1. The Greenhouse Effect

A. Does the atmosphere absorb much visible light?

No.

B. Does the ground absorb much visible light?

Yes.

C. In which band of electromagnetic radiation does the ground emit most energy?

IR.

D. Which two gases are most important in absorbing this radiation from the ground?

$H_2O$, $CO_2$

E. These atmospheric gases absorb the earth’s radiation and heat up. They radiate some of this absorbed energy into space and some of the energy back to the ground. What happens to the temperature of the ground from this re-radiation?

The temperature of the ground increases. The ground then emits even more radiation than before, the atmosphere absorbs some of this, re-emits it to the ground, where it warms the ground even more. Each circuit consists of a smaller and smaller amount of radiation. Eventually, the atmosphere and ground find an equilibrium. Overall, the whole earth system is the same radiative temperature as if it had no atmosphere (incoming solar must equal outgoing longwave), but the surface temperature is warmer than if there were no atmosphere.

F. What is the current average surface temperature of the earth in °F? What would be the earth’s temperature in °F if this “Greenhouse Effect” did not exist in our atmosphere?

$59 \, ^\circ F = 288 \, K \text{ or } 15 \, ^\circ C$.

$0 \, ^\circ F = 255 \, K \text{ or } -18 \, ^\circ C$
G. Opinion question: Do you think humans are warming the planet with CO₂ emissions or do you think the recent warming is due to some other effect that we do not understand? Explain.

*It is a fact that increased CO₂ will cause the earth’s surface temperature to rise, but because of the complexity of the earth system, it is very difficult to come up with an exact number.*

2. Vertical Structure of the Atmosphere

A. Why is the surface temperature typically greater than the atmospheric temperature?

*The surface absorbs visible radiation while in general the atmosphere is transparent to visible radiation from the sun.*

B. Why does temperature generally decrease with height in the troposphere?

*The two sources of heat in the lower atmosphere are the ozone layer in the stratosphere and the ground at the bottom of the troposphere. As you go away from the ground, you are getting away from one source of heat (ground) but are not close enough to the ozone layer to feel much of its warming influence.*

*In addition, the main absorbers of IR radiation, CO₂ and H₂O, are found in larger amounts lower in the atmosphere.*
C. Why does temperature increase with height in the stratosphere?

*As you go up in the stratosphere, you are getting closer to a source of heat, the ozone layer.*

D. The figure below shows the current vertical structure of the atmosphere. Imagine if the ozone layer were 80 km above the surface instead of 50 km. Draw the new vertical profile from the surface to the stratopause. Label the troposphere, tropopause, stratosphere, and stratopause. Indicate how the tropopause might change in this hypothetical scenario.
3. The Ozone Hole (pages 321-324 in Ahrens plus guest lecture 4/11)

A. Both poles have ozone holes but the one over the __South____ Pole is larger. The ozone hole forms primarily because (A. more ozone destroying chemicals are released in that hemisphere / B a polar vortex develops and temperatures get very cold). (A. Polar stratospheric / B. Polar lenticular) clouds that form here ( A. absorb ozone / B. enable ozone-destructing chemical reactions ). The primary chemical that destroys ozone in the stratosphere is __chlorine____which is released by CFCs.

B. How have humans responded to the discovery of an ozone hole? Do we still release the same amount of CFCs and why or why not?

After the discovery of the ozone hole, many governments got together and signed the Montreal Protocol (plus many subsequent modifications) to reduce the amount of CFCs emitted into the atmosphere. This agreement has largely been followed, and the amount of CFCs released to the atmosphere is declining.

C. Will our changed habits lead to an immediate shrinkage of the ozone hole or will it take many years for the hole to disappear?

The residence time of a CFC in the atmosphere is 50-100 years. This means that if you release a CFC today, it will take 50-100 years for it to leave the atmosphere. We have drastically reduced the release of CFCs, but because of this residence time, it will take several decades before the ozone hole goes away.

4. Convection and Conduction Demonstration

A. In one beaker, the ice/chunk initially sank (beaker A), and in the other the ice initially floated (beaker B). As both ice chunks melted, heat was transferred by __conduction____ in beaker A, whereas in B heat was transferred by __convection____. Which method was more efficient (which took less time to melt the ice)? Which one was a more stable situation? In which was more mixing done? How could you tell?

Convection is a more efficient way to transfer energy.
Beaker A (conduction) was a more stable case (cold fluid stayed at the bottom, warm fluid stayed toward the top).
More mixing was done in beaker B, where the ice initially floated. Convection increases mixing. This was obvious because the dye in this beaker became evenly distributed,
whereas most of the dye remained at the bottom in the case where the ice was at the bottom.

B. Which of these two processes do you think is more responsible for transferring heat from the surface air to the rest of the troposphere? Why?

Convection. Conduction takes a long time to transfer much energy anywhere.

5. The Earth’s Orbit and Seasonal/Diurnal Cycles.

Temperature changes at the surface of the earth are dominated by two cycles, the seasonal cycle (i.e. if it is summer or winter) and the diurnal (daily) cycle (i.e. if it is daytime or nighttime).

A. Suppose the tilt of the earth's axis were 0° (instead of 23.5°). Would the seasonal or the diurnal cycle more strongly affect the temperature? Explain.

The tilt of the earth’s axis is now zero degrees from the vertical. The earth continues to spin about this axis (one revolution per day) as it goes around the sun (one revolution per year). In this case, the daily (diurnal) cycle is always 12 hours of light and 12 hours of dark everywhere on earth, all year. There is no more seasonal cycle (the length of day remains the same all year). Therefore the daily cycle is now the most important factor.

B. Suppose the tilt of the earth's axis were 90°. Would the seasonal or the diurnal cycle more strongly affect the temperature? Explain.

Now the axis that the earth spins about is 90 degrees from the vertical (it’s horizontal in this picture). Now the winter each hemisphere is totally dark all day, and the summer is light all day. Therefore, at least in summer and winter, there is no daily cycle. So the seasonal cycle is the most important factor in this case.
The equator is vertical in this picture.

C. The earth’s orbit around the sun is elliptical, rather than circular. The earth is closest to the sun in January. Why is Seattle warmest in July?

First of all, the difference in distance from the sun in summer and winter does not affect the earth’s seasonal cycle. The major factor is the tilt of the earth’s axis.

Second, the reason the earth is not warmest in June but in July is the same reason that the warmest part of the day is not at noon, but later. The Northern Hemisphere receives most solar radiation on (around) June 21st, and least on December 21st. But the net radiative balance continues to be negative after December 21st, so the temperature continues to decrease. In late January, the energy emitted from the earth becomes equal to the energy received from the sun (minimum temperature). After this, the energy received is greater than the energy lost, so the temperature increases. In late July, the energy coming in and energy going out are equal again (maximum temperature). After this, the energy emitted is greater than the energy received, so the temperature begins to decrease. Refer to the figure showing the diurnal cycle in your notes – the concept is very similar.