates the phases of the Moon and lunar and solar eclipses
- How the year is defined and how the calendar was developed

Learning Objectives

At the end of this chapter, the student should be able to.

1. Explain the importance of distance measurements in astronomy.
2. Describe the nature and use of constellations.
3. Define the elements of the equatorial coordinate system on the celestial sphere.
4. Define two solstices and two equinoxes.
5. Explain the orientation of the ecliptic on the celestial sphere and how it produces seasons on the Earth.
6. Describe the daily and yearly motions of the Earth.
7. Describe what precession is, what effect it has on our observations of stars, and why it occurs.
8. Draw a diagram explain how lunar phases are controlled by the relative positions of the Sun and the Moon.
9. Explain when and why solar and lunar eclipses occur and why there are not such eclipses every month.

What Do You Think?

Chapter 1

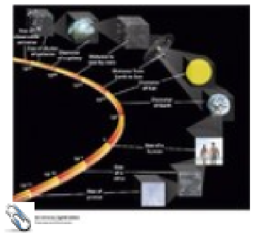
Without looking up any information answer the *WDYT* questions in your lab book.

- Pages should be neat, organized, dated, and kept in good condition. These books will be collected periodically.

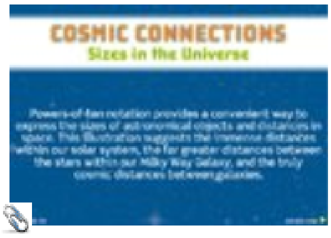
- Clearing up astronomy *misconceptions* will be an underlying theme of the course (see the movie *Armageddon*).

Astronomical Distances

Measure or calculated using scientific notation.

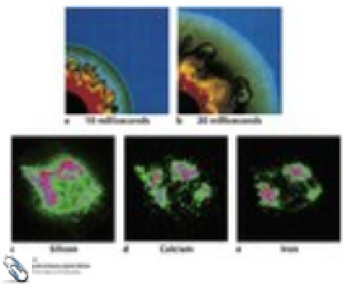


- 1.49×10^{11} m
- 9.37×10^{-7} m
- 8.0×10^{6} light years
- We will use the metric system (next page).



Distance Units of Astronomy

- To fully understand astronomy you need to incorporate many other fields of science (physics, chemistry, biology, meteorology, seismology, etc.). One reason for this is the wide range of distance scales used in studying astronomy.



Prefix	Symbol	10^{α}	Factor by Which Base Unit is Multiplied
exa	E	10^{18}	1 000 000 000 000 000 000 (Em, Eg, El, Es)
peta	P	10^{15}	1 000 000 000 000 000 (Pm, Pg, Pl, Ps)
tera	T	10^{12}	1 000 000 000 000 (Tm, Tg, Tl, Ts)
giga	G	10^{9}	1 000 000 000 (Gm, Gg, Gl, Gs)
mega	M	10^{6}	1 000 000 (Mm, Mg, Ml, Ms)
kilo	k	10^{3}	1 000 (km, kg, kl, ks)
hecto	h	10^{2}	100 (hm, hg, hl, hs)
deca	da	10^{1}	10 (dam, dag, dal, das)
		10^{0}	1 (metre – m, gram – g, litre – l, second – s)
deci	d	10^{-1}	(dm, dg, dl, ds) 0.1
centi	c	10^{-2}	(cm, cg, cl, cs) 0.01
milli	m	10^{-3}	(mm, mg, ml, ms) 0.001
micro	μ	10^{-6}	(μm, μg, μl, μs) 0.000 001
nano	n	10^{-9}	(nm, ng, nl, ns) 0.000 000 001
pico	p	10^{-12}	(pm, pg, pl, ps) 0.000 000 000 001
femto	f	10^{-15}	(fm, fg, fl, fs) 0.000 000 000 000 001
atto	a	10^{-18}	(am, ag, al, as) 0.000 000 000 000 000 001

(exa to kilo) Numbers differ by multiplying (up) or dividing (down) by 1000. → Move 3 decimal places

(kilo to milli) Numbers differ by multiplying (up) or dividing (down) by 10. → Move 1 decimal place.

(milli to atto) Numbers differ by multiplying (up) or dividing (down) by 1000. → Move 3 decimal places

↑ Decimal place moves to the left.

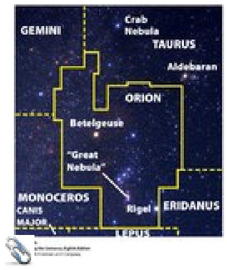
↓ Decimal place moves to the right.

- The number of decimal places to move is the same as the difference of the exponents.
- The above prefixes can be used for any unit by placing the symbol for the prefix in front of the unit's symbol.

Asterisms and Constellations

- Connect-the-dots with the brightest stars (as seen from Earth).
- Called *asterisms* (constellation is the *street* name).
- Technically, a *constellation* is an area of the sky.

Orion Asterism



Orion Constellation

- Constellations are helpful in locating specific stars or other constellations.

- Ancient civilizations were very imaginative when picturing constellations (*Starry Night: SkyGuide » Our Solar System, the stars and galaxies » Shape-shifting constellations » Introduction*).

- Do the constellations look the same from Mars? Pluto? Alpha Centauri?

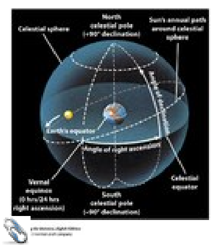
- Everything in space is in motion. The stars in our galaxy are no exception. They all have *proper motion* and move (mostly) independent of each other.
- It doesn't look like they move because of their extreme distances from us.
- In about one hundred thousand years the constellations will look quite different.

The Celestial Sphere

- A map of the sky created by thinking that all of the stars are attached to the inside of a shell.

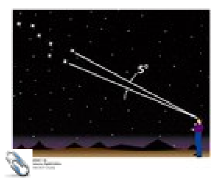
- Divided up into 88 constellations of different sizes and shapes. Generally the area in the sky is determined by the size of the asterism.
- This is a quick way to find the general location of an object in the sky (e.g. Saturn is located in Virgo).
- Especially helpful for planets and comets as they move through the night sky relatively quickly).

- Project geographic features from Earth into space to establish directions and bearings.
- The Earth's poles and equator become the celestial poles and equator, respectively.
- Latitude becomes *declination* (measure 0 - 90^{o}) and longitude becomes *right ascension* (measured from 0 - 24 h).
- Boundaries of constellations run along lines of constant declination and right ascension (no curved boundaries).
- The origin of this coordinate system is the Vernal Equinox (where the Sun's path intersects the celestial equator - this marks the start of spring in the northern hemisphere).
- Separation and sizes of objects in the sky are measured by their angular separation (see astronomer's toolbox on page 11).



Celestial Sphere

Estimating Angular Separation



Angle your eyes make

- Read *An Astronomer's Toolbox* on page 13 and answer the *try these questions*.

Constellation Assignment - Due Monday, Feb. 8

Write a brief report on two of the 88 constellations. One constellation from each hemisphere. Include:

- The asterism's meaning/translation.
- Image of the constellation (area of the sky).
- Description of the mythology or story behind the asterism.
- One or two interesting objects (nebula, galaxy, star system, etc.) to observe within the constellation.
- 1 to 2 typed (double spaced) pages (12 font).

Alphabetical listing of constellations

* Andromeda
* Antlia
* Apus
* Aquarius
* Aquila
* Ara
* Aries
* Auriga
* Boötes
* Caelum
* Camelopardalis
* Cancer
* Canes Venatici
* Canis Major
* Canis Minor
* Capricornus
* Carina
* Cassiopeia
* Centaurus
* Cepheus
* Cetus
* Chamaeleon
* Circinus
* Columba
* Coma Berenices
* Corona Austrina
* Corona Borealis
* Corvus
* Crater
* Crux
* Cygnus
* Delphinus
* Dorado
* Draco
* Equuleus
* Eridanus
* Fornax
* Gemini
* Grus
* Hercules
* Horologium
* Hydra
* Hydrus
* Indus
* Lacerta
* Leo
* Leo Minor
* Lepus
* Libra
* Lupus
* Lynx
* Lyra
* Mensa
* Microscopium
* Monoceros
* Musca
* Norma
* Octans
* Ophiuchus
* Orion
* Pavo
* Pegasus
* Perseus
* Phoenix
* Pictor
* Pisces
* Piscis Austrinus
* Puppis
* Pyxis
* Reticulum
* Sagitta
* Sagittarius
* Scorpius
* Sculptor
* Scutum
* Serpens
* Sextans
* Taurus
* Telescopium
* Triangulum
* Triangulum Australe
* Tucana
* Ursa Major
* Ursa Minor
* Vela
* Virgo
* Volans
* Vulpecula

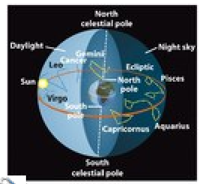
Earth's Rotation and Revolution

Rotation: Why there is day and night. Also why objects in the sky appear to rise in the east and set in the west. Time exposure photographs show an object's *diurnal motion*.

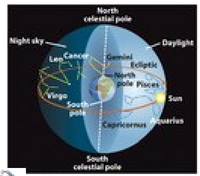
Revolution: The motion of an astronomical object around another astronomical object. For the Earth, one revolution is the definition of a year.

One year on Earth is measured by the motion of our planet relative to the stars. Any length of time (for any object) measured relative to the stars is called a ***sidereal period***.

Because the Earth is revolving about the Sun stars rise about 4 minutes earlier each day. That accumulates and is the reason some constellations are not visible during the year (they are on the same side of the Earth as the Sun).



Start of Autumn



Start of Spring

Some constellations (asterisms) never go below the horizon (called circumpolar) and some are never seen. At the poles no stars rise or set, they appear to move in big circles. At the equator they rise or set perpendicular to the horizon.

North or South Pole

Equator

Latitude = ?

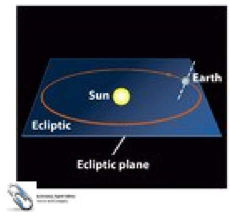
The closer you are to the equator, the fewer circumpolar stars you see (*Starry Night:* SkyGuide » Your first night out » The Earth in motion » How long is a day? » The rotation of the night sky)

Course Work

Read Sections 1-1 to 1-4.
Questions Pg. 32 #s 1 - 12

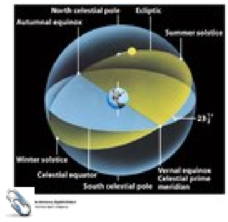
Earth's Seasons

Season's result from Earth's 23.5^{o} tilt (not from the distance from the Sun).

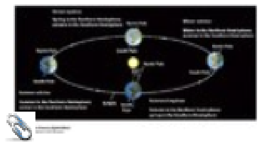


Ecliptic: The circle the Sun appears to trace through the sky.

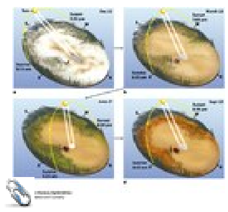
Equinoxes: Means *equal night*. The time of year when the ecliptic intersects the celestial equator.



Solstices: The date when the Sun reaches its highest and lowest point above the horizon.



Earth's tilt affects the angle that sunlight strikes Earth's surface. That is the reason for the seasons. It also explains why certain areas will have no (or constant) sunlight during parts of the year (at latitudes 66.5^{o} or higher).



(*Starry Night:* SkyGuide » Your first night out » The Earth in motion » The Seasons.)

Clocks and Calendars

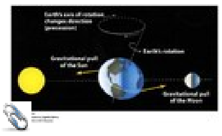
- The Sun's motion across the sky creates the ***solar day***, our 24-h clock. That is the length of time, on a yearly average, between the Sun's highest point two days in a row (noontime-to-noontime).
- There are a few reasons it is not exactly 24-h between noon hours. On, because Earth's path through space is not circular, it is elliptical (Kepler's 1st Law). Two, Earth's speed through space changes - it speeds up when close to the Sun and slows down when farther away (Kepler's 2nd Law). Thirdly, the tilt of the Earth's axis being 23.5^{o} from being perpendicular to the ecliptic.

The Sun rises above the horizon at different times (depends on your location). This is why the Earth is divided up into time zones. Before global time zones each city would set its clock by astronomical noon - creating much traveling and communication confusion (*Starry Night*)

- The Earth also has a ***sidereal day***. The length of time between when a star is in one place in the sky until it returns to the same location.
- Because the Earth revolves about the Sun the sidereal time is about 4 minutes earlier each day. The sidereal day is 23 h 56 min long.
- Our calendar is based on 24 hours a day - this has, and will, lead to many problems - like winter weather occurring in the month of July as the calendar becomes out of sync with Earth's location in space.
- To alleviate this problem Julius Caesar, in 46 B.C., implemented an extra day every four years and created the leap year.
- Still not perfect though. There is not exactly 365.25 days in a sidereal year and the Earth's rotational axis changes direction.
- Astronomical and cultural events were falling on the wrong dates.
- The calendar was refined once more by dropping 10 days: Oct 5, 1582 became Oct 15, 1582 - that placed the first day for spring back to March 21.
- Caesar's calendar displaced three days for every four centuries (even with the leap year). That was fixed, for the most part, by having a leap years if the year was divisible by four but century years must be divisible by 400 (1700 was not a leap year, 2000 was).
- The current *Gregorian* calendar only loses one day for every 3300 years.
- The sidereal year differs from the ***Tropical year*** (Vernal Equinox to Vernal Equinox) slightly due to Earth's precession (see next page). (*Starry Night:* SkyGuide » Your first night out » The Earth in motion » How long is a year.)

Precession of the Earth

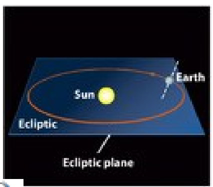
- The combined gravitational effect (pulling and pushing on the Earth) of the Sun and the Moon results in the North pole slowing tracing a large circle in space.
- Earth's 23.5° tilt means the Sun and Moon are not located directly over the Earth's equator. Gravity tries to make the Earth's equator point to the Sun at certain times and the Moon at other times.
- Earth's equatorial bulge doesn't change shape, instead it changes the direction the axis of rotation points. That is called ***precession***.



- It takes about 26,000 years for one "wobble" - very long by human standards but very short in astronomical standards (age of Earth is about 4.5 *billion* years).
- If not for the Moon the Earth would not maintain its 23.5° tilt - which would end the seasons we experience.

- As the Earth precesses the celestial equator also changes direction. That periodically changes the location of the equinoxes (where the ecliptic meets the celestial equator)

- Eventually the Earth's seasons will not be aligned with our current calendar - without careful watch on the calendar summer will occur in January!

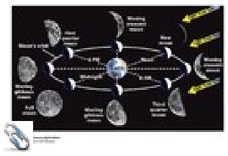


Earth's orientation
in our winter.

Course Work

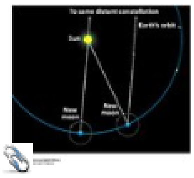
Read Sections 1-4 to 1-8.
Questions Pg. 32 #s 13 - 18.

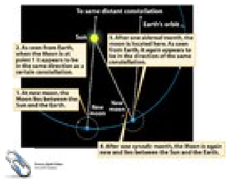
Phases of the Moon



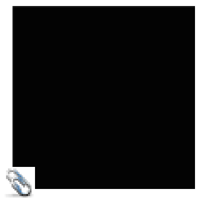
- This is something we are very familiar with and is the original reason for the creation of a month.
- Careful with the wording: *far side of the Moon* and *dark side of the Moon*.

- ***Sidereal Month***: Time to complete one revolution relative to the background stars.
- ***Synodic Month***: Time between consecutive new moons.
- The above differ slightly because of Earth's motion through space.





Lunation of Full Moon (simulation)

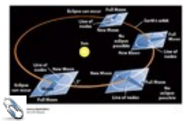


Lunation during phases.

- ***Lunation***: Apparent change in the orientation of the Moon as viewed from Earth. This is because of eccentricity in the Moon's orbit and is not precession (caused by interacting gravitational processes).
- The Moon also precesses but it is not as defined as Earth's.

Solar and Lunar Eclipses

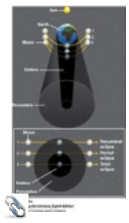
- Occur when the Moon crosses the ecliptic during new or full Moon phases.
- Moon's orbit is tilted 5^{o} from the plane of the ecliptic.
- ***Line of Nodes***: Occurs when the Moon crosses the ecliptic.



- Solar system objects cast two different shadow regions: The ***penumbra*** and ***umbra***.
- Penumbra: An observer can see part of the Sun.
- Umbra: An observer can see no part of the Sun.

- Two eclipses occur in the Sun-Earth-Moon system: ***Solar*** and ***lunar***.

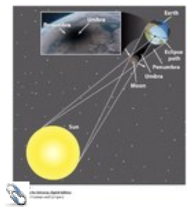
Lunar Eclipses - Moon moves through Earth's shadow. There are three types: Penumbral, partial, and total eclipse.



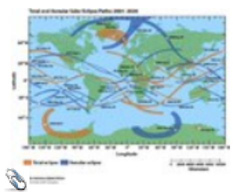
- During totality the Moon usually looks red or copper-like. This is because the yellow, orange, and red sunlight is refracted by the Earth's atmosphere (refraction happens when light enters a material and slows down).

APOD1 *APOD2*

Solar Eclipses - Earth moves through Moon's shadow. Three possible eclipses can occur: Total, partial, or annular eclipse.



- Total: You view the eclipse with the Moon's umbra.
- Partial: You view it from the penumbra.
- Annular: Eclipse is viewed from the penumbra directly behind the umbra. No one on Earth sees a total eclipse.



Course Work

Read Sections 1-9 to 1-13.
Questions Pg. 32 #s 19 - 29.

More Review
Questions Pg. 32-33, #s 30 - 36, 41 - 54, 61, 64
For #53 R_{Sun} = 6.960 x 10^{8} m.

Ch. 2: Gravitation and the Waltz of the Planets

Chapter Outline
2-1 Science is both a body of knowledge *and* a process of learning about nature
2-2 The belief in a Sun-centered cosmology came slowly
2-3 Copernicus devised the first comprehensive heliocentric cosmology
2-4 Tycho Brahe made astronomical observations that disproved ancient ideas about the heavens
2-5 Kepler's laws describe orbital shapes, changing speeds, and the lengths of planetary years
2-6 Galileo's discoveries strongly supported a heliocentric cosmology
2-7 Newton formulated three laws that describe fundamental properties of physical reality
2-8 Newton's description of gravity accounts for Kepler's laws
2-9 Frontiers yet to be discovered

In this chapter you will discover
• What makes a theory scientific
• The scientific revolution that dethroned Earth from its location at the center of the universe
• Copernicus's argument that the planets orbit the Sun
• Why the direction of motion of the planets on the celestial sphere sometimes appears to change
• That Kepler's determination of the shapes of planetary orbits depended on the careful observations of his mentor Tycho Brahe
• How Isaac Newton formulated an equation to describe the force of gravity and how he thereby explained why the planets and moons remain in orbit

Learning Objectives
At the end of this chapter, the student should be able to
1. Compare and contrast the Ptolemaic and Copernican cosmologies by explaining a variety of naked-eye observations, using both models
2. State Kepler's three laws of planetary motion; describe the geometric content and observational consequences of each
3. List Galileo's telescopic observations and explain the success or failure of Ptolemaic and Copernican models in accounting for them
4. State and identify examples of Newton's three laws of motion
5. State Newton's law of universal gravitation; identify the characteristics of this law that explain Kepler's laws in terms of Newton's laws

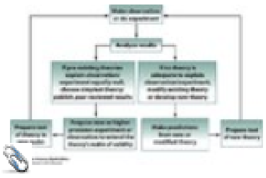
What Do You Think?

Chapter 2

Without looking up any information answer the *WDYT* questions.

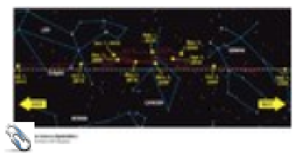
Science: Key to the Cosmos

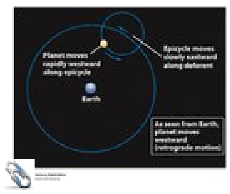
- scientific method
- model the system



<u>Geocentric Universe</u>

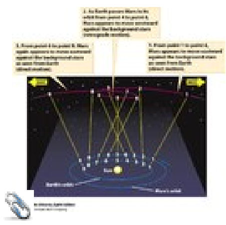
- Earth at the centre.
- Was consistent with observations for about 2000 years.
- Biggest problem was explaining retrograde motion of Mars (and other planets)
- Pg 44 - 45.

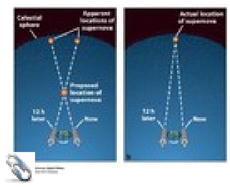




Heliocentric Solar System

- Sun at the centre of universe, and then the centre of the solar system.
- *Remember Occam's Razor*.
- Retrograde motion explained.
- Order of the planets from the Sun determined by Copernicus.
- Tycho Brahe determined a new star was very far away (thought to be a new object in the sky)



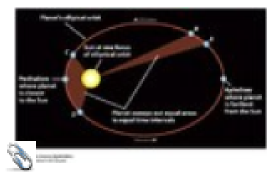


Read to Pg 50.
Pg. 62 #'s 1 - 6.

Kepler's Laws

Kepler's Laws

- Planets orbital path is an ellipse (explained inconsistences with planets traveling in circles).
- Planets sweep out equal area in equal time.
- Square of a planet's sidereal period (in AU) equals the cube of that planet's period (in years).
- 1 AU = astronomical unit = Earth's average distance from the Sun.
- $P^2 = a^3$ (P=period, a=semimajor axis)
- These laws are for any object in orbit about another (Moon about Earth).

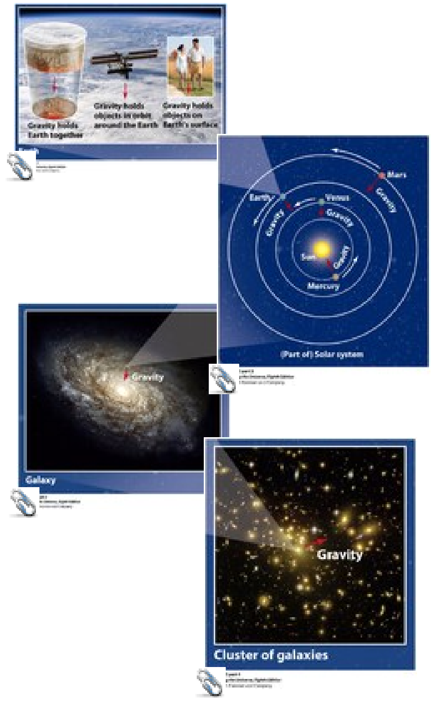


Galileo Destroys Geocentric Universe

- Used the power of the telescope!
- Phases of Venus.
- Moons (satellites) orbiting Jupiter.
- Condemned by Roman Catholic Church for "vehement suspicion of heresy".

Newton's Laws

- 1st Law: Objects in motion tend to stay in motion.
- 2nd Law: Force = mass x acceleration.
- 3rd Law: For every action there is an equal an opposite reaction.
- Law of Gravity: Force of gravitational attraction is directly proportional to the product of their masses and inversely proportional to the square of their distances.



Read through Chapter 2
Questions Pg. 63 #'s 10 - 15,
17, 18, 20 - 22, 25, 28 - 30, 32.

Start Reading through Chapter 3
Pg 68 - 75

Ch. 3: Light and Telescopes

In this chapter students will discover

• The connection between visible light, radio waves, and other types of electromagnetic radiation
• The debate over what light is and how Einstein resolved it
• How telescopes collect and focus light
• Why different types of telescopes are used for different types of research
• The limitations of telescopes, especially those that use lenses to collect light
• What the new generations of land-based and space-based high-technology telescopes being
developed can do
• How astronomers use the entire spectrum of electromagnetic radiation to observe the stars and other astronomical objects and events

Learning Objectives

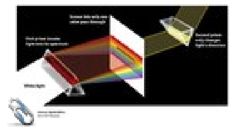
At the end of this chapter, the student should be able to
1. List the major regions of the electromagnetic spectrum in order of wavelength and give common examples of each
2. List the colors of the visible spectrum in order of wavelength
3. Name the two main classes of telescopes and describe the physical laws that each uses to form images
4. Describe how the focal length and diameter of a telescope influence its angular resolution, light-gathering power, and magnifying power
5. Draw a refracting telescope and reflecting telescopes with Newtonian, Cassegrain, prime, and Coude focus locations, showing the path of parallel light rays through each
6. Compare the merits and deficiencies of the two major classes of telescopes
7. Discuss the similarities and differences of radio telescopes and optical telescopes
8. List the advantages of orbiting telescopes over Earth-bound telescopes in detecting electromagnetic radiation in each of the major spectral regions
9. Identify examples of observations impossible from the ground that have been made by the Hubble Space Telescope
10. Describe how X-ray and gamma-ray telescopes focus incoming radiation

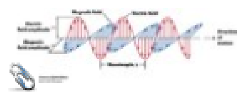
What Do You Think?

Chapter 3

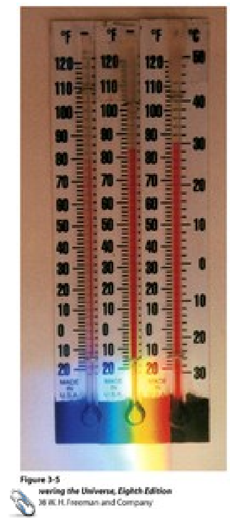
Without looking up any information answer the *WDYT* questions in your notebook.

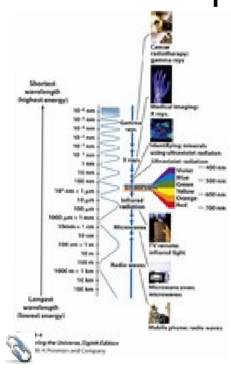
The Nature of Light



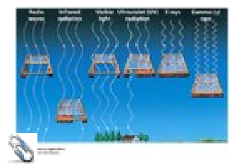


- White light and sunlight is made up of all the colours. (Newton showed this.)
- Light travels as a wave, specifically an ***electromagnetic*** wave. All forms of radiation is an EM wave.
- Light also behaves like a particle with mass - referred to as a ***photon*** (think of it as a packet of light).
- The different colours happen because of their different ***wavelengths***.
- These waves are very small so we use nanometers to measure the size of these waves.
- We see only a small part of the EM spectrum.
- Light travels at a finite speed: ***c*** = 3.00×10^{8} m/s.



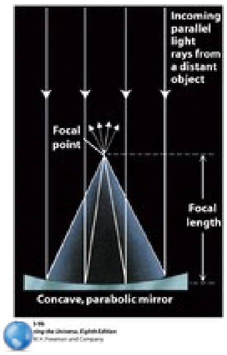


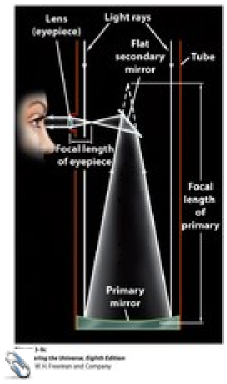
- Earth's atmosphere only allows certain types of radiation through.



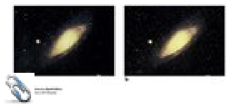
Optics and Telescopes: Reflecting & Refracting

- ***Reflecting telescopes*** use mirrors to collect and focus incoming light.
- Light is reflected to a focal point.
- Consists of a primary mirror (large to collect as much light as possible) and a secondary mirror (small to redirect light to be observed).
- Larger mirrors collect more light (twice the diameter = 4 times the area).





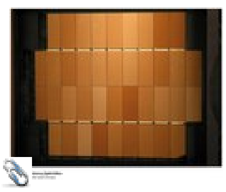
- Magnification is the ratio of focal lengths (Primary mirror to eyepiece). High magnification does not mean great image! (i.e. high resolution)
- There is a limit to the magnification of any telescope.



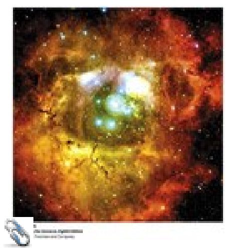
Same magnification, different telescope.

Same telescope, different eyepiece.

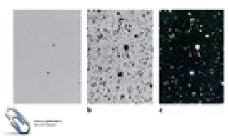
- The EM radiation (light) from the universe has to be stored or collected to be studied.
- Current CCDs (Charged Couple Devices) are the best technology. They replaced photographic plates.
- Typically in the hundreds of megapixels.
- Incoming light charges a pixel during exposure. The charge of each pixel is read and stored into a computer.



378 million light sensitive pixels.

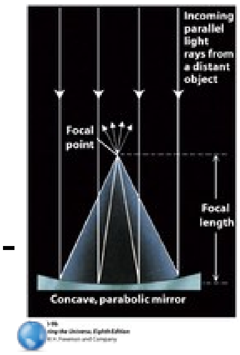


Rosette Nebula taking with the CFHT.

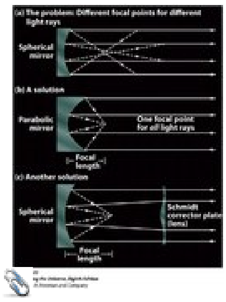


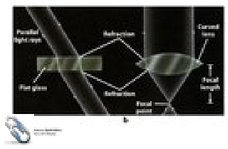
Photographic Plates vs CCD

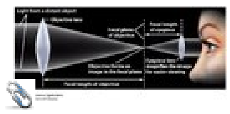
Using Lenses

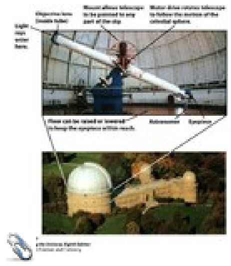


- Although mirrors are the material of choice for astronomical research, lenses are used in eyepieces, binoculars, and refracting telescopes.
- These instruments work on the principal of ***refraction*** - the way light changes direction as it enters a new medium.
- Light can be made to focus if the new medium is curved. This curvature is also necessary for magnification.





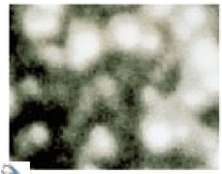


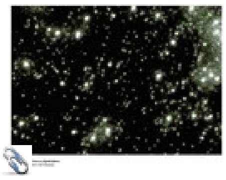


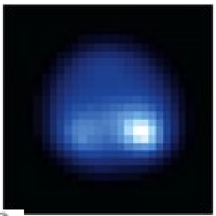
Sections 3-1 to 3-9.
Questions Pg 99 #'s 1 - 9, 16, 20

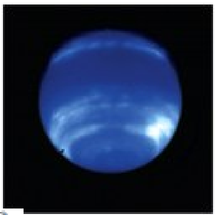
Earth's Atmosphere

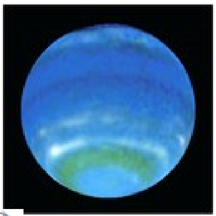
- Different densities of air refract light (seeing water on the road as you drive).
- The changing path of light cause stars to twinkle.
- This blurs images (significantly with high power telescopes).
- The solution has been ***adaptive optics***. A computer program that helps negate the motions of the Earth's atmosphere.
- The use of adaptive optics and powerful, yet cheap, multi-mirrored telescopes allows for excellent images obtained from the surface of the Earth.

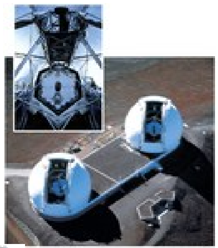








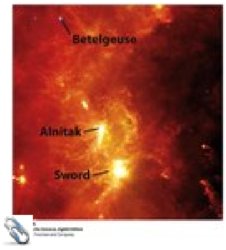


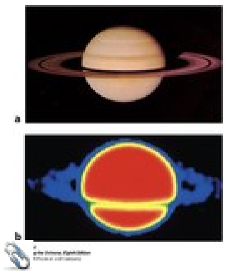


Non-Optical Astronomy

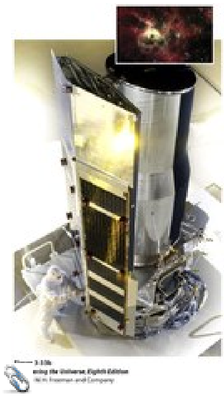
- The majority of the EM radiation hitting Earth is not in the optical spectrum.
- Many fields of astronomical research can only be studied using the non-optical part of the EM spectrum: radio waves, micro waves, infrared, ultra violet, x-ray, and gamma rays.
- Different types of telescopes must be created because of the different wavelengths (and energies) of EM radiation.

Radio waves

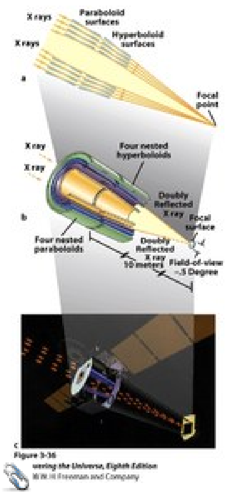


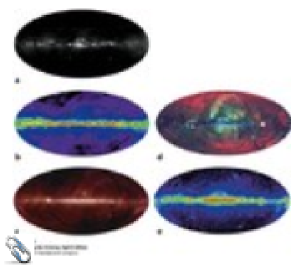


Infrared



X-Ray





Atomic Physics and Spectra

Chapter Outline
4-1 An object's peak color shifts to shorter wavelengths as it is heated
4-2 The intensities of different emitted colors reveal a star's temperature
4-3 Each chemical element produces its own unique set of spectral lines
4-4 The brightnesses of spectral lines depend on conditions in the spectrum's source
4-5 An atom consists of a small, dense nucleus surrounded by electrons
4-6 Spectra occur because electrons absorb and emit photons with only certain wavelengths
4-7 Spectral lines shift due to the relative motion between the source and the observer
4-8 Frontiers yet to be discovered

In this chapter students will discover

- ***The origins of electromagnetic radiation***
- ***The structure of atoms***
- ***That stars with different surface temperatures emit different intensities of electromagnetic radiation***
- ***That astronomers can determine the chemical compositions of stars and interstellar clouds by studying the wavelengths of electromagnetic radiation that they absorb or emit***
- ***How to tell whether an object in space is moving toward or away from Earth***

Learning Objectives

At the end of this chapter, the student should be able to

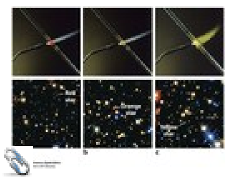
1. State the Stefan-Boltzmann law and Wien's law and explain their meaning in the context of blackbody radiation and temperature determination
2. Describe the evidence for the particle nature of light and indicate how the energy per photon is related to the wavelength and frequency in the wave model
3. State Kirchoff's three laws of spectral analysis and indicate what information is derived about the nature of the light source in each case
4. Describe the Bohr model of the atom in terms of its constituents and their distribution and explain how spectral lines can be produced by a low-density gas
5. Describe how spectroscopic analysis provides information about the chemical composition of celestial objects and indicate for which part of the object the information is valid
6. Indicate how the numbers of protons, neutrons, and electrons are used to define elements, ions, and isotopes
7. Describe the origin of line series in the hydrogen atom and explain why the Balmer lines occur at visual wavelengths but the other line series do not
8. Describe how the Doppler shift reveals the radial motion of star
9. Define excitation and ionization in the context of the Bohr model of atoms

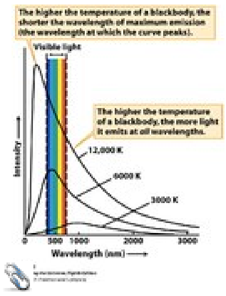
What Do You Think?

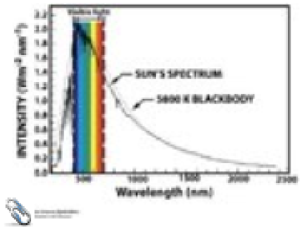
Chapter 4

Without looking up any information answer the *WDYT* questions in your notebook.

Blackbody Radiation



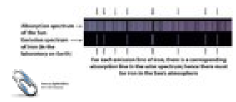




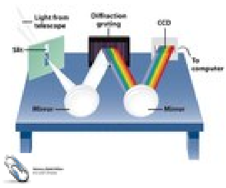
- As an object heats up, it gets brighter, emitting more EM radiation at all wavelengths.
- The brightest colour (most intense wavelength) of the emitted radiation changes with temperature.

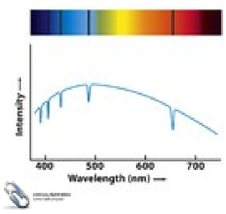
Know how to use the radiation laws on page 107.

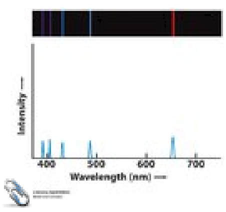
Spectra

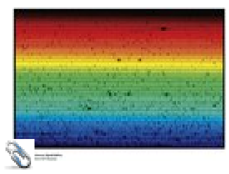


- Each element has a unique spectra.
- Spectrographs are used to image a spectrum.
- Graphs of an absorption spectrum shows valley, whilst an emission graph shows sharp peaks.
- Absorption lines are black lines in a colour spectrum.



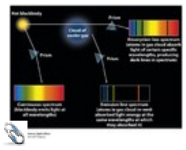


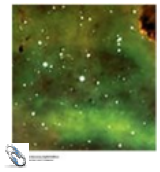




Creating the Spectra

- Three laws for observing a spectrum - Kirchoff's Laws.

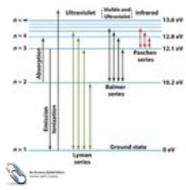




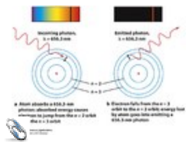
Quantum Physics

Not an atom.

- Although helpful, do not imagine an atom like a mini solar system.



- Atomic particles have properties of particles and waves - studied in the field of quantum mechanics.
- Absorption spectrum happens when incoming EM radiation excites an electron into a higher, quantified, orbital (energy level).

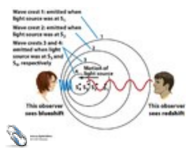


- Emission spectrum occurs when an electron goes to a lower energy level and releases energy at a specific energy.

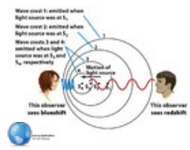
- Statistical physics explains the probability of having electrons in certain orbitals and the relative number of atoms in various stages of ionization - both depend on temperature.

Spectra Reveal More Information than just Composition and Temperature

- The observed wavelength is affected by motion of the object - the Doppler shift.



- If the component of a star's (galaxy, etc.) is approaching Earth, then all of the spectral lines show a smaller wavelength than if the star was stationary. The spectrum is ***blueshifted***.
- Conversely, the spectrum is ***redshifted***.



- Spectra then reveals the star's (galaxy's) radial velocity (component of the star's velocity toward or away from the Earth).
- Rising and sinking of the gases on the Sun's surface.

- Speed of stars orbiting each other.
- Reveals information of the rotation of the star (or planet). Half of the surface is moving towards us and the other half away.
- All of the distant galaxies are moving away from us.
- This leads to a relation between the shift in wavelength, $\Delta\lambda$, and the radial velocity, v.

Review Questions
Pg 122 #s 3, 8, 10 - 14, 18 - 20, 24 - 27.