

**Multiple Choice Questions (Answer All 32 Questions) -- 3 Points Each**

1. At what time of day is the occurrence of severe thunderstorms and tornadoes most likely?  
(a) At night      (b) Morning      (c) Afternoon      (d) All times are equally likely
2. The downdraft in a single-cell thunderstorm is created mainly by the  
(a) converging gust fronts  
(b) electrical potential between the cloud and ground  
(c) release of latent heat as cloud water freezes  
(d) evaporation of raindrops that cool the air
3. If you see a lightning stroke and 10 seconds later hear the thunder, the lightning is about \_\_\_\_\_ miles away.  
(a) 2      (b) 5      (c) 10      (d) 20
4. Lightning often occurs within a cloud without ever hitting the ground. (True / False)
5. The inside of a car provides a relatively safe shelter from lightning. (True / False)
6. The inside of a car provides a relatively safe shelter from a tornado. (True / False)
7. On average, which weather phenomenon is responsible for the most deaths in the United States per year?  
(a) Hurricanes      (b) Lightning      (c) Tornadoes      (d) Heat Waves
8. At solar noon on a cloudless day, the UV exposure in Tucson is \_\_\_\_\_ the UV exposure on Mt. Lemmon.  
(a) greater than      (b) less than      (c) the same as
9. In the summer months, the average high temperature in Phoenix is hotter than it is in Tucson. Therefore, people living in Phoenix are more susceptible to getting sunburned than people living in Tucson. (True / False)
10. Even though the industrialized nations of the world ceased production of CFCs, the ozone hole will still occur for several more decades. (True / False)
11. In the Bergeron process of precipitation formation, \_\_\_\_\_ shrink while \_\_\_\_\_ grow large enough to fall toward the ground.  
(a) liquid cloud droplets; ice crystals      (b) ice crystals; liquid cloud droplets

12. The greatest number of thunderstorms per year occurs over which area of the Earth?  
(a) Tropical oceans      (b) Mount Everest      (c) Tropical land areas      (d) Polar regions
13. Which state averages the most thunderstorms per year per square mile?  
(a) Oklahoma      (b) California      (c) Colorado      (d) Florida
14. Which state averages the most tornadoes per year per square mile?  
(a) Oklahoma      (b) California      (c) Colorado      (d) Florida
15. Which states averages the most days with hail per year per square mile?  
(a) Oklahoma      (b) California      (c) Colorado      (d) Florida
16. Thunder will not occur \_\_\_\_\_ .  
(a) without lightning  
(b) in wintertime storms when it is too cold  
(c) over the oceans or large lakes  
(d) until precipitation begins to fall from the clouds
17. On average, which ocean basin produces the most hurricanes per year?  
(a) Western North Pacific (near southeast Asia) where they are called typhoons  
(b) Eastern North Pacific (off Mexico Coast)  
(c) North Atlantic Ocean  
(d) Western South Pacific (near Australia) where they are called severe tropical cyclones
18. The peak in the Atlantic hurricane season occurs during which month?  
(a) May      (b) July      (c) September      (d) November
19. The strongest winds and heaviest rain are associated with which part of a hurricane?  
(a) The eye      (c) The eyewall  
(b) The spiral rain bands      (d) The outflow
20. No one foresaw the possibility that so many U.S. citizens could be killed by a single hurricane in today's world such as happened with Hurricane Katrina in 2005. (True / False)

21. The average number of people in the U.S. who are killed by extreme weather events each year is about the same as the number who are killed in vehicle accidents. (True / False)
22. The NY Times article “Most Deadly of Natural Disasters: the Heat Wave” reports a death toll of \_\_\_\_\_ people from the 1995 Chicago heat wave. In comparison, this is \_\_\_\_\_ people than died in the infamous Chicago Fire of 1871.  
(a) 7000 - 8000; more (c) 700 - 800; more  
(b) 7000 - 8000; less (d) 700 - 800; less
23. The stratospheric “ozone hole” occurs \_\_\_\_\_.  
(a) over Antarctica during the Northern Hemisphere spring (April-June)  
(b) over Antarctica during the Southern Hemisphere spring (Sept-Nov)  
(c) everywhere on Earth during the Southern Hemisphere spring (Sept-Nov)  
(d) everywhere on Earth during the Northern Hemisphere spring (April-June)
24. If the atmosphere is stable for lifted parcels, which of the following is most correct?  
(a) Clouds can not form  
(b) If clouds form, then they will be cumuliiform-type clouds  
(c) If clouds form, then they will be stratiform-type clouds  
(d) Only fog can form surface parcels can never rise above the ground
25. Single-cell thunderstorms only last about one hour and begin to dissipate when  
(a) lightning neutralizes all the electrical charge in the cloud  
(b) all the precipitation particles in the cloud turn to ice  
(c) downdrafts spread throughout the cloud and cut off updrafts  
(d) solar heating at the ground begins to decrease
26. There is a good deal of conclusive evidence that shows extreme weather events, such as hurricanes and tornadoes are becoming more frequent and severe in recent years, and the increase is due to global warming. (True/False)
27. Which phenomenon associated with thunderstorms was described in class as being particularly dangerous for airplane travel and the cause of several airline crashes?  
(a) Plane flying low to the ground near a microburst  
(b) Plane being struck by lightning  
(c) Plane being pelted by large hail  
(d) Plane icing over when flying through supercooled water droplets in the cloud

28. Which aspect of land-falling hurricanes is usually responsible for the most destruction?
- (a) Strong winds                      (c) Storm surge  
 (b) Heavy rains                        (d) Embedded tornadoes

Fill in the table below by lifting a parcel of air from the surface up to 4000 m above the surface, then answer the next 4 questions.

Elevation	Environmental Temperature	Parcel Temperature	Parcel Dew Point Temperature
4000 m	-8° C	-10° C	-10° C
3000 m	-1° C	-4° C	-4° C
2000 m	7° C	2° C	2° C
1000 m	14° C	12° C	2° C
0 m	22° C	22° C	2° C

29. What is the parcel temperature at 4000 m?
- (a) -18° C                      (b) -10° C                      (c) -6° C                      (d) -2° C
30. Where, if at all, will a cloud begin to form in the parcel?
- (a) As the parcel moves above 1000 m                      (c) As the parcel moves above 3000 m  
 (b) As the parcel moves above 2000 m                      (d) A cloud does not form in the parcel
31. Where, if at all, does the parcel become unstable?
- (a) When the parcel reaches 2000 m                      (c) When the parcel reaches 4000 m  
 (b) When the parcel reaches 3000 m                      (d) The parcel remains stable up to 4000 m
32. Which two changes to the **environmental temperature** will tend to make the parcel less stable or more unstable as it is lifted upward?
- (a) Cool the air at 0 m and cool the air above 3000 m  
 (b) Cool the air at 0 m and warm the air above 3000 m  
 (c) Warm the air at 0 m and warm the air above 3000 m  
 (d) Warm the air at 0 m and cool the air above 3000 m

### Short Answer Questions (Select 4 of the 7 Questions) -- 6 Points Each

Write your answers on the attached answer sheets. If you need more space, please use the back of the multiple choice answer sheet. Your answers should be short and to the point. Make sure you answer all parts of each question. **Points will be deducted for incorrect or unnecessary statements in your answer, even if the correct answer is embedded within.** Be sure to clearly indicate which 4 questions you would like graded.

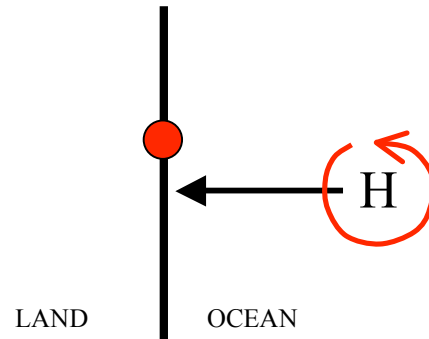
1. The Hawaiian Islands are an isolated island chain located in the warm waters of the tropical Pacific Ocean near 20° N latitude. Prevailing surface trade winds blow year round *from the northeast to the southwest*. Each island has mountains near its center. This geography and prevailing winds cause two distinct climate zones to be found on each island: a rain forest-like climate on one side each island and a desert-like climate on the opposite side. **In terms of compass directions (e.g., east, northwest, etc.), which side of each island is the wet side and which side is the dry side? Provide an explanation with your answer.**

The northeast slopes would be wet; the southwest slopes would be arid. As air parcels flow to the southwest, they would rise up the northeast slopes of the mountains, and with sufficient lifting condensation and precipitation would occur. Parcels would descent down the southwest slopes and decrease their relative humidity.

2. Describe the shapes of both stratiform and cumuliform type clouds. Relate their shape to the different conditions under which each form.

Stratiform/cumuliform clouds form where stable/unstable environmental conditions exist. Stable air parcels experience a downward buoyancy force that resists upward displacement, so any clouds are flat with a wide horizontal extent. Unstable air parcels experience an upward buoyancy force that accelerates parcels away from the ground, so clouds are narrow with a deep vertical extent.

3. A hurricane moving at 30 mph is approaching the coastline. The large H denotes the center of the hurricane. The arrow shows the direction of the storm motion and where the center of the storm will hit land. What is a “storm surge”? Where will the most severe storm surge occur (indicate on the diagram)? Why? Name at least two factors that influence the damage potential for the storm surge.



A storm surge is an abrupt rise in the level of the sea associated with strong coastal storms like hurricanes. The highest surge is located at the point slightly downwind of fastest *onshore* winds. The fastest winds for a hurricane are located where the fastest tangential wind (eyewall) and translational speed of the storm positively superimpose (both point in the same direction). If the circular arrow denotes the position of the eyewall, then the arrowhead is positioned at that point of positive superposition. *The red dot marks the location that would have the highest surge.* Major factors that influence damage are the net rise in the water level, the height of the waves, and the slope of the shoreline and coastal sea floor, which affects surge height and how far inland the surge can penetrate.

4. A large thunderstorm develops about 20 miles south of Tucson. Although Tucson does not get any rain, strong 40 mph winds from the south occur about a half an hour after rain began to fall from the thunderstorm to the south. **What is the cause of the strong winds in Tucson? Explain how the winds develop.**

The Tucson winds are produced by the outflow from the downdraft of the thunderstorm. When a thunderstorm downdraft hits the ground, surface air will rapidly diverges away from underneath the thunderstorm. The divergence causes the outflow. Hence a thunderstorm south of Tucson would produce southerly (i.e. from the south) winds. Depending on strength and persistence of the thunderstorm, outflows winds can propagate more than 100 km away from the point of generation.

5. Why is there concern about the amount of ozone in the stratosphere? Briefly discuss how human activity has influenced the amount of ozone in the stratosphere. What is the future outlook for ozone levels in the stratosphere? Explain your answers.

Stratospheric ozone is the gas that absorbs radiation with wavelengths between 0.2-0.3 microns and thus prevents the penetration of harmful UV radiation to the ground. Human have released a specific family of trace gases, chlorofluorocarbons (CFC) that can reside in the atmosphere for up to 100 years. Through complex chemical interactions that can only occur at temperatures below -85 to -90 degrees Celsius, chlorine from CFC molecules becomes a catalyst that destroys ozone. The future outlook is for ozone levels to gradually recover back to 1900 levels within the next 100 years.

6. Although the number of deaths in the United States caused by hurricanes has decreased in recent decades, the dollar cost of damage has increased significantly. Explain the reasons for these opposing trends.

As our ability to predict hurricanes has greatly improved over recent decades, emergency managers are now able to order pinpoint evacuations with sufficient lead-time (24 to 48 hours) to get millions safely out of harms way. However, with rampant population growth along hurricane prone coastlines comes rampant development. Appreciation of buildings, homes, property values and the cost of building supplies to repair/replace the damage is the other major contributing factor.

7. A picture of a mature thunderstorm is shown. Answer each of the parts below. Parts (a)-(d) do not require an explanation; part (e) requires a short explanation.

(a) What is the name of this type of cloud?

Cumulonimbus if it is producing precipitation, otherwise (towering) cumulus. (Either answer is marked correct.)

(b) What is the name of the portion of the cloud labeled with A's?

Anvil

(c) What two main types of cloud particles are found in region B where the temperature is between  $0^{\circ}\text{C}$  and  $-40^{\circ}\text{C}$ ?

Ice and supercooled droplets

(d) A region of negative charge will most likely be found in region A or B?

B, the bottom of cloud

(e) This thunderstorm contains both updrafts and downdrafts. Based on the diagram, where are updrafts most likely occurring, in the left or the right half of the cloud? How do you know?

Left. The isotherms are at higher elevation on the left side, consistent with an updraft pushing them upward.

