

ATMO 336 -- Exam 1 (110 possible points)

Name: _____

The following equations and relationships may prove useful.

$$F_{d1} = F_{d2} \left(d_1^2 / d_2^2 \right) \text{ (Inverse Square law);}$$

$$\lambda_{\text{MAX}} = \frac{0.29 \times 10^4 \mu\text{mK}}{T} \text{ (Wien's Displacement law);}$$

$$E = \sigma T^4 \text{ (Stefan-Boltzmann law);}$$

$$T_{\text{SFC}} = \sqrt[4]{\frac{(1-A)S_o}{4\sigma(1-\epsilon/2)}} \text{ (one-level atmosphere, climate model);}$$

where d is distance, T is temperature, S_o = solar radiant flux (1368 Wm^{-2}), A=albedo, ϵ =emissivity and $\sigma=5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$.

Multiple Choice Questions (Answer All 45 Questions) -- 2 Points Each.

- The two gases that are mainly responsible for the atmospheric greenhouse effect are _____.
(a) nitrogen and oxygen (c) oxygen and ozone
(b) carbon dioxide and ozone (d) carbon dioxide and water vapor
- Which two gases are most abundant in the Earth's atmospheric?
(a) nitrogen and oxygen (c) oxygen and ozone
(b) carbon dioxide and ozone (d) carbon dioxide and water vapor
- If the temperature of an object doubles, then the wavelength of maximum radiation that is emitted by the object would _____.
(a) increase by a factor of 2 (b) decrease by a factor of 2 (c) increase by a factor of 16 (d) decrease by a factor of 16
- If the temperature of an object doubles, then the total radiation that is emitted by the object would _____.
(a) increase by a factor of 2 (b) decrease by a factor of 2 (c) increase by a factor of 16 (d) decrease by a factor of 16
- If an air parcel's temperature remains constant but its density doubles, then its pressure would _____.
(a) increase by a factor of 2 (b) decrease by a factor of 2 (c) increase by a factor of 16 (d) decrease by a factor of 16
- Which process cools the surrounding environment?
(a) condensation (Gas \rightarrow Liquid) (b) evaporation (Liquid \rightarrow Gas) (c) deposition (Gas \rightarrow Vapor)
- When you can "see your breath" on a cold morning, you are seeing an air parcel that contains _____.
(a) a high concentration of water vapor coming from your mouth (c) a high concentration of CO_2 coming from your mouth
(b) a low concentration of O_2 coming from your mouth (d) tiny droplets of liquid water

8. Why does a metal object at room temperature (70° F) often feel colder to the touch than a wooden object at a same temperature?
 (a) Metal is a better heat conductor than wood (c) Metal is a better radiator than wood
 (b) Wood is a better heat conductor than metal (d) Wood is a better heat convector than metal
9. On a given day, the wind chill equivalent temperature in Chicago IL is lower than it is in Boston MA. Which of the following MUST be true?
 (a) The air temperature in Chicago is lower than it is in Boston
 (b) The wind speed in Chicago is faster than it is in Boston
 (c) The rate of heat loss from the human body is slower in Chicago than it is in Boston
 (d) The rate of heat loss from the human body is faster in Chicago than it is in Boston
10. 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
11. The peak in the Atlantic hurricane season occurs during which month?
 (a) May (b) July (c) September (d) November
12. 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
13. If the air temperature is 60° F and the dew point temperature is 30° F, what percentage of the air is composed of water vapor?
 (a) 50% (b) 30% (c) less than 4 %

Use the table of saturation mixing ratios to answer the next two questions. This is the same table you used in homework #3.

Temperature (°F)	Saturation Mixing Ratio (g/kg)	Temperature (°F)	Saturation Mixing Ratio (g/kg)
5	1.21	55	9.32
10	1.52	60	11.19
15	1.89	65	13.38
20	2.34	70	15.95
25	2.88	75	18.94
30	3.54	80	22.43
35	4.33	85	26.48
40	5.28	90	31.16
45	6.40	95	36.56
50	7.74	100	42.78

14. If the air at a temperature of 100° F and a dew point temperature of 60° F, then the relative humidity would be closest to?
 (a) 16% (b) 26% (c) 36% (d) 46%
15. If the air temperature is 70° F and the relative humidity is 85%, then the dew point temperature would be closest to?
 (a) 35° F (b) 45° F (c) 55° F (d) 65° F

16. 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)
17. 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 [credit for (a) too] (c) 700 - 800; more
 (b) 7000 - 8000; less (d) 700 - 800; less
18. 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
19. 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 3 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

20. 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
21. 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
22. 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

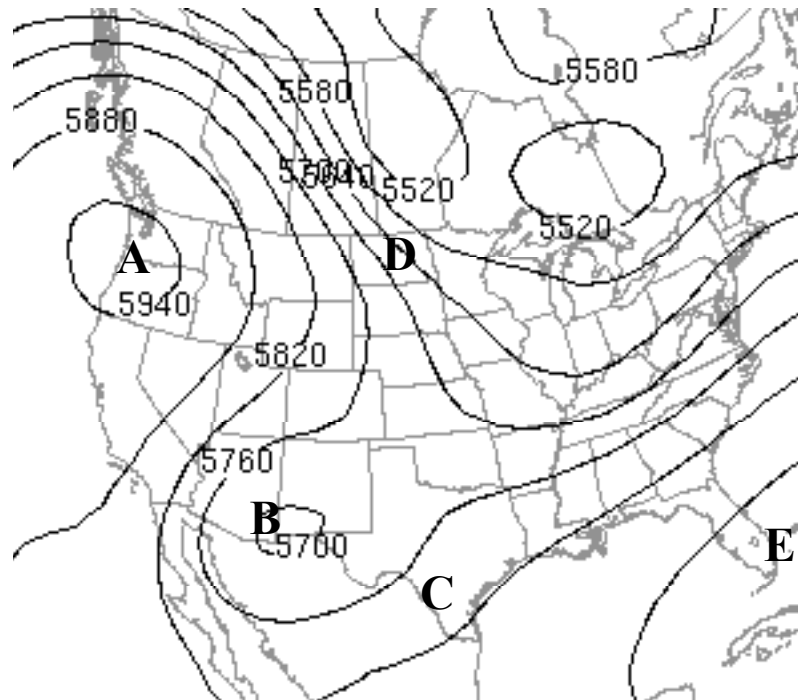
23. The stratospheric “ozone hole” occurs _____.
- (a) over Antarctica during the Northern Hemisphere spring (April-June)
 - (b) over Antarctica during the Southern Hemisphere spring (Sept-Nov)
 - (c) everywhere on Earth during the Southern Hemisphere spring (Sept-Nov)
 - (d) everywhere on Earth during the Northern Hemisphere spring (April-June)
24. Our simple, one-layer atmospheric climate model was constructed from which combination of assumptions and laws?
- (a) Radiative equilibrium and the Stefan-Boltzmann Law
 - (b) Convective equilibrium and Wien’s Displacement Law
 - (c) Conservation of energy and the Inverse Square law
 - (d) Conservation of mass and Newton’s Laws
25. The source of essentially all atmospheric O₂ on Earth is _____.
- (a) volcanic emissions
 - (b) photosynthesis
 - (c) disassociation of water
 - (d) disassociation of stratospheric ozone
26. Most of the radiation energy that escapes from the planet Earth to outer space is emitted by _____.
- (a) the Earth’s surface
 - (b) the Earth’s interior
 - (c) gases and clouds in the atmosphere
27. Which region on Earth emits the most radiation energy to space per square kilometer of surface area?
- (a) Polar regions
 - (b) Mid-latitude regions
 - (c) Tropical regions
28. Most climate models predict that by the year 2100, the Earth’s global average temperature will increase somewhere in the range of _____.
- (a) (1 – 4)° C
 - (b) (6 – 10)° C
 - (c) (10 – 15)° C
 - (d) (40 - 50)° C
29. As the global temperatures warm, sea surface temperatures will _____ and hurricanes should _____ in both frequency and intensity.
- (a) cool; increase
 - (b) cool; decrease
 - (c) warm; increase
 - (d) warm; decrease
30. If we assume that global warming does occur, the outcome (of the choices given) that we are most certain will occur is _____.
- (a) the number of hurricanes will increase
 - (b) farming production in the U.S. will decline (too hot), but harvests in Canada and Russia will increase (longer growing season).
 - (c) tropical diseases will spread farther away from the equator
 - (d) sea level will rise
31. Since 1900, the global average surface temperature has _____.
- (a) risen steadily to be about 0.6° C warmer today
 - (b) fluctuated up and down, but overall it is about 0.6° C warmer today
 - (c) fluctuated up and down, but overall it is about the same today
 - (d) declined steadily to be about 0.6° C cooler today

32. The most recent ice age cycles on Earth (over the last two million years) were most likely triggered by _____.
(a) changes in the positions of the continents
(b) decreases in the energy output of the Sun
(c) volcanic eruptions that eject massive amounts of aerosols into the atmosphere
(d) variations in Earth's orbit around the Sun
33. Ice core samples from Antarctica are used to estimate changes in surface temperatures and the atmospheric concentrations of carbon dioxide and methane. The data indicate that when temperatures are relatively warm, levels of carbon dioxide and methane are _____.
(a) relatively high (positive correlation)
(b) relatively low (negative correlation)
(c) sometimes high, sometimes low (no correlation)
34. A land bridge connecting Asia and Alaska formed during an _____ when sea levels were _____.
(a) interglacial warm period ; much lower than today
(b) interglacial warm period ; much higher than today
(c) ice age ; much lower than today
(d) ice age ; much higher than today
35. Which condition appears to be the most important seasonal factor that initiated Pleistocene glacial periods in the Northern Hemisphere?
(a) cooler summers (b) cooler winters (c) warmer summers (d) warmer winters
36. The onset of snowball earth episodes and ice age glacial periods is an example of the _____ feedback.
(a) icehouse-greenhouse (b) ice-albedo (c) wind-evaporation (d) clouds-temperature
37. The most rapid rise increase in the concentration of carbon dioxide in the atmosphere occurred during which period?
(a) 1860-1900 (b) 1900 – 1940 (c) 1940 – 1980 (d) 1980 – today
38. The atmospheric greenhouse effect exists because _____.
(a) the atmosphere is opaque to both incoming solar radiation and outgoing infrared radiation
(b) the atmosphere is transparent to both incoming solar radiation and outgoing infrared radiation
(c) the atmosphere is transparent to incoming solar radiation but opaque to outgoing infrared radiation
(d) the atmosphere is opaque to incoming solar radiation but transparent to outgoing infrared radiation
39. According to the NOVA video “Dimming of the Sun”, the atmospheric pollution layer can cut down the amount of sunlight that hits the Earth’s surface by approximately _____.
(a) 1% (b) 10% (c) 30% (d) 50%
40. According to the NOVA video “Dimming of the Sun”, if we continue to decrease the level of particle pollutants while pumping more greenhouse gases into the atmosphere, temperatures could rise another _____ over current projections by mid-century (2050).
(a) 0-1° C (b) 2-3° C (c) 4-5° C (d) 6-7° C

41. The globally averaged albedo of the earth is presently closest to what value?
(a) 10% (b) 30% (c) 50% (d) 70%

Use the five points labeled A, B, C, D and E on the 180-hour forecast of 500 mb height for 0600 UTC May 16, 2008 to answer the following four questions.

42. Which point is located under a trough? **B** (By far, the best choice. It is located in the largest negative height anomaly.)
43. At which point would you expect the warmest temperatures? **A** (Location of the highest heights anomaly)
44. At which point would you expect strong northwesterly winds? **D** (Location with a height gradient to support NW geostrophic winds)
45. At which point would you expect the best chance for precipitation? **C** (Downwind of the trough)



Short Answer Questions (Answer two of next three questions) -- 10 Points Each

Write your answers on the attached blank sheet(s). Let us know if you need more paper. Your answers should be concise and to the point. No more than a few sentences (2 or 3) should be needed. 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 found somewhere.** Use legible penmanship; if the graders can't read it, then they can't (and won't) award credit. Be sure to clearly indicate which two questions you would like graded.

1. Astronomical physicists estimate that 4 billion years ago (4 Gya) the sun was 30% less intense than it is today; this means that the climate should have been 25°C colder than the current temperature. Yet the earth's oldest rocks (4 Gya) indicate that the terrestrial climate was warm enough to support an abundance of water, i.e. the temperature was at least as warm as it is today. Geologists also know that internal heating from the Earth's interior was much too weak to account for even a small fraction of the necessary difference. This apparent contradiction between solar models and the geological record is known as the *Faint Young Sun* paradox. Use your knowledge of the history of the ancient atmosphere and climate dynamics to put forth a sound solution that can account for this apparent paradox.

If the atmosphere 4 Gya was both denser and contained more greenhouse gases than it does today, then it could support surface temperature as warm or warmer than the current value despite a much weaker sun. Proxy data and chemical reactions that can occur in an atmosphere with no free O₂ suggest that methane levels, a GHG more powerful than CO₂, were much higher than today. Of course, solar theory could be in error, and the ancient sun was about as bright as it is today.

2. Commercial passenger jets typically cruise at altitudes near 36,000 ft, which is approximately 11 km. When traveling by commercial jet, it is common to hear the pilot or attendant announce, "The cabin has been pressurized for your comfort." Cabin pressure is typically near 800 mb. The temperatures outside are typically -60° C.

(a) Compute the pressure outside of the cabin at cruising altitude? (Hint: the altitude of the 500 mb surface is near 5.5 km).

The decrease in atmospheric pressure with increasing altitude has a logarithmic profile. The hint shows that the atmospheric drops by a factor of two with every 5.5 km increase in altitude. An additional 5.5 km increase in elevation equates to another factor of two decrease. Therefore, the pressure at 11 km would be close to 250 mb.

(b) As fresh air outside the cabin is exchanged for oxygen-deprived air inside, the outside air must be pressurized. Why?

An atmospheric pressure of 250 mb contains too little oxygen to support respiration in humans. If a person were subjected to pressures that low, he/she would quickly pass out owing to lack of oxygen and shortly thereafter die.

(c) Health experts recommend that passengers drink a lot of water prior to and during the flight. Why?

The outside air, even if it is saturated, is essentially bone dry because the saturation vapor pressure over ice zero at -60° C is near. As the air is pressurized and becomes warmer, its relative humidity would drop to a value near zero. Under such conditions, even healthy people at rest can quickly become dehydrated. (Thankfully, the air inside the cabin is also humidified a small amount via expiration from fellow passengers.)

3. The air temperature in your kitchen is 76°F and the relative humidity is 25%. You wet a rag under the faucet and squeeze out the excess water, leaving the rag damp. At first the temperature of the rag is the same as the water, which is 66°F .

(a) Name one process that will tend to warm the rag.

Conduction since the environmental air is 10°F warmer than the water/rag temperature.

(b) Name one process that will tend to cool the rag.

Evaporation since the relative humidity of 25% would correspond to a wet-bulb temperature well below 66°F .

(c) At first, which will likely win out? In other words, at first, will the rag warm up or cool down? Why?

Evaporation would likely win out. It takes a lot of energy to evaporate one gram of water (540 cal/gm), and air near the rag energy supplies the energy. The dominance of evaporation is the reason why swamp coolers can work so well. Conduction, on the other hand, is not an efficient mechanism for heat transport in the earth's atmosphere.