Purdue Science Olympiad 2016 Regional Tournament
Meteorology Test Answer Key
Created by Peter Cattani

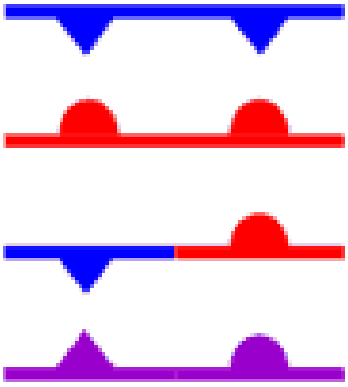
1. List the layers of the atmosphere, from closest to the surface to furthest into space. (2 pts)
    a. **Troposphere, Stratosphere, Mesosphere, Thermosphere, Exosphere (2 pts)**
    OR Troposphere, Stratosphere, Mesosphere, Ionosphere (2 pts, no partial credit)
2. Briefly describe a main reason why the atmosphere is thicker at the equator than the poles. (2 pts)
    a. The air at the equator is warmer and thus less dense, which means the same mass of air takes up more space (2pts)
3. What are the 2 main components of the atmosphere, and what percent of the volume does each account for? (2 pts)
    a. Nitrogen (78%) (1 pt for 77-79) and Oxygen 21% (1 pt for 20-22).
4. Which one of the following items is not considered a pollutant? Circle the correct answer. (2 pts)
    a. Nitrogen Oxides
    b. Ozone
    c. Carbon Monoxide
    d. Argon
    a. Argon is not a pollutant. (2 pts)
5. Which region of the atmosphere contains the ozone layer? (2 pts)
    a. The stratosphere (2 pts)
6. In which layer of the atmosphere to most weather patterns occur? (2 pts)
    a. **The troposphere (2 pts)**
7. Is the temperature hotter at the bottom or the top of the mesosphere? (2 pts)
    a. **The temperature is hotter at the bottom of the mesosphere. (2 pts)**
8. About what percent of incoming solar radiation is reflected directly back to space by the atmosphere? (2 pts)
    a. **30% (2 pts for 27-33)**
9. Briefly define conduction, convection, and radiation. Give one example of each. (6 pts)
    a. Conduction is heat transfer from two substances that are touching, or heat transfer within a substance (1 pt). Heat is transferred by direct molecular contact. Radiation is heat transferred by radiation (1 pt). Convection is heat transfer in a fluid due to internal flow (1 pt). Examples: Answers will vary, 1 pt each.
10. What are beam spreading and beam depletion, and how does each contribute to the effects of seasons? (3 pts)
    a. **Beam spreading is when sunlight approaches the earth at a steep angle, a wider area is illuminated but the intensity of the radiation is reduced. (1 pt) Beam depletion occurs when sunlight enters the atmosphere at a steep angle. It must travel a greater distance through the atmosphere, and more energy is dissipated in this process, so the beam is depleted (1 pt). Both of these effects are pronounced in winter when there is less direct sunlight, and contribute to the part of the globe facing away from the sun receiving less energy (1 pt).**
11. Which of the following gasses is a greenhouse gas? (2 pts)
    a. Water vapor

b. Nitrogen
c. Argon
d. Hydrogen
a. **Water vapor (2pts)**

12. How does the tilt of the earth lead to seasons? (2 pts)
    a. **The part of the earth tilted towards the sun gets sunlight at a more direct angle. This reduces the effects of beam spreading and tilt, and means more radiation reaches the part of the earth tilted toward the sun. Additionally, the parts tilted toward the sun experience longer days that the parts that face away. (2 pts for valid reasons)**
13. What causes coastal regions to have more temperate climates than nearby inland regions? (3 pts)
    a. **Water has a very high heat capacity (1 pt), so it takes a lot of energy to change its temperature. This means that it is both harder to warm up and cool down, and so the temperature of the water doesn't change as much as land (1 pt). The water will transfer heat to and from nearby land, which keeps the land at a moderate temperature (1 pt).**
14. Define sensible and latent heat. (2 pts)
    a. **Sensible heat is heat that causes a change in temperature (1 pt), latent heat is heat that leads to a change in the state of a substance but doesn't change the temperature (1 pt).**
15. Why does hot air rise and cold air fall? (2 pts)
    a. **The particles in hot air have more energy, causing them to take up more space. This makes hot air less dense than cold air (1 pt). The denser cold air will displace the less dense hot air, which will be forced up (1 pt).**
16. What is an air mass? (2 pts)
    a. **An air mass is a mass of air with fairly uniform characteristics (1 pt) for temperature and humidity and density (1 pt).**
17. How would you describe an air mass that contained warm, moist air? (1 pt)
    a. **Maritime, tropical (1 pt)**
18. What is atmospheric stability? (1 pt)
    a. **The resistance of the atmosphere to vertical motion. (1 pt)**
19. What is advection? (2 pts)
    a. **Advection is the horizontal (1 pt) transfer of heat, mass or some other property (1 pt).**
20. What is the difference between specific humidity and relative humidity? Which one is measured in percents? (3 pts)
    a. **Specific humidity is the mass of the water vapor in a fixed mass of air (1 pt). Relative humidity is the amount of water vapor relative to the amount required for saturation at the current temperature and pressure (1 pt). Relative humidity is measured in percents (1 pt).**
21. What does the dew point mean? (2 pts)
    a. **The dew point is the temperature that the air at ground level would need to be cooled to for the relative humidity to reach 100% (1 pt) with no change in water content or pressure (1 pt).**
22. How do most clouds form? (2 pts)

a. **Warmer air near the surface rises due to its density. This leads to expansion and then cooling of the air (1 pt). The cooler air holds less water, so the water condenses on little particles in the air. When enough tiny droplets condense on particles in the air, a visible cloud is formed. (1 pt)**

23. Describe the process in which sleet forms. (3 pts)
    a. **Sleet begins as snowflakes (1 pt), then falls through a layer of warmer temperatures where it melts into raindrops (1 pt), then finally enters a layer of below freezing temperatures in the last few thousand feet above the ground. The precipitation reaches the ground and small frozen pellets (1 pt).**
24. What is the difference between freezing fog and ice fog? (2 pts)
    a. **Ice fog occurs when fog is composed of ice crystals (1 pt). Freezing fog is fog that is a supercooled liquid that freezes upon contacting object below freezing (1 pt).**
25. In the atmosphere, are vertical or horizontal changes in pressure usually larger? (1 pt)
    a. **The vertical pressure gradient is steeper (1 pt).**
26. Label the fronts in the picture below. (4 pts)



_____

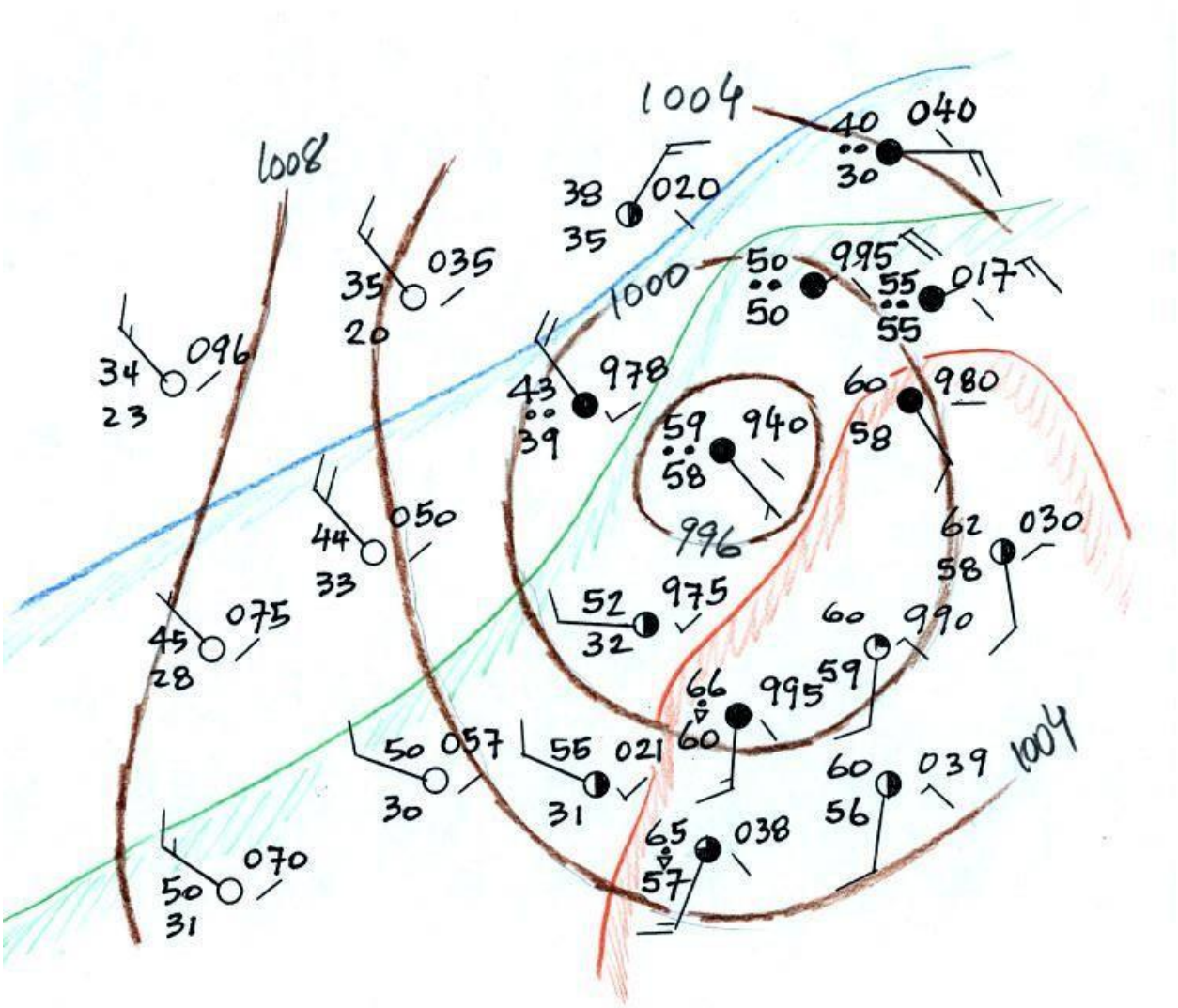
_____

_____

_____

    a. **Top to bottom: Cold, warm, stationary, occulded (1 pt each)**
27. Is rising air associated with the center of a low pressure system or a high pressure system? (1 pts)
    a. **Rising air occurs at the center of a low pressure system. (1 pts)**
28. Are cloudy and rainy conditions associated with high or low pressure systems? (1 pt)
    a. **Low pressure systems. (1 pt) Rising air causes air to cool and water to condense.**

29. Is this system a high or low pressure system? How can you tell? (2 pts)



a. The system is a low pressure system (1 pt) because the pressure is smallest in the center of the feature (1 pt).

30. Is the feature in the question above found in the northern or southern hemisphere? How can you tell? (3 pts)

a. The system is in the northern hemisphere (1 pt) because the wind flags show the air spiraling in counter-clockwise (1 pt), the direction wind moves in cyclones in the northern hemisphere (1 pt).

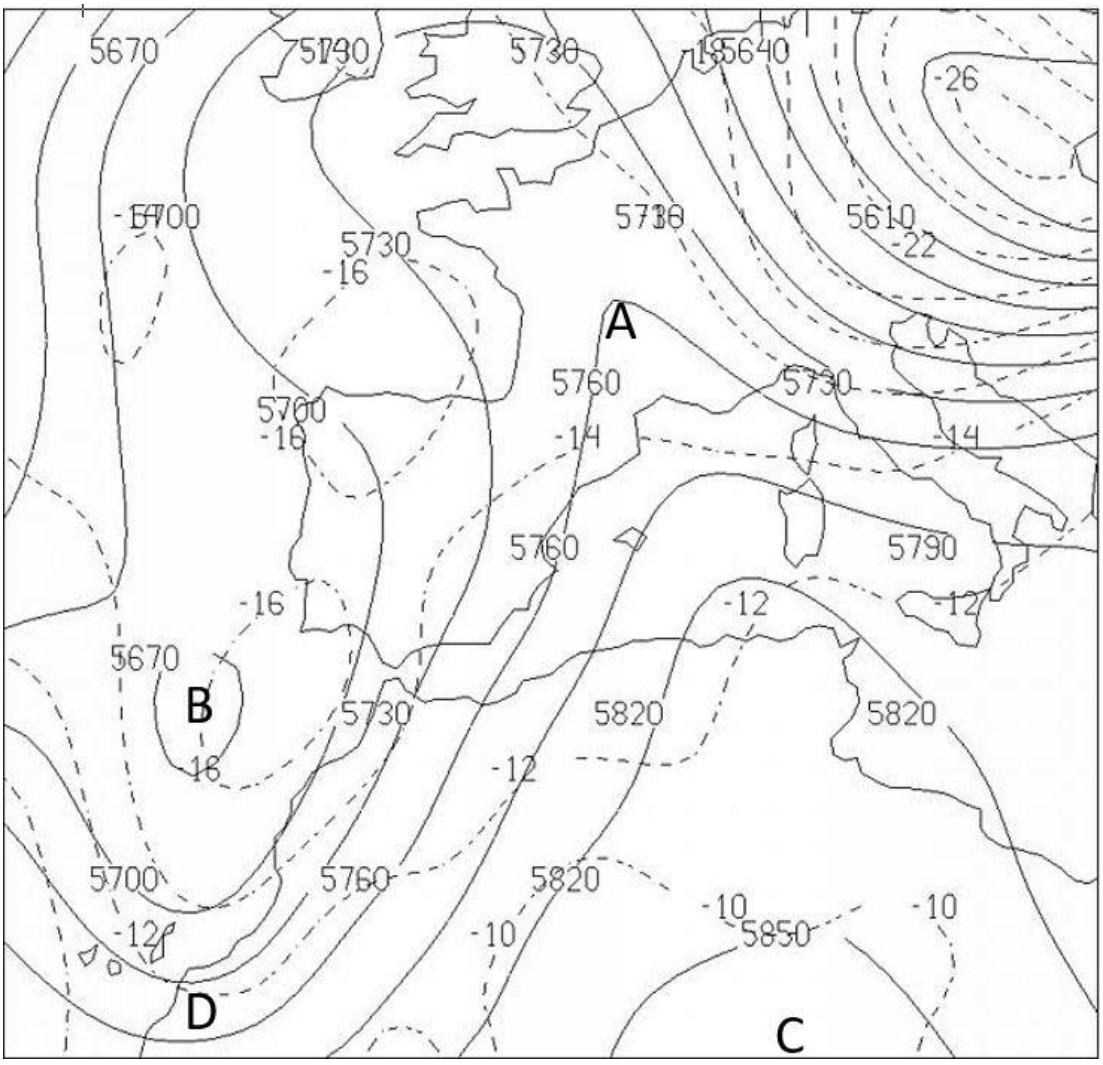
31. Match the features listed below with their locations on the following map with isobars. Use terms from this list: Polar cell, high, low, warm front, cold front, trough, ridge, jet stream. For each letter, pick the feature it best describes. The isobars are the solid lines. (4 pts)

A: _____

B: _____

C: _____

D: _____



    a. **A = ridge, B = low, C = high, D = trough (1 pt each)**
32. What atmospheric circulation pattern carries air upward near the equator and back downward about 30 degrees latitude North and South of the equator? (1 pt)
    a. **The Hadley Cell. (1 pt)**
33. What is the Coriolis Effect and why does it occur? (3 pts)
    a. **The Coriolis Effect is the apparent deflection of objects moving along the surface of the Earth. (1 pt) It occurs because the coordinate system of earth is a moving reference frame (1 pt), so the surface of Earth slides underneath as objects in the atmosphere continue on a straight path causing the objects to appear to deflect when viewed from earth's surface (1 pt).**
34. Why does the wind near the ground move slower than wind in the upper atmosphere? (1 pt)
    a. **Friction slows down air moving near the surface. (1 pt)**
35. What is the name for wind that is blowing parallel to isobars? (1 pt)
    a. **Geostrophic wind (1 pt)**
36. Which jet stream is stronger: polar jets or subtropical jets? (1 pt)
    a. **Polar jets (1 pt)**

37. Match the following terms with their descriptions (8 pts).

Terms:
Santa Ana winds Chinook winds Foehn winds Sea breezes Nor'easter
Mountain breeze Alberta Clippers Panhandle hook

a. A low pressure area that travels just off the coast of New England bringing the region heavy precipitation and strong wind. (Label each below)

b. A low pressure system that moves out of southwest Canada and brings cold weather, strong winds, and light snow to the Midwest and Great Lakes region.

c. A wind pattern that occurs at night where cool air moves to replace warmer air.

d. A wind pattern that occurs during the day where cooler air moves to replace warmer air.

e. A wind pattern caused by air being pushed from higher ground inland to lower ground towards the coast. As the wind sinks it becomes dry and hot, accelerates as it squeezes through mountains, and reaches the coast as strong winds of hot, dry air.

f. A low pressure system that forms in winter as Pacific air dips down after crossing the Rocky Mountains. The low pressure systems attract moisture from the gulf, then hook northward, bringing large quantities of snow to the upper Midwest and Great Lakes.

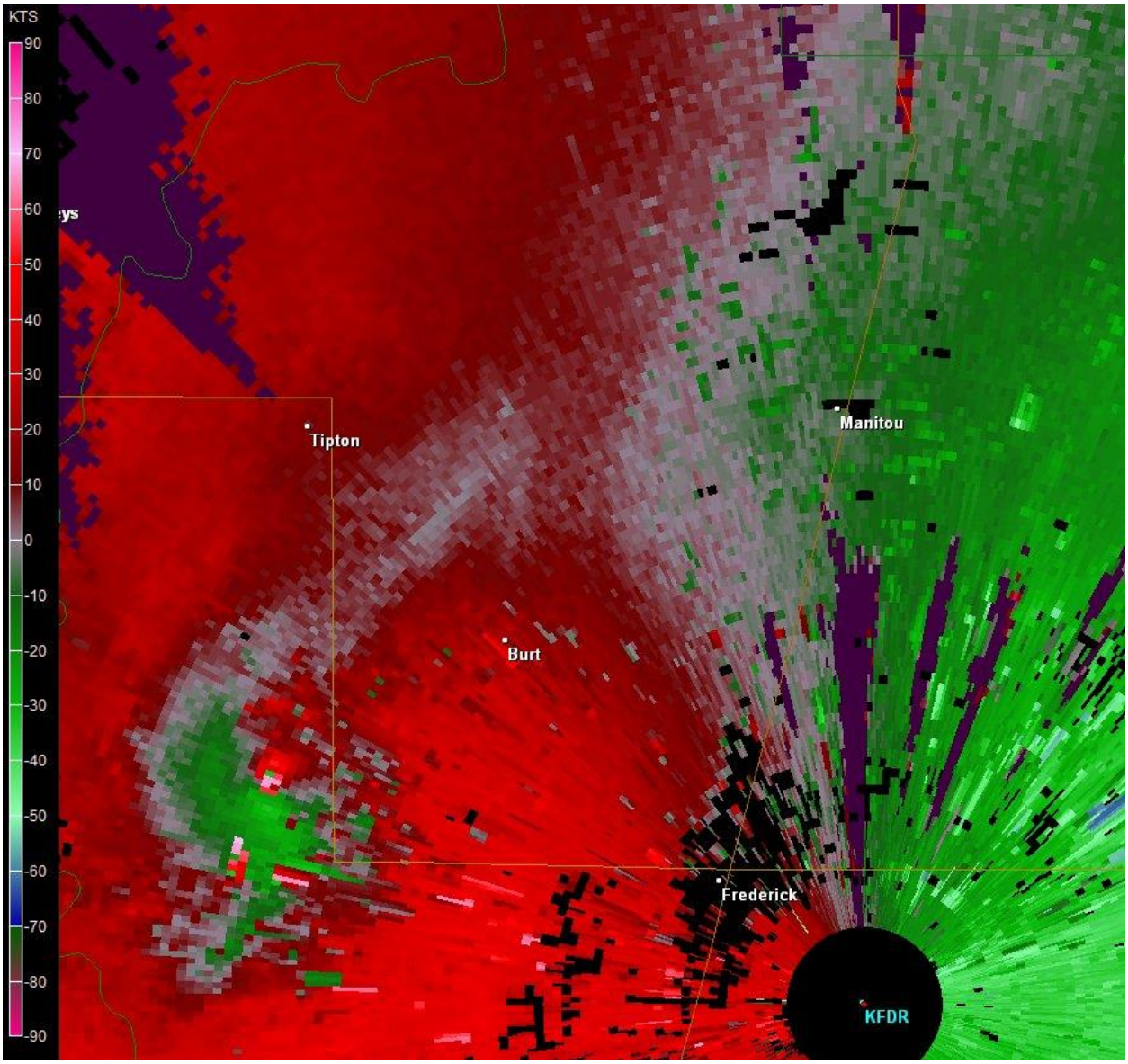
g. Air from the Pacific travels over the Rocky Mountains and dries out, then warms a lot as it descends just east of the Rockies. Regions just east of the Rockies see temperatures rise substantially.

h. Generic term for winds that bring warm and dry air to the leeward side of a mountain range.

a. Nor'easter, Alberta Clipper, Mountain breeze, sea breeze, Santa Ana winds, Panhandle Hook, Chinook winds, Foehn winds

38. What does an anemometer measure? (1 pt)
    a. **Wind speeds (1 pt)**
39. What is a radiosonde and how is it different from a rawinsonde? (2 pts)
    a. **A radiosonde measures weather in the upper atmosphere (1 pt), collecting data about pressure, temperature, and relative humidity (1 pt). A rawinsonde is similar but also collects information about wind speed and direction (1 pt).**
40. How is Doppler radar different from regular radar? (2 pts)
    a. **Regular radar detects the position of objects (1 pt), Doppler radar can detect not only position but also velocity of objects (1 pt).**
41. What are Rayleigh scattering and Mie scattering, and which type is responsible for the blue appearance of the sky? (3 pts)
    a. **Rayleigh scattering is scattering that occurs when the particles in the atmosphere are much smaller than the wavelength of the radiation passing through them (1 pt). Mie scattering occurs when the particles are about the same size as the wavelength of the radiation (1 pt). Rayleigh scattering is the type of scattering that makes the sky appear blue because the small particles deflect the shorter wavelengths (blues) more than the longer wavelengths (red). (1 pt for Rayleigh)**

42. In the following Doppler image of radial velocity, conditions for what weather event are present in the lower left corner of the image, and how can you tell? (2 pts)



a. **There is a possibility of a tornado (1 pt). Parts of the storm are moving towards the sensor and away from the sensor in close proximity, meaning there are swirling winds, conditions for a tornado (1 pt).**

43. What layer of the atmosphere do aurora occur in? (2 pt)
    a. **The ionosphere (2 pt) OR thermosphere (1 pt)**
44. What is the name for precipitation that does not reach the ground due to evaporation or sublimation? (1 pt)
    a. **Virga (1 pt)**
45. What is the phenomenon in the picture below and what is the cause of this phenomenon? (2 pts)

a. The image shows crepuscular rays (1 pt), which are caused by dust in the atmosphere scattering sunlight into shaded regions (1 pt).

46. What is the phenomenon in the figure below, and what conditions cause it? (2 pts)

    a. **The figure shows parhelion/sundogs (1 pt). They appear due to refraction of the sun's rays by ice crystals in the upper atmosphere (1 pt).**

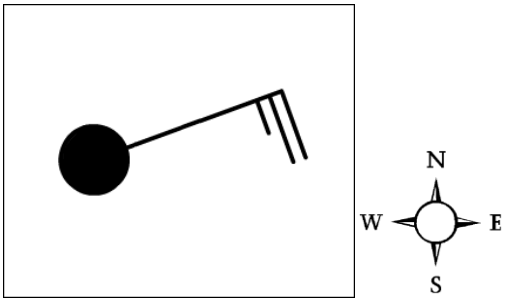
47. What does a wind chill temperature mean? (2 pts)
    a. **Wind chill refers to how cold the temperature feels based on the temperature and the wind speed (1 pt for feels, temperature, and wind). The wind chill temperature is the temperature with no wind at which a person would lose heat at the same rate as current conditions with wind (1 pt for heat loss rate).**
48. What does a heat index temperature mean? (2 pts)
    a. **The head index measures how hot a temperature feels based on the temperature and humidity (1 pt for feel, temperature, and humidity). The heat index represents how fast a person can lose heat by sweating in current conditions as compared to a defined standard humidity and temperature (1 pt for heat loss rate).**

49. How many heating degree days are in the following week? Assume the desired temperature of a building is 70 degrees Fahrenheit. Show work. (3 pts)

    Average Outside Temperature (Fahrenheit):
    Monday: 53
    Tuesday: 46
    Wednesday: 35
    Thursday: 37
    Friday: 41
    Saturday: 49
    Sunday: 43

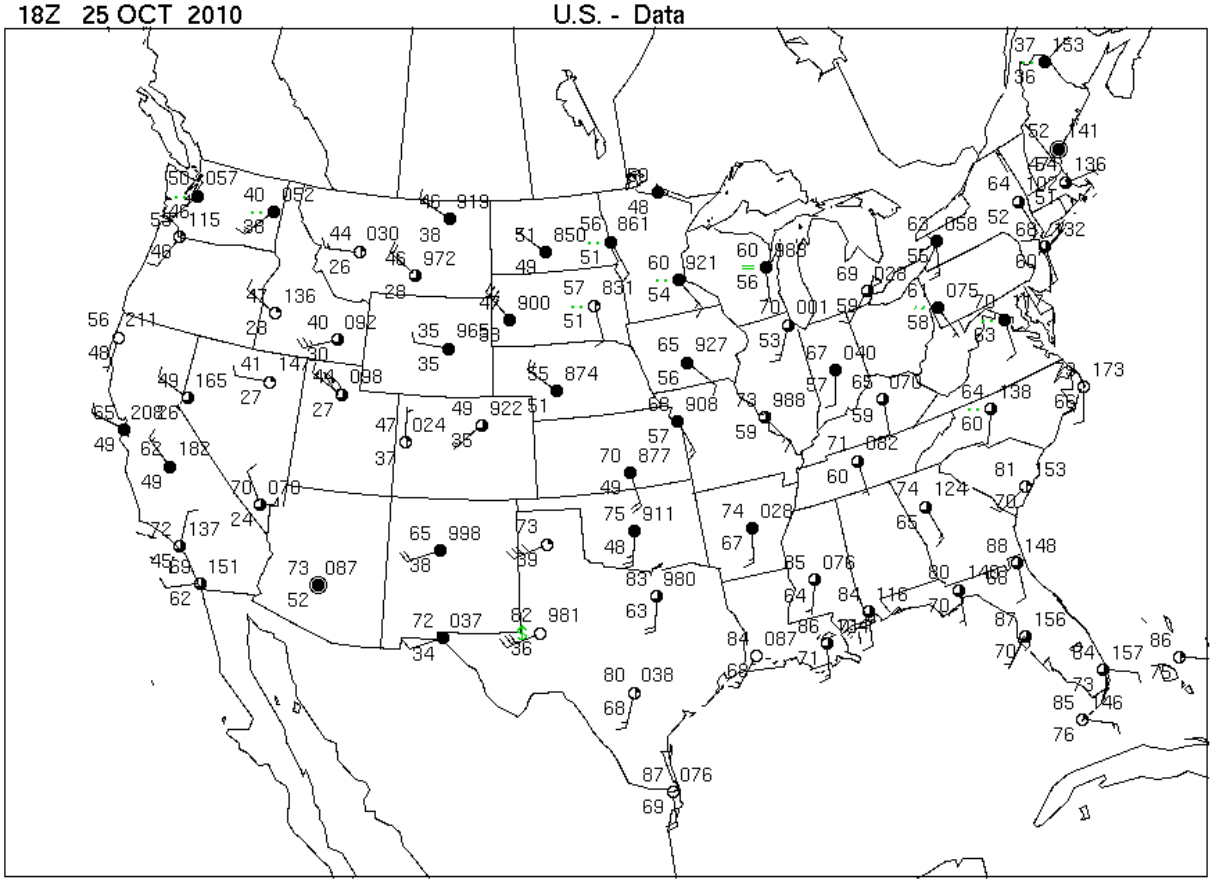
    a. **Monday (70-53= 17degrees * 1 day = 17HDD), Tuesday = (70-46 = 24 HDD), W = 35, TH = 33, F = 29, SA = 21, SU = 27. Sum up each day of the week => 186 Heating degree days. (1 pt for subtracting daily temps from 70, 1 pt for at least 4 days calculated correctly, 1 pt for answer of 186)**

50. Based on the following station model, how strong is the wind in knots, and which direction is it coming from? Additionally, is the weather sunny or cloudy? (3 pts)



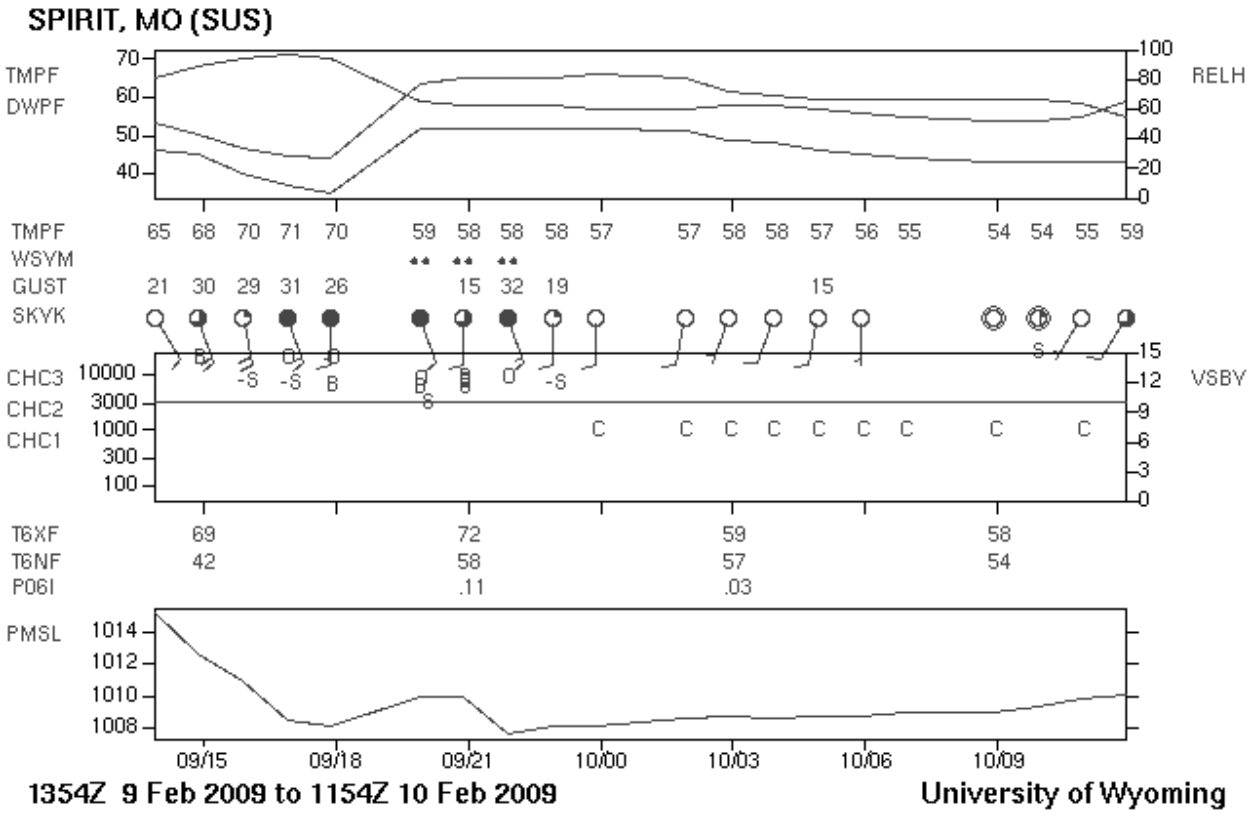
    a. **The wind is 25 knots (1 pt) from the Northeast (1 pt for NE). As the circle is filled in completely, it is overcast (1 pt for cloudy).**

51. Based on the following surface map, what is the temperature, cloud cover, wind direction, and wind speed in Indianapolis? (4 pts)



a. It is 67 degrees F (top left number) (1 pt), it is overcast (filled in circle)(1 pt), wind speed is 10 knots (1 pt) from the South (1 pt).

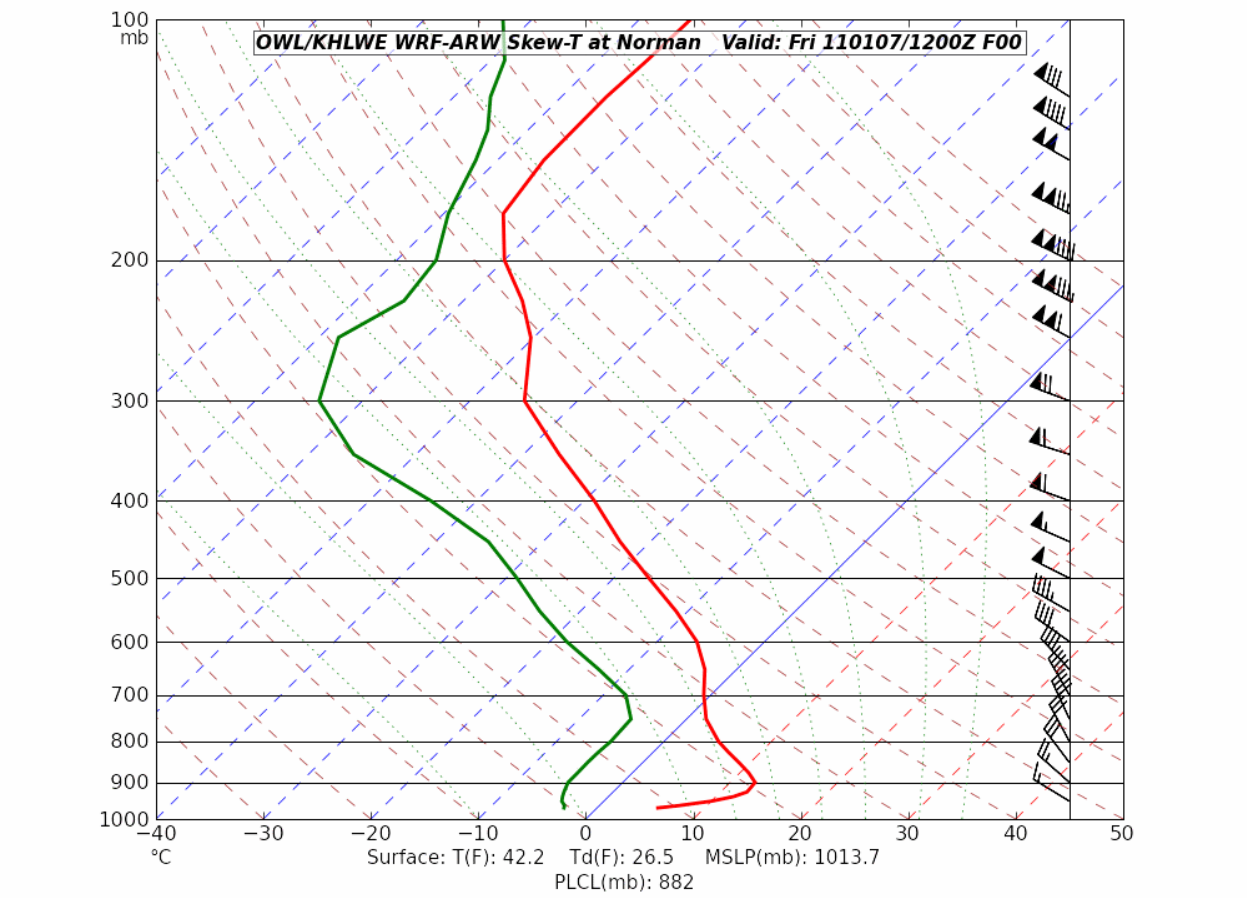
Based on the following meteogram, answer the following four questions. Assume Spirit, MO is on Central Daylight Time (UTC -0500).



52. At the time when there was no wind, what was the temperature? (1 pt)
    a. **The temperature was 54 degrees F as shown above the calm wind symbol (2 concentric circles) (1 pt for 54 degrees F)**
53. During the second hour in which the temperature was 70 degrees, what types of cloud cover were present, and at what heights? (2 pts)
    a. **Complete cloud cover, or overcast, above 10,000 ft (1 pt), broken cloud cover, or mostly cloudy, between 3,000 and 10.000 ft. (1 pt)**
54. What is the local time when the light rain occurred? (1 pt)
    a. **The tick marks below the top plot represent 15Z, 18Z, and 21Z. The rain occurred around 20-22Z, which corresponds to 15:00-17:00 local time, or 3-5pm. (1 pt for 15-17 or 3-5pm)**
55. How much precipitation fell during the rainstorm? (1 pt)
    a. **.14 inches (1 pt). Add up each of the totals in the P061 line for time periods encompassing the rainstorm.**

56. What is an isopleth? (1 pt)
    a. **An isopleth is a curve on a graph or map representing equal values of some characteristic of interest. (1 pt)**
57. Draw a vertical profile of the atmosphere showing how temperatures vary across the following layers: stratosphere, mesosphere, troposphere, and thermosphere. Exact values are not needed, just trends. (2 pts)
    a. **Temperature decreasing with height in troposphere and mesosphere, increasing with height in stratosphere and mesosphere. (2 pts, -1 pt if not in correct order of troposphere, stratosphere, mesosphere, and thermosphere from bottom to top)**
58. Draw a vertical profile of the atmosphere showing how the pressure varies. Exact values are not needed, just trends. (2 pts)
    a. **Pressure decreases logarithmically with height. (1 pt for decreasing with height), (1 pt for nonlinear with faster decrease at lower heights).**

Use the following Skew-T diagram to answer the next 3 questions.



59. Circle the temperature inversion on the diagram (1 pt).
    a. **The temperature curve (right one) should be circled between 1000 and 900mb, the area in the troposphere where temperature increases with height. (1 pt)**
60. Identify an absolutely stable region and a conditionally stable region. (2 pts)

    a. **Absolutely stable: 900-1000, 100-300 (1 pt for either of these regions), conditionally stable: 800-900, (1 pt)**

61. What is the stability of the region from 400-600mb, and how can you tell? (2 pts)
    a. **The region is neutral, or neutrally stable (1 pt), meaning rising air parcels are not hindered or aided in this region. You can tell this from the skew T plot because the temperature curve is roughly parallel to the saturation adiabat (1 pt for parallel to adiabat).**