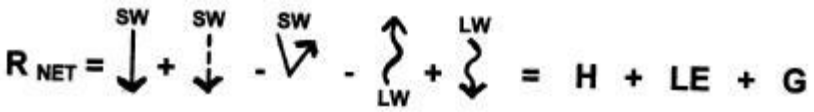
ANSWER KEY TO THE PRACTICE QUESTIONS ON THE FINAL EXAM STUDY GUIDE -- 2014

1. Y (visible) 2. Z (infrared) 3. X (ultraviolet)

4. d (the absorption is occurring almost entirely in the infrared (LW) part of the spectrum)

5. d (This is the curve for OZONE btw) absorption is taking place in BOTH the infrared and ultraviolet parts of the spectrum)

6. 

7. a (remember convection is the actual movement of a gas or liquid, as in "rising currents of air" Conduction is energy transfer by one molecule jiggling the next molecule, infrared energy (d) and ultraviolet or visible light (e) are not the movement of "matter" or material, they are waves or pulses of photons/energy.

8. d (see explanation for #7 above)

9. d (be sure your understand how to reason your way through . . . the answer to #10 below "talks you through" another example)

10. a (They are both positive feedbacks that will amplify warming. Here's how:

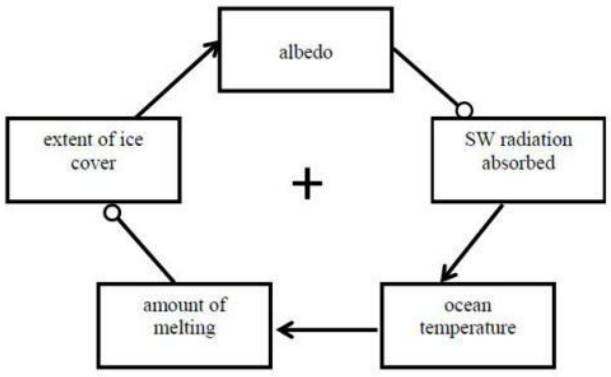
Left diagram: If Ts (temperature of the surface) increases: warmer surface temperatures will lead to more evaporation and more water vapor in the atmosphere, and since water vapor is a greenhouse gas, the greenhouse effect will be amplified and lead to more warming.

Right diagram: If Ts (temperature of the surface) increases: warmer surface temperatures will lead to more melting of snow and ice cover, which will lead to a reduction in albedo, which will then allow more incoming solar radiation to be absorbed (instead of reflected) which will lead to a warmer surface and the amplification of the warming effect.

11. (Review the original explanation of these feedback loops on pp 53-54 of SGC-E-Text.) To answer this, you would start out by stating the Feedback A is negative (self-regulating) and Feedback B is positive (self-enhancing or self-amplifying). Then explain each feedback loop coupling by coupling: e.g., for Feedback A: "if the Earth's surface temperature INCREASES, then MORE outgoing IR will be radiated from the surface to space ==> if MORE IR is radiated to space from the Earth's surface, the surface will cool down and surface temperature will DECREASE, therefore regulating the system. Or you could also explain it this way: "if the Earth's surface temperature DECREASES, then LESS outgoing IR will be radiated from the surface to space ==> if LESS IR is radiated to space from the Earth's surface, the surface will not cool down as much and surface temperature will INCREASE, therefore regulating the system.

Then go on to explain the positive feedback processes coupling by coupling as above, contrasting the self-amplifying end result of Feedback B with the self-regulating end result of Feedback A.

12. The answer is here: If ocean temperature warms UP, then the amount of melting will go UP, if the amount of melting goes UP, then the extent of sea ice cover will go DOWN if the sea ice cover goes DOWN, then the albedo will also go DOWN, if albedo goes DOWN, the amount of SW radiation absorbed will go UP, if radiation absorbed goes UP, then the ocean temperature will go UP even more!



13. a (the ozone hole allows more harmful UV shortwave radiation to reach the Earth's surface)

14. b (more CO_2 in the atmosphere leads to a stronger greenhouse effect and hence more absorption of LW in the atmosphere and radiating it back down to the Earth's surface.)

15. d (a reduction in GH gases will lead to the opposite of #14, a weaker greenhouse effect -- more longwave terrestrial radiation will go right out to space and less will be absorbed in the atmosphere and radiated back down to the surface.)

16. c c (deforestation will increase albedo and hence the reflection of incoming shortwave radiation. **Important follow-up point:** Deforestation also tends to decrease the amount of energy stored in **LE** (latent energy) and therefore allow more energy to go into **H** (sensible heat) The first factor (higher albedo) leads to *cooling,* the second factor (more H) leads to *warming.* Several model results show that the H factor "wins" and that widespread deforestation is *most* likely to lead to warming.

17. troposphere 18. stratosphere 19. mesosphere 20. thermosphere 21. a (the troposphere)

[HINT: if this appears as a multiple choice question, don't get thrown off by similar sounding, but incorrect choices such as: *tropopause, stratopause, "menopause"* etc. etc.]

22. b see p 74 in Class Notes -- the sulfate aerosols in the stratosphere *reflect* incoming SW so that it doesn't reach the troposphere and the troposphere cools; these same aerosols can also *absorb* some incoming SW and outgoing LW and this causes the stratosphere (where the aerosols are located) to warm up, at the same time the troposphere is cooling.

23. b (see p 83 in Class Notes) 24. b

25. (a) your answer should say something about 20th century increased burning of fossil fuels and GHG emissions to explain the trend (b) your answer should say something about the seasonal "breathing" of the Northern Hemisphere forests and explain what this means, as in answer (b) for #24 and why the CO2 values go up in Northern Hemisphere fall/winter and down in spring/summer.

26. so many to choose from!! See Part 3 of the *Dire Predictions* text and your notes from various classes, films, etc.

27. b (representing emitted LW (infrared) radiation going out.) Note that the symbol for the solid line would be choice a: 

28. b *How to figure this one out:* Look at the process depicted in Diagram X vs. Diagram Y. Remember that LE (latent energy) involves energy stored in the air when evaporation occurs. Hence the movement of water-vapor-laden air can transport energy even though it may not be sensed with a thermometer. In contrast, H (sensible heat) involves warm air whose energy can be "sensed" with a thermometer. Hence if the atmospheric circulation transports a mass of warm air, this is another way to transport energy from low to high latitudes in the form or H.

> Diagram X depicts evaporation in the low latitudes and the wind arrows indicate that this tropical air, (which is now laden with water vapor and therefore contains energy in the form or LE), is being transported to higher latitudes, where it will eventually cool and condense and release the LE ==> H as precipitation occurs
>
> Diagram Y depicts the "Rossby Wave / Jet stream" circulation, showing how it moves a mass of warm air (containing lots of energy in the form of H) to higher latitudes

29. c 30. **Follow up "connection" question:** In the Energy Balance diagram of #27, the latitude band of ~ 35-40 degrees north is about where the low-latitude energy SURPLUS shifts to a higher-latitude energy DEFICIT -- driven by incoming SW minus outgoing LW radiation. This surplus/deficit imbalance is what drives atmospheric and oceanic circulation, which together work to even out the imbalance. The *connection* between the two figures is that the figure for #29 shows HOW energy is transported from the latitudes of surplus to the latitudes of deficit (shown in the figure in #27 to even out the imbalance.. The band of 35-40 deg N (in the mid-latitudes) is where the energy transport processes of oceanic and atmospheric circulation are especially active in transporting energy from the surplus to deficit regions.

31. See p 88 in CLASS NOTES. See also the Nov 20th (Topic #13) presentation in the Class Follow Up. The Hockey Stick graph in Practice Question #31 shows a yellow "uncertainty" region – this uncertainty regions is shown as pale gray in a slightly different version of the "Hockey Stick" graph on CLASS NOTES p 88. The uncertainty region represents the range within which we can have 95% confidence that proxy data give the *correct* estimate of past global temperatures. The range of temperature variability over the past millennium is seen in a *different* way in the "Spaghetti Plate" graph from the updated IPCC 2007 report. (See the bottom of Class Notes p88 and also Dire Predictions p 47.) This graph is based on many different analyses which all show the same "hockey stick" shape of a sharp upturn in temperatures in the last few decades. The key point is that the temperatures during the most recent warming are not only much warmer than the *average* reconstructed temperatures of the past , they ALSO *exceed even the highest values of the past within the range of uncertainty* ! The Hockey Stick points to an unprecedented warming occurring at exactly the same time that GH gas concentrations from anthropopgenic activity rose rapidly

32. These figures are discussed in SGC Chapter 15 on p 302.

33 & 34 See pp 74-75 in class notes for the answers -- Also see the G-5 ANSWERS

35. c 36. b (see p 72 in Class Notes the presentation on **Topic #11 Natural Climatic Forcing** (Part I) in Class Follow Up.

37. The two correct phrases are shown by **=>**
=> the **X bar** representing **stratospheric ozone** is **below the zero line** and hence this means that if stratospheric ozone increases, the radiative response will be that of C**OOLING**
___ the **X bar** representing **stratospheric ozone** is **below the zero line** and hence this means that if stratospheric ozone increases, the radiative response will be that of **WARMING**
___ the **Y bar** representing **tropospheric ozone** is **above the zero line** and hence this means that if tropospheric ozone increases, the radiative response will be that of C**OOLING**
=> the **Y bar** representing **tropospheric ozone** is **above the zero line** and hence this means that if tropospheric ozone increases, the radiative response will be that of **WARMING**

38. If stratospheric ozone DECREASES and tropospheric ozone INCREASES, the radiative forcing response will be that of [**warming** / ~~cooling~~] -- but for two different reasons: Stratospheric ozone primarily affects the **[UV /~~IR~~]** *(circle one)* part of the spectrum, while tropospheric ozone primarily affects the **[~~UV~~ / IR]** *(circle one)* part of the spectrum parts of the electromagnetic spectrum.

The combined influence on GLOBAL WARMING of stratospheric ozone depletion and an increase of tropospheric ("bad ozone") is **small** when compared to the radiative forcing influence of the other Greenhouse gases shown in bar W.

To improve your understanding of this VERY important **Radiative Forcing Diagram,** see the section of the **Nov 20th presentation** on **Topic #13 Global Warming & Anthropogenic Forcing**

39. d See p 54 in Class Notes on Tropical Deforestation and the Energy Balance and also Topic # 13 (pp 83-84) and the last parts of the presentation on Nov 18th

40. d 41. b The problem with (a) is that there are no natural processes that operate quickly to remove CO2 from the atmosphere
The problem with (c) is that the medieval warming was not globally warmer than the present
The problem with (d) is that natural processes alone cannot explain the recent warming

#42-46 Start by reviewing Question # 25 above to be sure you understand this graph -- See p 65 in Class Notes as well. A hint for answering questions like these is to first decide whether a low latitude surplus or a deficit of energy would occur under the given scenario. Once you figure that out, you can narrow your choices down to just two by focusing on the two figures that show either a *deficit* (smaller cross hatched area, #1 and #2) or a *surplus* (larger cross-hatched area, #3 and #4). Then you just have to figure out if the scenario would affect the absorption at the Earth's surface of incoming shortwave/solar radiation (Curve A moves up if SW *increases*, Curve A moves down if SW *decreases*) __ OR __ the amount of terrestrial longwave (infrared) energy going out to space (Curve B moves up if *more* LW escapes to space, Curve B moves down if *less* LW escapes to space.)

42. d 43. a 44. b 45. a
Additional thought question: Can you think of a scenario that would lead to Graph #3?? HINT: it's the opposite of question #44!

46a. c Remember that longest lines on the skeleton plot graph correspond to the narrowest rings. On the core, rings 4,11, 28 & 29 are the most narrow rings. The skeleton plot that shows this is skeleton plot (c)

46b. d there is a lot of variation in ring widths in this core, some wide and some narrow, that means it's showing a sensitive ring growth pattern. If the tree's growth is sensitive it means that it responds to climate variability and therefore the sensitive wide and narrow ring pattern means can provide a lot of information about the climate during each year of growth

47. Oooooh . . .this is a good one! The excerpt is a classic example of mixing up the processes involved in the enhanced Greenhouse Effect with those involved in Stratospheric Ozone Depletion. The scientifically incorrect parts are highlighted below. You should be able to re-write this so it is properly stated. **Some hints:** "Greenhouse refers (something missing here, the sentence is really referring to the Enhanced Greenhouse Effect) to carbon-dioxide emissions from the world's use of fossil fuels, which in turn are said to be depleting the ozone layer – (yikes! are carbon dioxide emissions -- or even fossil fuels -- involved in the processes that are depleting the ozone layer?) the layer that protects humankind from dangerous ultraviolet radiation."

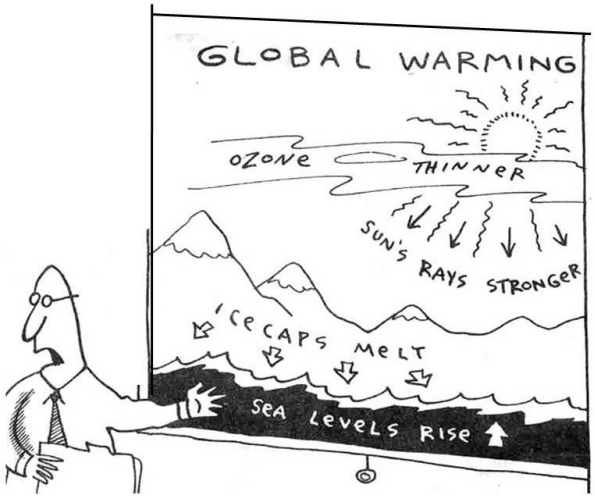
48. S**uggested ways to approach this question:**

- For a good description of the TROPOSPHERE & STRATOSPHERE, and why they are each important, review pp 46-47 in SGC. Also review the information about atmospheric structure and composition on pp 35-39 in CLASS NOTES and recall that is in the TROPOSPHERE that the greenhouse gases are concentrated, and therefore this is the place in the atmosphere where the greenhouse effect (and hence global warming) is the strongest.
- Also recall that the principle global change issue that involves the STRATOSPHERE is the depletion of the ozone layer and the ozone hole and that this process does not involve carbon dioxide (CO2). It is caused by a photochemical reaction with chloroflourocarbons (CFC's) that breaks apart the CFC's to releases chlorine atoms which destroy ozone in the stratosphere.
- You could also think about the three different "signature" diagrams we've looked at this semester: The *Greenhouse Effect / Greenhouse Warming Signature* (p 37 in Class Notes), *The Solar Irradiance Signature* (p 73 in Class Notes) and *The Volcanic Aerosol Signature* (p74). Know what causes the different patterns of warming and cooling in the two layers, and how this provides important information about the role of each layer – including which layer has a high concentration of CO_2, and what that does to the layer's temperature, and why that's important.

49. **Here are some clues as to why the cartoon is a scientifically inaccurate depiction of Global Warming:**

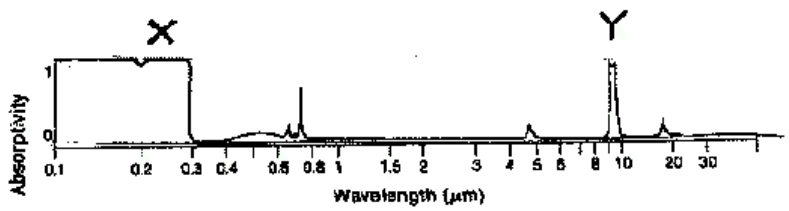
The cartoon implies that a thinner ozone layer will result in rays from the sun that are stronger which in turn causes global warming and all the consequences, such as melting ice caps and rising sea levels.

What's wrong about the cartoon is that the global warming we are concerned about is primarily due to the **enhanced greenhouse effect** which operates in the outgoing LW & reradiated LW **infrared / longwave part of the electromagnetic spectrum**, and is **NOT due to *incoming* solar energy in the ultraviolet/visible light /shortwave part of the spectrum** (which might increase slightly with a thinner ozone layer)



This essay question is a super one for tying together different aspects of the course. A good place to start your answer and tie in the **ABSORPTION CURVE OF OZONE** (as the question asks you to) might be to include the concepts that first appeared in **Topic #5 The Radiation Laws and** reappeared in **Topic #12 on Ozone Depletion in the Stratosphere**.

Following are two additional practice questions about **the ABSORPTION CURVE for ozone** to refresh your memory about the "dual personality" of ozone in the types of radiation that it absorbs (both UV and IR) . . . .



Extra Ozone Q #1: Circle the CORRECT completion to this sentence: "The global change issue usually referred to as **the Enhanced Greenhouse Effect** is related to **ozone** due to the part of the absorption curve that is **b**."

a) **labeled X** because this part of the curve indicates that ozone **is able to absorb *some wavelengths of terrestrial longwave radiation*** and hence can be considered one of the greenhouse gases.

b) **labeled Y** because this part of the curve indicates that ozone ***is able to absorb some wavelengths of terrestrial longwave radiation*** and hence can be considered one of the greenhouse gases.

c) **labeled X** because this part of the curve indicates that ozone *is* ***able to absorb radiation in the ultraviolet part of the spectrum*** and hence can be considered one of the greenhouse gases.

d) **labeled Y** because this part of the curve indicates that ozone ***allows the easy transmission of wavelengths of terrestrial longwave radiation out to space*** and hence can be considered one of the greenhouse gases.

Extra Ozone Q #2: Circle the CORRECT completion to this sentence: "The global change issue usually referred to as **Stratospheric Ozone Depletion** is related to the part of the absorption curve that is **d** ."

a) **labeled Y** because this part of the curve indicates that ozone ***is able to absorb some wavelengths of terrestrial longwave radiation*** which harm the ozone layer.

b) **labeled X** because this part of the curve indicates that ozone **is able to absorb *some wavelengths of terrestrial longwave radiation*** which harm the ozone layer.

c) **labeled Y** because this part of the curve indicates that ozone ***allows the easy transmission of wavelengths of terrestrial longwave radiation out to space*** which then disappear out to space through the ozone hole.

d) **labeled X** because this part of the curve indicates that **ozone *is able to absorb* harmful solar *radiation in the ultraviolet part of the spectrum*** and hence if ozone is depleted, more ultraviolet radiation will reach the Earth's surface.

By discussing the absorption curve of ozone you can illustrate that ozone is connected to the enhanced greenhouse effect problem because it IS a greenhouse gas (and point to the IR part of the curve showing that ozone can absorb terrestrial infrared radiation.) That's how ozone and the GHE are connected. Remember, the ozone hole is NOT a major cause of global warming. However . . . because stratospheric cooling occurs during an enhanced GHE (from global warming), that cooling can enhance the stratospheric ice clouds and hasten ozone destruction over Antarctica, thereby preventing the ozone hole from healing quickly.

However, you would also want to point out that in terms of GHG concentrations in the atmosphere, the amount of ozone in the lower troposphere (where the greenhouse effect takes place) is much less than that of H_2O and CO_2, which are the main GHG's (see Topic #6 Atmospheric Structure & Chemical Composition). Also, the amount of "forcing" (temperature increase) due to ozone as a greenhouse gas in the troposphere is much lower than the warming due to other GHG's (as seen on the **RADIATIVE FORCING DIAGRAM** provided in the question):

The **FORCING DIAGRAM** is a good one for trying to sort out the different roles that ozone plays in the energy balance. Note that in the figure, stratospheric ozone has a slight COOLING effect (forcing) -- why? Because a healthy ozone layer will absorb incoming (harmful) UV radiation in the stratosphere and it will not reach the Earth's surface and be absorbed at the surface. If this cooling effect is reduced because of the depletion of the ozone layer, a *very slight* warming could occur -- but this effect would be minor compared to the primary cause of anthropogenically induced global warming, e.g. increased GHG's (esp. CO_2).

Is all this starting to fit together now? I hope so!! The differentiation between the ozone depletion issue and the global warming issue is one of the most important concepts you should (hopefully) obtain from this course -- but it requires the weaving together of many things we've learned all semester.

50. A good basic question tying together the energy balance and the Greenhouse Effect . CLICK the following link to see:

EXAMPLES OF ANSWERS (w/ FEEDBACK) FOR AN ESSAY QUESTION ON THE GREENHOUSE EFFECT

Use the examples of good and weak answers in the link above to clarify and refine your understanding of these important concepts and also to help you learn how to write a more accurate and precise essay answer to a question like this one or any other essay question you might get!

THAT'S IT!

I hope the ANSWER KEY has helped you understand and learn these concepts better!
STUDY HARD & DO WELL!
-- Dr H