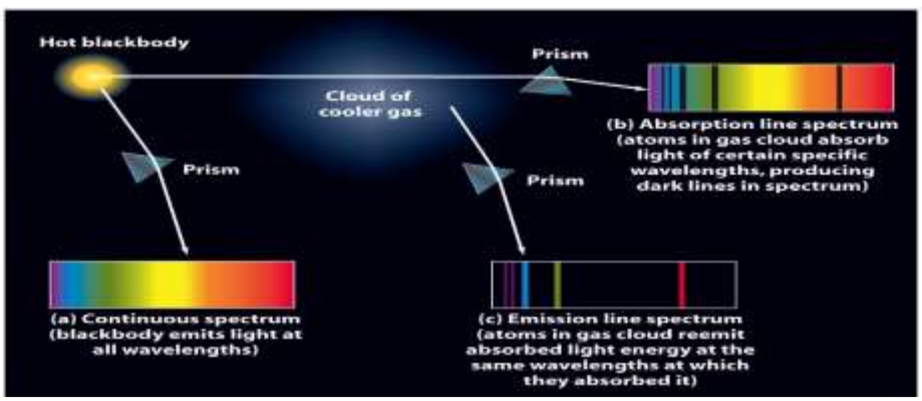
Physics 200 Notes (Exam 2)

Chapter 4 - Spectroscopy

1. Spectral lights

- Radiation can be analyzed by a spectroscope, or spectrometer. Measuring spectra, or spectroscopy, is one of the most important uses of telescopes.
- An essential tool of spectroscopy is the spectrograph, a device that records spectra.
- Continuous Spectrum: Thin slit in a barrier creates a narrow beam. The prism splits the light into its component colors. The lens focused the colors
- Emission Lines: Distinct bright lines result when the gas is heated, for example thru
- electrical discharge
- Absorption Lines: When cool gas is placed between a source of continuous radiation like a light bulb and a screen the resulting spectrum is crossed by a series of dark line (absorption lines). It is the gas which absorbs the light. These lines are at the same positions of the emission lines created when the gas is heated.
- Two Ways to Represent Spectra: When a CCD (compact disc) is placed at the focus of a spectrograph, it records the rainbow-colored spectrum. A computer program can be used to convert the recorded data into a graph of intensity versus wavelength. (a) Absorption lines appear as dips on such a graph, while (b) emission lines appear as peaks. The dark absorption lines and bright emission lines in this example are the Balmer lines of hydrogen.



- Kirchhoff's Laws:
    - *Law 1:* A hot opaque body, such as a perfect blackbody, or a hot, dense gas produces a continuous spectrum—a complete rainbow of colors without any spectral lines.
    - *Law 2*: A hot, transparent gas produces an emission line spectrum—a series of bright spectral lines against a dark background.
    - *Law 3:* A cool, transparent gas in front of a source of a continuous spectrum produces an absorption line spectrum—a series of dark spectral lines among the colors of the continuous spectrum. Furthermore, the dark lines in the absorption spectrum of a particular gas occur at exactly the same wavelengths as the bright lines in the emission spectrum of that same gas.

2. Atomic & Radiation

- To explain the formation of emission and absorption lines, one should understand the structure of atoms.
- The simplest atom is *hydrogen* which has the electron orbiting the proton. The electron is bound to the proton by the electric force. If the hydrogen atom absorbs light, an internal change occurs.
- The basic characteristics of the Bohr model are:
  - Hydrogen has a state of lowest energy called **ground state.**
  - There is a maximum energy that the electron can have and still bound the proton. Beyond this energy the hydrogen becomes **ionized (loses its electron).**
  - Between the minimum and maximum energy levels, the electron can only exist in certain energy levels called orbitals. In other words, the orbital energies are **quantized.**
- If light falls on a hydrogen atom, the light energy must correspond precisely to the energy difference between the energy levels. But the light carries energy packets called photons. The photon is a "particle" of electromagnetic radiation.
- **$E=hf=hc/\lambda$** h = planck constant = 6.625 x 10-34 J.S. c= speed of light in vacuum
- The light that comes from the daytime sky is sunlight that has been scattered by the molecules that make up our atmosphere. Air molecules are less than 1 nm across, far smaller than the wavelength of visible light, so they scatter blue light more than red light *which is why the sky looks blue*. Distant mountains often appear blue thanks to sunlight being scattered from the atmosphere between the mountains and your eyes.
- Light scattering also explains *why sunsets are red*. The light from the Sun contains photons of all visible wavelengths, but as this light passes through our atmosphere the blue photons are scattered away from the straight-line path from the Sun to your eye. Red photons undergo relatively little scattering, so the Sun always looks a bit redder than it really is. When you look toward the setting sun, the sunlight that reaches your eye has had to pass through a relatively thick layer of atmosphere. Hence, a large fraction of the blue light from the Sun has been scattered, and the Sun appears quite red.

3. Formation of Spectral Lines:

- Kirchhoff's Laws explained. Continuous spectrum: a beam of radiation shines through a hydrogen gas. The beam contains photons of all energies, but most of them cannot excite the gas. Those photons, having the right energy, can be absorbed. They excite the gas and are removed from the beam. We obtain the dark lines in this way. But the excited atoms return very quickly to the original state, thereby emitting one or more photons. Since the photons are randomly emitted, they can make it to the screen and are observed as emission lines.
- Energy-Level Diagram of Hydrogen is a convenient way to display the structure of the hydrogen, which shows the allowed energy levels. The diagram shows a number of possible electron jumps, or transitions, between energy levels.
- An upward transition occurs when the atom absorbs a photon; a downward transition occurs when the atom emits a photon.

- Electrons can make transitions to higher energy levels by absorbing a photon or in a collision between atoms; they can make transitions to lower energy levels by emitting a photon.

4. Spectral-Line Analysis

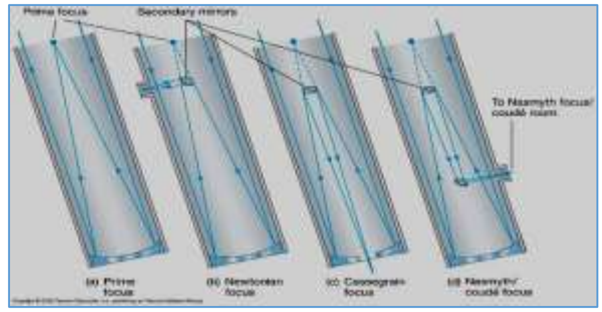
- Let us make the following replacements:
  - The light bulb replaced by a star
  - Cool gas is replaced by interstellar gas or star's atmosphere
  - The prism is replaced by a spectrograph
- Stars are hot systems. This is the reason why they exist. But their atmospheres are relatively cool such that the spectral lines are formed there.
- If all the hydrogen would be in ground state that is the gas is at low temperature.
- Then the only transitions that could occur would be the Lyman series (UV part of the spectrum). No visual spectra would then be observed. Of course not because hydrogen is not present
- Our Sun is also a case. Its relatively cool surface temperature of 5800 K implies that only few hydrogen atoms have electrons in excited states. Thus, hydrogen lines are weak in the Sun

Chapter 5 – Telescopes

1. Refracting and Reflecting Telescopes

- A telescope collects light. Optical telescope collect visible light.
- Optical telescope: A telescope designed to detect visible light.
- Refraction: The bending of light rays when they pass from one transparent medium to another
- Refracting telescope: A telescope in which the principal optical component is a lens. Uses a lens to concentrate a beam of light. A refracting telescope actually uses two a lenses: an objective and an eyepiece.
- Eyepiece lens: A magnifying lens used to view the image produced at the focus of a telescope.
- Objective lens: The principal lens of a refracting telescope.
- A refracting lens changes the direction of the light depending on the prism's face. A lens can be thought as a series of prisms. A light ray traveling along the axis remains straight line. Parallel rays pass through one point, *the focus*.
- Reflection: The return of light rays by a surface.
- Reflecting telescope: A telescope in which the principal optical component is a concave mirror. A curved mirror is used. All parallel rays are focused into one point. The mirror is called *primary mirror* and the focus is called *primary focus*
- Reflecting telescopes are favored because:
  - Light passing through the lens, as in refractors is a disadvantage, since dispersion occurs and different colors are focused differently. This is known as chromatic aberration.
  - Some light is absorbed when passing through the lens, especially infra-red light
  - Lenses can be rather heavy and have to be supported around their edges.
  - A lens have two sides to be polished.

- Chromatic Aberration is the most severe optical problem facing the construction of refracting telescopes. An optical defect whereby different colors of light passing through a lens are focused at different locations.
- <u>Lens:</u> A piece of transparent material (usually glass) that can bend light and bring it to a focus. lenses reverse images



- <u>Focus (of a lens or mirror):</u> The point to which light rays converge after passing through a lens or being reflected from a mirror.
- <u>Focal plane:</u> The plane in which a lens or mirror forms an image of a distant object.
- Types of Reflector telescopes:
  - Prime focus used only in large telescopes
  - Newtonian focus: Light intercepted before it reaches the prime focus, and is deflected by 90° by a secondary mirror to reach the eyepiece. It's a popular design for small telescopes used by amateur astronomers.
  - Cassegrain focus: Light reflected by the primary mirror toward the prime focus, is intercepted by a small secondary mirror which reflects it back through a small hole at the center of the primary mirror.
  - Nasmyth/coude focus: Light is deflected to a different lab where heavy instruments are mounted separately. Light path to Coudé focus lies along the axis of the telescope's mount – that is the axis around which the telescope rotates.

2. *<u>Magnification</u>*

- <u>Magnification:</u> The factor by which the apparent angular size of an object is increased when viewed through a telescope. <u>It is the focal length of the objective divided by the focal length of the eyepiece.</u> The shorter the focal length of the eyepiece, the larger magnification. The light-gathering power of a telescope depends on the diameter of the objective lens.

3. *<u>Resolving Power</u>*

- Large telescope have finer resolution. Resolution is the ability to separate images of objects lying close together. It produces star images that are sharp and crisp. A quantity called angular resolution gauges how well fine details can be seen. Poor angular resolution causes star images to be fuzzy and blurred together.
- One factor limiting angular resolution is *diffraction*, which is the tendency of light waves to spread out when they are confined to a small area like the lens or mirror of a telescope. As a result of diffraction, a narrow beam of light tends to spread out within a telescope's optics, thus blurring the image. As a result of diffraction, the resolution of a telescope depends on the wavelength and on the diameter of the mirror.
- Raleigh formula:

$$Angular resolution(arc\sec) = 0.25\frac{\lambda(\mu m)}{mirror\ diameter(m)}$$

4. *Spectrographs and Spectra*

- Diffraction grating: This is a piece of glass on which thousands of very regularly spaced parallel lines have been cut. Some of the finest diffraction gratings have more than 10,000 lines per centimeter, which are usually cut by drawing a diamond back and forth across the glass. When light is shone on a diffraction grating, a spectrum is produced by the way in which light waves leaving different parts of the grating interfere with each other.
- Two equivalent ways of representing a spectrum: absorption and emission lines.

5. *Charged-Coupled Devices (CCD)*

- The most sensitive light detector currently available to astronomers is the charge-coupled device (CCD). At the heart of a CCD is a semiconductor wafer divided into an array of small light-sensitive squares called picture elements or, more commonly, pixels When an image from a telescope is focused on the CCD, an electric charge builds up in each pixel in proportion to the number of photons falling on that pixel. When the exposure is finished, the amount of charge on each pixel is read into a computer, where the resulting image can be stored in digital form and either viewed on a monitor or printed out.
- Compared with photographic film, CCDs are some 35 times more sensitive to light (they commonly respond to 70% of the light falling on them, versus 2% for film), can record much finer details, and respond more uniformly to light of different colors.

6. *High-Resolution Astronomy*

- In practice, however, ordinary optical telescopes cannot achieve such fine angular resolution. The problem is that turbulence in the air causes star images to jiggle around and twinkle. Even through the largest telescopes, a star still looks like a tiny blob rather than a pinpoint of light. A measure of the limit that atmospheric turbulence (mass motion) places on a telescope's resolution is called the seeing disk. This disk is the angular diameter of a star's image broadened by turbulence. The constantly shifting rays reaching our eyes, produces the illusion of a motion. The size of the seeing disk varies from one observatory site to another and from one night to another.
- The blurring effects of atmospheric turbulence can be minimized by placing the telescope atop a tall mountain with very smooth air.

7. *Telescopes*

- The Keck telescopes (I and II) has 36 hexagonal 1.8 m mirrors equivalent to 10 m reflector. Two of them are on Mauna Kea (Hawaii), 4.2 km altitude. The Keck I and II telescopes used together should give an angular resolution as small as 0.005 arcsec.
- The largest telescope is the VLT (Very Large Telescope) of the ESO (European Southern Observatory) at Cerro Paranal, Chile. Four 8.2 m mirrors can operate as on single instrument.
- The Hubble Space Telescope (HST) Largest telescope placed in orbit. Joint project by NASA and ESA. Can operate at any wavelength from infrared to visible to ultraviolet. Placed at 600 km above the Earth. 2.4 m objective mirror Wavelength range: 115 nm to 1 μm

- James Webb Space Telescope (JWST): 6.5 m mirror. Wavelength: 600 nm to 28 μm (visible to Infrared). It will orbit the Sun 1.6 million km away from the Earth. It is naturally cooled for the infrared detectors to work properly. It is a super Hubble Space Telescope.
- Infrared Telescopes: Water vapor is a main absorber of infrared radiation from space. This telescope can see through dust, have observed first galaxies formed after Big Bang. The Spitzer Space Telescope Launched in 2003, this is the largest infrared telescope ever placed in space. Its 85-cm objective mirror and three science instruments, kept cold by 360 liters of liquid helium, enable the Spitzer Space Telescope to observe the universe at wavelengths from 3 to 180 um.
- X-ray astronomy: Space telescopes have also made it possible to explore objects whose temperatures reach the almost inconceivable values of 106 to 108 K. Atoms in such a high-temperature gas move so fast that when they collide, they emit X-ray photons of very high energy and very short wavelengths less than 10 nm. X-ray telescopes designed to detect these photons must be placed in orbit, since Earth's atmosphere is totally opaque at these wavelengths. X-ray telescopes do not send a beam toward astronomical objects, rather they detect X-rays from these objects.
- X rays are absorbed by ordinary mirrors like those used in optical reflectors, but they can be reflected if they graze the mirror surface at a very shallow angle. In the Chandra X-ray Observatory, X rays are focused in this way onto a focal plane 10 m (33 ft) behind the mirror.
- Gamma rays, the shortest-wavelength photons of all, help us to understand phenomena even more energetic than those that produce X rays. As an example, when a massive star explodes into a supernova, it produces radioactive atomic nuclei that are strewn across interstellar space. Observing the gamma rays emitted by these nuclei helps astronomers understand the nature of supernova explosions. The most important gamma ray observatory is the Compton Gamma Ray Observatory (CGRO).
- Radio Telescopes: Radio telescopes use large reflecting dishes to focus radio waves onto a detector. A very large radio telescope can produce a somewhat sharper radio image, because as the diameter of the telescope increases, the angular resolution decreases. In other words, the bigger the dish, the better the resolution. For this reason, most modern radio telescopes have dishes more than 30 m (100 ft) in diameter. This is also useful for increasing light gathering power, because radio signals from astronomical objects are typically very weak in comparison with the intensity of visible light.

Chapter 6 – Our Solar System

- The Greeks were aware of 5 planets: Mercury, Venus, Mars, Jupiter and Saturn; in addition to the Sun and the Moon. Other types of objects were known: Comets, Meteors (called shooting stars)
- Solar System contains:
  - 1 star: the Sun (99.9% of the total mass)
  - 9 planets
  - 100 moons orbiting the planets
  - 6 Asteroids (diameter > 300km)
  - >400 Asteroids (diameter of few km)

  - The voids between these objects are called “Interplanetary Space”.
- Asteroid: One of tens of thousands of small, rocky, planet like objects in orbit about the Sun. Also called minor planets.
- Asteroid belt: A region between the orbits of Mars and Jupiter that encompasses the orbits of many asteroids.
- Comet: A small body of ice and dust in orbit about the Sun. While passing near the Sun, a comet’s vaporized ices give rise to a coma and tail. They move through the solar system in elliptical orbits ranging from few years to several hundred thousand years.
- Meteors are the Meteoroids (A small rock in interplanetary space) which become visible when they enter the Earth’s atmosphere. They are visible due to Friction caused by the air molecules hitting the meteor’s surface. They glow while moving. Most of the meteors burn in the atmosphere, but some can fall down to the Earth’s surface; they are the so called Meteorites.
- When we compare the physical properties of the planets, we again find that they fall naturally into two classes—four small inner planets and four large outer ones. The four small inner planets are called terrestrial planets because they resemble the Earth. They all have hard, rocky surfaces with mountains, craters, valleys, and volcanoes. You could stand on the surface of any one of them, although you would need a protective spacesuit on Mercury, Venus, or Mars. The four large outer planets are called Jovian planets because they resemble Jupiter.
- An attempt to land a spacecraft on the surface of any of the Jovian planets would be futile, because the materials of which these planets are made are mostly gaseous or liquid. The visible “surface” features of a Jovian planet are actually cloud formations in the planet’s atmosphere.
- The Sun contains 99% of all solar system material.
- The planetary orbits are not evenly spaced. The orbits get further and further as we move away from the Sun. But there is a certain regularity in their spacing given empirically as Titus-bode rule:

$$a = 0.4 + 0.3 \times 2^n \qquad n = -\infty, 0, 1, 2, 3, ...$$

Whether Planets have Atmospheres

- Why do planets have atmospheres? gravity holds the air down
- A moving object has energy due to its motion which is called **kinetic energy.** It is given by:

$$E_K = \frac{1}{2} m \mathrm{v}^2$$ M=mass of object v=speed of object

- If the mass is expressed in kilograms and the speed in meters per second, the kinetic energy is expressed in joules (J).
- In a hot gas, the molecule have large speeds. If the gas has a temperature T, the physics of gases tell that the average kinetic energy is related to the temperature by:
- $$E_K = \frac{3}{2} kT \qquad k = 1.38 \times 10^{-23}\, J/K$$

- The two equations give the Average speed of a gas atom or molecule:

$$\frac{1}{2}mv^2 = \frac{3}{2}kT \quad \Rightarrow v = \sqrt{\frac{3kT}{m}}$$

- For a given gas temperature T, the greater the mass of a given type of gas atom or molecule, the slower its average
- In some situations, atoms and molecules can be fast enough to overcome the planet's attractive gravity and escape into space. If this to happen, the molecule speed should exceed the escape velocity of the planet: which is given by:

  $v_{esc} = \sqrt{\frac{2GM}{R}}$ M=mass of the planet, R=radius of the planet, G=6.67x10^{-11} N.m^2/kg^2

Spacecraft Exploration of the Solar System

- Mission to Mercury: Mariner 10 in 1974 came within 10,000 km to Mercury. The path of Mariner received a gravitational boost from Venus. This spacecraft is still orbiting the Sun, but silent.
- Mission to Mars: Mariner 4 was the first spacecraft to reach the red planet in 1965. Then Mariner 6 and 7 in 1969. The data sent by these spacecraft indicated that the red planet is geodetically dead.

Spectroscopy reveals composition of planets and moons

- If a planet has an atmosphere, then sunlight reflected from the planet must have passed through its atmosphere. Some of the wavelengths will have been absorbed depending on the composition of the atmosphere.
- Titan is the only satellite in the solar system with a substantial atmosphere. (b) The dips in the spectrum of sunlight reflected from Titan are due to absorption by hydrogen atoms (H), oxygen molecules (O2), and methane molecules (CH4). Of these, only methane is actually present in Titan's atmosphere.
- For example, astronomers have used spectroscopy to analyze the atmosphere of Saturn's largest satellite, Titan. The graph in Figure 7-3b shows the spectrum of visible sunlight reflected from Titan. The dips in this curve of intensity versus wavelength represent absorption lines. However, not all of these absorption lines are produced in the atmosphere of Titan. Before reaching Titan, light from the Sun's glowing surface must pass through the Sun's hydrogen-rich atmosphere. This produces the hydrogen absorption line in Figure 7-3b at a wavelength of 656 nm. After being reflected from Titan, the light must pass through the Earth's atmosphere before reaching the telescope; this is where the oxygen absorption line in Figure 7-3b is produced. Only the two dips near 620 nm and 730 nm are caused by gases in Titan's atmosphere. The absorption lines in Figure 7-3b indicate the presence in Titan's atmosphere of molecules of Methane. This shows that Titan is a curious place indeed, because on Earth, methane is a rather rare substance that is the primary ingredient in natural gas! When we examine other planets and satellites with atmospheres, we find that all of their spectra have absorption lines of molecules of various types. In addition, the UV spectra from Titan reveals existence of N_2 molecules and the infrared spectra show that Carbon and Hydrogen are present.

Extrasolar planets

- Planets orbiting other stars are called extrasolar planets.
- Planet and its star both orbit around their common center of mass, always staying on opposite sides of this point. Even if the planet cannot be seen, its presence can be inferred if the star's motion can be detected. The astrometric method of detecting the unseen planet involves making direct measurements of the star's orbital motion. (c) In the radial velocity method, astronomers measure the Doppler shift of the star's spectrum as it moves alternately toward and away from the Earth. The amount of Doppler shift determines the size of the star's orbit, which in turn tells us about the unseen planet's orbit.

Analyzing Extrasolar Planets with the Transit Method

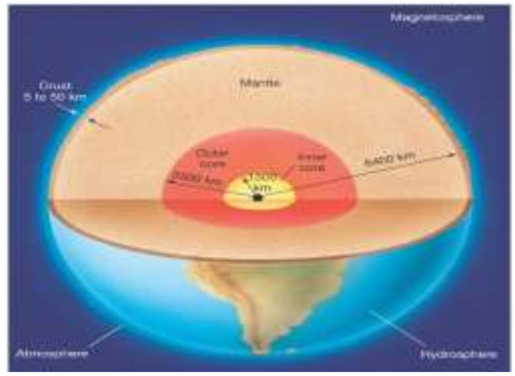
- If the orbit of an extrasolar planet is nearly edge-on to our line of sight, like the planet that orbits the star HD 209458, we can learn about the planet's (a) diameter, (b) atmospheric composition, and (c) surface temperature.
- A technique called the transit method makes it possible to fill in these blanks about the properties of certain extrasolar planets. This method looks for the rare situation in which a planet comes between us and its parent star, an event called a transit. As in a partial solar eclipse this causes a small but measurable dimming of the star's light. If a transit is seen, the orbit must be nearly edge-on to our line of sight. Knowing the orientation of the orbit, the information obtained by radial velocity measurements of the star tells us the true mass (not just a lower limit) of the orbiting planet.
    - When the planet transits (moves in front of) the star, it blocks out part of the star's visible light. The amount of dimming tells us the planet's diameter
    - When the planet transits the star, some light from the star passes through the planet's atmosphere on its way to us. The additional absorption features in the star's spectrum reveal the composition of the planet's atmosphere
    - When the planet moves behind the star, the infrared glow from the planet's surface is blocked from our view. The amount of infrared dimming tells us the planet's surface temperature.
- One example of what the transit method can tell us is about the planet that orbits the star HD 209458, which is 153 light-years from the Sun. The mass of this planet is 0.69 that of Jupiter, but its diameter is 1.32 times larger than that of Jupiter. This low-mass, large-volume planet thus has only one-quarter the density of Jupiter. It is also very hot: Because the planet orbits just 0.047 AU from the star, its surface temperature is a torrid 1130 K (860°C, or 1570°F). Observations of the spectrum during a transit reveal the presence of hydrogen, carbon, oxygen, and sodium in a planetary atmosphere that is literally evaporating away in the intense starlight. Discoveries such as these give insight into the exotic circumstances that can be found in other planetary systems.

Chapter 7 – The Earth

- About 71% of the Earth's surface is water. Without water no life, no ecology. The vaporization of water makes the weather, makes the rain. Most of the carbon dioxide (CO_2) has been resolved in the Ocean water.

Overall Structure of the Earth

- What powers all of this activity in the Earth's oceans, atmosphere, and surface? There are three energy sources: radiation from the Sun, the tidal effects of the Moon, and the Earth's own internal heat.
- The average density of the earth is 5500 kg/m^3. Water has a density of 1000 $kg/m^{3.}$ The sea floor has a density of 2000 to 4000 kg/m^3. This indicates a dense inner core of the Earth.



- The earth consists of:
  - Thin Crust
  - Thick mantle surrounding two-part core
  - Hydrosphere, the oceans
  - Atmosphere
  - Magnetosphere
- The earth's atmosphere is composed of 78% Nitrogen, 21% oxygen, 0.9% argon, 0.03% CO2 and 3% water vapor. Hydrogen and Helium escaped the Earth's atmosphere
- <u>Troposphere:</u> The lowest level in the Earth's atmosphere.
- The lowest layer, called the troposphere, extends from the surface to an average altitude of 12 km (roughly 7.5 miles, or 39,000 ft). It is heated only indirectly by the Sun. Sunlight warms the Earth's surface, which heats the lower part of the troposphere. By contrast, the upper part of the troposphere remains at cooler temperatures. This vertical temperature variation causes convection currents that move up and down through the troposphere. All of the Earth's weather is a consequence of this convection.
- Actually, what drives convection is that the air is a bad heat conductor. The lower part of the troposphere is warmer than the upper part. In this way, winds are formed.
- <u>Stratosphere:</u> A layer in the Earth's atmosphere directly above the troposphere.
- It extends from about 12 to 50 km (about 7.5 to 31 mi) above the surface, an appreciable amount of oxygen is in the form of ozone, a molecule made of three oxygen atoms (O3). Unlike O2, ozone is very efficient at absorbing ultraviolet radiation from the Sun, which means that the stratosphere can directly absorb solar energy. The result is that the temperature actually increases as you move upward in the stratosphere. Convection requires that the temperature must decrease, not increase, with increasing altitude, so there are essentially no convection currents in the stratosphere. Ozone layer is our planet's umbrella, life without it is impossible. Killer is: chlorofluorocarbon CFC (spray, air conditioner, plastic foam, refrigerator, etc.). 1% decrease in ozone may increase skin cancer by 5%.
- <u>Ozone:</u> A type of oxygen whose molecules contain three oxygen atoms.
- <u>Ozone hole:</u> A region of the Earth's atmosphere over Antarctica where the concentration of ozone is abnormally low.
- <u>Ozone layer:</u> A layer in the Earth's upper atmosphere where the concentration of ozone is high enough to prevent much ultraviolet light from reaching the surface.

- Above the stratosphere lies the mesosphere. Very little ozone is found here, so solar ultraviolet radiation is not absorbed within the mesosphere, and atmospheric temperature again declines with increasing altitude.
- This minimum marks the bottom of the atmosphere's thinnest and uppermost layer, the thermosphere, in which temperature once again rises with increasing altitude. This is not due to the presence of ozone, because in this very low-density region oxygen and nitrogen are found as individual atoms rather than in molecules. Instead, the thermosphere is heated because these isolated atoms absorb very-short wavelength solar ultraviolet radiation (which oxygen and nitrogen molecules cannot absorb).
- Ionosphere: 100 km and above. Short UV and X-rays ionize the atoms. Many electrons are released. Therefore this region is highly conductive. AM radio waves are reflected there, but not shortwave FM.
-