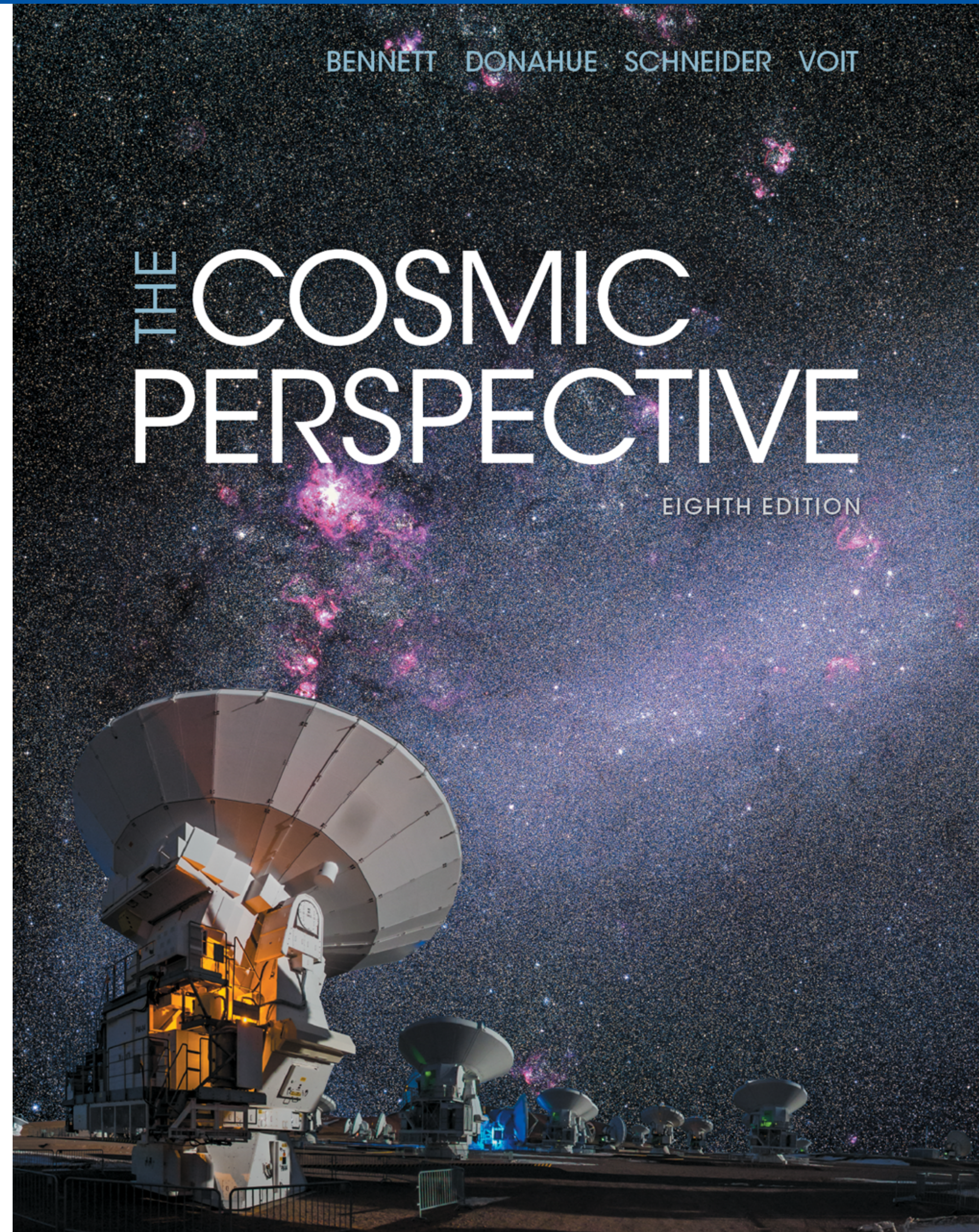
Final Exam Preparation

ASTR1010: Astronomy of the Solar System



ASTR1010 Structure

- Chapter 1: A Modern View of the Universe
- Chapter 2: Discovering the Universe for Yourself
- Chapter 3: The Science of Astronomy
- Chapter 4: Making Sense of the Universe (Gravity, Motion, Energy)
- Chapter 5: Light and Matter: Reading Messages from the Cosmos
- Chapter 6: Telescopes: Portals of Discovery
- Chapter 7: Our Planetary System
- Chapter 8: Formation of the Solar System
- Chapter 9: Planetary Geology: Earth & the Other Terrestrial Worlds
- Chapter 10: Planetary Atmospheres: Earth & the Other Terrestrial Worlds
- Chapter 11: Jovian Planet Systems
- Chapter 12: Asteroids, Comets & Dwarf Planets (Nature, Orbits, Impacts)
- Chapter 13: Other Planetary Systems: New Science of Distant Worlds

- Special Topic (S1): Celestial Timekeeping and Navigation

One astronomical unit (AU) is about 150 million kilometers. It is

a) the average size of the solar system
b) our average size from our Galaxy's center
c) the average distance between Sun and Earth
d) the average distance between Sun and the closest star

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Our solar system, say until Pluto's orbit, has an average diameter of

a) 40 AU
b) 80 AU
c) 150 AU
d) 300 AU

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b) 80 AU (Pluto’s average orbit radius is 40 AU)
c) 150 AU
d) 300 AU

The approximate diameter of our Galaxy (the Milky way) is 100,000 light years. This roughly corresponds to

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b) 6 billion AU (6×10^9 AU)
c) 6 trillion AU (6×10^{12} AU)
d) 6 quadrillion AU (6×10^{15} AU)

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1 light year $\simeq 9.5 \times 10^{12}$ km

The Universe is about 14 billion years old. This mean that a rough estimate of its current size is

a) 150,000 times our Galaxy and 9×10^{14} AU
b) 500,000 times our Galaxy and 3×10^{15} AU
c) 1,000,000 times our Galaxy and 6×10^{15} AU

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Seasons in a planet are an outcome of the tilt of its axis of rotation. Earth has seasons. Which planets are not expected to have substantially different seasons throughout the year?

a) Jovian planets, because of their distance from Sun
b) Jupiter and Saturn, because of their small axis tilt angles
c) Uranus and Neptune, because they are not giant planets and they are far from Sun

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Why does Moon show phases when observed from Earth?

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In case of eclipses, Sun, Earth and Moon are aligned. Why are lunar eclipses seen from the entire nightside hemisphere of Earth but solar eclipses are seen only from a part of Earth?

a) Because in case of lunar eclipses the Moon is between Sun and Earth, while in solar eclipses the Earth is between Sun and the Moon.
b) Because in case of lunar eclipses the Moon goes entirely under Earth’s umbra, while in case of solar eclipses the Moon’s umbra and penumbra cast shadows over parts of Earth.
c) Because of the Moon’s synchronous rotation and orbit around Earth.

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What does synchronous rotation mean for the Moon? Why do we see only one hemisphere of the Moon from Earth?

a) Because there is no rotation of the Moon around its axis
b) Because the Moon rotates too slowly so it takes ages for its other hemisphere to be visible from Earth.
c) Because the time it takes for a full rotation of the Moon around its axis is equal to the time it takes for it to complete a full revolution around Earth.

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What is the celestial sphere?

a) It is an imaginary sphere defined by the extension of Earth’s equator and rotation axis, allowing us to monitor the locations of objects in the sky
b) It is the sphere of influence of the Sun on the solar system
c) It is an imaginary sphere defined by the extension of the ecliptic and an axis perpendicular to it in the sky.

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The geocentric model, most notably the one of Ptolemy, maintained that all celestial bodies revolve around Earth. Which were the first scientists to overturn it?

a) Galileo, with his invention of the telescope and Newton, with his laws of gravity.
b) Aristotle, with his natural philosophy principles and a follow-up by Galileo.
c) Copernicus, with his first Sun-centered model, Tycho Brahe with his accurate measurements and Kepler, who managed to bridge observations with theory via his elliptical orbit model

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Science is a process of attaining knowledge via study and expert knowledge via deepening into the philosophical questions of the studied topic. Astronomy being a science, why is astrology a pseudo-science?

a) This is a flawed notion. Astrology is a science, as well
b) Astrology is a pseudo-science because it searches for hidden influences of stars and planets in human lives
c) Astrology is a pseudo-science because it simply promotes lies and superstitions
d) Astrology is a pseudo-science because it violates at least one of the three hallmarks of science

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How to understand motion: what is the difference between velocity and speed?

a) Speed is a vector quantity: it has a magnitude and a direction
b) Speed is a scalar quantity: it only gives the magnitude of the change of position in a unit time
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d) Velocity is a vector quantity: it has a magnitude and a direction. Speed is the magnitude of velocity.
e) A and C
f) B and D

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Momentum is the product of

a) Mass and speed
b) Mass and velocity
c) Mass and acceleration

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The gravitational attraction is an inverse square law. A four-times smaller distance between two bodies implies a gravitational force that is

a) Four times stronger
b) Four times weaker
c) Sixteen times stronger
d) Sixteen times weaker
e) 64 times stronger
f) 64 times weaker

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Newton's law of gravitational attraction can be shown to be equal to mass times gravitational acceleration. Of these:

a) Both mass and gravitational acceleration are constant, so the gravitational force is constant throughout the Universe
b) Gravitational acceleration is constant throughout the Universe but the mass of the body changes depending where it is
c) The mass of the body, as the amount of matter in it, is constant throughout the Universe, but gravitational acceleration changes

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We have witnessed ISS astronauts drinking bubbles of water floating in the air. How is this even possible?

a) No gravity. Everything floats freely, including the astronauts, the water bubbles and the entire ISS
b) ISS spins very fast so everything in it floats.
c) Gravity is there, but everything, the ISS, astronauts and bubbles of water constantly fall in their orbital path around Earth

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Photons are thought to be particles of light. Why is their frequency always linked to their wavelength?

a) Because the higher the frequency the longer their wavelength.
b) Because the higher the frequency the shorter their wavelength.
c) Because the product of photon wavelength and frequency is constant, namely the (constant throughout the Universe) speed of light
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$$c = \lambda \times f$$

The constant light speed being about 300,000 kilometers per second, how long do photons need to cover the 150 million km between Sun and Earth?

a) Three minutes, roughly
b) One hour and 5 minutes
c) A bit more than 8 minutes

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$$Time = \frac{Distance}{Speed} = \frac{150 \times 10^6 km}{300 \times 10^3 km/sec} = \frac{1}{2} \times 10^3 sec$$

$$= 500sec = (8 \times 60) + 20sec = 8min\ 20sec$$

From the photon frequency (or wavelength) I can directly compare the energy of different photons by just the ratio of their frequencies.

a) A photon with frequency twice as much (so with a wavelength double) that of another photon will have double energy.

b) A photon with frequency twice as much (so with a wavelength double) that of another photon will have four times higher energy.

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$E = h \times f$

h: Planck's constant

There is constant interplay between matter and light. Which of the following are true?

a) Atoms get excited by moving an electron to a lower energy level when absorbing a photon
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d) A and C
e) **B and C**

The atomic number of Uranium is 92. What is the atomic structure of isotopes Uranium-235 and Uranium-238?

a) ^{235}U: 92 protons, 143 neutrons, 92 electrons
b) ^{235}U: 143 protons, 92 neutrons, 143 electrons
c) ^{238}U: 92 protons, 146 neutrons, 92 electrons
d) ^{238}U: 146 protons, 92 neutrons, 146 electrons
e) A and C
f) B and D

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Earth's atmosphere operates as a filter of solar electromagnetic emission. It pretty much blocks photon energies higher than

a) Infrared (so, visible, ultraviolet, X-rays, gamma rays)
b) Radio (so, infrared, visible, ultraviolet, X-rays, γ-rays)
c) Visible (so, ultraviolet, X-rays, γ-rays)
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Interferometry and spectroscopy are two valuable techniques that help us

a) Achieve higher angular resolution (interferometry) and decipher the chemical composition of a target (spectroscopy) by the light we receive from it
b) Achieve higher light collecting area (interferometry) and decipher the chemical composition of a target (spectroscopy) by the light we receive from it
c) Achieve higher sensitivity (interferometry) and study the Doppler effect of a target (spectroscopy) by the light we receive from it

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The planets of our solar system have been structured around

a) Jupiter and Saturn, the two gas giants
b) a frost line, with jovian planets within and terrestrial planets beyond it
c) a frost line, with terrestrial planets within it and jovian planets beyond it
d) terrestrial planets, with all remnants ending up condensed into jovian planets

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The constitution of terrestrial planets is different than that of jovian planets. Metals and rock concentrated mostly within the frost line and are coming from

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b) the Big Bang itself
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Radiometric dating is used to determine the age of rocks and metals in the solar system. It relies on the half-life of radioactive elements. If the half-life of an element has elapsed six times, then its mass has decreased by

a) 6 times
b) 12 times
c) 24 times
d) 32 times
e) 64 times

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$2^1, 2^2, 2^3, 2^4, 2^5, \mathbf{2^6}$

$\mathbf{= 64}$

Both terrestrial and jovian planets show differentiation. Which layers characterize terrestrial planets?

a) Core, mantle, crust and lithosphere
b) Core, mantle and crust
c) Core, metallic hydrogen and atmosphere
d) Core, helium rain and atmosphere

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Apollo 11 was a space mission that combined

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b) flyby, orbiter and lander phases
c) orbiter, lander and sample return phases
d) lander and sample return phases

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Conservation laws play a major role in understanding nature. Physical parameters whose conservation we use are

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Both terrestrial and jovian planets produce heat, but via different mechanisms. There are

a) Tidal heating for jovian and radioactive decay for terrestrial planets.
b) Radioactive decay for jovian planets, contraction for terrestrial planets
c) Radioactive decay for terrestrial planets, contraction and ‘raining’ of dense material for jovian planets
d) Tidal heating for terrestrial planets and radioactive decay for jovian planets

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Heat produced by planets is eventually escaping them. How does this work for terrestrial planets from inside out?

a) Radiation, conduction, convection
b) Conduction, convection, radiation
c) Convection, conduction, radiation
d) Radiation throughout

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The surface-over-volume ratio is an inverse law for planetary radii. What does this mean for planetary cooling?

a) Planets with twice as large radii from a reference planet will need about twice as much time to cool down

b) Planets with three times as large radii from a reference planet will need about three times as much time to cool down

c) Planets with 20 times as large radii from a reference planet will need about 20 times as much time to cool down

d) All of the above

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$$\frac{A}{V} = \frac{4\pi R^2}{\frac{4}{3}\pi R^3} = \frac{3}{R}$$

Take any stellar system and assume that a small object is coming from beyond its frost line. You would expect this object to be

a) an asteroid
b) a meteorite
c) a planetesimal
d) a dwarf planet
e) a comet

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Thousands of new planetary systems have been so far discovered. Are there any problems that prompt us to continue research in this direction?

a) No problems whatsoever. It will take a lot of time to just study the cases we have already
b) The problem is that these stars are very different than our Sun. We need to find more Suns out there
c) We typically see very large planets very close to their star. We need more Earth-size planets
d) No knowledge exists for planetary atmospheres and no direct imaging of planets
e) C and D
f) B, C, and D

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e) **C and D**
f) B, C, and D

Knowing that I am at a geographic latitude of 40^{o} North, I measure a 50^{o} altitude for Polaris and a 40^{o} altitude of the celestial equator when it crosses my local meridian. Are my measurements correct?

a) Yes, they are. I am done with it.
b) No, they are not. My Polaris measurement is correct and my CE measurement is wrong.
c) No, they are not. Both my Polaris measurement and my CE measurement are wrong.

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Method 1: My latitude = Polaris altitude

Method 2: My latitude = 90^o – CE altitude

The right ascension is the celestial equivalent of …. and is measured in …

a) the geographic latitude; degrees
b) the geographic longitude; degrees
c) the geographic longitude; hours, minutes, seconds

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a) the geographic latitude; degrees
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c) the geographic longitude; hours, minutes, seconds

The geographic longitude is calculated by splitting the globe in 24 time zones, …. degrees each. Then, 60 degrees east means …. hours from the central meridian at Greenwich

a) 20; +3
b) 30; +2
c) 15; +4
d) 60; +1

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- Western longitudes mean hours lagging from Greenwich (-)
- 24 time zones x 15 deg each = 360 deg of the global sphere

BACKUP SLIDES

Chapter 1: A Modern View of the Universe

- What is our location in the Universe?
- What is a: Comet, Asteroid, Planet, Star, Solar System, Nebula, Galaxy, Universe?
- What is our Sun, in regard to other Stars in the Galaxy?
- What is an Astronomical Unit – what it its average magnitude?
- How many planets exist in our Solar System – is Pluto considered a planet?
- What is the shape of our Galaxy and how many stars does it have?
- How many Galaxies exist in the Universe?
- What is the size and the age of the Universe?
- What is the light year – what it its approximate magnitude?
- Does the Universe expand – how did we find this out?

Chapter 2: Discovering the Universe for Yourself

- What is the Milky Way – can it be observed from Earth and how does it look like?
- How many stars can we see on a clear night in the countryside with naked eyes?
- What is a Constellation – how many are there?
- What is the Celestial Sphere, the Celestial Equator and the Celestial Poles?
- What is the Ecliptic – how much is it tilted with respect to the Celestial Equator?
- Can we measure angles in the sky? How?
- What causes Seasons in Earth? Are Seasons, weather-wise, the same for the North and South hemispheres of Earth? Why?
- What are Solstices and Equinoxes? What do they mean for the progression of Seasons?
- What is the Precession of Earth's rotation axis – what is its period?
- What are the Phases of the Moon and why do they happen?
- Does the Moon rotate around itself? Why do we only see half (a hemisphere) of it?
- What are Eclipses? What is a Solar and a Lunar Eclipse?
- From a certain location on the surface of the Earth, why are Lunar Eclipses more frequent than Solar Eclipses?
- What is the Retrograde Motion of planet Mars and why does it happen?
- What is Stellar Parallax and why did the ancient Greeks miss it? What did they conclude because of not observing one?

Chapter 3: The Science of Astronomy

- What does Science mean and what did the ancient Greeks mean by it?
- How is modern Science rooted in ancient Astronomy?
- How many ancient civilizations can you find that relied on Astronomy for their needs?
- What is the Geocentric Model? Who defined it and which was the most elaborate one?
- What was the most important contribution of Ptolemy's Geocentric Model?
- What are the most important contributions of Copernicus, Tycho Brahe and Kepler?
- Which are Kepler's three laws? Which one is the most important for practical applications?
- What were Galileo's main contributions?
- How can Science and Non-Science be distinguished?
- What are the Hallmarks of Science?
- What is a Scientific Theory – can you think of some?
- Is Astrology a Science, like Astronomy? What is their single most important difference?
- Do Astrology's predictions have any scientific validity? Why?

Chapter S1: Celestial Timekeeping and Navigation

- What is a Solar and what is a Sidereal Day? Which one is longer, and why?
- What is a Synodic and what is a Sidereal Month? Which one is longer, and why?
- What is a Sidereal and what is a Tropical Year?
- What is a Sidereal and what is a Synodic planetary Period?
- What is a Planetary Transit and why does it happen?
- What is the simplest way of finding noon on a sunny day without looking at the time?
- What is Local Noon, Apparent Solar Time, Mean Solar Time, Standard Time and Universal Time? When is Daylight Time introduced and why?
- How many Time Zones exist on Earth?
- What is a Leap Year and why was it necessary to be introduced?
- What are the Celestial Coordinates and their units of measurement?
- What are Earth's Special Latitudes and why have they been introduced?
- What are the two rules for determining the Geographic Latitude at your location?
- Can the Sun only be used to determine the Geographic Latitude or stars can be used, as well? What are the key pieces of knowledge we need to have, either way?
- How can the Geographic Longitude be determined? Why was this arguably a harder problem than determining the Geographic Latitude?

Chapter 4: Making Sense of the Universe: Understanding Motion, Energy and Gravity

- Speed, velocity, acceleration
- Gravity: mass vs. weight
- Momentum & angular momentum: force; torque
- Apparent weightlessness in space: why?
- Newton's laws of motion
- Universality of Newton's laws
- Conservation of momentum, angular momentum and energy
- Energy transfer: can energy be created or lost?
- Temperature and heat
- Strength of gravity: what determines the gravity force?
- How do objects fall in Earth's gravitational field? Does gravitational acceleration depend on a body's mass?
- How do Newton's laws extend Keppler's laws?
- What is the escape velocity?
- How does gravity cause tides? Which planetary bodies exert tides on Earth?

Chapter 5: Light and Matter: Reading Messages from the Cosmos

- Light and its nature: waves, photons
- The colors of visible light: what do they mean?
- How does light interact with matter?
- Understand emission, reflection, absorption, scattering of light
- The electromagnetic spectrum: is there light beyond visible?
- How do we represent the electromagnetic spectrum?
- Are there colors beyond visible light?
- Wavelength and frequency of light: how are they related – can we obtain the one from the other?
  (Tip: $c = \lambda \times f$ → speed of light = wavelength x frequency)
- The energy of photons (Tip: $E = h \times f$ → energy = Planck's constant x frequency)
- Molecules & atoms: what are they?
- What is the structure of atoms?
- Atomic number, atomic mass number, isotopes
- Phases of matter: what is plasma?
- What is the field that holds atoms together? How it this different than the gravitational field?
- How do atoms interact with light? How is energy stored in atoms and how is it shed away?
- The three basic types of spectra
- What is a chemical fingerprint? How do we 'read' and extract information from spectra?
- Spectra and temperature
- The color of stars: Where does it depend on?
- The Doppler phenomenon: what does it mean in light and sound waves?
- What happens to the spectrum of a rotating object?

Chapter 6: Telescopes: Portals of Discovery

- How do our eyes and photographic cameras work?
- What is the refraction of light? Examples?
- What are the two important properties of telescopes?
- What are the two main telescope designs? What is their difference?
- Which telescope type is mostly used today? Why?
- What is angular resolution and what is diffraction limit? How can we improve them?
- Why do we get interference in astronomical images?
- What are the three main tasks telescopes are used for?
- How do we decide where to install a science-grade telescope?
- What is the main technology we use to deal with atmospheric turbulence?
- Why do we launch telescopes into space?
- Which wavelengths of the electromagnetic spectrum are not absorbed by Earth's atmosphere?
- Do we have telescopes, both on the ground and in space, that observe invisible (not seen by the human eye) light?
- What is interferometry? How is it achieved?
- Which wavelengths are typically observed by means of interferometry?

Chapter 7: Our Planetary System

- A “bird’s eye” view of the solar system: ordering of planets with respect to their distance from the Sun
- Differences between planets, dwarf planets and planetesimals
- Asteroids and comets: similarities and differences
- Major types of planets: terrestrial, jovian – what are the main similarities and differences
- Asteroid belt; Kuiper belt; Oort Cloud: where are they, what are their main properties
- Four types of space missions (flyby, orbiter, lander, sample return): understand main characteristics; place in order of complexity and cost
- How do we measure distances between Earth and planets closer to the Sun?

Chapter 8: Formation of the Solar System

- How did we arrive to the theory of solar system formation – what patterns should this theory explain?
- Initial solar nebula composition: what was it, and why?
- From the solar nebula to the solar system: main stages and conservation laws
- How have terrestrial and jovian planets been formed? Why do we have these two main planet types?
- Frost line: where is it – what does it mean?
- How here comets and asteroids formed?
- Accretion and formation of bodies: main acting forces at small and large scales
- The solar wind and its role
- What is the “heavy bombardment”? What is an impact crater?
- What explains peculiarities in the solar system, such as the extreme tilt of Uranus and the relatively large size of Earth’s Moon?
- The age of the solar system: what corroborates it and why? Why are we certain that the solar system could not have been formed at the initial stages of the Universe?
- Radiometric dating: why is it used; how does it work; where does it fail?

Chapter 9: Planetary Geology: Earth and the Other Terrestrial Worlds

- Differentiation: what is this process? How does this process shape the interiors of terrestrial planets?
- Main layers in the interior of terrestrial planets (core, mantle, crust): main properties – why are they ordered this way?
- What is the lithosphere? How is it different than the crust?
- How do we extract information about Earth’s interior?
- What are the main two wave types which we use to learn about Earth’s interior? What are their main properties?
- Why do bigger worlds (planets, dwarf planets, sizeable moons) attain spherical shapes?
- Where does interior heat in planets come from? How is this heat transferred outwards?
- Surface area to volume ratio: what does it mean – how does it affect smaller and larger worlds?
- How are magnetic fields formed in planetary interiors?
- What are the four processes shaping planetary surfaces (Impact Cratering, Volcanism, Tectonics, Erosion)? How are they initiated – where is each of them most important?
- Which of these four processes are most relevant for each of the terrestrial planets, Mercury, Venus, Earth and Mars?
- Lunar craters and maria: how have they formed – which ones are younger?
- What are martian “channels” and why were they misinterpreted as structures made by a civilization inhabiting Mars?
- Similarities between terrestrial and martian landscapes: what do they mean?
- Earth’s tectonics and the theory of continental drift
- What phenomena are associated with Earth’s tectonic motions? Think mountain ranges, subduction, rifts and faults, earthquakes, seafloor recycling
- Why do we believe that Mercury, Moon and Mars are geologically “dead”?

Chapter 10: Planetary Atmospheres: Earth and the Other Terrestrial Worlds

- Atmospheres of terrestrial planets: understand stratification (i.e., layering), density, temperature and how these vary with altitude
- Weather, climate and their differences
- The greenhouse effect: causes, main agents on Earth and Venus and what would happen if it did not exist
- Venus' runaway greenhouse effect: what does it explain?
- Albedo and its effect
- Earth's atmospheric structure and unique atmospheric composition
- Basic characteristics of atmospheres of Mercury, Venus and Mars
- Effects of scattered light on Earth's atmosphere: blue and red
- Earth's magnetosphere and its purposes. Magnetospheres of other terrestrial planets.
- Wind patterns, atmospheric convection, Coriolis effect and their manifestations on Earth
- Which factors can cause long-term climate change?
- Atmospheric loss and gain: how does it work?
- Why did Mars change so drastically?
- Nitrogen, Oxygen, Ozone and Carbon Dioxide in Earth's atmosphere: what is their origin and main roles?
- What would happen if sources of atmospheric oxygen ceased to exist?
- Anthropogenic (i.e., human-made) impact on the atmosphere and the greenhouse effect.
- What is global warming, how is it driven and what are its consequences?

Chapter 11: Jovian Planet Systems

- Jovian planets: what is their believed internal structure and how does it differ from that of terrestrial planets?
- How is internal structure of Jupiter and Saturn different than that of Uranus and Neptune?
- Why do Jupiter and Saturn have strong magnetospheres?
- What is the composition of Jupiter’s and Saturn’s atmospheres?
- What is weather like in Jovian planets, particularly Jupiter and Saturn?
- Jovian planet moons and their size classification: how does size affect their shape and geological history?
- Sources of heat in the moons of Jupiter and Saturn
- Jovian planet rings: origin, constitution, and shape
- What are resonances and what is their purpose on Jovian planet rings?

Chapter 12:Asteroids, Comets, and Dwarf Planets: Their Nature, Orbits and Impacts

- Small worlds: what are the differences between asteroids, comets and dwarf planets?
- What are meteors and what are meteorites? What are meteor showers and why do they typically originate from certain areas of the sky, at certain times of the year?
- Typical asteroid structure
- Asteroids and their moons (when existing): what can we learn from them?
- Typical composition of asteroids
- Why is the asteroid belt located where it is (i.e., between the orbits of Mars and Jupiter)? What do resonances have to do with this?
- What are the Trojan asteroids?
- Which are the two meteorite types and how are they different?
- What are the typical sources of meteorites discovered in Earth?
- What are sample return missions? Can you name one?
- What is the typical comet composition?
- What is a comet's tail, where and how does it form and how many types of tails exist?
- Where do comets come from? How do we distinguish between comets from the Kuiper belt and those from the Oort Cloud?
- Why was Pluto removed from the list of planets? What is it now believed to be?
- What were the main findings of the New Horizons mission in regard to Pluto?
- Cosmic collisions: how do they occur and what is their impact on Earth and occurrence frequency in regard to their size?
- Can you name an agreed-on extinction-level event caused by a cosmic collision?
- How do we know of this major event? What is the main evidence of impact?
- How do Jovian planets affect the rate of cosmic collisions for terrestrial planets?

Chapter 13: Other Planetary Systems: The New Science of Distant Worlds

- The challenges of detecting extrasolar planets
- The astrometric, transit and Doppler detection techniques
- What are the properties of extrasolar planets that can be detected with existing techniques?
- What are typical sizes of most extrasolar planets found so far and why?
- Do we need to revise current theories of solar system formation to understand findings in other stellar systems with planets?
- What is the habitable zone of stars – how does it change with the star’s size?