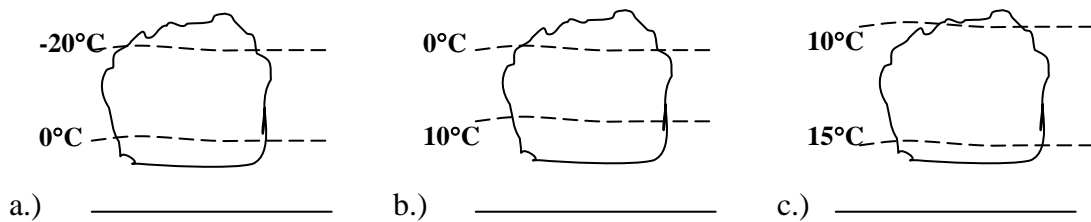


MEA 214 FUNDAMENTALS OF METEOROLOGY II
 Spring 2008
 Final Exam (Tu, 4/29/08, 8:00-11:00 a.m.)

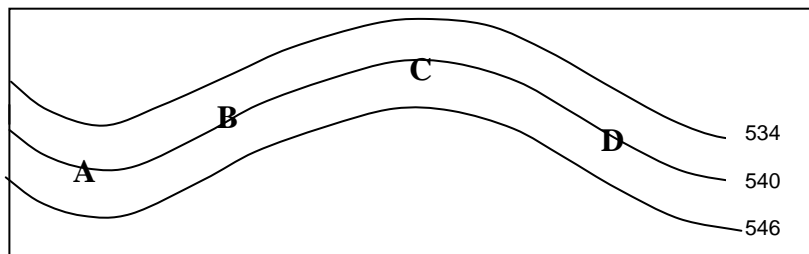
- ___ 1.) Which of the following is an example of cloud formation *without* rising air motion?
- a.) Advection fog
 - b.) Radiation fog
 - c.) Orographic clouds
 - d.) All cloud formation requires rising air motion.
 - e.) Both a.) and b.)

___ 2.) Consider the three hypothetical clouds shown below. Two isotherms are shown with each cloud. Which is most likely to produce precipitation at the ground?

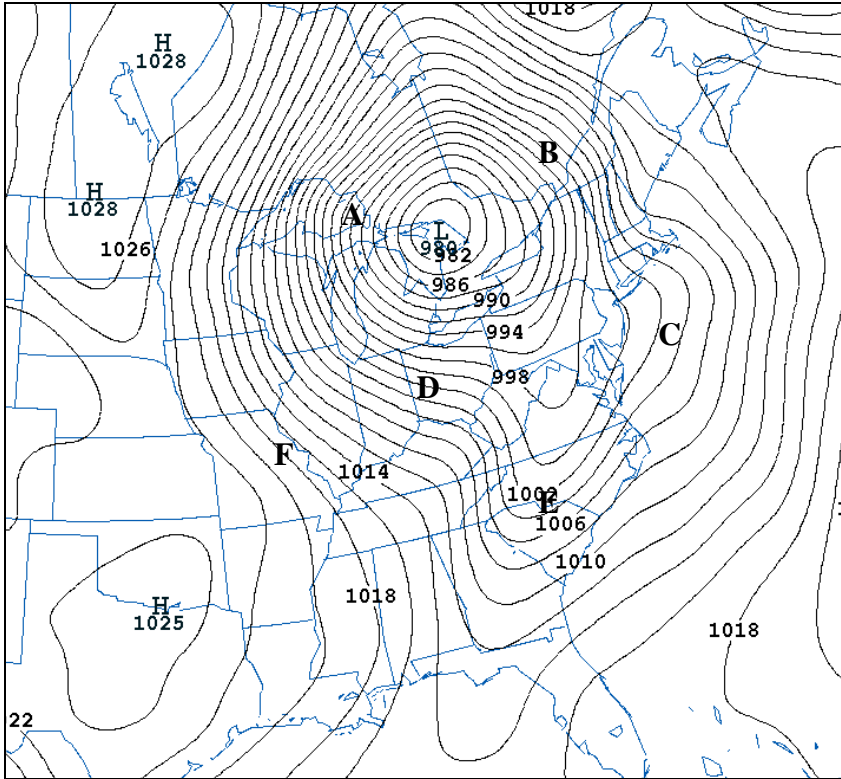


- ___ 3.) Which one of the following is *not* an important *lifting mechanism* in the atmosphere?
- a.) The Bergeron process
 - b.) Orographic lifting
 - c.) Frictional convergence
 - d.) An upper-level trough

Questions 4 and 5 refer to the hypothetical 500-mb height map pictured below. Consider that the height contours are equally spaced everywhere in the main belt of westerly winds, and that the wind is in gradient wind balance. The map is for a Northern Hemisphere location.

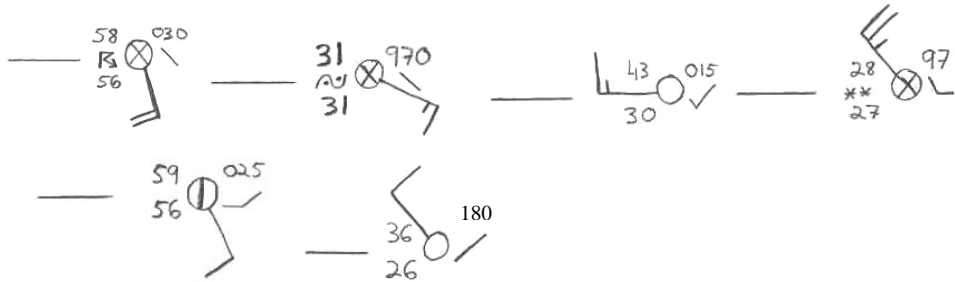


- ___ 4.) At which point is the wind strongest?
- ___ 5.) At which point would you most expect to observe a *low-pressure center* at the surface?



6.) Sketch the expected location of any frontal systems over the eastern U.S. and in the vicinity of the low-pressure center over the Great Lakes. Use proper symbols.

7.) Place the corresponding letter from the map above next to the observations below.



8.) Why do cyclones tend to form in the lee (to the east) of the Rockies?

- The enhanced temperature contrast there leads to strong cyclone formation.
- The presence of the Rockies allows warm, moist air to stream northward from the Gulf of Mexico, favoring cyclogenesis.
- Air columns are stretched as they pass to the lee of the Rockies, spinning up vorticity.
- “Self development” is favored to the east of major mountain barriers due to the combination of strong temperature contrasts and moisture availability.

9.) What is the approximate *altitude* of the midlatitude jet stream core?

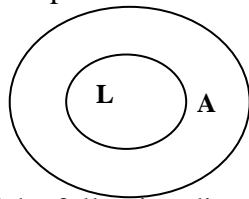
- 1 km
- 5 km
- 10 km
- 20 km
- 100 km

___ 10.) One day you observe thickening cirrostratus clouds in the morning, followed by thicker still altostratus clouds in the afternoon, and finally a steady, light rain by evening. The next morning the rain has ended, and it is clear and much warmer than the day before. A south wind has replaced the easterly winds of the previous day. What type of frontal system was most likely affecting the area?
a.) stationary b.) warm c.) cold d.) occluded

___ 11.) Which of the following statements concerning midlatitude cyclones is *false*?
a.) Cyclones generally move from east to west.
b.) Cyclones transport heat poleward.
c.) Cyclones have clockwise winds in the Southern Hemisphere.
d.) Cyclones are characterized by relatively lower pressure in the center.

___ 12.) Which of the following best explains why the wind speed increases with increasing height up to the jet stream level in the midlatitude troposphere?
a.) The wind in the upper troposphere is generally in *gradient* balance, meaning that in order for the centrifugal force to become important, winds speed must increase with height.
b.) The effects of surface friction are reduced as one moves aloft. Above the troposphere, friction again increases due to the close proximity to the “top” of the atmosphere.
c.) Temperature gradients lead to pressure gradients above. Over a deep layer of consistent temperature contrasts, the overall pressure gradient continually increases with height.
d.) The horizontal temperature gradient increases with height. Wind speed is directly related to the strength of the temperature gradient at that level.

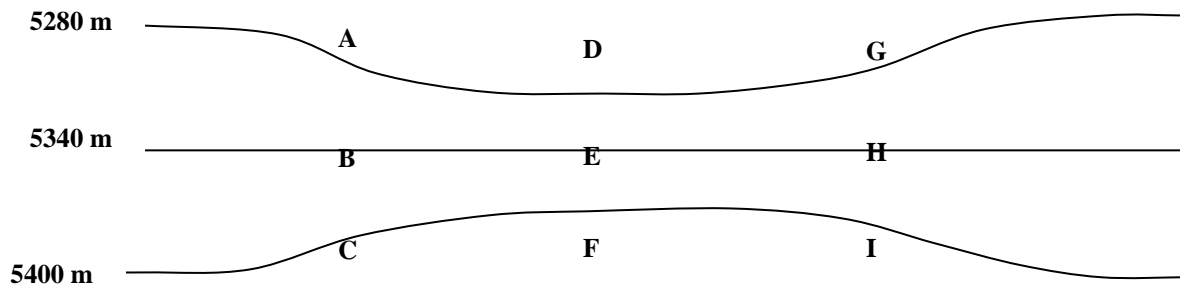
13.) Consider the Southern Hemisphere low-pressure system shown below. Draw vector arrows representing the expected force balance near the surface at point A.



___ 14.) Which one of the following divergence/convergence profiles would you most expect to find near the center of a surface *anticyclone*?
a.) Divergence aloft, convergence near the surface
b.) Divergence aloft *and* near the surface
c.) Convergence aloft and divergence near the surface
d.) Convergence aloft *and* near the surface

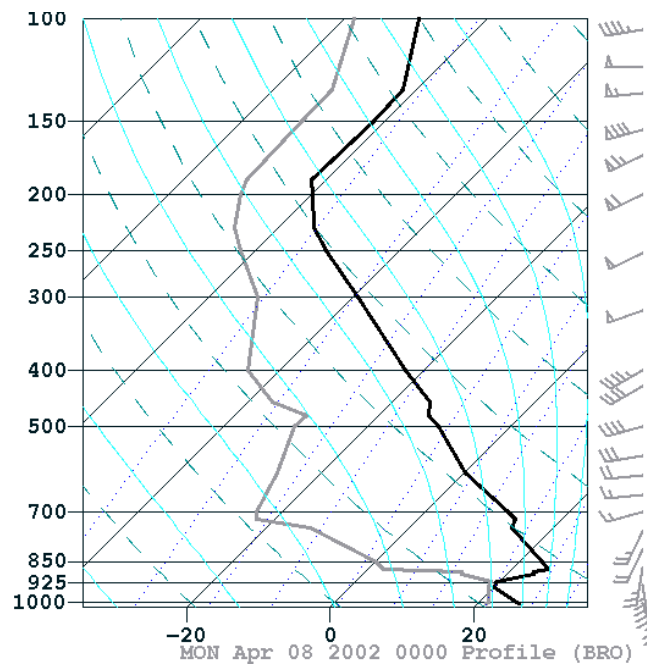
___ 15.) Which best describes the process of cyclone “self development”?
a.) *Temperature advection* near a surface low changes the temperature of the air column, *which in turn strengthens the upper-level wave* in a positive feedback.
b.) The *air column stretches in the lee of the Rockies*, and cyclones form there spontaneously, or “self develop”.
c.) *As cold fronts overtake warm fronts*, an occluded front forms. This process of frontal evolution is known as “self development”.
d.) East of the axis of an upper-level trough, *divergence aloft* is found. This divergence causes low pressure to “self develop” beneath.

For the next two questions, consider the Northern Hemisphere 500-mb map, featuring a jet streak pictured below.



16.) At which point would you expect to observe the strongest wind speeds? _____

17.) At which point(s) would you observe *convergence aloft and sinking air*? _____



18.) On the skew-T diagram above, determine (for an air parcel based at the surface):

- the LCL: _____ mb
- the LFC: _____ mb
- the CIN (label on diagram)
- the CAPE (shade and label on diagram)
- the EL: _____ mb

___ 19.) If the lower portion of the atmosphere for the sounding above (say, from the surface to 850 mb) were lifted by 200 mb, how would the stability of the layer change?

- The stability would remain constant.
- The stability would increase (it would become more stable).
- The stability would decrease (it would become less stable).

- ___ 20.) Physically, why would the stability change as indicated in the previous question?
- The moist air is less dense than dry air, so the layer would destabilize.
 - The top of the layer would cool at the dry adiabatic rate for a longer time.
 - More latent heat would be released into the bottom of the layer than the top.
 - Both b.) and c.)
- ___ 21.) Suppose that the environmental *lapse rate* was $-15^{\circ}\text{C}/\text{km}$ in a given layer. Which of the following best characterizes the stability of the layer?
- Absolutely unstable
 - Conditionally unstable
 - Absolutely stable
 - Convectively unstable
- ___ 22.) Which of the following best explains why the moist adiabatic lapse rate is smaller than the dry adiabatic rate?
- If air is dry, it has a smaller heat capacity and therefore cools more quickly as it rises.
 - Moist air holds heat more strongly than dry air due to the presence of water.
 - If saturated air rises, latent heat is released due to condensation, offsetting the cooling due to expansion.
 - both a.) and b.)
- ___ 23.) Which of the following processes are necessary in the cloud electrification process during a thunderstorm?
- Collisions between hail and other particles in a mixed-phase cloud.
 - A strong updraft.
 - Collisions between a warm and cold air mass.
 - Both a.) and b.)
- ___ 24.) Thunder is the result of
- rapid expansion of lightning-heated air.
 - sound waves generated by colliding air mass boundaries.
 - the sound of strong updrafts interacting with the Bergeron process.
 - lightning bolts hitting the ground with tremendous pressure and force.
- ___ 25.) What environmental characteristic is the most important in determining *thunderstorm type* (e.g., supercell vs multicell vs air mass)
- The presence and degree of convective instability
 - The presence of vertical wind shear.
 - The availability of moisture.
 - The presence of divergence aloft.
- ___ 26.) Which of the following is *not* an important source of error for numerical forecast models?
- Errors in the model initial conditions
 - Lack of knowledge concerning the equations that govern atmospheric flows
 - Predictability limitations due to the chaotic nature of the atmosphere
 - Errors in the representation of physical processes in the model atmosphere

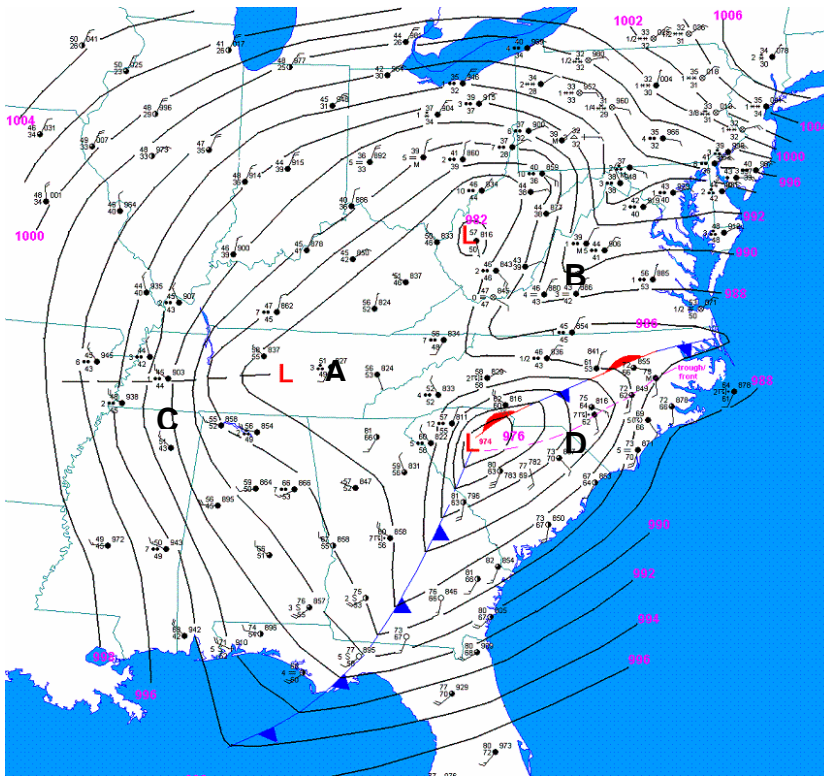
27.) True or False (answer T or F):

- ___ a.) Lightning “flickers” because the channel goes dark between return strokes
- ___ b.) The visible channel (return stroke) for most cloud-to-ground lightning progresses *upward from the ground towards the cloud*.
- ___ c.) “Heat lightning” is different from ordinary lightning because it is produced by the heat of the day, and does not have a true lightning channel.
- ___ d.) Lightning has been observed where mixed phase clouds are not present.

___ 28.) Which of the following best explains why fully developed thunderstorms have an “anvil” shape?

- a.) The updraft in cumulonimbus clouds gets so strong that the upper portions of the cloud fan out as the air rises.
- b.) The tropopause marks the base of the stratosphere, which is very stable; when a storm’s updraft hits the tropopause it spreads out.
- c.) As air rises it expands, and so the top part of the cloud will be bigger (and take on the shape of an anvil).
- d.) The upper parts of the cloud are composed of ice particles, which tend to spread out laterally more than the lower, liquid water portions of the cloud.

___ 29.) Based on this synoptic map, which one of the points on the map below would most be most likely to be under the treat of tornadoes in the next 6 hours?



___ 30.) Which of the following best describes the relation between vertical wind shear and tornado formation?

- a.) Vertical wind shear can split apart thunderstorms, and splitting storms are often tornadic.
- b.) Vertical wind shear provides rotation about a horizontal axis, which can be tilted by thunderstorm updrafts to produce rotation that may later contract into a tornado.
- c.) Vertical wind shear is unimportant to tornadoes.
- d.) Vertical wind shear helps to promote the formation of squall lines, which are often accompanied by tornadoes.

___ 31.) Which of the following best represents an estimate for the highest wind speed in a strong tornado?

- a.) 100 mph
- b.) 300 mph
- c.) 800 mph
- d.) 1000 mph

32.) Hurricane True-False:

- ___ a.) Rotational winds in a hurricane can be as strong as 200 mph.
- ___ b.) Airflow in the upper troposphere above hurricanes often rotates anticyclonically, opposite of the lower-tropospheric circulation.
- ___ c.) Sea-level pressure as low as 870 mb has been observed in hurricanes.
- ___ d.) Hurricanes frequently form at the equator in the “intertropical convergence zone”, which provides an initial disturbance.
- ___ e.) October is peak month for Atlantic hurricane activity.

33.) T/F Which of the following are true of the tropics relative to mid-latitudes?

- ___ a.) Geostrophic balance is less relevant there.
- ___ b.) Temperature gradients are generally weaker.
- ___ c.) Weather systems generally move from east to west.
- ___ d.) Hydrostatic balance is less relevant there.

___ 34.) Suppose the eye of a North Atlantic hurricane passed directly over you (and you survived the experience!) If winds were from due *north* as the eyewall first approached you, from what direction would the winds most likely blow when the eyewall reached you the second time?

- a.) N
- b.) NE
- c.) S
- d.) SW
- e.) E
- f.) W

___ 35.) For the same situation as in the previous problem, towards which direction is the storm moving?

- a.) N
- b.) NE
- c.) S
- d.) SW
- e.) E
- f.) W

36.) Which of the following are necessary conditions for hurricane formation? Check all that apply:

- ___ a.) Strong vertical wind shear
- ___ b.) Sea-surface temperatures of at least 26.5°C over some depth of ocean.
- ___ c.) An upper level jet streak or upper trough.
- ___ d.) Some form of initial disturbance
- ___ e.) At least some Coriolis force.

___ 37.) Which of the following best explains why hurricanes often exhibit anticyclonic (clockwise) rotation at upper levels?

- a.) In the tropics, the horizontal component of the Coriolis force is weaker, and so the winds can deviate from geostrophic balance there and spin the other way.
- b.) The warm core structure means pressure decreases less rapidly with height in the center of the storm, leading to high pressure aloft.
- c.) Without a jet stream or upper trough present, the flow at those levels is nearly always anticyclonic.
- d.) Both a.) and c.)

38.) For each phenomenon below, select the most typical approximate *horizontal size* of the disturbance from the list at right. You can use the same answer more than once if you like.

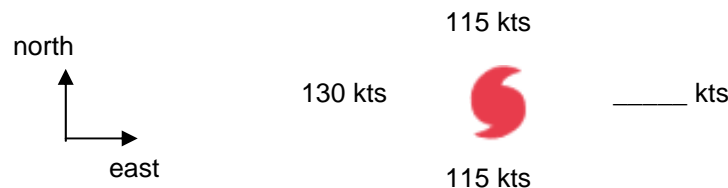
- | | |
|----------------------------------|--------------|
| ___ a.) Tornado | i.) 1 km |
| ___ b.) Hurricane eye | ii.) 10 km |
| ___ c.) Mid-latitude cyclone | iii.) 100 km |
| ___ d.) Supercell thunderstorm | iv.) 1000 km |
| ___ e.) Depth of the troposphere | v.) 10000 km |

___ 39.) The low pressure in a hurricane can contribute to local sea-level rise. About how much of an increase in sea level can this produce for a strong (cat 5) hurricane?

a.) 1 centimeter b.) 10 centimeters c.) 1 meter d.) 10 meters

40.) Consider the plot below, which shows wind speeds at different locations in a hypothetical Atlantic hurricane. Use this information to answer the following questions:

- a.) Towards which approximate direction is the hurricane moving? _____
select (N, S, E, or W)
- b.) What is the speed of movement? _____ (kts)
- c.) What is the strength of the rotational wind speed of the system? _____ (kts)



41.) On the diagram in the previous question, fill in the blank wind speed to the right of the storm.

- ___ 42.) Which of the following best describes the main source of energy for a hurricane?
- a.) The upper-level jet stream
 - b.) Rising of warm air and sinking of cold air with strong temperature contrasts
 - c.) Energy transfer from warm ocean water
 - d.) Release of latent heat of condensation
 - e.) both c. and d.

___ 43.) Which of the following best describes changes in global sea level in the past 100 years?

- a.) Steady fall, of about 10 centimeters

- b.) Slight fall, of about 1 centimeter
- b.) about constant, no detectable trend has yet been measured.
- c.) Slight rise, about 1 centimeter
- d.) Steady rise, about 10 centimeters

___ 44.) Which of the following are predicted to contribute significantly to sea level rise in the next 100 years or so?

- a.) Thermal expansion due to warming of oceans
- b.) Expansion of the oceans as they increase in volume from absorption of carbon dioxide
- c.) Melting of sea ice in the arctic
- d.) Melting of glaciers and land-based ice sheets
- e.) all of the above
- f.) a.) and d.) only

___ 45.) Thick sheets of ice advanced over North America as far south as New York as recently as

- a. 1816 ("the year without a summer")
- b. 1550
- c. 18,000 to 22,000 years ago
- d. 2 million years ago

___ 46.) Which of the following best describes problems with the historical record of tropical cyclones going back 100 years or so?

- a.) In the early part of the period, ships had little warning about hurricanes, and so they more often found themselves in the middle of these storms. Now, ships avoid them. So in the past, there were too many measurements of strong storms relative to today.
- b.) Prior to satellites, many open-ocean storms went unsampled, and it is likely that the record doesn't account for the strength and intensity of some past storms.
- c.) The operational hurricane centers around the world have long kept very reliable hurricane records, and the database is thought to be free from any biases or errors.
- d.) The historical data on hurricanes and tropical cyclones is completely unreliable, and should not be used for any research prior to about 1990.

___ 47.) Which theory explains how glacial material can be observed today near sea level at the equator, even though sea level glaciers probably never existed there?

- a. Milankovitch theory
- b. Theory of plate tectonics (continental drift)
- c. Volcanic dust theory
- d. Maunder theory

___ 48.) During a period when the earth's orbital tilt is at a *maximum*, which of the following would be most likely to be true?

- a. There should be less seasonal variation between summer and winter
- b. The formation of large ice sheets would be less likely than at other times.
- c. The formation of large ice sheets would be more likely than at other times.
- d. Both a.) and c.) are true.

49.) Climate change true/false

- ___ a.) A large eccentricity of the Earth's orbit could tend to favor ice ages.

- ___ b.) The United Nations population scenarios mostly show a leveling off or decline in global human population by the year 2100.
- ___ c.) The Maunder Minimum was when the sun & earth were closer than now
- ___ 50.) Which of the following is NOT a greenhouse gas?
- a.) ozone b.) water vapor c.) methane
d.) nitrous oxide e.) carbon dioxide f.) all of these are greenhouse gases
- ___ 51.) According to the Science article by Rahmstorf (2007), the IPCC Third Assessment Report _____ the expected amount of sea-level rise by the year 2100.
- a.) over-estimated b.) under-estimated
c.) accurately estimated d.) failed to provide a specific prediction for
- ___ 52.) Why are scientists confident that current global warming is due to anthropogenic greenhouse gas emissions?
- a.) Because other known physical processes that could explain this have been ruled out.
b.) Because it is logical that strong greenhouse emissions should enhance the greenhouse effect.
c.) Because climate models are unable to reproduce the current trends unless anthropogenic greenhouse gas emissions are taken in to account.
d.) All of the above.
- ___ 53.) Suppose that you are conducting an oxygen isotope analysis of a *Greenland ice core sample*. You locate a certain section of the ice core that has an unusually *high* concentration of O¹⁸ relative to the rest of the core. What should you conclude about the temperature at the time that portion of the core was produced?
- a.) It was colder than average. b.) It was warmer than average.
- ___ 54.) The best climate models of today predict a range of globally averaged surface warming by the year 2100 of:
- a.) 0-1°C b.) 1-5°C c.) 5-10°C d.) 10-20°C e.) 20-40°C
- ___ 55.) Recent observations from thermometers and other sources have shown a warming of _____ °C in the past 50 years.
- a.) ~0.1°C b.) ~0.5°C c.) ~2°C d.) ~5°C
- ___ 56.) Which of the following best describes primary and secondary pollutants?
- a.) Primary pollutants are those that occur naturally in the atmosphere, and are thus not technically “pollutants”.
b.) Primary pollutants are substances that break down in the presence of solar radiation (photodissociate), and then release harmful substances into the atmosphere.
c.) Secondary pollutants produce harmful chemicals via chemical reactions between primary pollutants and other gases.
d.) Secondary pollutants are not generally deemed as significant of a threat to society and the environment, hence the name “secondary pollutants”.
- ___ 57.) Why is the ozone layer located between 10 and 50 km in altitude?

- a.) Because this is the region where there is maximum overlap between the ingredients (molecular and atomic oxygen) in a three-body reaction.
- b.) Because ozone is light, and rises above much of the dense atmosphere below.
- c.) Because this is safely above the layer where CFCs are emitted.
- d.) No, actually the ozone layer is between 50 and 100 km.

___ 58.) Which of the following processes can break down a CFC molecule?

- a.) Reactions with ozone
- b.) Reactions with atomic oxygen, which can only take place in the stratosphere or above.
- c.) Extremely cold temperatures and Polar Stratospheric Clouds (PSCs)
- d.) Ultraviolet radiation

___ 59.) The concentration of Cl released from CFCs is *much* less than the concentration of stratospheric O₃; so which of the following best explains why the ozone layer is at risk?

- a.) Because there is so little ozone in the first place, that any depletion is serious.
- b.) There is no threat to ozone from CFCs
- c.) In reacting with ozone, Cl is re-generated, and so a single Cl can destroy many O₃.
- d.) If PSCs are present, then CFCs are capable of destroying many ozone molecules.

60.) Ozone true/false:

- ___ a.) CFCs are capable of destroying ozone in their native form; the reason that they don't destroy ozone in the troposphere is that there is little ozone there to destroy.
- ___ b.) The Montreal Protocol was designed to ban high-flying aircraft.
- ___ c.) CFC emissions worldwide have diminished greatly, and the ozone problem has stabilized.

61.) Ozone hole true/false:

- ___ a.) The ozone hole forms during spring in the arctic.
- ___ b.) The ozone hole is caused in part by reactions that take place on cloud particles.
- ___ c.) Polar Stratospheric Clouds (PSCs) form at very cold temperatures (e.g., -85C).

___ 62.) Which of the following best explains why the ozone hole is more of a problem for the Antarctic than the arctic?

- a.) The Antarctic is farther from the Northern Hemisphere, which is where most CFCs are emitted. This means that reductions in emissions have taken longer to reach there, and ozone depletion remains stronger there compared to the arctic.
- b.) The arctic has a colder spring than does the Antarctic, and this inhibits formation of an ozone hole there.
- c.) The Antarctic, being the site of a land mass, is cold enough for PSCs to form, whereas the arctic is relatively warm and has less PSCs. PSCs are needed for an ozone hole.
- d.) The Coriolis force acts in the opposite sense in the Southern Hemisphere. As this force acts on circulating air that contains CFCs, they are deflected to the left and accumulate near the South Pole, causing an ozone hole.