Name _________________________________

**Atmospheric Moisture**

Clouds, dew, and fog form when air cools to the dew point and water condenses. Many environments conditions can cause cooling, orographic lifting at wind encounters mountains, nighttime radiation cooling, and convective lifting. How much cooling is required for condensation depends on atmospheric conditions including the ambient air temperature, dew point, and amount of water in the air.

**Purpose:** Introduce the concepts of atmospheric water vapor, condensation, and cloud formation; practice taking environmental measurements; learn to derive meteorological variables from measurements.

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**Background**

Humidity refers to water vapor in the atmosphere. There are many different measures of humidity, but for this lab, we will only be using Vapor Pressure, Dew Point, and Relative Humidity. One of the simplest and most widely used measures of water in the atmosphere is **vapor pressure** (VP). It refers to the atmospheric pressure exerted by water vapor molecules. For example, typically in Hawai`i, this value might be 25 millibars (mb). So, if the overall atmospheric pressure is 1015 mb, then 25 mb is due to water vapor and 990 mb is due to the other atmospheric gases. The amount of water vapor in the air varies from less than 1 mb up to about 70 mb for different places around the globe.

The maximum amount of water vapor that the air can hold is called the **saturation vapor pressure** (SVP). Saturation vapor pressure varies with temperature: the warmer the air, the more water vapor it can hold. The relationship between SVP and Air Temperature is shown in Table 1 below.

The most widely reported measure of water in the atmosphere is **relative humidity** (RH). It is also, perhaps, the least understood. The key word is "relative." Vapor pressure tells you how much water is in the air, regardless of air temperature. Relative humidity tells you the ratio of water relative to the maximum amount air can hold (the SVP), which varies with temperature. Another way of stating the relationship is to say that the relative humidity gives you the degree of saturation of the air. Or, relative humidity is the ratio of actual moisture to the maximum possible. Remember, temperature change causes the relative humidity to change because it determines the SVP, but it does not directly cause a change in the vapor pressure (VP).
Finally, the dew point temperature is the temperature at which water condenses from the atmosphere onto surfaces like blades of grass, windshields, or cloud condensation nuclei. At the dew point temperature, the vapor pressure is equal to the saturation vapor pressure and the relative humidity is 100%. The dew point temperature is a measure of the amount of water in the atmosphere, like the vapor pressure. In fact, it is interchangeable with vapor pressure as shown in Table 1 below. Higher dew points indicate more water in the atmosphere.

Abbreviations

RH is Relative Humidity in percent, this is a measure of how saturated with water the air is. VP is vapor pressure in millibars (mb), this is the actual amount of water in the air. SVP is saturation vapor pressure in millibars (mb), this is the maximum amount of water possible in the air. DP is dew point temperature, this is the temperature at which water condenses from the atmosphere to form dew or cloud droplets.

Formula

RH = VP divided by SVP times 100 ( VP / SVP x 100 )

Materials provided:

1. empty tin can
2. ice cubes
3. immersion thermometer
4. wet-dry bulb thermometer (psychrometer)

Part 1: Classroom Exercise

The most widely reported measure of water in the atmosphere is relative humidity (RH). A simple formula for calculating relative humidity, as noted above is (NOTE: / means divide, x means multiply):

\[ \text{RH} = \frac{\text{VP}}{\text{SVP}} \times 100 \]

The key word is "relative." Vapor pressure gives you the absolute measure of how much water is in the atmosphere, regardless of air temperature. Relative humidity gives you the amount of water relative to the maximum amount air can hold (the SVP), which varies with temperature as shown above. Thorougly confused? Well, try a few simple calculations using the table below to guide you. Find the SVP values using Table 1 below, and then use the RH formula and the definitions given to fill in the blanks below.
1. Which lines in the table have the highest air temperature? ___________________

2. Which have the highest Relative Humidity? ________________________________

3. Which has the most water in the air? ________________________________

4. How can line 5 have the same amount of water as line 1, but twice the relative humidity?

5. Explain how line 8 can have 3 times as much water in the air as line 6, but lower relative humidity.

6. The dew point tells you which of the following: air temperature, SPV, or VP? ________ (Hint: look at Table 1)

7. If the air temperature goes up and the dew point remains the same, will the relative humidity increase or decrease? __________ Why? ______________________________
   (Hint: look at the relative humidity formula)

8. Explain the difference between the dew point temperature and the air temperature.

9. What do you think would happen to the vapor pressure if the air temperature dropped below the dew point temperature?
Part 2: Field Work

10. Record the date, time, location, and sky conditions and fill in values for the table below

Date ___________ Time ___________ Sky Conditions __________________________________________

Measure the Dew Point with Ice

For this exercise, you will use water and ice to determine the temperature that condensation (dew) forms on a tin can. This point is the dew point temperature.

- **Water.** Fill the can 1/2 full of water
- **Ice.** Add ONE ice cube. Stir while you carefully monitor the outside of the can. Watch the outside of the can closely for the first sign of condensation. If condensation does not form before the ice melts, add ONE more ice cube and continue stirring until it does form. You have to look very closely at the can as condensation happens suddenly and can be hard to see because the droplets are usually tiny. Wipe your finger across the can below the water line continuously to check for condensation. If a streak forms, water has condensed. Stop stirring and remove the remainder of the ice cube.
- **Condensation.** When the first condensation forms, remove the remainder of the ice cube and read the water temperature with your thermometer.
- **Warm up.** To confirm that you are at or near the dew point, cup the can in your hands for a minute or two to warm up the water a few degrees. Wipe off the old condensation. Does the condensation reform? If no, excellent. If yes, warm it up some more until water droplets no longer condense on the outside of the can. Check the water temperature. It should be just above the dew point temperature.
- **Repeat.** Cool down the water a bit by stirring in an ice cube again. You should see condensation form fairly quickly. Remove the ice and measure the water temperature again.
- **Final reading.** By this repetitive procedure of cooling and warming, you should be able to focus in on the dew point fairly closely. It is the water temperature at which the dew first forms.

11. Dew Point Temperature __________________________________________

Measure the wet and dry bulb temperatures

- Record the temperature of the air using the dry bulb
- Wet the cloth on the wet bulb and spin the thermometer for one minute
- Record the wet bulb temperature

12. Dry Bulb (Air) Temperature __________________________________________

13. Wet Bulb Temperature __________________________________________
PART 3: Calculate Humidity Variables

You can calculate quite a few properties of the air if you know the dew point. We will calculate the amount of water in the air (vapor pressure) and the relative humidity. We are going to calculate the relative humidity using the formula given above of $\text{RH} = \frac{\text{VP}}{\text{SVP}} \times 100$, so we need to find out the VP and SVP.

Using the dew point measurements from water and ice

Find the VP using the dew point temperature from #11 above and Table 1 below. Find the dew point temperature in the left hand column and read the corresponding VP in the right hand column.

14. Vapor Pressure (VP) using ice measurements ________________ (Using #11 and Table 1)

Now find the SVP using the air temperature that you measured in #12 above and Table 1 below. Find the air temperature in the left hand column and read the SVP in the right hand column. Notice that you are using the same pairs of numbers in Table 1 to find both the VP and SVP, in other words, Table 1 works for both the DP to VP relationship and the Air Temp to SVP relationship.

15. Saturation Vapor Pressure (SVP) using air temperature (#12) ________________ (From Table 1 below)

Now calculate the Relative Humidity using $\text{RH} = \frac{\text{VP}}{\text{SVP}} \times 100$

16. Relative Humidity ________________ (VP from #14, SVP from #15, SHOW your complete formula and solution!)

Using the psychrometer (wet/dry) measurements

Find the wet bulb depression by subtracting the wet from dry bulb temperature.

17. Dry bulb (#12) – Wet bulb (#13) = ____________________________________

Now find the relative humidity in Table 2 below using the depression (#17) and air temperature (#12). You will have to estimate the RH as not all values are given.

18. RH ____________________________________ (from Table 2)

19. SVP ____________________________________ (from #12 and Table 1)
20. Now determine the vapor pressure (VP) using the relative humidity and SVP from #18 and #19. (Hint: this is the same problem as lines 9 and 10 in the practice exercise table at the beginning of class.)  VP ________________________________

21. Using the above VP, find the corresponding dew point temperature.

Dew Point ________________________________ (From Table 1)

**Using the National Weather Service**

Either you or somebody near you with internet access can look up humidity values reported by the National Weather Service at: [http://w1.weather.gov/xml/current_obs/PHNL.xml](http://w1.weather.gov/xml/current_obs/PHNL.xml)

22. Air Temperature ________________________________ (from NWS)

23. Dew Point ________________________________ (from NWS)

24. Relative Humidity ________________________________ (from NWS)

25. Which of your dew points was closer to the dew point reported by the National Weather Service, the ice method or the psychrometer method? ________________________________

**PART 4: Discussion**

**Water in the Air.** In general, changing the air temperature changes the relative humidity, but it does not increase or decrease the amount of water in the air (the VP). How is water added and removed from the air? Do NOT say temperature change.

26. a. The amount of water in the air (VP) will increase when ________________________________

    b. The amount of water in the air (VP) will decrease when ________________________________

27. Why does a mirror fog when you are taking a shower? ________________________________

28. Why do water beads form on a cold beverage can? ________________________________
Relative Humidity at Night. Assume that at night, the VP (and, hence, the dew point) is the same as you measured with the psychrometer (#20), but the air temperature at night is 10 °F lower than the daytime air temperature (#12). Calculate the nighttime relative humidity and compare it to the daytime value.

Daytime Temp (#12)_____ SVP (#19) _____ VP (#20)_______ RH (#18) _______

29. Nighttime Temp _________ SVP ___________ VP (#20) __________ RH __________

30. When is the relative humidity higher (day or night)? ________________________
31. If the VP is the same both day and night, do you think the Dew Point changes? ____
   Explain why you chose that answer: _____________________________________________
                                                                                       _____________________________________________
32. Why does dew form at night and not in the day? ________________________________
                                                                                       _____________________________________________
33. What is "relative humidity?" In your own words, clearly explain the difference between relative humidity (RH) and the amount of water in the air (VP).

Clouds. Clouds form when air cools to the dew point. When dry air is lifted it cools at 5.5 °F per 1000 feet.

34. How high would you have to lift the surface air for clouds to form? Show your work! (Hint: compare air temperature (#12) and dew point temperature (#11) and divide by cooling rate.)
Table 1: Relation between atmospheric moisture and temperature

<table>
<thead>
<tr>
<th>Air Temperature (°F)</th>
<th>SVP (mb)</th>
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<tbody>
<tr>
<td>50</td>
<td>12.3</td>
</tr>
<tr>
<td>52</td>
<td>13.2</td>
</tr>
<tr>
<td>54</td>
<td>14.2</td>
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<td>51.2</td>
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Table 2: Relative Humidity Table

<table>
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<tr>
<th>Tdry</th>
<th>Wet Bulb Depression (°F)</th>
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</thead>
<tbody>
<tr>
<td>75</td>
<td>96 91 86 82 78 74 70 66 62 58 54 51 47 44 40 37 34 30 27</td>
</tr>
<tr>
<td>80</td>
<td>96 91 87 83 79 75 72 68 64 61 57 54 50 47 44 41 38 35 32</td>
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<tr>
<td>90</td>
<td>96 92 89 85 81 78 74 71 68 65 61 58 55 52 49 47 44 41 39</td>
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</tbody>
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