Astronomy 111, Section 001, Fall 2006

Examination #2 Review

Revised Version

(includes all solutions and a few corrections)

- Exam #2 will have 50 questions
- 25 questions will cover knowledge of the keyword definitions listed in the lecture notes, the equations, or the "scaling" equations (see below for a list)
- 25 questions will be based on topics and concepts covered in the lecture. Many of these topics and concepts are covered by questions on the following pages
- As you go over these problems, try to classify them as "definition", "concept", "scaling", or a combination thereof. For the concept questions, make sure you know what physical principle the question is testing your knowledge of. On questions 6, 7, and 17 I give example of what I mean by this.

Equations and scaling relationships: the equation that relates photon frequency to wavelength, the relationship between density, mass, and volume, how photon energy scales with wavelength, how energy flux from a blackbody scales with temperature, how the wavelength of the peak energy in a blackbody scales with temperature.

Keywords:

absorption/emission spectrum, blackbody, flux, Doppler shift

refraction/reflection, converging/diverging lens, focal point, angular resolution, magnification, chromatic aberration,

Scaling, Parallax, Escape speed, Jovian planet, Comet, Asteroid, Meteoroid,

albedo, atmospheric pressure, aurora (*plural* aurorae), biosphere, global warming, greenhouse effect, greenhouse gas, solar wind, plasma, magnetosphere, northern and southern lights, ozone, ozone layer, Van Allen Radiation belts

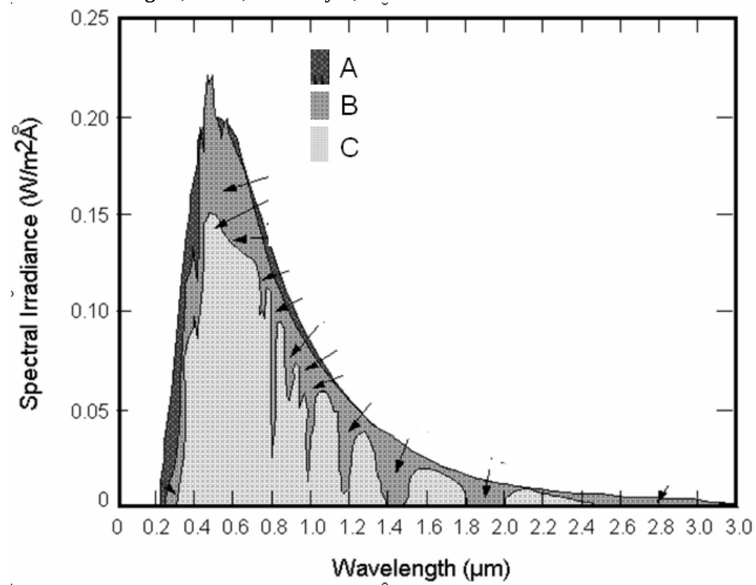


Figure 1: One curve is that of an ideal blackbody, one curve was measured above Earth's atmosphere and one was measured on the ground.

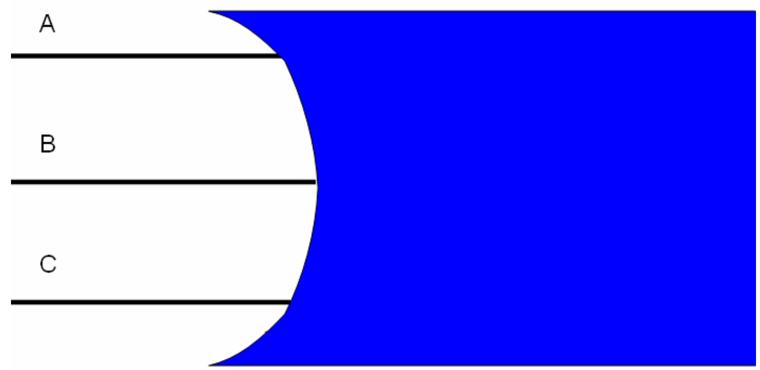


Figure 2: Light beams A, B, and C are created by a source to the left. The dark area represents glass and the light area represents air. The height of this figure is 1 cm.

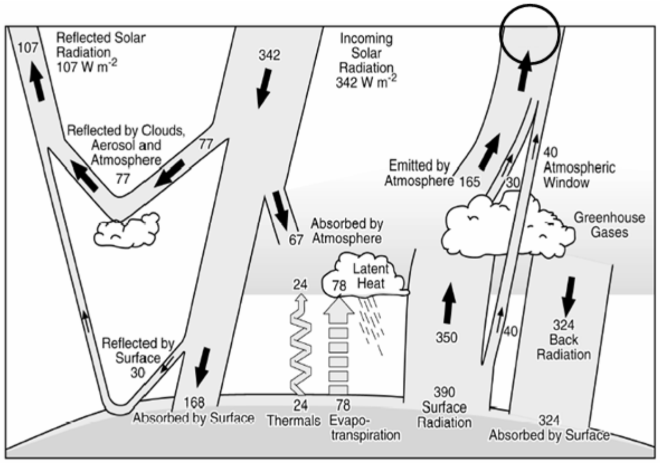


Figure 3

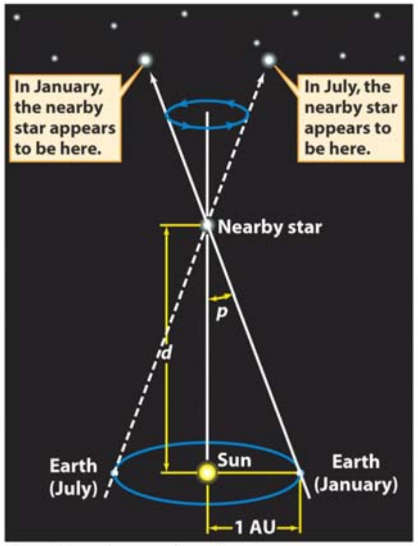


Figure 4

Parallax of a nearby star

Lecture 10 (Chapter 5)

1.If an object is a perfect blackbody then

a) it emits no energy.
b) it emits energy only at certain well-defined wavelengths called spectral lines.
c) it emits energy with a continuous distribution that peaks at a certain wavelength dependent upon temperature.

This is a definition problem. Answer a) is a misconception about blackbodies. When you think of blackbody you may think of blackhole, an astronomical object from which nothing can exit. Both have the word "black", but energy can escape from one of them. Answer b) may seem right because we talk about the sun being a blackbody, but when we look at its spectrum we see spectral lines (see Figure 1) in its blackbody curve. However, the sun is only approximately a blackbody.

2.A perfect blackbody is so-called by scientists because

a) it absorbs all energy falling upon it and emits a characteristic spectrum of radiation whose intensity as a function of wavelength depends only on its temperature.
b) it absorbs all energy falling upon it and emits no energy at all, hence its name.
c) the shape of the spectrum of energy emitted by it has a fixed shape independent of temperature and only the emitted intensity at each wavelength changes with the black-body's temperature.

This is a definition problem. b) is half true (it absorbs all energy falling upon it). The second part of b) is false (see question 1). (c) is false because a blackbody has a curve for each temperature.

3.A blacksmith heats a piece of steel until the wavelength of maximum emission of radiation is measured to be 1 mm (correction: 1 μm), in the infrared part of the spectrum. How would he have to change its temperature in order that this peak wavelength would move to 0.5 mm (correction: 0.5 μm), or 500 nm in the visible spectral range?

a) He would have to cool the steel to half its temperature.
b) He would have to raise the temperature by a factor of 24 (correction: 2^4), or 16.
c) He would have to double its temperature.

This is a Definition and Scaling problem. Try to draw two blackbody curves that illustrate this.

When I copied and pasted this, two typos were introduced. Can you spot them? First problem: wording of the sentence implies 0.5 mm = 500 nm, but 500 nm = $500 \times 10^{-9} = 5 \times 10^{-7}$, and 0.5 mm = $0.5 \times 10^{-3} = 5 \times 10^{-7}$ m. The resolution is that it should read 0.5 μm (and the "1 mm" should be "1 μm". Second problem: answer b) implies 24 = 16! The resolution is $2^4 = 16$. Lesson: when cutting and pasting, Greek letters and superscripts don't convert properly.

Now that the typos are fixed, we can answer the problem. Wien's law says $\lambda_{max} \sim 1/T$ (or $T \sim 1/\lambda_{max}$). If it starts at 1 μm = 10^{-6} m, then $T_1 \sim 1/10^{-6} = 10^6$, and we want to get it to $T_2 \sim 1/(5 \times 10^{-7}\text{ m}) = 0.2 \times 10^7 = 2 \times 10^6$.The ratio T_2/T_1 is 2, so we need to double the temperature.

4. The energy emitted per second by the Sun is greatest at a wavelength of about 500 nm. The energy emitted per second by a star having half the temperature of the Sun would be greatest at a wavelength of about

a) 1000 nm, in the infrared.
b) 8000 nm, in the infrared range, (16 times 500 nm).
c) 250 nm, in the near UV.

Correction: the original version of this had 250 nm selected as the solution and the explanation answered the question as if it asked about a star having *double* the temperature. The question and solution now match.

This is a Definition and Scaling problem. The definition is the Wien's law, which says $\lambda_{max} \sim 1/T$ (or $T \sim 1/\lambda_{max}$). $T_1 \sim 1/500$ nm and if we want half double T_1, we need to change 500 nm to 1000 nm. Note Stefan-Boltzmann law, which says the **total** energy (including all wavelengths) emitted by a blackbody is proportional to its temperature to the fourth power ($F \sim T^4$), does not apply here. The question is asking about the energy at one wavelength only.

5. Suppose the Sun had a temperature of 17,400 K (three times its present temperature), but had the same size that it has now. How much more energy would the Sun emit per second?

a) 9 times more
b) 81 times more
c) 3 times more

The Stefan-Boltzman law is Energy flux $\sim T^4 = 3^4 = (3^2)^2 = 9^2 = 81$. Wait! The problem asks about energy/time and the Stefan-Boltzman law is for energy flux. What is going on? To answer this, consider how is flux related to energy per time. If you were measuring the amount of energy per second collected by, say, a solar panel, you would say the energy flux = (Energy/time)/(Area of panel). In this problem the area does not matter because you are not changing the solar panel that collects it. You are only changing the energy/time in the equation.

6. In a beam of radiation from a blackbody, the amounts of energy per second at an ultraviolet wavelength (UV) of 300 nm and at an infrared wavelength (IR) of 800 nm are found to be equal. In this beam, how do the numbers of photons per second at each of these wavelengths compare?

a) There will be more UV photons than IR photons.
b) There will be equal numbers of photons at each of these wavelengths.
c) **There will be more IR photons than UV photons**.

This problem has two aspects:
Scaling: the energy of a photon is inversely proportional to its wavelength ($E \sim 1/\lambda$). So a UV photon has more energy than an IR photon.
Concept: Physical principle is flux – the amount of "stuff" that passes a point per unit time. In this case the "stuff" is photons.

7.In Figure 1, which curve represents an ideal blackbody?

a) Curve A
b) Curve B
c) Curve C

Definition: The ideal blackbody curve is smooth.

8.In Figure 1, what is the intensity of curve B at 550 nm?

a) Impossible to tell; 550 nm is not shown in this figure
b) Nearest 0.2
c) Nearest 0.1
d) Nearest 0.05
e) Nearest 0.0

Definition: 550 nm = 0.55 μm and read the graph (0.55 μm give an intensity of about 0.22)

9.If the object in Figure 1 were increased in temperature, what would happen to curves A, B, and C?

a) All would increase
b) All would decrease
c) A and C would decrease, B would increase

Defnintion and Concept. Definition: Energy radiated (both total and at all individual values of wavelengths) by a blackbody increases with temperature. Concept: All curves are measuring the same object, so they should all do the same thing.

10.In Figure 1, Curve C is more jagged. The locations of dips in curve C correspond to

a) Spectral lines of a blackbody
b) Spectral lines of atmospheric molecules
c) Instrumentation error
d) Diffraction lines
e) Spectral lines of the lens used to convert the light into colors

Concept: The intensity of photons (electromagnetic radiation) you receive from the Sun is affected by the atmosphere, which acts like a filter. Atmospheric particles absorb electromagnetic radiation with special frequencies (or wavelengths). At these frequencies, there will be a drop in the curve. Definition: If you did not know the answer was (b) you need to know the definition of a blackbody rule out a) as a possible answer.

11.Venus (Correction: This should read Mercury, because Venus has an atmosphere; you may have heard about the clouds of Venus) has no atmosphere. If you measure the solar spectrum from its surface,

a) Curves B and C in Figure 1 would not change
b) Curve C would look less like B in Figure 1
c) Curve C would look more like B in Figure 1
d) Curve B would be more jagged in Figure 1
e) Curve C would be more jagged in Figure 1

12.White light is composed of

a) Equal intensities of all colors of the rainbow
b) Unequal intensities of all colors of the rainbow
c) Equal number of photons of all colors of the rainbow
d) Unequal number of photons of all colors of the rainbow
e) Equal numbers of red, green, and blue photons

See Figure 5-11 in your text (page 99). Intensity at solar radiation at visible wavelengths (corresponding to different colors) is not the same for all colors.

13.Does a blackbody have color?

a) Yes, and they all appear the color of the sun
b) No, you cannot see a blackbody
c) Yes, but its depends on its temperature
d) Maybe, it depends on if it is an ideal blackbody

14.Why do different elements display different patterns of lines in their spectra?

a) they emit or absorb photons with different frequencies
b) they have a different number of neutrons
c) light passes through them at different speeds
d) they have a different number of protons

15.If the temperature of a blackbody increases by a factor of four, what happens to the total energy flux it radiates?

a) Same
b) 256x
c) 4x
d) 16x
e) 32x
f) Need more info

Energy flux ~ $T^4 = 4^4 = (4^2)^2 = 16^2 = 256$.

Lecture 11 (Chapter 6)

16. In Figure 2, where is the light source located?

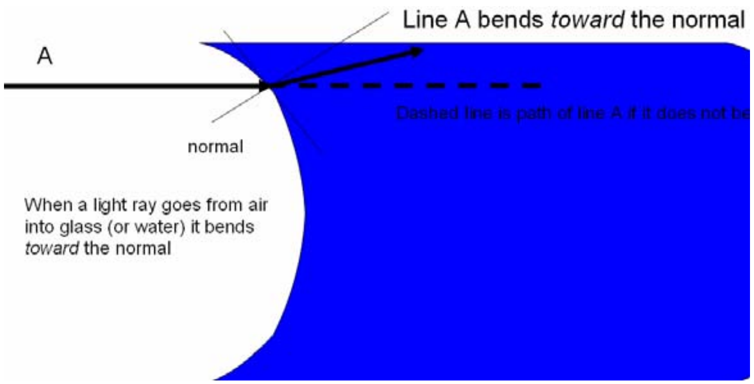
a) 1 km to the left
b) 1 cm to the left
c) 1 nm to the left
d) 1 km to the right

Concept: Rays of light from far distances are nearly parallel. Principle: 1 km is much smaller than 1 cm (the height of the object, according to the caption). Suppose the height of the object was 1 nm. Could the answer be (b)? Yes. In this case 1 cm and 1 km are both "distant", in the same way that two stars may be far separated, but when viewed from Earth, they are both "distant".

17.In Figure 2, what happens to beam A when it enters the glass?

a) It continues straight
b) It bends up
c) It bends down
d) It reflects back
e) It reflects up

See the following figure or the lecture notes to see how to zoom in on a surface and then use the principles of optics to tell you which way the light will bend.



18.In Figure 2, what happens to beam C when it arrives at the glass?

a) It bends down and to the right
b) It reflects up and to the left
c) Both of the above
d) Both of the below
e) It bends up and to the right
f) It bends down and to the right

19.Does any of the light from Beam A in Figure 2 get reflected?

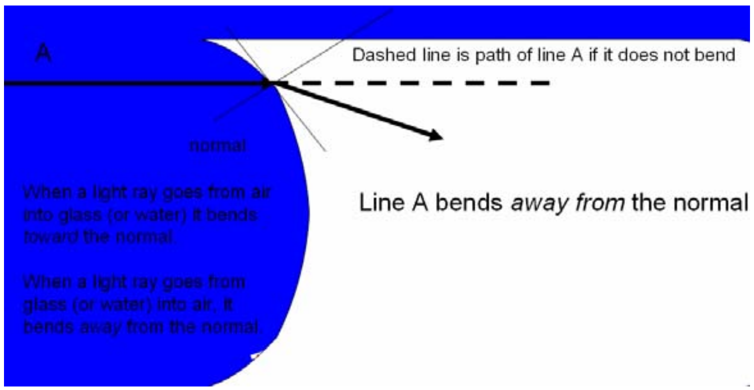
a) Yes, down and to the left
b) Yes, up and to the right
c) Yes, up and to the left
d) No

20. In Figure 2, if the light area represents glass and the dark area represents air, what happens to beam A when it enters the air from the glass (beam A is still going from left to right)?

a) Continues straight
b) Bends up

c) **Bends down**
d) Reflects along same direction

In class I skipped this problem because the wording did not make it clear that beam A was still coming from left to right. Below is a diagram that helps answer this question. I have reversed the colors in Figure 2 to emphasize that the light ray (beam) is going from glass to air. The optics rule that you should remember is that when a ray from air is incident on a surface such as glass or water at an angle to the normal, the ray bends towards the normal. If the ray is going from glass or water to air, the ray bends away from the normal. In the lecture notes I show this pictorially with a flat surface. To draw the normal line for a curved surface, zoom in until the surface looks almost flat. Zooming in makes the surface look flat in that same way that from space, an astronaut would say the Earth looks curved. If he zooms in with a cameral or comes back home, he would say the Earth looks flat.



21.Why are telescopes put in orbit?
a) **Reduce the influence of light pollution**
b) So they are closer to the stars
c) Both of the above
d) They are less expensive because they are computer controlled
.Why isn't it (b) or (c)?

22.A flash of light is transmitted simultaneously through two parallel tubes of length 1 km, one evacuated, the other filled with water. Detectors sense the arrival times of the light flash at the ends of these tubes. What will be the relationship between arrival times of these light flashes?
a) The flashes of light will arrive simultaneously at the ends of the tubes because light always travels at the same speed.
b) The flash will arrive earlier through the water-filled tube.
c) **The flash will arrive earlier through the evacuated tube.**

23.After passing from the vacuum of space through a piece of glass and then passing back into the vacuum, photons of light will be traveling
a) slower than when they entered the glass because they will have been slowed down by their passage through the glass.
b) faster than before they entered the glass, having been accelerated by their
c) passage through the glass. (Correction: The sentence that was here should be moved down and labeled as answer (d).)
d) **at the same speed as when they entered.**

24,Which way does a light ray bend when it strikes the flat surface of a block of glass obliquely (i.e., at an angle to the surface) and passes into the glass?
a) **Toward the perpendicular to the surface, making a greater angle to the surface.**
b) A light ray does not change direction when it passes into the surface of the glass because the surface is flat. Light rays change their directions only through curved glass surfaces.
c) Away from the perpendicular to the surface, bending toward the surface, making a smaller angle to the surface.

25.How much more light does a 2 cm radius lens capture than a 1 cm radius lens?
a) Same
b) Two times
c) **Four times**
d) 16 times

26.Many fortunate amateur astronomers have telescopes with primary mirrors 20 cm in diameter. The recently built Keck telescopes on Hawaii have mirrors 10 m in diameter. How much more light is collected by one of the Keck telescopes, compared to the amateur's telescope?
a) **2,500 times greater**
b) About 7 times greater
c) 50 times greater

27.In the primary mirror of a reflecting telescope, light of different wavelengths—such as red and blue light from a star—are focused
a) with the red focus closer to the mirror than the blue focus.
b) with the blue focus closer to the mirror than the red focus.
c) **at the same point.**

Correction: The original version had b), which is incorrect. Chromatic aberration occurs when light of different wavelengths **refracts** a different about as it passes through a lens. In this case we are talking about a mirror and the angle of **reflection** does not depend on wavelength.

28.What is diffraction of light?
a) **The spreading out of light waves after they pass through an opening such as the outer diameter of a lens or mirror.**
b) The bending of the path of a ray of light as it passes from one transparent medium to another; for example, from air to glass.
c) The distortion in the image when light passes through a lens or reflects from a mirror, due to imperfections in the lens or mirror surface.

29,A factor that has become much worse for many observatories, and now severely limits the number of useful sites for astronomy in the world, is

a) light pollution due to the increasing size of nearby cities.
b) the number of satellites in orbit, which disturb observations when they pass in front of the object being observed
c) the weather, which has deteriorated significantly due to global warming
d) greenhouse gasses, which block the starlight

30.After passing from the vacuum of space through a piece of glass and then passing back into the vacuum, photons of light will be traveling
a) slower than when they entered the glass because they will have been slowed down by their passage through the glass.
b) faster than before they entered the glass, having been accelerated by their passage through the glass.
c) at the same speed as when they entered.

31.At what distance from the objective lens in a refracting telescope is the image formed (i.e., where would the photographic film or electronic detector be placed)?
A) immediately behind the lens to collect the most light
B) its diameter
C) **its focal length**
D) twice its focal length
`
32.To correct for chromatic aberration in a refracting telescope a corrective lens is mounted next to the objective lens. In this corrective lens
A) **red light bends more than blue light.**
B) blue light bends more than red light.
C) all colors bend the same amount.
D) no bending is experienced by any of the colors.

33.In the reflection of a light beam from a flat mirror, the angle between the incident and reflected beams relative to the perpendicular to the surface of the mirror is
A) equal to the angle between the incident beam and the perpendicular.
B) equal to ½ the angle between the incident beam and the perpendicular.
C) always a right angle, or 90°.
D) **twice the angle between incident beam and the perpendicular.**

34.How much more energy does a 2 cm radius circular light collector absorb than a 1 cm radius collector?
a) Same
b) 2x
c) 4x
d) 16x
e) Need more info

Lecture 12 (Chapter 7)

35.If the radius of Earth was twice as much and its mass was the same, what would its density be
a) ½ as much
b) ¼ as much
c) 1/8 as much
d) Same
e) 2x as much
f) 4x as much
g) 8x as much

36. In Figure 4, it says the star "appears to be here". To be more specific it should say "appears to be here with respect to"
(a) the distant stars
(b) other nearby stars
(c) the Sun
(d) the Moon
The distant stars don't move, so they are used as a reference point.

37. If the nearby star in Figure 4 was the same distance from Earth but in the ecliptic plane, would there still be parallax?
(a) Yes, and much smaller than that shown in Figure 4
(b) Yes, and about the same as that shown in Figure 4
(c) Yes, and much larger than that shown in Figure 4
(d) No

38. If the nearby star in Figure 4 is farther away (d increases), what happens to its parallax as viewed from Earth?
(a) Increases
(b) Decreases
(c) Stays the same
(d) All of the above

39. As the Earth rotates on its axis, does the apparent position of the star change?
(a) Yes, more than that shown
(b) Yes, less than that shown
(c) No
(d) Yes, but the same amount as that shown

40. If Figure 4 showed the position of Earth in March and September, how would the angle p change?
(a) It would be nearly the same
(b) It would be twice as much
(c) It would be half as much
(d) It would be exactly the same

41. In our solar system, which of the following planets is not a member of the Jovian group?
A) **Mars** B) Saturn C) Neptune D) Jupiter

42. Suppose that observers using the Hubble Space Telescope detect around several solar-type stars the presence of planets with the following characteristics: low density, large size, polar diameters shorter than equatorial diameters, fluid surfaces, rapid rotation. How would these planets be classified, in terms of our solar system?
A) asteroids B) terrestrial planets C) comet nuclei **D) Jovian planets**

43. Most of the planets orbit the Sun on or close to the

A) plane containing both north and south celestial poles and the zenith at Greenwich, England.
B) plane of the Milky Way galaxy.
C) equatorial plane.
D) **ecliptic plane.**

44. Which of the following general statements about all of the planets in the planetary system is true?
A) They have hard, rocky surfaces, which can be seen and photographed.
B) **They orbit the Sun in the same direction.**
C) They have satellites or moons.
D) They have very dense atmospheres.

45. Viewed from the Earth, which planet has the smallest angular size?
A) Mercury B) Mars C) Jupiter **D) Pluto**

46. Determination of the chemical composition of the atmospheres of the planets is carried out most effectively by what type of study?
A) photometry—the measurement of the fading of light from their moons as they pass behind the planet's atmosphere
B) measurement of their relative mean densities
C) measurement of their atmospheric temperature
D) **spectroscopy—the measurement of absorption features in their spectra**

47. When astronomers look for evidence of hydrogen gas in the spectra of the Sun, planets, and nearby stars, the positions of the spectral features or "lines" due to hydrogen
A) **are always in the same pattern, characteristic of hydrogen gas, as seen in the laboratory.**
B) change systematically, depending on the distance from the source, starting with a laboratory pattern.
C) are in the same pattern for solar and planetary sources but very different for stars at larger distances because of absorption of light by the interstellar matter.
D) are in a very different pattern, depending on the location of the planet or star, and reproduced only with difficulty in the laboratory.

48. The asteroid belt is made up of
A) large, rocky bodies typically about the size of our Moon.
B) **rocky bodies from a few meters to tens of kilometers in diameter**.
C) several planet-sized objects with dense methane atmospheres.
D) irregularly shaped bodies composed primarily of ices.

49. A typical asteroid is made of
A) ices of water, methane, and ammonia or perhaps ices with dust-sized grains of rock mixed in
B) ice with a liquid water core.
C) **rock and metal**
D) rock and ice.

50. What is the basic difference between comets and asteroids?
A) Comets always emit their own light, while asteroids only reflect sunlight.
B) Comets always move in open orbits around the Sun, visiting the Sun only once in their lifetime, while asteroids move in closed orbits.
C) **Comets are mostly composed of ices, while asteroids are mainly composed of rocks.**
D) Comets are spherical, while asteroids are mostly irregular in shape.

51. The craters on the Moon are all nearly circular. Why is this?
A) Most of the craters on the Moon were formed by volcanoes, and this results in circular craters.
B) It is believed that the objects that formed the impact craters on the Moon's surface all struck the Moon approximately perpendicular to its surface, and this would result in circular craters.
C) **The objects that produced the impact craters came in at a variety of angles, but the craters were actually made by the shock waves generated by impact—and this results in circular craters.**
D) The objects that produced the impact craters had been rounded by many previous collisions in space, and round objects produce circular craters regardless of their direction of impact.

Lecture 13 & 14 (Chapter 9)

52. In Figure 3, what should the number in the circle be?
a) 235
b) 236
c) 136
d) 107
e) 342

There are two ways to answer this. The first is to take 165+40+30 = 235. The second uses a concept discussed in class: the amount of solar radiation energy in per time interval must equal the amount of radiation out per time interval* (otherwise the temperature of Earth would be increasing!). So if you were not given the numbers 165, 40, and 30, you would need to say input = 342 = (output from albedo = 107) + (output from everything else). To balance this, (output from everything else) must be 235.

*Note that I did not say the amount of **solar** radiation out. The outgoing radiation does not have the same characteristic Flux vs. wavelength curve. There is more long wavelength radiation going out. How is this related to greenhouse gasses? The total flux is the same area under the flux vs. wavelength curve, but the curves are a little different. Can you draw this?

53. In Figure 3, is energy transfer by thermals (rising hot air) is primarily
a) Conduction
b) Convection
c) Radiation
d) None of the above

54. In Figure 3, the amount of surface radiation is listed as 390. What are the units?
a) W/m^2 (Note: m^2 is the lazy way of writing m^2)
b) Watts
c) Joules
d) Joules/second

55. The greenhouse effect is the

a. absorption of solar ultraviolet radiation by gases in planetary atmospheres leading to atmospheric heating.
b. absorption of solar infrared radiation by the atmosphere and the subsequent heating of a planet's surface.
c. protection of the surface of a planet from harmful infrared rays by atmospheric gases.
d. absorption by atmospheric gases of infrared radiation emitted by a planet that has been heated by solar visible and ultraviolet radiation.

56. Energy calculations that simply equate the influx of solar energy on Earth with the outflow of energy from Earth lead to a very low average equilibrium temperature for Earth, of around -27°C or -16°F, which is much lower than the actual average surface temperature of Earth, +9°C or 48°F. What mechanism explains this discrepancy between the simple prediction and observation?

A) kinetic energy of meteoritic material that is dissipated in the atmosphere as the particles are stopped by friction
B) chemical action between molecules in Earth's atmosphere
C) **the greenhouse effect—the capture by gases in the atmosphere of heat radiation that would otherwise escape**
D) extra energy conducted outward from the hot interior of Earth

57. Which of the following is the major power source that drives the dynamics of Earth's atmosphere?
A) outflow of the original heat of production from Earth's interior
B) tidal effects from the Moon and Sun
C) the burning of fossil fuels such as coal, oil, and natural gas on Earth's surface
D) **solar radiation**

58. The albedo of a planet is the fraction of energy that is
A) reradiated into space as infrared radiation by the planet.
B) **reflected by the whole planet, including atmosphere and surface.**
C) absorbed.
D) reflected by clouds in the atmosphere.

59. What is the main mechanism by which the **lower** atmosphere of Earth is heated?
A) **Sunlight heats Earth's surface and the resultant heat is transferred to the atmosphere by infrared radiation and convective gas motions.**
B) Conduction carries heat from Earth's interior to the surface where conduction in the lower atmosphere transfers this heat to the higher layers.
C) friction between the winds in the atmosphere and the mountain ranges and land masses of Earth
D) absorption of sunlight by molecules of the gases of the atmosphere

60.. Which of the following molecular species plays a major role in the greenhouse effect in planetary atmospheres?
A) ozone B) nitrogen C) **carbon dioxide** D) oxygen

61. The Earth has a temperature and thus emits radiation somewhat like a blackbody. What is the source of the energy for this radiation?
A) **incoming radiation received from the Sun**
B) heat retained by the Earth's interior since it was created by the collisions of planetesimals
C) heat from radioactive decay deep within the Earth
D) tidal friction

62. The Earth's albedo is 0.39. The total amount of radiant energy emitted (rather than reflected) by the Earth is thus
A) 39% of the incoming radiation from the Sun.
B) **61% of the incoming radiation from the Sun.**
C) 100% of the incoming radiation from the Sun.
D) actually slightly more than 100% of the incoming radiation from the Sun because of the Greenhouse effect.

63. What is the basic structure of Earth's interior?
A) **solid iron inner core, molten iron outer core, rocky mantle, lighter rocky crust**
B) molten iron inner core, molten rocky outer core, solid rocky mantle, lighter rocky crust
C) molten iron core, molten rocky mantle, solid rocky crust
D) molten iron inner core, solid iron outer core, rocky mantle, lighter rocky crust

64. Earth's interior received its heat energy from the impacts of planetesimals and from radioactivity. This heat energy is gradually radiating into space. As the Earth's interior continues to cool, we can expect that, in the distant future,
A) the inner core will become molten like the outer core.
B) **the outer core will become solid like the inner core.**
C) the mantle will become molten while the core will become solid.
D) the entire interior will become one homogeneous solid.

65. Earth is not thought to have a permanent magnet in its interior because the
A) **magnetic field reverses direction over periods of tens of thousands of years.**
B) magnetic field distribution in space around Earth does not match that of a permanent magnet.
C) rotation of Earth quickly destroys the properties of a permanent magnet.
D) core is not made of magnetic material.

66. Earth's magnetic field originates in
A) a solid, permanently magnetized core in the interior of Earth.
B) intense electric currents flowing in the Van Allen belts within the magnetosphere of Earth.
C) the tidal ebb and flow of electrically conducting seawater in Earth's oceans.
D) **slowly moving currents of molten iron which produce electric currents in the deep interior of Earth.**

67. Earth's magnetic field is caused by
A) **electric currents flowing in the molten core.**
B) the motion of the electrically charged particles of the solar wind as they pass the Earth.
C) a solid iron magnet in its interior.
D) electric currents flowing in the ionospheric layer of its atmosphere.

68. Earth's magnetic field is generated by
- A) permanent magnetism in Earth's crustal rocks.
- B) **electric currents in Earth's core.**
- C) electric currents in Earth's mantle.
- D) the flow of electrons and ions in Earth's magnetosphere.

69. Earth's magnetic field is thought to be caused by
- A) the flow of solar wind particles around and within its outer atmospheric region—the magnetosphere.
- B) **electric currents flowing in the liquid core.**
- C) localized magnetic anomalies near the Earth's surface.
- D) a magnetized solid iron core in the interior.

70. Suppose that the Earth was somehow put into orbit around a cool star (cooler than our Sun) at the right distance for our oceans to remain liquid so that life could still exist but the star emitted no UV radiation. Which of the following statements would most likely be FALSE?
- A) Our ozone layer would disappear.
- B) **Our magnetosphere would disappear.**
- C) Our thermosphere would disappear.
- D) We would be closer to the star than we are to our present sun.

71. What protects us from the damaging radiation effects of the high-speed solar wind that flows through interplanetary space?
- A) the rapid rotation of the Earth, which deflects most of the solar wind
- B) the Moon, whose gravitational field shields us from the solar wind
- C) Earth's atmosphere
- D) **the Earth's magnetic field**

72. The Van Allen belts are
- A) regions of the Earth in which no seismic activity is detected from earthquakes.
- B) dense collections of small rocks surrounding the major planets.
- C) **two doughnut-shaped rings of charged particles, surrounding the equatorial regions of Earth at very high altitudes.**
- D) undersea mountain ranges in the centers of the oceans.

73. Aurorae on the Earth are caused by
- A) electrical currents in the ionosphere, generated by dynamo action in Earth's core.
- B) **charged particles from the sun moving through Earth's magnetic field and striking the upper atmosphere.**
- C) the reflection of sunlight from arctic and antarctic ice into the polar night skies
- D) ultraviolet radiation from the Sun ionizing atoms in the upper atmosphere.

74. One of the major differences between Earth and its neighboring planets, Venus and Mars, is the lack of large quantities of CO_2 in its atmosphere. If all three planets were originally formed with significant quantities of this gas in their atmospheres, where is the majority of this CO_2 on Earth at the present time?
- A) It is dissociated by UV and visible sunlight into carbon and oxygen that now exist in abundance as separate chemicals.
- B) It is concentrated high in the atmosphere where it contributes to the greenhouse effect.
- C) It is dissolved in seawater, a situation that cannot arise on the neighboring planets.
- D) **It is locked up in carbonate, and carbon-rich rocks and minerals formed in the sea and on Earth's surface.**

75. How does the temperature of Earth's atmosphere vary with height over the range 0 to 120 km?
- A) It remains approximately constant at room temperature over the whole range.
- B) It always remains well below the surface temperature.
- C) **It decreases and then increases two or three times.**
- D) It rises steadily until it reaches a high and constant value above 120 km.

76. In which layer of Earth's atmosphere does all weather occur?
A) thermosphere B) stratosphere C) mesosphere D) **troposphere**

77. In which layer of Earth's atmosphere is the ozone layer located?
A) **stratosphere** B) mesosphere C) thermosphere D) troposphere

78. The temperature in the stratosphere increases with increasing altitude because
- A) it is heated by solar infrared radiation absorbed by carbon dioxide and water vapor.
- B) **it is heated by the absorption of solar ultraviolet radiation by ozone.**
- C) charged particles from the magnetosphere collide with atoms in the stratosphere, depositing energy.
- D) these higher altitudes are closer to the Sun.

79. Earth's stratosphere is warmer than the layers above and below it because
- A) warm air heated by contact with the ground rises into the stratosphere, thereby heating it.
- B) CO_2 in the stratosphere absorbs infrared light radiated outward by the ground.
- C) the methane released when we burn fossil fuel absorbs infrared light in this layer.
- D) **ozone in the stratosphere absorbs ultraviolet radiation from the Sun.**

80. One might expect the dominant circulation in Earth's atmosphere to be one large convection cell in each hemisphere, with air rising at the equator due to solar heating, moving toward the poles at high altitude, cooling and sinking, then returning toward the equator along the surface. The actual circulation is more complicated than this primarily because of the
- A) **speed of rotation of Earth.**
- B) uneven heating of oceans and continents by the Sun.
- C) escape of heat outward through Earth's crust.
- D) uneven heating of the different atmospheric layers by the Sun.

81. Which of the following is NOT a major factor in the influence of humans on global warming?
- A) **increase in heat added by the bodies of humans and animals as their populations increase rapidly**
- B) use of gasoline (petrol) and natural gas in transportation vehicles, such as cars and aircraft

C) burning of wood, coal, and oil for heating and cooking
D) slash-and-burn methods that are destroying forests in South America

82. Which of the following areas of human endeavor and development is having the most impact on Earth at the present moment?
A) **rapid increase in human population**
B) development of mental telepathy, or communication without speech, between selected human beings
C) growth in the use of solar energy for heating, lighting, and power
D) exploration of the Moon and its exploitation for mineral resources