

STUDY GUIDE FOR PART 2 (Astronomy)

Light and Tools

INTRODUCTION:

Ancient Astronomers tried to make geometrical models of the universe that would be able to predict as accurately as possible the motions of the astronomical objects through the sky. They did not try to explain WHY the motions occurred, only WHAT those motions would be.

Since Newton formulated his laws of motion and gravitation, people have tried to explain the why of those astronomical motions in terms of more basic natural laws (like the law of gravity) assuming that the astronomical objects were composed of material like that of earth and obeyed the same natural laws that apply to the earth. These attempts have met with tremendous success.

At the end of Part 1 we covered Newton's laws of motion and his law of gravitation. They concerned matter and motion. But there is yet another basic element of nature that we must try to understand if we are to investigate the universe under the so very successful assumption that the astronomical objects obey the same natural laws as apply on earth. This other basic element of nature is LIGHT. Its importance is immediately obvious since light is the means by which we obtain information about the astronomical objects.

In Section A we investigate the properties of light. Only by knowing the properties of light can we fully extract all the information the light contains. The light can not only tell us in what direction an astronomical object lies, but also its surface temperature, the composition of its atmosphere, its speed toward or away from us, and possibly something of the space that lies between it and us. This will be the major source of the knowledge that will be covered in the remaining three parts of the course.

In Section B we use our knowledge of the properties of light from Section A to understand the basic tools of the astronomer. These are the tools that will be used to first gather the light and then to extract the information from the light. Of course, the basic astronomical tool is the telescope. Both the basic workings of the telescope and the types of telescopes will be covered. In addition, the spectroscope and the photomultiplier will be briefly described.

In Section C we cover the earth. Having covered the basic ideas of gravity and motion in Part 1 and the idea of light in Sections A and B of this Part 2, we now consider the earth as a physical body. We need to do this in order to have a basis for understanding the astronomical objects themselves. Only by comparing and contrasting other objects to the earth can we really begin to get an idea of what is really out (up) there when we cover Parts 3, 4, and 5.

A. LIGHT AND THE ATOM

OUTLINE:

1. The speed of light
 - a) for reference, speed of sound in air is ≈ 350 m/s ≈ 750 mph
sound moves relative to medium (such as air)
 - b) speed of light in vacuum = $300,000,000$ m/s ≈ 670 million mph
light moves relative to what ???
2. The nature of light
 - a) a form of energy
 - b) way this energy is transmitted - two theories:
 - (1) as waves (Electromagnetic oscillations)
 - (2) as particles (photons)
3. The properties of light
 - a) color (wavelength or frequency of waves; energy of photon)
 - b) reflection (both waves and photons [particles] reflect)
 - c) refraction (bending: waves predict correct behavior, photons don't)
 - d) diffraction (shadows: waves spread out, photons don't)
 - e) electricity theory (light as electromagnetic waves)
 - f) energy theory (photon emission correct, waves fail)

- g) interactions with matter (photon collide and are absorbed, waves fail)
- 4. Heat, light, and color
 - a) heat and light: the continuous spectrum
 - (1) total power output depends on temperature and area
 - (2) power output peaks at certain color (wavelength) depending on temperature
 - b) atoms: discrete (emission & absorption) spectra
- 5. The Doppler effect: frequency depends on speed towards or away

Study Questions for Part A:

1. What properties of light can be explained by thinking of it as a particle? as a wave? both?
- *2. Know the approximate wavelengths for the colors of: violet, blue, green, yellow, orange, and red.
- *3. Be able to list the following in order of increasing or decreasing energy and/or increasing or decreasing wavelength: gamma rays (γ), x-rays, ultraviolet (UV), visible, infrared (IR), microwaves, radio.
- *4. Know at what approximate wavelength the intensity of light from the sun peaks and what its surface temperature is.
- *5. By knowing at what color the intensity of a star peaks, be able to tell whether that star's surface is hotter or cooler than the sun's.
6. Know qualitatively how the luminosity of a star depends on its temperature and size.
7. What is an emission spectrum? an absorption spectrum?
8. Know what red-shift and blue-shift refer to.

B. THE TOOLS OF THE ASTRONOMER

OUTLINE:

1. The telescope
 - a) construction
 - (1) properties of a lens: focal length (f); diameter (d)
 - (2) the telescope in its simplest form has two lenses
 - b) properties of a telescope
 - (1) magnification: $M = f_o/f_e$
 - (2) light gathering ability: proportional to d^2
 - (3) resolving ability: $= 4.56 \text{ arcsec} / d$ (in inches)
 - c) relations between properties
 - (1) maximum useful magnification: $= (60 \text{ X/in}) * d$ (in inches)
 - (2) brightness, field of view, and magnification
 - d) types of telescopes:
 - (1) refractors (two lenses: objective and eyepiece)
 - (2) reflectors (objective mirror, eyepiece lens)
 - 1) prime focus (inside telescope)
 - 2) Newtonian focus (light comes out the side)
 - 3) Cassegranian focus (light comes out the back)
 - (3) Schmidt (one correcting lens, objective mirror, eyepiece lens)
 - (4) other: radio / IR / UV / γ -ray

2. Other tools

- a) spectroscope
- b) photomultiplier

Study Questions for Part B:

- **1. What are the three major properties of a telescope?
- 2. What is the smallest angle a 5 inch telescope can theoretically resolve?
- *3. Be able to determine how much more (or less) light will be gathered by one telescope than by another given the diameters of the objective lenses of each telescope.
- **4. Be able to determine the magnifying power of a telescope given the focal length of the objective lens and the focal length of the eyepiece. Also, given the focal length of the objective lens and the desired magnifying power, be able to specify the focal length of the needed eyepiece.
- 5. Name one advantage and one disadvantage of a reflecting over a refracting telescope.
- *6. What is an equatorial telescope mount?
- *7. What advantage does an equatorial telescope mount have over an altazimuth mount?
- *8. Be able to describe each of the following types of reflector telescopes: Newtonian, Cassegranian and prime focus,.
- 9. What is a Schmidt telescope?

C. THE EARTH AS A PLANET**OUTLINE:**

1. Physical properties

- a) size and shape (roughly a sphere, 25,000 miles \approx 40,000 km in circumference; around equator a little longer than around the poles)
- b) mass
- c) interior
 - (1) plate tectonics
 - (2) heat due to cooling down & radioactive elements (determine age using these); volcanoes result
- d) surface (highest mountain \approx 5 miles [8 km], deepest trench \approx 10 mi)
- e) atmosphere (troposphere \approx 8 miles [14 km]; 79% N₂, 20% O₂, 0.9% Ar; 0.1% other including .03% CO₂)
 - (1) absorbs light (UV protection: ozone; IR warming: "greenhouse" effect)
 - (2) reflects light (25% of sunlight reflected off atmosphere & clouds)
 - (3) bends light (we see sun earlier at sunrise & later at sunset; stars twinkle)
- f) radiation belts

2. Motion

- a) rotation about its axis
- b) rotation about the sun

Study Questions for Part C:

- *1. What is the approximate diameter and the approximate circumference of the earth (in kilometers) ?
- 2. What fraction of the earth's circumference is the distance from Memphis to St. Louis (about 400 km) ?
- 3. How have we determined the mass of the earth?

4. Is the earth a perfect sphere? (If not, how does it differ from a perfect sphere?)
5. What is the age of the earth according to the best scientific estimates? How is this age determined?
- *6. What are the main forces that affect the earth's surface?
7. How high does the troposphere extend?
- *8. Does the sun actually rise earlier or later than it appears to? What causes this?
- *9. How does the atmosphere affect light from astronomical bodies? Give one example for each of the three major ways.
- *10. What are the Van Allen radiation belts?
11. Because of the earth's rotation about its axis, which way do the winds seem to deflect in the norther hemisphere?

Study TRUE/FALSE questions for all of Part 2:

(questions similar to these may appear on the test)

_____ a) Red light has a wavelength larger than blue and consists of photons of energy less than those of blue.

_____ b) A star with a temperature higher than the sun and not moving will have its energy peak in the red (rather than in the yellow like the sun).

_____ c) A spectral line normally in the red will be shifted toward the yellow in a star that is going away from the earth at a speed close to the speed of light.

_____ d) A star that has a higher temperature and is the same size as the sun will have a luminosity higher than the sun.

_____ e) A telescope whose objective lens has a diameter of 5 inches and a focal length of 100 cm will collect about half as much light as a telescope whose objective lens has a diameter of 10 inches and a focal length of 200 cm.

_____ f) A telescope whose objective lens has a diameter of 5 inches and a focal length of 100 cm will only be able to resolve detail half as small (i.e., twice as large) as a telescope whose objective lens has a diameter of 10 inches and a focal length of 200 cm.

_____ g) The circumference of the earth is (within 10%) about 40,000 km.

_____ h) The sun actually appears to rise later and set earlier than it would if there were no atmosphere.

_____ i) The winds in the Northern Hemisphere rotate clockwise around a low pressure center because the earth is rotating about its axis.

_____ j) Because of the earth's atmosphere the earth is warmer on average than it would be without its atmosphere.

_____ k) Except for mountains and deep sea trenches (± 15 km), the earth is a perfect sphere.

_____ l) The age of the earth is about $4\frac{1}{2}$ billion years old according to science's best estimate, and this age is determined to a large extent by radioactive dating.